Regional Review Workshop on Completed Research Activities

Proceedings of Review Workshop on Completed Research Activities of Natural Resource Research Directorate Held at Batu Fishery and Aquatic Life Research Center, Batu, Ethiopia, 31/10-04/11/2022

Editors: *Kefyalew Assefa, Kasahun Kitila, Tilahun Abera, Abera Donis, Bikila Mengistu and Mekonnen Daba, Zeleke Asaye*

Oromia Agricultural Research Institute

Oromia Agricultural Research Institute
P.O. Box 81265, Addis Ababa, Ethiopia
FAX 0114, 70, 71, 29 tel. 0114707021
E- mail oari.info@gmail.com

Correct citation: Kefyalew Assefa, Kasahun Kitila, Tilahun Abera, Abera Donis, Bikila Mengistu, Mekonnen Daba and Zeleke Asaye (eds). 2021. Proceedings of Review Workshop on Completed Research Activities of Natural Resource Research Directorate Held at Batu Fishery and Aquatic Life, Batu, Ethiopia, **31/10-04/11/2022**. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia.

Contents **Page**

Soil Fertility Improvement

Verification of Determined Soil test based phosphorous critical and Requirement factor for Bread wheat in Shashemene district

Abay Chala, Kasahun Kitila and Mekonnen Workina
Oromia Agricultural Research institute, Adami Tulu Agricultural Research Center
***Corresponding author**: abaychalla@gmail.com

Abstract

*Verification of P-critical value, P-requirement factor and optimum level of nitrogen fertilizer for bread wheat were conducted in Shashemene district during 2021 growing season. The verification activity was under taken at 10 farmer's fields. It had three treatments that include calibrated phosphorus (critical concentration) with recommended optimum N fertilizer for the area, existing NP fertilizer recommendation (blanket recommendation) and one control plot without NP application. The treatments were applied 10m by 10m plot area that was replicated over the farmers. The yield was harvested and means comparison of grain yield was computed at (α < 0.05). The grain yield response were highly significantly different (P<0.05). Plots treated with soil test based fertilizer recommendation gave the highest grain yield (4312kg/ha) followed by the blanket recommendation that gave 3175kg/ha. The minimum grain yield was obtained from the negative control (1600kg/ha). In addition, maximum total biomass (10500kg/ha) and harvest index (41%) were also obtained from the plots treated with soil test based fertilizer recommendations. The partial budget analysis also indicated that the maximum net benefit of (*103370.*00ETB) and highest MRR (143%) were obtained from application of soil test based recommendation. Therefore, soil test based fertilizer application was recommended and selected for further pre scaling up of demonstration activities.*

Keywords – P-critical, P-requirement factor, Verification.

Introduction

Wheat (Triticum spp.) is one of an important cereal crop grown around the world. Ethiopia is the largest producer of wheat in sub-Saharan Africa (SSA), over 1.8 million hectares annually (Abbey et al., 2012). In Ethiopia, currently wheat ranks fourth in terms of volume of production (about 4.5 million tons), contributing 16.6% and 18% of total area and production of cereal crops, respectively (CSA, 2016). Even though the nutritional and economic contribution of wheat in Ethiopia is rewarding, the productivity is far below the potential because of several biophysical and socio-economic constraints including traditional production and inadequate technological interventions. Several biophysical and socioeconomic factors have been identified as key constraints limiting productivity growth in agriculture (Misiko and Ramisch, 2007). Among others, soil fertility depletion is considered as the main biophysical limiting factor for increasing per capita food production (Beedy et al., 2010).

In Ethiopian, fertilizer use trend has been focused mainly on the use and application of only urea and di-ammonium phosphate (DAP), sources of N and P. Continuous application of nitrogen (N) and phosphorus (P) fertilizers without due consideration of other nutrients led to the depletion of other important nutrient elements such as potassium (K), magnesium (Mg), calcium (Ca), sulfur (S) and micronutrients in soils (Abiye et al., 2004). An imbalanced fertilizer use results in low fertilizer use efficiency leading to less economic returns and a greater threat to the environment (Abiye et al., 2004).

Recently soil inventory data revealed that the deficiencies of most of nutrients such as, nitrogen (86%), phosphorus (99%), sulfur (92%), born (65%) and zinc (53%) are widespread in Ethiopian soils (Ethio-SIS, 2016). The results of several studies conducted on the status of P in Ethiopian soils (Tekalign and Haque, 1987) indicated that most of the soils studied require addition of P fertilizer for profitable crop growth. It is essential that the results of soil tests could be calibrated or correlated against crop responses from applications of plant nutrients in question as it is the ultimate measure of fertilization program. Sound soil test calibration is essential for successful fertilizer program and crop production (Abaidioo et al., 2000). Even though, an effort has been made to replace blanket recommendation over soil test crop response based phosphorus recommendation, still very small districts were addressed. Fertilizer recommendation in Shashamane district is also not based on soil test results. To alleviate this problem Adami Tulu agricultural research center under taken site specific soil test based crop response fertilizer calibration trail in this district on bread wheat and determined optimum nitrogen to be applied for this specific area (46kg/ha), P critical value (21ppm) and P-requirement factors (4.43) Kasahun et al., 2022. However, the study must be further strengthened by conducting verification of soil test crop response for bread wheat in the same district having the following objectives.

Objective:

To verify the feasibility of the phosphorous critical and requirement factor determined during site specific soil test based crop response fertilizer recommendation

To determine economically optimum rate of chemical fertilizer for bread wheat in the study area

Materials and Methods

Description of the study area

The activity was conducted in Shashemene districts of West Arsi Zone, Ethiopia. Shashemene districts are located at an average altitude of 2002 m.a.s.l. The rainfall pattern of the district is characterized by bimodal distribution with small rainy season belg (March-June) and main rainy seasons Meher (July-November). The annual total rainfall is 1520 mm and means annual average temperature of 19.7. As far as soil type is concerned, the dominant soil unit of the Shashemene district is andosol. Texturally, the soils of the area are classified as sandy loam. Wheat, Barley, potato, maize, and teff are the major crops produced in this district.

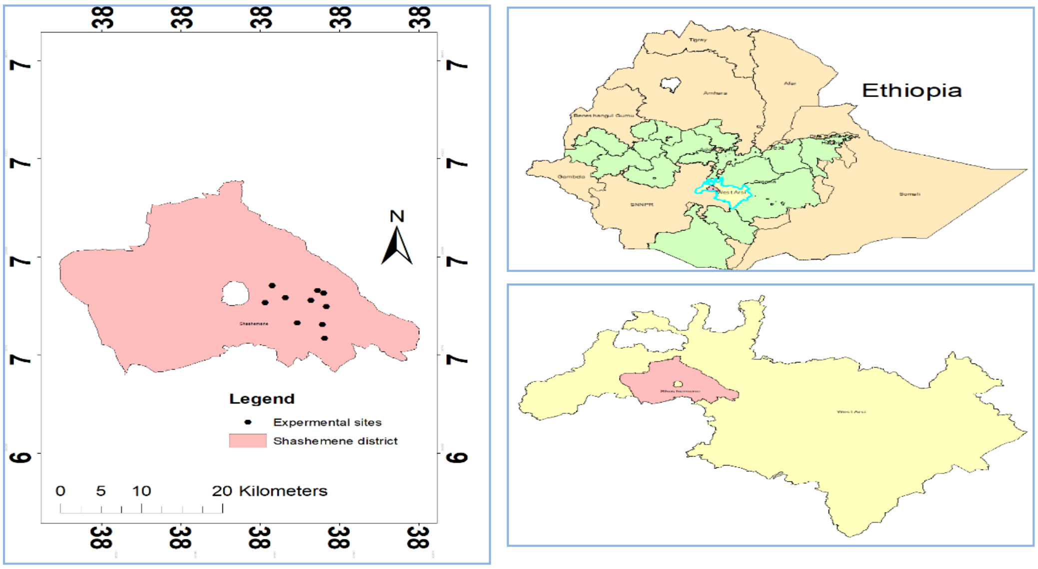


Fig: Map of the study area

Experimental Procedures

The verification trial was conducted at 10 purposively selected sites based on their interest and contribution for the first phase trial on determination of pc and pf. Then representative composite soil samples were taken at the soil depth of (0-20 cm) in a zigzag method from all sites to identify initial available phosphorus level and soil pH. Bread wheat variety called 'king bird' was used as a test crop. Urea and TSP fertilizers were used as source of N and P fertilizers, respectively.

Treatments

Phosphorus recommendation was calculated and applied according to the formula, P (kg ha-1) = (Pc – P0)* P requirement factor (whereas Pc= 21 ppm, and Pf= 4.43) with determined optimum N (46 kg) and average initial available p (pi) was 15ppm. The treatments were:

1. Soil test based recommendation
2. Blanket recommendation
3. Control (No fertilizer)

Blanket recommendation was 100kg NPS and100 kg Urea and control was plot without fertilizer). The experimental fields were prepared by using oxen plow in accordance with conventional farming practices. The experimental design was simple plot replicated per farmers. The gross plot size was 10 m x 10 m. Full dose of phosphorous as per the treatment and one-half of N was applied at sowing. The remaining one-half of N was top dressed after three weeks of planting. All recommended agronomic management practices including disease and insect pest control were done. Farmers' field visit were conducted to give awareness on importance of soil test based fertilizer recommendations

Data collection and Analysis

Yield data was collected from 2m x 2m from all treatment plots and the result was converted to actual plot size and hectare. In addition, economic analysis was performed to investigate the economic feasibility of the treatments. Partial budget, dominance, marginal and sensitivity analyses were done using (CIMMYT, 1988). Finally, the collected data was subjected to the analysis of variance using the SAS computer package version 9.0 (SAS Institute, 2002) statistical software.

Result and Discussions

Effect of treatments on grain yield

The grain yield response of the treatments was highly significantly different ($P<0.05$). Plots treated with soil test based fertilizer recommendation gave the highest grain yield (4312kg/ha) followed by the blanket recommendation that gave 3175kg/ha. The minimum grain yield was obtained from the negative control (1600kg/ha). Both total biomass and harvest index were found to be highly significantly different among the treatments (table1). In addition, maximum total biomass (10500kg/ha) and harvest index (41%) were also obtained from the plots treated with soil test based fertilizer recommendations followed by the blanket fertilizer recommendation (8538kg/ha) and harvest index (37%). Yield advantage of Soil test based fertilizer recommendation over the blanket and control treatment were computed (Table1). Accordingly, treatment applied using Pc has 169% and 36% yield advantage over the control and blanket recommendations respectively. Similarly, previous research output reported by Dejene et.al (2009), Gidena (2016), Kefyalew *et al.* (2016) and Mengistu et al. (2022) also supports this experimental result. According to Mengistu et al. (2022), experiment made in Southeastern Ethiopia, higher grain yield was observed at soil tests based fertilizer recommendation than the blanket type of fertilizer application.

Table 1: Effect of treatments on grain yield and yield components

Treatments	Mean GY in Kg/ha	Total BM (kg)	HI (%)	Yield adv. (%) over	
				Over Control	Over blanket application
STBFR	4312^{a}	10500^{a}	41.06^{a}	169	36
Blanket Recommendation	3175^{b}	8538^{b}	37.18^{b}	98	-
Control	1600^{c}	4005^{c}	39.99^{ab}		
CV (%)	14.17	12.99	9.44		
LSD(0.05)	678.34	1252.4	2.60		
Significance	**	**	**		

** Highly significant, STBFR=soil test based fertilizer recommendation

Partial budget analysis

The partial budget analysis indicated the maximum net benefit of (103370.00ETB) and highest MRR (1736%) were obtained from application of recommended fertilizer P-critical and optimum N (46kg /ha). The lowest net benefit was obtained from the control treatment (table 7)

Table 7: Partial budget (ETB) analysis using CIMMT, 1988

Treatments	Mean Gy kg/ha	Unit price	NPS in kg/ha	Unit cost	UREA in kg/ha	Unit cost	TVC/ha	Gross income/ha	Net income	MRR (%)
Control	1600.0	25.00	0.00	0.00	0.00	0.00	0.00	40000.0	40000.00	0
Blanket	3175.0	25.00	100.00	18.50	59.00	17.50	2882.5	79375.0	76492.50	1266.00
STBFR	4312.0	25.00	160.00	18.50	84.00	17.50	4430.0	107800.0	103370.00	1736.83

STBFR: soil test based fertilizer recommendatio

Conclusion and Recommendation

It was identified that application of soil test based fertilizer application gave maximum grain yield with highest yield advantage over the blanket recommendation. Therefore, it was highly recommended for the farmers and other beneficieries to use the recommended fertilizer rate instead of the blanket ones. NPS rate determination and wider demonstration of the technologies are the remaining activities in the study area.

Acknowledgements

I acknowledge Oromia Agricultural Research Institute (OARI) and Adami Tullu Agricultural Research Center for granting the research fund and facilitation of the resources respectively.

References

Abeyo B, Braun H, Singh R, Ammar K, Payne T., 2012. The performance of CIMMYT wheat germplasm in East Africa with special emphasis on Ethiopia. In: Book Abstracts of Wheat for Food security in Africa, Quilligan E, et al. In: (Eds.), conference AA, Ethiopia, pp: 22.

Abiye, A., T. Mamo, D. Peden, and M. Diedhiou, M. 2004. Participatory on Farm Conservation Tillage Trial in the Ethiopian highland Vertisols: The Impact of Potassium Application on Crop Yields. *Experimental Agriculture* 40(3):369-379.

Beedy, T. L., Snapp, S. S., Akinnifesi, F. K. and Sileshi, G. W., 2010. Impact of gliricidia sepium intercropping on soil organic matter fractions in a maize-based cropping system, Agriculture, *Ecosystems & Environment*, vol. 138, pp. 139–146.

Central Statistical Agency (CSA) [Ethiopia] and ICF, 2016. Ethiopia Demographic and Health Survey.

Ethio-SIS (Ethiopia Soil Fertility Status), 2016. Fertilizer Recommendation Atlas of the Southern Nations, Nationalities and Peoples' Regional State, Ethiopia. Pp 81.

Gidena Tasew, 2016. Verification and Demonstration of Soil Test Based Phosphorus Fertilizer Recommendation Rate on Yield of Teff (Eragrostis Tef (Zucc) Trotter) in Vertisols of Northern Ethiopia. *Journal of Natural Sciences Research.*

Kefyalew A. Tilahun F. and Tadesse H., 2016. Verification and Demonstration Pc and Pf Determined Through Soil Test Based Crop Response Study for P on Bread Wheat at Lume Area of Oromia Region, Ethiopia. *International Journal of Research and Innovations in Earth Science.* 3: 6, ISSN: 2394-1375

Mengistu C, Kasu T, Gobena N, Anbessie D,And Almaz A.,2022. Verification an Demonstration of Soil Test Based Phosphorous Calibration for Wheat Crop under Nitisols of Southeastern Ethiopia. *J Ecol & Nat Resour*. 6(1): 000269.

Misiko, M., Tittonell, P. A., Ramisch, J. J., Richards, P., & Giller, K.E. , 2008. Integrating new soyabean varietes for soil fertility management in smallholder systems through participatory research: Lessons from western Kenya. *Agricultural Systems*, *97*(1-2), 1-12. https://doi.org/10.1016/j.agsy.2007.10.002

Evaluation of the Application rate of Organic integrated with Chemical Fertilizer on yield and yield components of Maize (Zia Maize) in Dugda District of East shewa Zone, Oromia

Kasahun Kitila, Abay Chala and Mekonnen Workineh
Oromia Agricultural Research institute, Adami Tulu Agricultural Research Center
Cooresponding Author: kiyafenu@gmail.com

***Abstract*:**
*Integrated soil fertility management is the application of inorganic in combination with organic fertilizer to maintain soil fertility and improve crop yield. A study was conducted in East Shoa Zone, Dugda District on farmers' fields to determine the combined effects of conventional compost as organic fertilizer and NPS as inorganic fertilizer on soil chemical properties and maize production. There were five treatments: Recommended rate of inorganic fertilizer, 100, 75, 50 and 25% equivalent level of compost for nitrogen fertilizer. Recommended level of 69 P_2O_5/ha were equally applied at all treatments. The experiment was laid out in RCBD design with three replications. The analysis of variance showed no significant differences ($P > 0.05$) in maize grain yield response. However, the highest maize grain yield (8728.20 kg ha-1) was obtained from treatment two that received 100% equivalent compost for nitrogen fertilizer and the lowest (8325 kg ha-1) was obtained from treatment one where recommended chemical fertilizer alone was applied. Composite Soil samples were also collected before compost application and after harvesting to evaluate the residual effect of compost on soil physiochemical properties. Accordingly, laboratory analysis showed no significance differences ($P > 0.05$) in total N, available P, soil organic carbon and CEC. However, analysis of variance of post-harvest composite soil samples indicated significant different and higher in soil available P, OC, TN and CEC as compared to initial soil sample. On the other hand, partial budget analysis was done to determine economically optimum rate of compost integrated with chemical fertilizer. Accordingly, the highest NB (*127649 ETB*) was recorded from treatment two where 100% compost (4.6t/ha) plus 177kg NPS fertilizers were applied. Therefore, the present study showed that combined application of organic and NPS fertilizer enhanced maize productivity and soil fertility status in the study area. Hence combined fertilizer application of 4.6 t ha^{-1}conventional compost integrated with 177kg NPS improved maize productivity and soil chemical properties, and recommended for the study area and similar agro-ecology.*

Key words: Soil fertility, Soil Organic Carbon, Integrated application, Organic and inorganic fertilizer

Introduction

Continuous uses of inorganic fertilizers lead to deterioration of soil chemical and physical properties and in general the total soil health (Mahajan et al., 2008). Application of chemical fertilizers alone lead to unsustainable productivity over the years (Mahajan et al., 2008; Satyanarayana et al.,2002). However, Organic fertilizer application has been reported to improve crop growth by supplying plant nutrients including micro-nutrients as well as improving soil physical, chemical, and biological properties thereby provide a better environment for root development by improving the soil structure (Dejene et al., 2011). In addition, the price of inorganic fertilizers is currently increasing and becoming unaffordable for resource-poor small-holder farmers. Therefore, a combination of both inorganic and organic fertilizers, where the inorganic fertilizer provides readily available nutrients and the organic fertilizer mainly increases soil organic matter and improves soil structure and buffering capacity of the soil (Alemu et al., 2015).

Due to the extensive and improper use of chemical fertilizers in the soil, soil is degrading to an alarming level, causing an imbalance in the ecosystem and environmental pollution as well. More recently, attention is being focused on the global environmental problems, utilization of organic wastes, farm yard manure, compost, compost and poultry manures as the most effective measure for the purpose. The use of bio-products for plant nutrition purposes is taken as a basic approach so that Food and Agriculture Organization (FAO) recently has taken some measure to implement the Integrated Plant Nutrition Management (IPNM) systems for the development of sustainable agriculture in developing countries. Adequate Input Sustainable Agriculture (AISA) is currently practiced based on the integrated use of chemical and organic fertilizers, especially bio-fertilizers as an approach to alternative agriculture for producing and maintaining yield at an acceptable level.

The ISFM paradigm acknowledges the need for integration of both organic (compost) and mineral inputs to sustain soil health and crop production due to positive interactions and complementarities between them (Vanlauwe et al., 2010). According to Getachew, (2009) the use of compost double the grain yield of cereal crops as compared to the chemical fertilizer, hence, Continuous usage of inorganic fertilizer affects soil structure and microbial biomass and their activities, whereas compost reduces production cost and it is an environmentally friendly method of agricultural in puts technology. However, successful use of either compost alone or its combination with chemical fertilizer relies on evaluating the soil to be amended followed an evaluation of available compost materials, and then determining the best materials and rate of compost and mineral fertilizer to meet the desired objective. So, this experiment is required with the objectives of assessing the effects of different levels of compost alone and its combination with mineral fertilizer as compared to the recommended inorganic fertilizer on the maize yield and yield components.

Recently, areas for maize cultivation and its consumption have been increased rapidly in all over the world and this may be because of its importance for consumption and raw material for producing different products. Maize is the largest and most productive crop in Ethiopia in general and mid rift valley in particular. According to the report by ministry of agriculture and Natural resource report, in 2015/16, maize production was 4.2 million tons, which was 40 percent higher than teff, 56 percent higher than sorghum, and 75 percent higher than wheat production. Maize needs different kinds of nourishment during its growth which can be obtained from the chemical fertilizers. Nitrogen is the one of the most important element which used for the maize cultivation and its deficiency can be limiting the nutritional elements of this crop. However, excessive or under use of chemical fertilizers decline soil fertility and grain quality (Singh et al., 2007, Liu et al.,2009). Considering the environmental pollution related to excess use of chemical fertilizer, and its cost needs of an alternative approach based on biological origin, which is safe for use and less expensive to generate adequate plant nutrient through **‘’integrated soil fertility management’’** assuming that fully or partially replacements of chemical fertilizer in the soil through application of compost have both environmental and Economic benefit in maintaining crop production more sustainable.

Therefore, this project is designed to evaluate the effect of compost as organic source of fertilizer applied alone and in combination of chemical fertilizer on yield and yield components of Maize.

Objective:

To evaluate the effect of compost integrated with chemical fertilizer on yield and yield components of Maize.

To recommend best compost and chemical fertilizer integration based on the yield response

Materials and Methods

Description of the Study Area

Dugda district is one of the districts in East Shewa Zone in the Great Rift Valley of Oromia Region. The altitude of this district ranges from 1500 to 2300 meters above sea level. Mount Bora Mariam (2007 meters) is the highest point. It is located at 8°6̀00'' to 8°10̀00'' N Latitude and 38°42'30'' to 38°51'30''E Longitude. A survey of the land in this district shows that 36.9% is arable or cultivable, 8.7% pasture, 9.6% forest, 0.4% swampy and the remaining 44.3% is considered degraded or otherwise unusable. Fruits and vegetables are important cash crops (CSA, 2016). The district is generally characterized by dry low land agro-climate. The rainfall pattern is erratic, insignificant mean monthly precipitation and higher potential evapo-transpiration as compared with precipitation. Mean daily temperature is 25°C during the rainy season. Sandy loam is the dominant soil texture identified during the soil salinity assessment and characterization (Kasahun et al., 2016). As far as vegetation is concerned, mid rift valley in general and Dugda district in particular is characterized by scattered acacia wood lands.

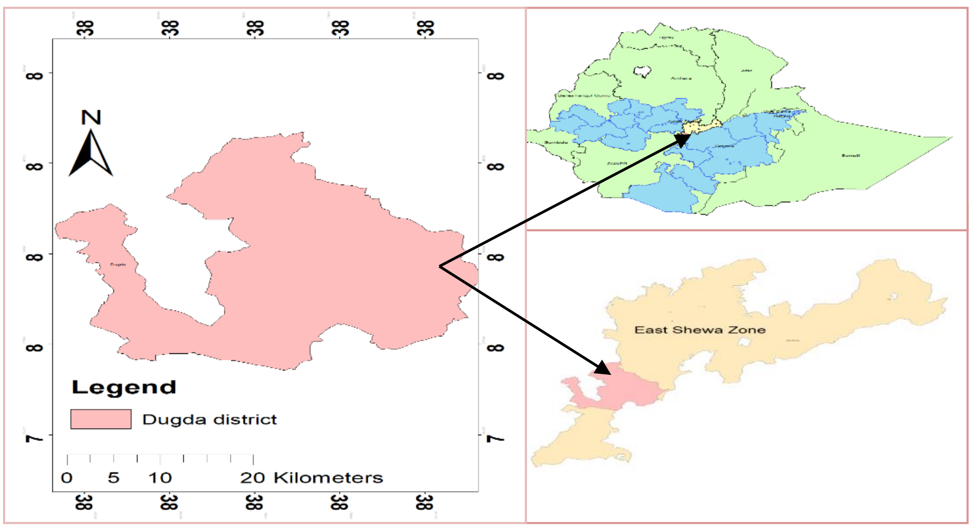


Fig1: Geographical location of Dugda district

Compost preparation and Analysis

Conventional compost was prepared from Animal manure, Haricot bean straw ,wheat straw, green grasses, forest soil, and ash following conventional compost preparation standard at Adami Tulu Agricultural Research Center. Before conducting the experiment Compost Samples were taken to evaluate its quality in terms of total nitrogen content to compute the compost and chemical fertilizer equivalency. Accordingly, conventional compost contains 1% total nitrogen on average which is equivalent to 1kg nitrogen fertilizer per 100kg compost. Therefore, one kuntal UREA (46kg nitrogen) is equivalent with 46 kuntal of conventional compost

Experimental Design and Treatments

The experiment has five treatments with three replications designed in RCBD. The area will be 3mx4m for each plot. BH546 maize variety, which is the most commonly, sown by the farmers in the area, was used to evaluate the treatments. Recommended chemical fertilizer was applied based on site specific crop response p-calibration study recommended by EIAR, Melkassa, 2017 for maize production in Dugda district. According to the report, P-critical, average initial-p, optimum-N and P requirement factor for maize is 15, 7, 46kg and 3.1 respectively

Treatments

T1= Recommended rate of chemical fertilizer (control)

T2 = 100% Eq. level of vermicomost + Recommended P2O5

T3=75% Equivalent level of vermicompost+25%N + Recommended P2O5

T4= 50%N +50% Equivalent level of vermicomos + Recommended P2O5

T5 = 25% Equivalent level of vermicomost + 75% N++ Recommended P2O5

Data collection:

Soil samples were collected to the depth of 0-20cm before planting and after harvesting to evaluate the effect of compost on soil chemical properties. Yield and yield components data were also collected after harvesting from all plots. Economic importance of integrated soil fertility management was also collected.

Data Analysis

The collected data was interred to the Microsoft excel and analyzed using R- software version 4.2.2. Soil and compost samples were analyzed for physical and chemical properties following analytical standards. The economic analysis was done using partial budget analysis model developed by CIMMYT (1998) to recommend the economically important combination of organic and inorganic fertilizer. In addition, the cost of compost was estimated based on its total nitrogen content. This technique was commonly used in different parts of the country like in UK.

Result and Discussion

Grain Yield and Yield Components

The effect of integrated soil fertility management on yield and yield component of maize was presented in Table 1 below. The result showed that there was no significant (P<0.05) differences among the treatments in grain yield response (Table 1). In the same table, mean of thousand seed weight and the number of cobs per plant also showed no significant difference (P<0.05) between the treatments. However, the maximum grain yield of 8728.20 kg/ha was obtained in treatment two (2) where compost substitute nitrogen fertilizer by 100% followed by the treatment 3(three) where compost substitutes N-fertilizer by 75%. The minimum grain yield (8325kg/ha) was obtained from the control treatment where recommended rate of fertilizer was applied without compost (table1). On the other hand, yield advantage (4.8%) was slightly greater for treatment two where compost substitutes N-fertilizer by 100% as compared with other treatments. This result was strongly in agreement with Wakene N. et.al (2002), and Kasahun K et.al (2019) who were reported that sole compost with the substation of N fertilizer increased maize yield. In addition, Abunyewa et al. (2007) and Rajeshwari et al. (2007) found higher maize grain yield from integrated use of organic and inorganic fertilizer application. This was mainly due to the compost, which can supplement both macro and micro nutrients for better nutrient use efficiency and better grain development. Nutrient use efficiency can also increase as the soil is amend with organic and inorganic fertilizers Ayoola and Makinde (2006). Other similar studies also reported that maize grain yield was increased by 0.47t/ha in the first cropping season at the plots treated with organic and inorganic fertilizer in western Hararghe zone Heluf (2002).

Tabale 1. Effect of treatments on yield and yield components

Treatments	Mean grain Yield in Kg/ha	000'kernal weight in kg	No. of cobs/plant	Yield advantage (%)
Recommended rate (46kg N+69 P2O5)	8325.30	0.42	1.16	-
100% Compost+69P2O5	8728.20	0.46	1.19	4.80
75% Compost+25%N+69P2O5	8602.30	0.44	1.17	3.32
50% Compost+50%N+69P2O5	8500.10	0.40	1.18	2.09
25% Compost+75%+69P2O5	8407.20	0.41	1.16	0.98
CV	9.12	11.33	7.11	
LSD (0.05)	717.99	0.08	0.04	
Significance	ns	ns	Ns	

Residual Effect of compost and Chemical fertilizer on soil properties

The residual effect of applying compost integrated with chemical fertilizer was evaluated after comparing soil chemical properties before treatment application and after crop harvest. The result from soil sample analysis indicated that total nitrogen, organic carbon CEC and phosphorous content of the soil before treatment application was not significantly different ($p \geq 0.05$) between the experimental plots. However, CEC, total N, available phosphorous, and soil organic carbon content of the soil after harvesting were highly significantly different ($p \leq 0.05$) between the treatments (Table 2).

Table2: Soil chemical properties before planting and after harvesting

Treat ments	Soil chemical properties before planting					Soil chemical properties After harvesting				
	Initial pH	Initial TN (%)	Initial OC (%)	Initial CEC me/100g	Initial P (ppm)	Final pH	Final TN (%)	Final OC (%)	Final CEC me/100g	Final P (ppm)
1	7.54	0.24	1.45	12.80	12.96	7.52	0.25[b]	1.47c	12.31[b]	13.59[c]
2	7.46	0.26	1.47	11.98	14.39	7.65	0.33[a]	2.21a	24.91[a]	24.96[a]
3	7.55	0.25	1.44	12.87	14.27	7.71	0.30[a]	2.17a	23.34[a]	24.52[a]
4	7.60	0.24	1.43	11.99	14.10	7.43	0.27[ab]	1.68b	21.98[a]	22.84[a]
5	7.47	0.23	1.39	12.97	13.67	7.46	0.26[b]	1.57bc	15.26[b]	17.11[b]
CV (%)	5.89	17.75	20.28	13.78	13.28	6.31	19.50	9.74	14.04	11.47
LSD 0.05	0.39	0.06	0.38	2.37	2.43	0.44	0.05	0.27	3.62	3.05

T1=Recommended fertilizer rate (46kg N+Rec P2O5) 100% T2= 100%Equv. Compost+ Rec.P2O5, T3= 75% Equv.Compost+25%N+Rec. P2O5 T4=50% Equv. Compost+50%N+RecP2O5 T5= 25% Equv. Compost+75%+RecP2O5

On the other hand, mean of soil chemical parameters such as pH, Total nitrogen TN, organic carbon (OC), cation exchange capacity (CEC), and available phosphorous (av,P) at the initial or before treatment application were lower than their status post-harvest (table3). This parameters were also lower in treatment one where only chemical fertilizer was used as compared with other treatments that were treated with compost at different rate. This result is strongly in agreement with the study by Getachew et al. (2009) and Kasahun et al 2019 who were reported that after the first crop harvesting, total N, available phosphorous, potassium, CEC and soil organic carbon significantly higher for the plots treated with compost as compared with application of sole inorganic fertilizer. In addition, the residual effects of compost application can maintain crop yield level for two years after compost application since only a fraction of the N and other nutrients in compost become plant available in the first year after application (Eghball, 2002).

Other similar studies also reported that, compost application have strong positive effect on the physicochemical and biological properties of the soil which often leads to higher crop growth and yield (Abedi et al. 2010; Hafidi et al. 2012). This was mainly due to compost provides nutrients to the crop and improve land productivity

Previous studies also indicated that the residual effect of compost and inorganic fertilizers gave positive yield benefits on rice, wheat (Sarwar et al. 2007; Abedi et al. 2010) and sorghum (Ouedraogo et al. 2001). This indicates that farmers who cannot afford to apply compost every year could improve productivity by applying compost every other year. Nahar et al. (1995) reported 97 % yield increase in wheat from residual effects of compost.

Table 3: Mean of soil chemical properties before planting and post-harvest

Treatments	Soil chemical properties before planting					Soil chemical properties After harvesting				
	Initial pH	Initial TN (%)	Initial OC (%)	Initial CEC me/100g	Initial av. P(ppm)	Final pH	Final TN (%)	Final OC (%)	Final CEC me/100g	Final av. P (ppm)
1	7.54	0.24	1.45	12.8	12.96	7.52	0.25	1.47	12.31	13.59
2	7.46	0.26	1.47	11.98	14.39	7.65	0.33	2.21	24.91	24.96
3	7.55	0.25	1.44	12.87	14.27	7.71	0.3	2.17	23.34	24.52
4	7.6	0.24	1.43	11.99	14.1	7.43	0.27	1.68	21.98	22.84
5	7.47	0.23	1.39	12.97	13.67	7.46	0.26	1.57	15.26	17.11
Mean	**7.52**	**0.24**	**1.43**	**12.52**	**13.87**	**7.55**	**0.28**	**1.82**	**19.56**	**20.60**

T1=Recommended fertilizer rate (46kg N+Rec P2O5) 100% T2= 100%Equv. Compost+ Rec.P2O5, T3= 75% Equv.Compost+25%N+Rec. P2O5 T4=50% Equv. Compost+50%N+RecP2O5   T5= 25% Equv. Compost+75%+RecP2O5

Integrated Soil Fertility Management as Climate Change Mitigation Strategy

Soil organic carbon significantly increased in a plot treated with compost and combination of compost and chemical fertilizers at different levels after the first crop harvest as compared with the plots treated only with inorganic fertilizer (table 2). Therefore, when managed properly, soils can play an important role in climate change mitigation by storing carbon or decreasing greenhouse gas emissions to the atmosphere (Scharlemann et al., 2014, FAO, 2015). On the other hand, if soils are cultivated through unsustainable agricultural practices, soil carbon can be released into the atmosphere in the form of carbon dioxide (CO_2), which can contribute to climate change (Figure1).

It was identified that, a substantial amount of global CO_2 comes from soil through decomposition, mineralization and soil respiration. However, integrated application of organic and inorganic fertilizers reduced decomposition rate of organic matters that consequently alter carbon dioxide emissions (Jabro et al., 2018). On the other hand, combined application inorganic fertilizers and organic have resulted in higher aboveground biomass yield than the application of 100% recommended rate of inorganic alone Shata et al. (2007).

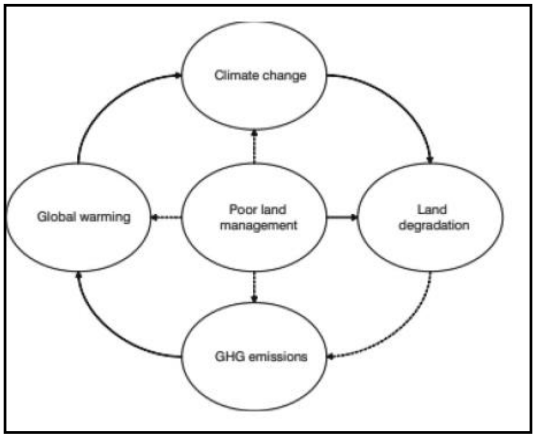


Figure1: The relationship between climate change and soil management (adapted from Bayu et.al, 2020)

Partial Budget Analysis for Integrated Soil Fertility Management

Partial budget analysis and marginal rate of return were carried out for the integrated use of compost and NP fertilizers in maize production. The cost of compost was estimated based on its nutrient content particularly total nitrogen (table 4). As indicated in the Table 5, the highest net benefit (127649.00ETB Birr ha-1) was recorded for treatment 2 (two) where 100% equivalent compost (4.6t/ha) was applied integrated with recommended P2O5 followed by treatment 3(three) where 75% Equivalent Compost was combined with 25%N and recommended P2O5 with the net income of 125323 ETB

Table 4: Estimated cost of conventional compost based on its Total nitrogen

Parameters	Compost ratio				
	1	2 (100%)	3 (75%)	4 (50%)	5 (25%)
Compost applied in kg/ha	0	4600	3450	2300	1150
TN/100kg compost in kg	0	1	1	1	1
Cost of Urea/kg	0	17.5	17.5	17.5	17.5
Amount of Urea/kg N	0	2.17	2.17	2.17	2.17
Cost of 1kgN or 100 kg compost/kg in ETB	0	37.97	37.97	37.97	37.97
Total cost of compost/ha	0	1746.85	1309.96	873.31	436.65

Table 5: Partial budget analysis (ETB) using CIMMYT (1998)

Treatm ents	Mean yield in kg/ha	Unit cost	NPS in kg/ha	Unit cost	URE A in kg/ha	Unit cost urea	TVC	Gross income	Net income
T1	8325.3	15	177	18.5	100	17.5	5024.5	124880	119855
T2	8728.2	15	177	18.5	0	17.5	3274.5	130923	127649
T3	8602.3	15	177	18.5	25	17.5	3712	129035	125323
T4	8500.1	15	177	18.5	50	17.5	4149.5	127502	123352
T5	8407.2	15	177	18.5	75	17.5	4587	126108	121521

T1=Recommended fertilizer rate (46kg N+Rec P2O5) 100% T2= 100%Equv. Compost+ Rec.P2O5, T3= 75% Equv.Compost+25%N+Rec. P2O5 T4=50% Equv. Compost+50%N+RecP2O5 T5= 25% Equv. Compost+75%+RecP2O5

Conclusion and Recommendations

For sustainable land management, implementation of Integrated Soil Fertility Management (SFI) is very important. Organic fertilizers maintains soil health, improves soil nutrient and increase crop yield. Maize grain yield was not statistically different between the treatments but higher for the treatments treated with compost as compared with the one treated with inorganic fertilizer alone. Laboratory analysis results of soil samples collected before sowing showed no significance differences in soil chemical properties. However, post-harvest analysis of soil samples indicated that significantly difference and positive increment on soil fertility status. Therefore, 100% equivalent compost (4.6 t ha-) conventional compost integrated with 177 kg NPS ha-1 fertilizer were recommended for maize production to the study area and similar agro-ecology.

Acknowledgements

I acknowledge Oromia Agricultural Research Institute (OARI) and Adami Tullu Agricultural Research Center for granting the research fund and facilitation of the resources respectively.

References

Abedi T, Alemzadeh A, KazemeIni SA (2010) Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of wheat. Aust J Crop Sci 4:384–389

Alemu, M. M. (2015) Effect of tree shade on coffee crop production. Journal of Sustainable Development, 8 (9), 66

Ayoola, O.T. (2006). Effects of fertilizer treatments on soil chemical properties and crop yields in a cassava-based cropping system. J. Appl. Sci. Res., 2, 1112-1116.

Central Statistical Agency (CSA) [Ethiopia] and ICF (2016) Ethiopia Demographic and Health Survey 2016

Dejene, K., Dereje, A., & Daniel, G. (2011). Synergistic effects of combined application of organic and inorganic fertilizers on the yield and yield components of tef (Eragrostis tef (Zucc.) Trotter) under terminal drought at Adiha, Northern Ethiopia. Journal of the Drylands, 3(1)

Eghball, B. (2002). Soil properties as influenced by phosphorus and nitrogen – Based manure and compost applications. Agronomy Journal, 94(1), 128–135.

Jahangir, M. M. R. *., Jahan, I., & Mumu, N. J. (2018). Management of Soil Resources for Sustainable Development under a Changing Climate. Journal of Environmental Science and Natural Resources, 11(1– 2), 159–170

Hafidi M, Amir S, Meddich A, Jouraiphy A, Winterton P, El Gharous M, Duponnois R (2012) Impact of applying composted biosolids on wheat growth and yield parameters on a calcimagnesic soil in a semi-arid region. Afr J Biotechnol 11:9805–9815

Getachew, A. and Y. Chilot. 2009. Integrated Nutrient Management in Faba Bean and Wheat on Nitisols of central Ethiopian Highlands. Research Report No. 72. Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia, pp. 24.

Kasahun Kitila and Abay Chala,2019. Evaluation of Compost Integrated with Chemical Fertilizer for better production of Maize in Shashemene District of West Arsi Zone, Oromia, AJAR, 2019; 4:43

Kasahun Kitila, Ayub Jalde and Workina M. 2016. Evaluation and Characterization of Soil Salinity Status at Small-Scale Irrigation Farms at Bora and Lume Districts of East Showa Zone, Oromia, Ethiopia. Science Journal of Analytical Chemistry. 4 (6): 95-102. doi: 10.11648/j.sjac.20160406.13

Liu B, Gumpertz M L, Hu S &Ristaino J B (2007). Long-term effects of organic and synthetic soil fertility amendments on soil microbial communities and the development of southern blight. Soil Biology and Biochemistry, 39:2302-2316.

Mahajan, A., Bhagat, R. M., & Gupta, R. D. (2008). Integrated nutrient management in sustainable rice wheat cropping system for food security in India. SAARC Journal of Agriculture, 6(2), 29–32

Nahar K, Haider J, Karim AJMS (1995) Residual effect of organic manures and influence of nitrogen fertilizer on soil properties and performance of wheat. Ann Bangl Agric 5:73–78

Ouédraogo, E., Mando, A., Zombré, N.P., 2001. Use of compost to improve soil properties and crop productivity under low input agricultural system in West Africa. Agriculture, Ecosystems and Environment 84: 259 - 266

Sarwar G, Hussain N, Schmeisky H, Muhammad S (2007) Use of compost an environment friendly technology for enhancing rice-wheat production in Pakistan. Pak J Bot 39:1553–1558

Satyanarayana, V., Prasad, P. V., Murthy, V. R. K., & And Boote, K. J. (2002). Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. Journal of Plant Nutrition, 25(10), 2081–2090.

Scharlemann, J. P., Tanner, E. V., Hiederer, R., & Kapos, V. (2014). Global soil carbon: understanding and managing the largest terrestrial carbon pool. Carbon Management, 5(1), 81–91

Singh, R. P., Singh, P., Araujo, A. S. F., Hakimi Ibrahim, M., & Sulaiman, O. (2011). Management of urban solid waste: Vermicomposting a sustainable option. Resources, Conservation, and Recycling, 55(7), 719–729

Vanlauwe, B., Bationo, A., Chianu, J., Giller, K. E., Merckx, R., Mokwunye, U., Ohiokpehai, O., Pypers, P., Tabo, R., Shepherd, K., Smaling, E. M. A., & Woomer, P. L. (2010). Integrated soil fertility management: Operational definition and consequences for implementation and dissemination. Outlook on Agriculture, 39(1), 17–24

Wakene, N., Kefyalew, N., Friesen, D.K., Ransom, J. and Abebe, Y., 2001. Determination of optimum farmyard manure and NP fertilizers for maize on farmers' fields. pp. 387-393. In: Seventh Eastern and Southern Africa Regional Maize Conference.

Determination of NPS Fertilizer Rates Based on Phosphorus Calibration Study for Bread Wheat (Triticum aestivum L.t Production at Jima Arjo District, Western Oromia Region

Temesgen Chimdessa*, Chalsissa Takele, Firaol Gemada, Mintesinot Desalegn, Chaltu Regassa, and Olifan Fikadu.
Nekemte Soil Research Center P.O. Box 587, Nekemte
*Corresponding Author: temesgenchimdessa468@gmail.com

Abstract
The study was conducted for two years on ten (10) farmers' fields in (2020/21- 2021/22) at Jima Arjo district to determine the economically optimum blended NPS fertilizer rate for bread wheat production in the study area. The experimental design was a randomized complete block design (RCBD) with three replications. The treatments consist of 100% Pc from DAP and recommended N fertilizer and 100%, 75%, 50%, 25% Pc from NPS fertilizer with recommended N fertilizer and control (no fertilizer application). Kakaba seed variety with a rate of 150 kg ha^{-1}was used for the trial. The two years (2020/21-2021/22) analysis of variance showed that plant height, biomass yield and grain yield of bread wheat were highly and significantly affected by the rate of NPS, while spike length and number of seeds per spike were not statistically affected by the treatments. The highest grain yield (3888.9 kg ha^{-1}) was obtained in response to the application of 100% of Pc from NPS with Rec. N; which is not statistically different from the grain yield obtained from the application of 75% and 50% of Pc from NPS with Rec. N. The lowest grain yield (2731.5 kg ha^{-1}) was obtained from control treatment. The highest net benefit of 79472.3Birr ha^{-1}was obtained from 50% of Pc from NPS with optimum N fertilizer application. Based on the results of both agronomic data and partial budget analysis, 50% of Pc from NPS plus recommended nitrogen fertilizer (2018 NPS and 92 N each kg per hectare) was chosen as the best and led to the maximum yield and net benefit for bread wheat production in Jima Arjo district. Therefore, demonstrating the technology for popularization should be followed up.

Keywords: Blended, Bread wheat, Calibration, Fertilizer, Optimum, Rate

Introduction

Ethiopia is the second-largest wheat producer in sub-Saharan Africa, after South Africa (Demeke and Marcantonio, 2013). Wheat in Ethiopia has become one of the most important cereal crops ranking 3rd in total grain production (5.32 mil. ton) and area (1.75 mil. ha) next to teff (*Eragrostis Teff*) and maize CSA, 2020). The average productivity of wheat at the national level, Oromia Region, East Wollega zone and Jima Arjo District is 2.97, 3.19, and 3.01 and 3.20 ton ha^{-1} respectively (CSA, 2020, EWZAO and JADAO, 2022). The current yield trends are insufficient to meet forecasted food demands (Ray *et al. 2013*). The declining agricultural crop productivity is primarily allied to the depletion of soil fertility due to continuous nutrient mining of crops, low fertilizer uses and insufficient organic matter incorporation (Gorges, 2015). The growth of the global food production is projected to demand increased use of chemical fertilizers, but since the current environmental impact of agriculture and fertilizer use has reached its global boundaries (Steffen *et al*., 2015), the nutrient use efficiency of fertilizers should be increased dramatically.

In Ethiopian dominant use of chemical fertilizers like diammonium phosphate (DAP) and Urea to improve major crop yields for about five decades and this did not consider soil fertility status and crop requirement. Moreover, the soil fertility mapping project in Ethiopia reported the deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils and thus recommend application of customized and balanced fertilizers (EthioSIS 2014); Moreover, (Habte *et al.*, 2013*;* Tegbaru, 2014; Laekemariam Fanuel 2015 and

Habtamu *et al*., 2014) reported that S content in the soils they studied were found to be very low in some Ethiopian soils. Depending upon available sulfur levels, the wheat yield can increase from 0 to 42% (De Ruiter and Martin, 2001) usually obtaining the best response with sulfur application between 10 and 20 kg ha^{-1} (McGrath *et al.*, 1996). Due to these, new fertilizers such as NPS (19% N, 38% P_2O_5 and 7% S) are currently being used by the farmers in Ethiopia including the study area. Critical phosphorus level of 13ppm, Phosphorus requirement factor of 9.1ppm and economically optimum N of 92 kg h^{-1} were recommended for bread wheat production at Jima Arjo district (Chalsissa *et al*., 2021)

However, in the study area fertilizer trials involving multi-nutrient blends of NPS fertilizer were not conducted in the study area. Therefore, it needs calibration of the NPS fertilizer rate based on soil tests in the study area to increase bread wheat production and productivity in the study area.

Objective/s:

To determine economically appropriate NPS fertilizer rate on yield and yield components of bread wheat at Jima Arjo district.

Materials and Methods

Description of the Study Area

Location

The study was conducted in Jima Arjo district, East Wollega Zone of Oromia region, which capital town located 378 kilometers far from Finfinnee (Addis Ababa) to the west. Geographically Jima Arjo district is located between 8^0 33' to 8^0 55'N latitudes and 36^0 22' to 36^0 44'E longitudes and has a total area of 77,258 hectares (Figure 1). The elevation of the District ranges from 1500 to 2600 meters above sea level.

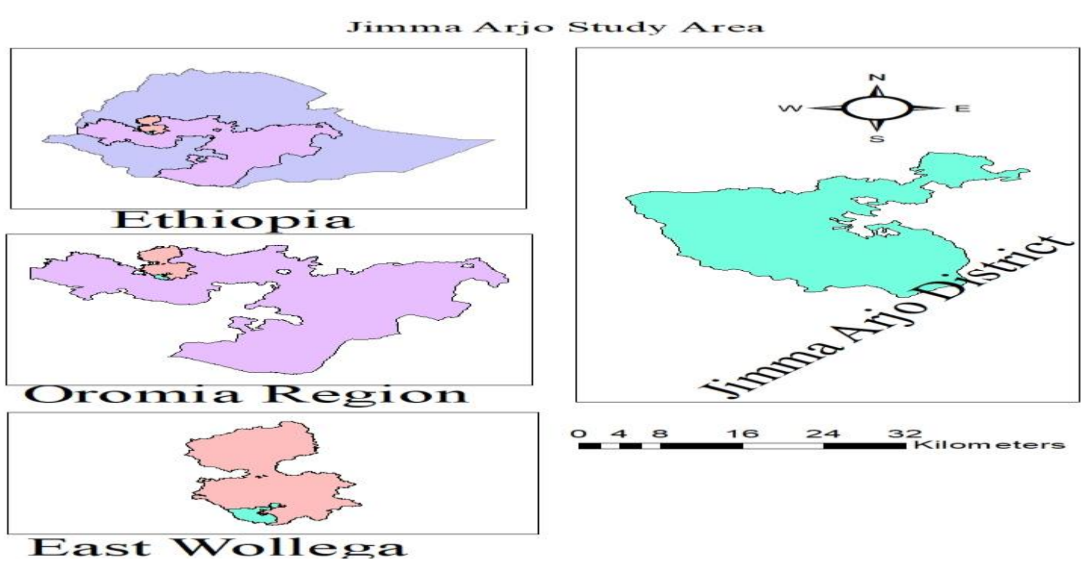


Figure 1: Location map of Jima Arjo district

Agro Climate, Soil Type, and Topography

According to the agro-climatic classification of Ethiopia by MoA and RDE *et al*., (2005), the study area can be grouped into three major physiographic units based on their elevation. The mean rainfall based on 19 years of record (2000 – 2018) at Nekemte Metrological agency is 1855.3 mm. April-September are months with high rainfall. The lowest mean monthly rainfall (14.1 mm) was recorded in the month of January while the highest 332 mm was recorded in August. Rainfall in the study area is unimodal with monthly rainfall rising steadily from March to a peak at August and then descending gradually to the month of December. Months from May to September are when the area receives more rain (76.3% of the total rain in the area). The temperature of the study area ranges from 10 ^{0}C to 23 ^{0}C. The average annual temperature is about 16 ^{0}C. The hottest and coldest months are March and July, respectively. The physical landscape of Jima Arjo is quite diversified. The major topographic features of the area are composed of hilly, flat to undulating rugged topography, plain, plateau and valley with altitude variation from 1264 to 2599 masl. Most areas of Didessa valley and foot slopes of Imbatu ridge have silty clay loam, gravely clay and sandy loam soils (Geremew *et al*., 1998). The area has 4 major soil classes based on FAO/UNESCO soil classification system. They are dystric nitisols, pellic vertisols, dystric gleysols and orthic acrisols. Agriculture is the dominant sector and biggest employer of the economically active population in the District (more than 88% of the total population). The farming system in the District is a mixed agriculture type (grain crop and livestock production).

Experimental Design and Procedures

The study was conducted in 2020/21 and 2021/22consecutive years during the main cropping seasons at Jima Arjo district, East Wollega Zone, Oromia region. Jima Arjo district was selected for the implementation of the trial due to its potential for bread wheat production. The study was conducted on ten experimental sites/farmers' fields across the district. Those fields were selected based on farmers' willingness to provide land for the experimental purpose, initial phosphorous soil test value, best performing farmers in bread wheat production and accessibility to the road. Composite soil samples before planting were collected from all experimental sites. Important soil chemical analysis for available phosphorus, pH, and exchangeable acidity were done.

Experimental Materials, Treatments, and Design

The experiment design was a randomized complete block design (RCBD) with three replications. The plot size was 4m by 3m with 20cm inter row spacing. The spacing between blocks and plots of the experiments was 1m and 0.5m, respectively. The treatments consist of 100% Pc from DAP and recommended N fertilizer and 100, 75, 50 and 25% Pc from NPS fertilizer with recommended N fertilizer and control (no fertilizer application). Bread wheat variety of *kakaba* was with a rate of 150 kg ha^{-1}.

Data Collection

Agronomic data like Grain yield, Biomass yield, Plant height, Spike Length and Number of seeds per spike were collected. Harvesting was done at physiological maturity. Grain yields were measured based on plant samples taken from five central rows (0.8m * 3m = 2.4 m^2) at full maturity stage. Grain yield recorded on plot basis was converted to kg ha^{-1} for statistical analysis.

Economic Analysis

The average open market price (Birr kg^{-1}) for bread wheat during the harvesting time and the official prices of fertilizers were used for economic analysis. The dominance analysis procedure as detailed in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The selected and discarded treatments using this technique are referred to as un dominated and Dominated' treatments respectively. For each pair of ranked treatments, a marginal rate of return (MRR %) was calculated. The % MRR between any pair of undominated treatments denotes the return per unit of investment in fertilizer expressed as a percentage. Grain yield was adjusted down by 10% in order to minimize the effect of trial managed on small plots that may vary from the yield level on farmer's fields. The optimum level of blended NPS fertilizer rate was determined for bread wheat production in the district.

$$MRR(\%) = \frac{\mathbf{\Delta NB(NBb-NBa)}}{\mathbf{\Delta TCV(TCVb-TCVa)}}$$

Where NBa = NB with the immediate lower TCV, NBb = NB with the next higher TCV, TCVa = the immediate lower TCV and TCVb = the next highest TCV

Data Analysis: All data recorded and collected were subjected to the procedure of analysis of variance (ANOVA) using SAS software program. The comparisons among treatment means were employed by using of Least Significance Difference (LSD) at 5% significant level.

Results and Discussions

Soil Reaction and Available Phosphorus

The soil pH (H_2O) of the study area was very strongly acidic to moderately medium acidic with the value ranged from 4.88 to 5.67 according to the ratings suggested by chude *et al*, (2005). Thus; the pH of the experimental soil was within the range for productive soils. The available phosphorus content of soils. Available phosphorus level of experimental soil in the district ranged from 2.48 to 11.38 ppm (Table1 below). According to Cottenie (1980) rating, available soil P level of the study sites were ranged from very low (<5 ppm) to medium (10-17 ppm). Tekalign and Haque (1987) and Dawit *et al.* (2002) reported that availability of P in most soils of Ethiopia decline by the impacts of fixation as a result of low pH. In order to increase bioavailability of P in such soil, increase in soil pH is the best management option to minimize fixation by Fe and Al. Exchangeable acidity (EA) indicates the presence of excess Al^{3+} and H^{+} ion on the soil colloid as compared to total cation exchange capacity of the soil. The soil analysis results showed that the concentration of exchangeable acidity before planting of the experimental sites were ranged from 0.44 to 0.94cmol (+) kg^{-1}.Thus, according to Daryl D (1983) rating, the exchangeable acidity of soil of the experimental sites were very low (< 4.5 cmol (+) kg^{-1}) (Table 1).

Table 1. Selected experimental soil properties before planting in Jima Arjo District

Sites	PH (H_2O)	Av. P (ppm)	Ex. Acidity (cmol(+)/kg)
1	5.37	3.38	0.53
2	5.67	8.46	0.47
3	4.91	8.54	0.94
4	4.89	8.5	0.68
5	4.88	10.46	0.90
6	5.43	3.1	0.45
7	4.94	2.48	0.93
8	5.14	11.38	0.78
9	5.58	1.85	0.91
10	5.37	4.33	0.44

Responses of Yield and Yield Related Parameters of Bread Wheat to the Treatments

Analysis of variance (ANOVA) revealed that plant height, biomass yield and grain yield were highly and significantly affected by NPS fertilizer rate. However, spike length and number of seeds per spike of the crop did not significantly ($P<0.05$) influenced by the treatments. The highest (90.71 cm) plant height, biomass yield (10861.8kg/ha) and grain yield (3888.9kg/ha) were recorded from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen. While the lowest (82.09 cm, 7250.0 kg/ha and 2731.5 kg/ha respectively) were recorded from control (without fertilizer) (Table 2 below). The result showed that most of recorded parameters increased with an increase of NPS fertilizer rate application. The highest grain yield (3888.9 kg/ha) recorded from the plot of 100% P-critical from blended NPS fertilizer rate supplemented with recommended Nitrogen did not statistically significant from the grain yield obtained from the application of 50% and 75% phosphorus critical level with recommended Nitrogen.

The increment in those parameters might be due to increase in cell elongation, improved root growth and better growth which enhanced yield components and yield of crops. Different nutrient content of fertilizer containing NPS and the increasing of sulfur content caused a significant increase in wheat root and shoot growth as well as nutrient uptake. This result is in lined with different authors' like Abebaw and Hirpa, 2018; Bizuwork. 2018;Diriba *et al.*, 2019; Doberman, A. and Fairhurst, 2000; Melesse. 2017 and Tilahun and Tamado T. 2019) results.

Table 2 . Treatment influences on mean grain yields and selected yield related traits of bread wheat in J/Arjo District for 2020/21 and 2021/22 cropping season.

Treatments	Yield and yield related parameters				
	PH(cm)	**SL(cm)**	**SPS (No)**	**BY(kg/ha)**	**GY(kg/h)**
Control (without fertilizers)	82.09^{b}	6.32	35.19	7250.0^{c}	2731.5^{b}
25% of Pc from NPS + Rec. N	90.33^{a}	7.71	36.68	9322.8^{ab}	3170.5^{b}
50% of Pc from NPS + Rec. N	90.13^{a}	7.69	39.39	10400.5^{a}	3772.8^{a}
75% of Pc from NPS + Rec. N	93.32^{a}	7.83	39.55	10302.3^{ab}	3625.0^{a}
100% of Pc from NPS + Rec. N	90.71^{a}	7.98	38.90	10861.8^{a}	3888.9^{a}
100% of Pc from DAP + Rec. N	84.54^{b}	7.96	40.58	8829.4^{b}	3169.5^{b}
P value	0.0049	0.0785	0.3168	0.0031	0.0007
LSD(5%)	5.31	1.86	5.42	1567.1	439.07
CV(%)	3.37	10.05	7.94	9.28	7.28

Where PH = Plant height; SL = Spike length; SPS = Seeds per spike; BY = Biomass yield; GY = Grain yield; LSD = Least significance difference; CV = Coefficient; ** = highly and significantly different at $p \leq 0.01$ and NS = Not significant at $p \leq 0.05$.

Partial Budget Analysis

The partial budget analysis showed that the highest net income(79472.3 ETB ha^{-1}) with the marginal rate of return (MRR) (273.7%) was obtained from the fertilizer application of 50% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) (Table 3 below). Therefore, application of NPS fertilizer at the rate of 50% P-critical in NPS fertilizer with recommended nitrogen fertilizer (92 kg N ha^{-1})

for the production of bread wheat was more economically beneficial and recommended for Jima Arjo district.

Table 3 : Partial budget analysis for verification of bread wheat at Jima Arjo District.

Treatments (Values of NPS/ or TSP and Urea in kg/ha)	AGY (qt/ha)	GFB (birr/ha)	TVC (birr/ha)	NB (birr/ha)	MRR (%)
Control	24.6	73737.0	11060.6	62676.5	
25% of Pc from NPS + Rec. N (109 NPS+92 N)	28.5	85617.0	18049.2	67567.8	70.0
50% of Pc from NPS + Rec. N (218 NPS+92 N)	34.0	101871.0	22398.7	79472.3	273.7
75% of Pc from NPS + Rec. N (327 NPS+92 N)	32.6	97875.0	23710.7	74164.3	D
100% of Pc from NPS + Rec. N (436 NPS+92 N)	35.0	105030.0	26695.3	78334.7	139.7
100% of Pc from DAP + Rec. N (360 TSP+92 N)	28.5	85590.0	22469.8	63120.2	360.1

Where: qt = Quintal; ha = Hectare; AGY = Adjusted Grain Yield; GFB = Gross field benefit; TVC =Total variable cost; NB = Net benefit and MRR = Marginal rate of return. While the unit price of bread wheat at farm gate, urea, NPS and TS were30, 16.48, 17.54 and 17.60 birr/kg respectively.

Conclusion and Recommendation

The productivity of bread wheat is declining due to the depletion of soil fertility, low fertilizer uses and insufficient organic matter incorporation. Soil test crop response based fertilizer rate recommendation has been conducted across the country. However, fertilizer trials involving multi-nutrient NPS fertilizer were not conducted in many areas. Therefore, for increasing bread wheat production and productivity it need calibration of NPS fertilizer rate based on soil test crop response based. The study was conducted to determine economically optimum NPS fertilizer rate based on phosphorus calibration study done previously for bread wheat production in Jima Arjo District. Plant height, grain yield and biomass yield of the test crop were highly and significantly (<0.01) influenced by NPS fertilizer rate application.

The highest grain yield (3888.9 kg ha^{-1}) of bread wheat was obtained from the application 100% of phosphorus critical level from NPS with recommended nitrogen (92 kg ha^{-1}). But it did not statistically significant from the grain yield obtained from the application of 50% and 75% phosphorus critical level with recommended Nitrogen. Partial budget analysis has shown a variation among the treatments and depicted that, application of NPS fertilizer at the rate of 50% Phosphorus critical level from NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of bread wheat was more economically beneficial. Based on the results of both agronomic data and partial budget analysis, 50% of Phosphorus critical level from NPS plus recommended nitrogen fertilizer was chosen as the best and led to the optimum yield and maximum net benefit for bread wheat production in Jima Arjo District. Therefore, Demonstrating of the technology for wider popularization should be followed up.

References

Takale, C., Chimdessa, T., Bayata, G., Fikadu, O., & Regasa, C. (2021). Soil Test Crop Response Based Phosphorous Calibration Study for Bread Wheat (Triticum Aestivum L.) in Jimma Arjo District, East Wollega Zone of Western Oromia, Ethiopia. In *Regional Review Workshop on Completed Research Activities* (p. 79).

CIMMYT (International Maize and Wheat Improvement Center), *An Economic Training Manual: From Agronomic Data Recordation*, CYMMT, Mexico City, MX, USA, 1988.

CSA (Central Statistical Agency), "Agricultural sample survey report on area and production of major crops for private peasant holdings, Maher season," *Statistical Bulletin 584*, Vol. I, CSA (Central Statistical Agency), Addis Ababa, Ethiopia, 2020.

Chude, V. O., Jayeoba, O. J., & Oyebanji, O. O. (2005). *Handbook on soil acidity and use of agricultural lime in crop production*. Soil Fertility Initiative (SFI), National Special Programme for Food Security (NSPFS) and Food and Agriculture Organization of the United Nations (FAO).

Solomon, D., Lehmann, J., Mamo, T., Fritzsche, F., & Zech, W. (2002). Phosphorus forms and dynamics as influenced by land use changes in the sub-humid Ethiopian highlands. *Geoderma*, *105*(1-2), 21-48.

Demeke, M., & Di Marcantonio, F. (2019). Analysis of incentives and disincentives for wheat in Ethiopia. *Gates Open Res*, *3*(419), 419.

East Wollega Zone Agricultural Development Office (EWZADO). (2022). Annual Report for theyear 2021-2022. (unpublished report). Jima Arjo District Agricultural Development Office. Nekemt, Ethiopia.

Ethio-SIS (Ethiopian Soil Information System), *Soil Analysis Report Agricultural Transformation Agency*, EthioSIS (Ethiopian Soil Information System), Addis Abeba, Ethiopia, 2014.

Giorgis, K. (2015). Dryland agriculture production systems in Ethiopia.

Habtamu, A., Heluf, G., Bobe, B., & Enyew, A. (2014). Fertility status of soils under different land uses atWujiraba Watershed, North-Western Highlands of Ethiopia. *Agriculture, Forestry and Fisheries*, *3*(5), 410-419.

Habte, M., Gebrekidan, H., & Haile, W. (2013). Decomposition and nutrient release of selected green manure species at different stages of growth on Alisols at Areka, southern Ethiopia. *International Journal of Natural Sciences Research*, *1*(5), 30-42.

Jima Arjo District Agricultural Development Office (JADADO). 2022. Annual Report for the year 2021-2022. (unpublished report). Jima Arjo District Agricultural Development Office. Arjo, Ethiopia.

Laekemariam, F. (2015). Soil spatial variability analysis, fertility mapping and soil plant nutrient relations in Wolaita zone, Southern Ethiopia. *Haramaya University Ethiopia*.

Ray, D. K., Mueller, N. D., West, P. C., & Foley, J. A. (2013). Yield trends are insufficient to double global crop production by 2050. *PloS one*, *8*(6), e66428.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., ... & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *science*, *347*(6223), 1259855.

Mamo, T., & Haque, I. (1987). Phosphorus status of some Ethiopian soils. *Plant and soil*, *102*(2), 261-266.

Verification of Soil Test Crop Response Based Phosphorous Calibration Study for Maize (Zea mays L. at Abay Choman District, Western Oromia Region

Chalsissa Takele, Temesgen Chimdessa, Mintesinot Desalegn, Firaol Gemeda, Amanuel Tadesse and Olifan Fikadu

Oromia Agricultural Research Institute, Nekemte Soil Research Center P.O. Box 587, Nekemte

*Corresponding Author Email: chalsissat@gmail.com

Abstract

A major challenge is recommendations on the amount and type of fertilizers to be applied at the country level and in the study area. As a result, farmers are using blanket fertilizer recommendations which are not recommended based on soil fertility status and crop nutrient requirements, to alleviate this problem the soil test based crop response fertilizer calibration trail in Abay Choman District determined optimum N (92 kg/ ha) rate to be applied and Pc (12 ppm) and Pf (10.55 for maize production. Verification of soil test crop response based on calibrated phosphorous for maize was conducted in Abay Choman District, Oromia in the 2021 cropping season. The study aimed to verify the recommended nitrogen fertilizer (92 kg N ha-1), P-critical level (12 ppm) and P- requirement factor (10.55) for maize during soil test crop response based phosphorus calibration study in the district. The trial was conducted on four (4) farmer's fields across the District for one year (2021/2022 cropping season). The treatments included three fertilizer rates: control (no fertilizer), blanket fertilizer recommendation, and soil test based recommendation. Before planting, composite soil samples were obtained and evaluated for the selected attributes. Agronomic data analysis and economic feasibility of treatments utilizing partial budget analysis were carried out. The available P of the sites ranged from 4.58 to 9.93. Which is less than PC this demonstrates the importance of the external application of phosphorus fertilizer sources for good crop growth and output. The maximum mean grain yield (7622.8 kg/ha) was obtained from soil test crop response-based fertilizer recommendation, while the lowest (2912.7 kg/ha) was obtained from the control plot. The economic analysis revealed that soil test-based suggested fertilizer rates with appropriate (>100%) MRR produced the maximum net income (107825.1 ETB). Soil test crop response-based fertilizer application in Abay Choman District was validated as capable of producing consistently high grain yields while remaining economically viable for maize farming. It was critical to boosting crop production while also enhancing the income of small-scale farmers in the research area. As a result, it should be popularized more broadly through Pre-extension demonstrations in Abay Choman District.

Key Words: Verification, P-critical, *P- requirement factor*, recommended rate,

Introduction

Phosphorus (P) is the most important nutritional element (after nitrogen) limiting agricultural production in most parts of the world. It is particularly chemically reactive, and over 170 phosphate minerals have been found. In all of its natural forms, only a very small amount exists in the soil solution at any given time. Plant roots absorb P from the soil solution as phosphate, primarily in the form of $H_2PO^-_4$ from soil solution (Vance, *et al.*, 2003). The concentration of P in soil solution gives useful information regarding P nutrition because concentration gradients drive the flow of P to the roots and its uptake by roots is likewise concentration dependent. Plant-available P can be analyzed quantitatively or intensively. The amount of accessible P varies according to time and crop.

Maize is one of the most important cereals in productivity and second in area coverage after teff in Ethiopia, Research results in high potential maize growing areas are high. However, yield levels obtained by small scale farmers remained stagnant despite the availability of improved varieties even in high maize growing potential areas of western Oromia. In addition, declining of soil fertility and crop yields are the major problems experienced by farmers in the western part of Oromia where maize is the first both in area coverage and in production than other cereals. Soil fertility and plant nutrition are two closely related subjects that emphasize on the forms and availability of nutrients in soils, their mobility, uptake by plant roots, and the utilization of nutrients within plants (Henry *et al*, 1997 and Dagne, 2016). The secret of ensuring food security for the ever-increasing world population is strongly linked to the productivity of soils (Wakene, 2004). Crop plants are living indicators of the status of the overall soil physical, chemical, and biological environment. Hence reduced soil productivity is an indication of soil fertility decline.

Now day declining soil fertility is a major constraint on crop production in the Region. Farmers are either entirely abandoning the traditional practice of using natural fallow to restore soil fertility, or are unable to leave land fallow for long enough for it to be effective (Corbeels *et al*., 2000). Due to this, farmers are intending to find other options for mitigating continuous decline of soil fertility status for crop production. This is why the popularization of urea and DAP (Diammonium Phosphate) fertilizers is increasing from time to time through extension programs. However, there is a major challenge in recommendations on the amount and type of fertilizers to be applied for most crops and soil types. As a result, farmers are using blanket type fertilizer recommendations (that forced them either to use an excess or low amount of these inputs), which are not recommended based on soil fertility status and crop nutrient requirements.

To alleviate this problem Nekemte Soil Research Center took a soil test-based crop response fertilizer calibration trail in District on maize and determined the optimum nitrogen to be applied based on P critical and P requirement factors. But to ensure confidence in our recommendations these determined values should be verified for grain yield and economic feasibility as compared to blanket recommendation and control. Therefore, to have confidential technology dissemination to end users, economic visibility and acceptance of the technology, The Nekemte soil research center decided to verify it in the same area to achieve the following objectives.

Objectives

- To verify P critical level and P requirement factors value on recommended P fertilizer rate and optimum N for maize in Abay Choman District.
- To compare P recommended rate and blanket fertilizer recommendation in Abay choman District.

Materials and Methods

Description of the Study Area

Abay Chomen District is found in the Oromia region, Ethiopia, containing 19 kebeles, located at 9° 31’ 42” to 9° 59’ 48” N latitude and 37° 10’ 03” to 37° 28’ 44” E longitude and the capital of the district Fincha town is 289 km northwest of Finfinnee. The area receives high rainfall in one season of the year. The total area of the District is estimated to be 801.7 km^2; approximately 45, 37, 4, 3 and 11% of the total area are cultivated land, non-cultivated, water bodies, settlements and woodlands and forests, respectively (Tegbaru, 2014).

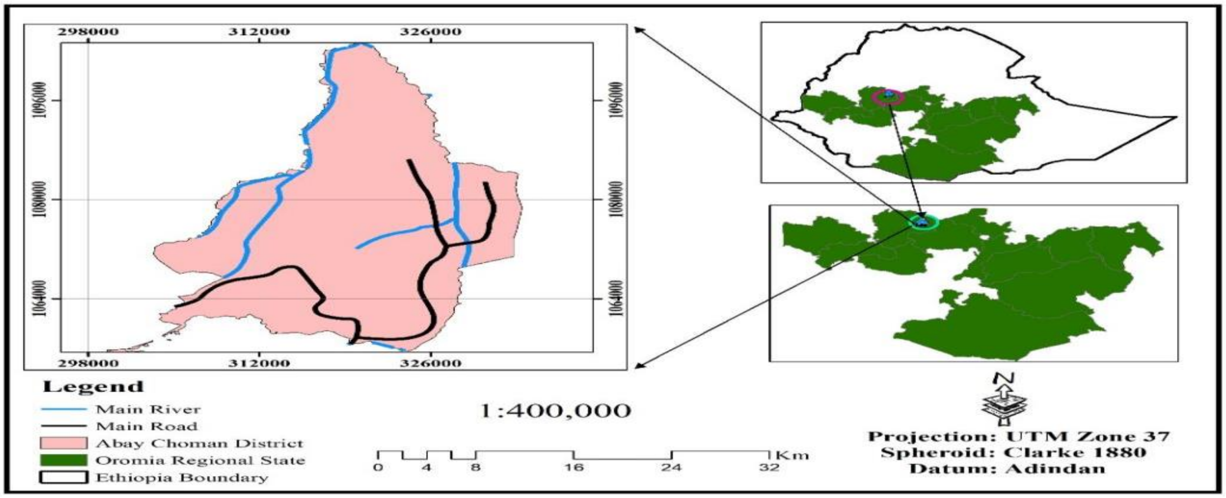


Figure 1: Location map of Abay Choman District, Oromia, Ethiopia

Treatments and Experimental Design

Four farmers were selected purposely based on their willingness, wealth and initial soil P-value. As much emphasis as, possible was placed on gender and youth. Based on this, the experiment was carried out on four different farmer's fields. The calibration research used an improved maize variety (BH-661). The experimental plot was prepared and plowed following farmers' standard agricultural practices. As a result, the field was only plowed three times with oxen-drawn implements. The treatment under consideration was computed using the following formula: P (kg/ha) = (P critical - P initial)*Pf. The recommended critical phosphorus was compared to a blanket fertilizer recommendation and the control. The optimum N (92 kg/ha) found during the calibration investigation was evenly applied to all treatments studied and was applied in the form of urea in two splits (1/3 at planting and 2/3 three weeks after planting). The plot size was 10 m × 10 m, with plots within a block divided by 0.5 m and blocks separated by 1 m.The experimental design was simple arrangement of treatments and replicated three times. The treatment arrangements are as follows. Plot size was 10 m x 10 m and there was 1m between blocks and 0.5m between plots.

Control (P0) = T1
Blanket fertilizer Recommendation = T2
Soil test based fertilizer recommendation = T3

Data collection and analysis

Before planting/fertilizer application, composite soil samples were obtained at random from each field in a zigzag pattern from 0 to 20 cm depth using an auger. The composite soil sample was air dried before being pulverized using a pestle and mortar and passing through a 2mm sieve size for chemical analysis. The Olsen method was used to determine the amount of phosphorus in the soil. Soil response (Soil pH) was measured using a bench pH meter at a soil to water ratio of 1:2.

The grain data and biomass yield of the crops were collected. Grain yield, biomass yield, plant height, spike length and number of seeds per spike were collected on the plot bases and analyzed. The treatments' economic feasibility was investigated using economic analysis. We employed partial budget, dominance, marginal, and sensitivity analyses. The average yield was reduced to account for the difference in yield between the experimental plot yield and the yield farmers may expect from the same treatment. For the analysis, the average open market price (Birr kg^{-1}) for various crops and the official fertilizer prices were employed. The minimum acceptable rate of return (MARR) for a therapy to be regarded a desirable alternative for farmers is 100% (CIMMT, 1988), which is indicated to be reasonable. This will allow for farmer recommendations based on marginal analysis. The EXCEL computer software was used to manage all agronomic and soil data that was collected. The data obtained from the experiment were analyzed using one way analysis of variance (ANOVA) with SAS software version 9.1 Windows. The Least significance difference test (LSD) was employed to test the significant difference between treatment means.

Result and Discussion

Soil Reaction and Available Phosphorus

According to Table 1, the soil reaction of the experimental locations prior to planting ranged from 4.75 to 5.75 (Bruce and Rayment, 1982). As a result, the soils became very to extremely acidic. According to FAO (2000), the ideal pH values for most crops and fertile soils are 4 to 8. Furthermore, according to Karltun *et al.* (2013) evaluations, all of the locations contained relatively low available P (4.58-9.93ppm). This could be due to P fixation in acid soils. Furthermore, the availability of P in most Ethiopian soils is steadily decreasing due to the effects of plentiful agricultural harvest, land management techniques, and soil erosion (Chimdessa and Takale, 2020; Dawit *et al.*, 2002; Birhanu *et al.*, 2016; Bereket *et al.*, 2018). The variation in available P content of the locations could be attributable to changes in acidity strength, organic matter content, rocks, and the quantity of residual P-fertilizers detected in the soils.

Table 1. Initial available soil phosphorus and soil pH of experimental sites

Experiment Sites	pH(H 2O)	Available P(ppm)
1	5.44	9.93
2	4.75	6.90
3	5.07	5.73
4	5.22	4.58

Plant Height, Seed per Cob and Grain Yield

Maize grain yield differed significantly ($P<0.05$) between treatments. The highest mean grain yield (7622.8 ha^{-1}) was obtained from the application of soil test crop response based phosphorus fertilizer recommendation, while the lowest (2912.7 ha^{-1}) was obtained from the control plot (Table 2).Soil test crop response based fertilizer recommendation gave 24% higher yield advantage than blanket (farmer's practices) fertilizers application.

The result revealed that plant height and seed per cob affected by application soil test crop response based fertilizer application. The effect of fertilizer showed that the highest plant height (279.75cm) was recorded from soil test crop response based fertilizer application with recommended N fertilizer rate (Table 2). The lowest seed per cob was obtained from the control (without application of fertilizer) (Table 2).

Table 2. Response of maize grain yield and yield related parameters to the treatments in Abay Choman District

Treatments	Plant height(cm)	Cob Length(cm)	Seed per cob(no)	Grain yield(kg/h)
Control/without fertilizer	246.3b	16.3b	436.5b	2912.7[c]
Blanket recommendation	272.2a	19.8a	514.6a	6144.1[b]
Soil Test based recommendation	279.7a	20.3a	525.89	7622.8[a]
P value	0.0321	0.0009	0.0012	<0.0001
LSD (5%)	23.933	1.425	33.768	820.49
CV (%)	4.502	3.801	3.4328	7.38

Partial Budget Analysis

Partial budget analysis is necessary to discover experimental treatments that provide the best return on investment for farmers and to generate recommendations based on agronomic data. Experimental yields are frequently larger than yields that farmers may expect using the same treatments; thus, in economic calculations, farmer yields are adjusted by 10% less than research yields (CIMMYT, 1998). According to Table 3, the economic analysis showed that the highest net income (**107,825.1** ETB) was obtained from soil test based recommended fertilizer rates with acceptable (>100).

$$MRR(\%) = \frac{\Delta NB(NBb-NBa)}{\Delta TCV(TCVb-TCVa)}$$

Table 3: Partial budget analysis for verification of STBFR for maize at Abay Choman

Treatments	AGY (qt/ha)	GFB (ETB/ha)	TVC (birr/ha)	NB (birr/ha)	MRR (%)
Control (Without fertilizer) (0 urea +0 TSP)	26.2	52428.6	7864.3	44564.3	
BFR (100kg/ha urea+ 100 kg/ha TSP)	55.2	110395.8	19960.4	90435.4	379.2
STBFR (200 kg/ha urea+ 318 kg/ha TSP)	68.6	137210.4	29385.3	107825.1	184.5

Where: qt = Quintal; ha = Hectare; GY = Grain yield; AGY = Adjusted Grain Yield; GFB = Gross field benefit; TVC =Total variable cost; NB = Net benefit and MRR = Marginal rate of return, BFR = Blanket fertilizer recommendation and STBFR =Soil test based fertilizer recommendation. Also while the unit price of maize, Urea and TSP were 20, 16.48 and 17.53 birr/kg respectively

Conclusion and Recommendation

Soil test based fertilizer recommendation is very important to maintain soil productivity and increase crop yield. Accordingly, verified P-critical level, P requirement factor and N signified the economic benefit of recommended soil test crop response based calibrated phosphorus for maize in Abay Choman District. Soil test crop response based fertilizer application in Abay Choman District was verified as it can gave consistently high grain yield and economically feasible for Maize production. This study show that the highest mean grain yield 7622.8 ha^{-1} was obtained from the application of soil test based phosphorus fertilizer recommendation, while the lowest 2912.7 ha^{-1} was obtained from the control plot. The highest net income (**107,825.1** ETB) was obtained from soil test based recommended fertilizer rates. It was paramount to increase the crop production with improving the income of small scale farmers of study area. Soil test crop response based phosphorus calibration based on agronomic and economically feasible for maize at P-critical level (12 ppm) and P- requirement factor (10.55) and optimum Nitrogen 92 kg ha^{-1}) were recommended for maize production in Abay Choman district. Therefore, it could be recommended further wider popularized through Pre-extension and demonstration the soil test based phosphorus fertilizer recommendation on maize production in Abay Choman District.

Acknowledgement

First and foremost, we would want to express our gratitude to Almighty God for providing us with important gifts of health, strength, patience, and protection in order for us to begin and complete our study. Second, the authors would like to express their gratitude to IQQO for financial assistance and the Nekemte Soil Research Center for providing all of the essential facilities for the activity. Last but not least, we would like to express our heartfelt gratitude to Abay Choman District Agricultural Office experts, DAs, and participating farmers for their active participation in this study.

References

Ayenew, B., Tadesse, A. M., Kibret, K., & Melese, A. (2018). Phosphorous status and adsorption characteristics of acid soils from Cheha and Dinsho districts, southern highlands of Ethiopia. *Environmental Systems Research*, *7*(1), 1-14.

Birhanu, I., Muktar, M., & Kibebew, K. (2016). Impact of deforestation and subsequent cultivation on soil fertility in Komto, Western Ethiopia. *Journal of Soil Science and Environmental Management*, *7*(12), 212-221.

CIMMYT (International Maize and Wheat Improvement Center). 1998. from agronomic data to farmer recommendations*: An economic workbook*. CIMMYT, Mexico.

FAO (Food and Agriculture Organization), 2000. *Fertilizers and their use 4th ed*. International fertilizer industry association, FAO, Rome, Italy.

Karltun, E., Lemenih, M., & Tolera, M. (2013). Comparing farmers' perception of Soil fertility change with soil properties and crop performance in Beseku, Ethiopia. *Land Degradation & Development*, *24*(3), 228-235.

Chimdessa, T., & Takele, C. (2020). Verification of Soil Test Based Phosphorous Calibration Study for Bread Wheat (Triticum Aestivum L.) Production in Horo District, Oromia Regional State, Ethiopia. *Advances in Biochemistry*, *8*(3), 52.

Vance, C. P., Uhde-Stone, C., & Allan, D. L. (2003). Phosphorus acquisition and use: critical adaptations by plants for securing a nonrenewable resource. *New phytologist*, *157*(3), 423-447.

Verification of Soil Test Crop Response Based Phosphorous Calibration Study for Maize (Zea mays L.) at Sibu Sire District, Western Oromia Region

Temesgen Chimdessa*, Chalsissa Takale, Obsa Aga, Nafirom Negassa, Firaol Gemada, Olifan Fikadu and Amanuel Taddesse.
Nekemte Soil Research Center P.O. Box 587, Nekemte
*Corresponding Author Email: temesgenchimdessa468@gmail.com

Abstract
Nitrogen and phosphorus fertilizers are the major limiting factors in most Ethiopian soils. Phosphorus calibration experiments were conducted at Sibu Sire District for phosphorus fertilizer recommendation on maize. From the experiment, critical concentration and requirement factor of Phosphorus fertilizer were developed. Economically optimum N (138 kg/ha), critical level phosphorus (10 ppm), and phosphorus requirement factor (20.63 kg/ha) for maize production in the district were gained and recommended during the calibration study. These P critical and P requirement factor were verified in the same area on five (5) farmer's fields by the year 2021/22 cropping season. The treatments were Control (without fertilizer), blanket recommendation (46 kg N ha^{-1}, 46 kg P2O5 ha^{-1}) and soil test crop response based phosphorus fertilizer recommendation. The Plot size was 10 m * 10 m. Improved Maize *Limu* was used for the trial. Soil data before planting and yield data were collected throughout the trial. Soil reaction pH (H2O) of all the sites ranged from 4.80 to 5.78 and available P ranges from 2.1 to 9.9 ppm. Soil acidity of the experimental sites was amended with lime. The result of Soil test based phosphorus fertilizer recommendation rate (STCRB) on maize shows that higher yield as compared to blanket fertilizer recommendation. Plant height, cob length, number of seeds per cob and grain yield of the maize were significantly ($p< 0.05$) affected by different fertilizer rates used as treatments. The highest grain yield (6875.3 kg/ha) has resulted in soil test crop response based on phosphorus fertilizer rate recommendation. It was significantly higher than the grain yield gained from the farmers' practice (5646.4 kg/ha) and control/without fertilizer (2931.3 kg/ha). Similarly, soil test crop response based phosphorus fertilizer rate recommendation was economically feasible for maize production that higher net benefit (96,388.3ETB birr per hectare) could gain. Therefore, it should be wider popularized through demonstration.

Keywords: Calibration, Fertilizer, Maize, Recommendation and Soil test

Introduction

Maize (*Zea mays* L.) is an important cereal crop growing across all the agro-ecological zones in Ethiopia as well as in the world. Considering its importance in terms of having wider adaptation, higher total production and higher productivity, compared to other crops, maize has been selected as one of the high priority crops to feed the ever increasing human population of Ethiopia. Maize yields under farmers' conditions in Oromia region average 3.38 t ha^{-1} or less than 62% of the potential yield of 5.5 t ha^{-1} underrain fed conditions (CSA, 2020). Many authors have identified different limiting factors of maize production in the world; among which are, frequent droughts; the inherently poor soils (Arije, D.N. *et al,* 2018). Practices (especially planting densities and dates) coupled with low use of improved inputs such as fertilizers and seeds; especially in high rainfall belt (Badu-Apraku *et al.*, 2009).

The low soil fertility is due to increasing pressure on land because of an increase in the human population in Ethiopia. This farming system results in soil nutrient deficiency, particularly for the essential soil nutrients; Nitrogen (N) and Phosphorus (P) (Bationo, A. *et al.*, 2003).Declining of soil fertility and crop yields are the major problems experienced by farmers in western part of Oromia where maize is the first both in area coverage and in production than other cereals. Phosphorus is one of the seventeen essential nutrients required for plant growth (Ragothama, 1999). Phosphorus is a non-renewable resource found naturally at high concentrations in some minerals as well as in manures, the latter being the most economically exploitable sources of P. Due to its many uses, P is in high demand globally and the fact that the many functions it performs cannot be substituted by any other element; makes its purported declining availability so serious. As a result, there is substantial global interest in minimizing P losses from land application and the overuse of P fertilizers, i.e., applications above crop requirements that do not increase crop productivity (Dodd and Mallarino, 2005).

Farmers are either entirely abandoning the traditional practice of using natural fallow to restore soil fertility, or are unable to leave land fallow for long enough for it to be effective (Corbeels *et al.,* 2000). Due to this, farmers are intending to find other options for mitigating continuous decline of soil fertility status for crop production. This is why the popularization of urea and DAP (Diammonium Phosphate) fertilizers are increasing from time to time through the extension programs.

Phosphorus calibration is a means of establishing a relationship between a given soil test value and the yield response from adding nutrient to the soil as fertilizer. It provides information how much nutrient should be applied at a particular soil test value to optimize crop growth without excessive waste and confirm the validity of current P recommendations (Agegnehu,. and Lakew, 2013 and Agegnehu, G *et al*., 2015). They enable to revise fertilizer recommendations for an area based on soil and crop type, pH and soil moisture content at time of planting. An accurate soil test interpretation requires knowledge of the relationship between the amount of a nutrient extracted by a given soil test and the amount of plant nutrients that should be added to achieve optimum yield for a particular crop (Muir, and Hedge, 2002). Soil tests are designed to help farmers predict the available nutrient status of their soils.

Nekemte Soil Research Center under taken soil test crop response based phosphorus calibration study in Sibu Sire on maize and determined P critical and P-requirement factors and as well as optimum nitrogen to be applied. But to ensure confidence in our recommendations these determined values should be verified for grain yield and economic feasibility as compared to blanket recommendation and control. Therefore, to have confidential on technology dissemination to end users, the economic visibility and acceptance of the technology, we decided to verify it at the same area to achieve the following objectives.

Objectives

- To verify P critical level and P requirement factors value on recommended P fertilizer rate and optimum N for maize in Sibu Sire District.
- To compare P recommended rate and blanket fertilizer recommendation in Sibu Sire District.

Materials and Methods

Description of the Study Area

Location

The study area, Sibu Sire District, is located about 270 km west of the capital city of Ethiopia, Addis Ababa. It lies between 8°56' to 9°23'N latitudes and 36°35' to 36°56' E longitudes and the study area (Figure 1).

The altitude of the District varies from 1336 to 2500 meters above sea level. It has an estimated area of 1,132.51 km. About 74.2% of its surface area belongs to Mid-altitude.7.53% of the land is highland agro climate and the remaining 18.27% is classified as low land agro climate. The mean annual temperature and mean annual rain fall is 250 ^{O}C and 1050 mm, respectively Ngigi (2003).

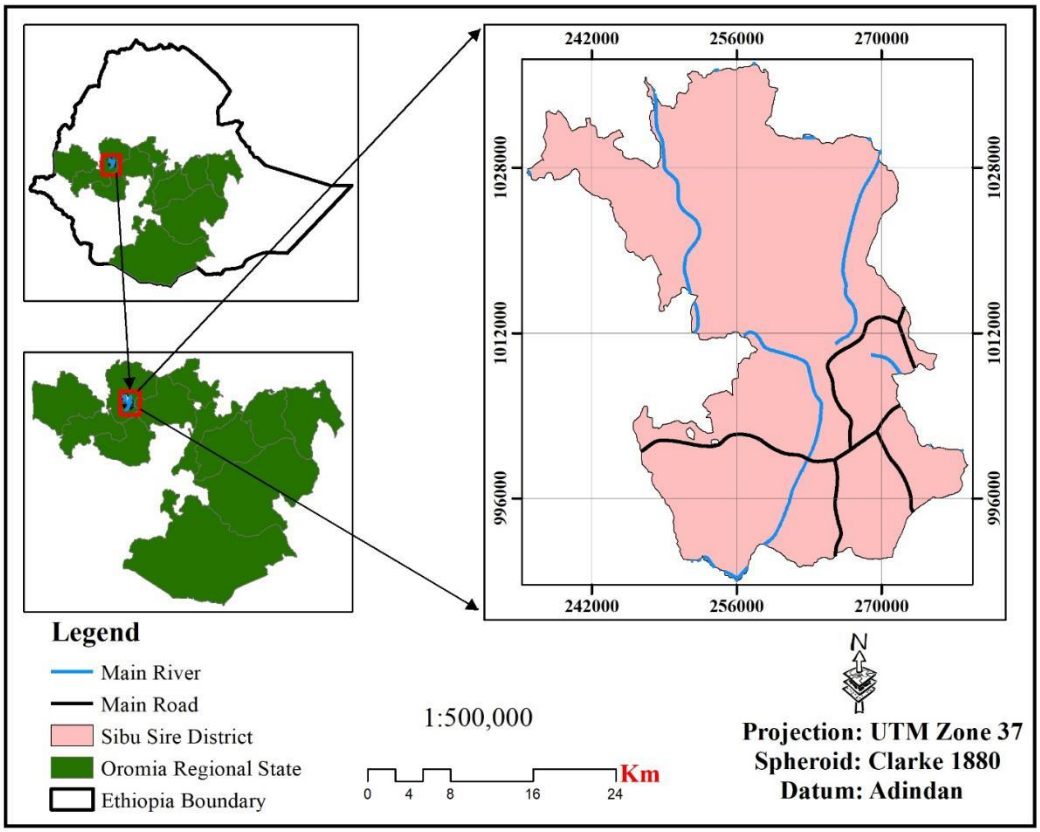


Figure 1: Location map of the study area

The terrain is generally undulating to rolling plains. The major soil types are generally described as Nitisols according to FAO soil classification system (FAO, 1986). This soil is characterized as deep, well-drained, red, tropical soils with diffuse horizon boundaries and a clay-rich nitic subsurface horizon (Quantin P.*et al*., 2001). In general this soil is highly weathered, well drained, clay in texture and strongly to moderately acidic in reaction (Mesfin, 1998). The major annual and perennial crops grown in the study area are maize (Zea mays L.), sorghum (Sorghum bicolor L.), teff (Eragrostis tef), hot pepper (Capsicum frutescence L.), sweet potato (Ipomoea batatas L.), coffee (Coffe arabica L.), and sugarcane (Saccharum officinarum L.) (Negassa *et al.2015).*

Treatments and Procedures

The trial was done on nine farmers' field that selected purposely based on their willing, wealthy and initial soil value. But the agronomic data were summarized from only five (5) sites while the before planting soil data were analyzed and expressed. Because after the time of plantation; security problem situated around four experimental sites. So, it could not properly manage, supervised, monitored and harvested. Improved maize variety ("*Limu"*) was used as the test crop.The experimental plots were plowed and prepared

according to farmers' conventional farming practice. Accordingly, the fields were plowed three times exclusively using oxen-drawn implements. The soil test crop response based fertilizer considered as the treatment was calculated according to P (kg/ha) = (P critical – P initial)*Pf.This recommendation was compared with *blanket recommendation and control*. The optimum N (92 kg/ha) determined during the calibration study was used. The plot size was 10 m x 10 m while plots within a block and blocks were separated by 0.5 m and 1 m a path respectively. The experimental design was simple arrangement of treatments and replicated three times. The treatment arrangements are as follows. Nitrogen was applied in the form of urea in two splits (1/3 at planting and 2/3 at three weeks after planting).
Control (C) = T1
Blanket recommendation = T2
Soil test based fertilizer recommendation (RR) = T3

Data collection and analysis
Agronomic parameters to be collected: All necessary yield, and yield components of maize were collected. All collected agronomic and soil data were properly managed using the EXCEL computer and subjected to the analysis of variance using the SAS software (SAS , 9.0 version).

Partial Budget Analysis
For a treatment to be considered as worthwhile to farmers (100% marginal rate of return (MRR)) was considered as the minimum acceptable rate of return (CIMMYT, 1988). Partial budget, dominance and marginal analyses were used. The average yield was adjusted downwards to reflect the difference between the experimental plot yield and the yield farmers was expected from the same treatment. The average open market price (Birr kg^{-1}) for the crop and the official prices of fertilizers were used for analysis. $MRR(\%) = \frac{\mathbf{\Delta NB(NBb-NBa)}}{\mathbf{\Delta TCV(TCVb-TCVa)}}$

Results and Discussion

Soil Reaction, Available Phosphorus and Exchangeable Acidity
The results revealed that the soil reactions, pH (H2O) of the experimental sites were ranged from 4.80 to 5.78 (Table 1). Based on acidity class established by FAO (2006) the soils acidity of the study area ranged from strongly acidic to moderately acidic. In The fact that, soils were derived from weathering of acidic igneous granite and leaching of basic cations such as K, Ca and Mg from the surface soil (Frossard *et al.*, 2000).

The maximum and minimum values of available P were 9.90 and 2.10 mg kg^{-1} respectively (Table 1). According to the critical level set by FAO, (2006), available phosphorus values of the experimental sites ranged from very low (<5 mg kg^{-1}) to low (5.001- 10 mg kg^{-1}) category (Table 1). Phosphorus is among the factors that are highly limiting the productivity of the soils. In agreement with this observation, many researchers including Harrison, (1987); Warren, (1992) and Buehler *et al.*, (2002) have also reported that soil P deficiency is a wide spread phenomenon and it is believed to be the second most important soil fertility problem throughout the world next to N and often the first limiting element in acid tropical soils. Whereas, the exchangeable acidity (Al + H) varied from 0.22 to 2.21 cmolc kg^{-1} for soils with pH values < 5.5 and the mean value was 0.915 cmolc kg^{-1} of soil.

Table 1. Initial available soil phosphorus, soil pH and exchangeable acidity of experimental sites

Sites	pH	Av.P(ppm)	Ex.A(cmol(+)/Kg)
1	5.42	5.70	0.31
2	5.66	3.70	0.32
3	5.78	6.08	0.33
4	5.13	2.11	0.95
5	5.09	2.10	0.91
6	5.12	6.30	0.78
7	5.58	8.86	0.22
8	5.57	9.90	0.28
9	4.8	6.30	2.21

Response of plant height, cob length, seeds per cob and grain yield to the treatment

Plant height, cob length, number of seeds per cob, and grain yield of maize were highly and significantly influenced by the treatments (Table 2). The highest mean of all yield and yield related parameters were recorded from soil test crop response-based fertilizer recommendation, while the lowest were from control plot (Table 2 below)

Plant height: The analysis of variance for plant height (Table 2) showed significant response to the treatments. The highest plant height (224.13cm) was obtained from soil test crop response based phosphorus recommendation with optimum N whereas the lowest plant height(181.30cm) was recorded in the control treatment. This might be the nutrient are involved in vital plant functions and contribute to enhanced growth in the height of the plant. This result also resembles the finding of Jain and Trivedi (2005) who reported an increase in plant height with phosphorus fertilizer application. Phosphorus improves the root growth which has a great effect on the overall plant growth performance; therefore the regimes of P at the rate of 0 kg ha^{-1} resulted in the shortest stature plants. Promotion effect of balanced P level on plant height was probably due to better development of root system and nutrient absorption (Hussain,.*et al.*, 2006).;l Selassie, 2016) reported that plant height of maize increased with increase in P application in acidic Alfifisols of North-Western Ethiopia.

Cob Length: Cob length was measured after harvest and it showed statistically significant ($P<0.01$) difference due to the treatment (Table 2). Significantly higher cob length (17.77 cm) was recorded with soil test crop response based fertilizer rates. However, there is no significant difference between applied blanket fertilizer rate recommendations. The shortest cob length (15.30 cm) was recorded at control (no application of fertilizer).

Grain Yield: Grain yield was highly and significantly affected by the treatments. The maximum (6875.3 kg ha^{-1}) grain yield was recorded at application of soil test crop response based fertilizer recommendation whereas the minimum (2937.3 kg ha^{-1}) was recorded on control (without fertilizer) (Table 2). The magnitude of increase in grain yield due to application of soil test crop response based fertilizer recommendation was 21.7 % higher as compared to the blanket recommendation. This might be due the importance of phosphorus in a number of metabolic functions and is especially important for grain formation. Similar findings were reported by Masood *et al*. (2011) ; Hussien (2009) ; Yosefifi *et al*. (2011) , and Omar(2014).

Table 2. Mean plant height (cm), cob length (cm) and grain yield (kg/ha) of maize as influenced by different fertilizer application at Sibu sire district (2013/14)

Treatments	**Parameters**			
	PH(cm)	**CL(cm)**	**SPC (No)**	**GY(kg/ha)**
Without fertilizer	181.30[c]	15.30[b]	478.80[b]	2931.3[c]
Blanket recommendation	206.92[b]	17.10[a]	547.84[a]	5646.4[b]
STCRBR	224.13[a]	17.77[a]	582.86[a]	6875.3[a]
P value	0.0023	0.0194	0.0245	0.0010
LSD (5%)	16.80	1.55	67.70	1228
CV (%)	4.12	4.64	6.32	12.30

*Where PH = Plant height; CL = Cob length; SPC = Seeds per cob; GY = Grain yield; STCRBR = Soil test crop response based fertilizer recommendation;LSD = Least significance difference; CV = Coefficient; * = Significant different at p ≤ 0.05 and ** = Highly and significantly different at p ≤ 0.01.*

Economic Analysis

According to CIMMT (1988), on the farm-economic analysis of major cereals training reported that MRR that range from 50% to 100% was the minimum recommended rate in most agricultural production and it is better when the MRR was >100% (Table 3). The economic analysis showed that the highest net income (96388.3 ETB) was obtained from soil test crop response based fertilizer recommended treatment. So, those treatments that receive recommended fertilizer record the acceptance range of MRR and so, farmers use this soil test crop response-based fertilizer application than other treatments which is cost effective and economically feasible.

Table 3 : Partial budget analysis for verification of STBFR for maize at Sibu Sire District

Treatments	**GY (qt/ha)**	**AGY (qt/ha)**	**GFB (birr/ha)**	**TVC (birr/ha)**	**NB (birr/ha)**	**MRR (%)**
Without fertilizer (0 Urea + 0 TSP)	29.31	26.4	52763.4	7914.5	44848.9	
BFR (100 kg/ha urea+ 100 kg/ha TSP)	56.46	50.8	101635.2	18646.3	82988.9	355.4
STCRBFR (300 urea + 270 TSP)	68.75	61.9	123755.4	27367.1	96388.3	153.6

Where: GY = Grain Yield; qt = Quintal; ha = Hectare; AGY = Adjusted grain yield; GFB = Gross field benefit; TVC =Total variable cost; NB = Net benefit; MRR = Marginal rate of return; BFR Blanket fertilizer recommendation and STCRBR = Soil test crop response based recommendation.

Conclusion and Recommendation

In Ethiopia, the blanket recommendations that are presently in use all over the country were issued several years ago. Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P fertilizer rate to their fields regardless of soil fertility differences. Phosphorus calibration experiments were conducted at Sibu Sire District for phosphorus fertilizer recommendation on maize. From the experiment, critical concentration and requirement factor of Phosphorus fertilizer were developed. Economically optimum N (138 kg/ha), critical level phosphorus (10 ppm) and phosphorus requirement factor (20.63 kg/ha) for maize production in the district were gained and recommended during the calibration study. These P critical and P requirement factor were verified at the same area on farmer's field by the year of 2021/22 cropping season. Based on the results of this study, it is generally concluded that, soil test crop response based fertilizer application in Sibu Sire district gave consistently high yield and yield related parameters of maize and economically feasible. Since, by applying recommended rate of P and optimum urea fertilizer application rate, yield of maize in Sibu Sire district could be increased by 21.7% over the blanket fertilizer recommendation. Therefore, it should be suggested and recommended for wider popularized through demonstration.

Acknowledgement

First and foremost, we would like to thank Almighty God for blessing us with invaluable gifts of health, strength, patience and protection to start and complete this study. Secondly, the authors would like to thank Agricultural growth program project for financial support and Nekemte Soil Research Center for providing all the necessary facilities needed for the activity.

References

Agegnehu, G. and B. Lakew (2013). Soil test phosphorus calibration for malting barley (*Hordeumvulgare* L.) on Nitisols of central Ethiopian highlands. *J. Trop. Agric.*, 90: 177- 187

Agegnehu, G., P.N. Nelson, M.I. Bird and C. van Beek (2015). Phosphorus response and fertilizer recommendations for wheat grown on Nitisols in the central Ethiopian highlands. *Commun. Soil Sci. Plant Anal.,* 46: 2411-2424

Arije, D.N., F.M. Akinseye and B.S. Ewulo (2018). Response of maize (*Zea mays* L.) growth and yield to different fertilizer application in Rainforest agroecological zone of Nigeria: Evaluation of CERES-maize crop model. *Net J. Agric. Sci.,* 6: 70-76

Badu-Apraku, B., M.A.B. Fakorede, A.F. Lum and R. Akinwale (2009). Improvement of yield and other traits of extra-early maize under stress and nonstress environments. *Agron. J.*, 101: 381-389

Bationo, A., U. Mokwunye, P. Vlek, S. Koala and B.I. Shapiro (2003). Soil Fertility Management for Sustainable Land use in West Africa. In: Soil Fertility Management in Africa: A Regional Perspective, Gichuru, M.P., A. Bationo, M.A. Bekunda, H.C. Goma and P.L. Mafongonya *et al*. (Eds.)., *Academy of Science Publishers, Kenya, pp:* 253-292.

CIMMYT (1988). From Agronomic data to farmer recommendation: An economicstraining manual. Completely revised edition, Mexico,

D.F.Corbeels, M., Shiferaw, A. and Haile, M., (2000). *Farmers' knowledge of soil fertility and local management strategies in Tigray, Ethiopia*. IIED-Drylands Programme.

CSA., (2020). The federal democratic republic of Ethiopia, agricultural sample survey. Report on Area and Production of Major Crop. Statistical Bulletin. Central Statistical Agency, Addis Ababa, Ethiopia.

Mesfin Abebe (1998). Nature and management of Ethiopian soils. Alemaya University, Ethiopia. 272p.

Hussain, N., A.Z. Khan, H. Akbar and S. Akhtar (2006). Growth factors and yield of maize as influenced by phosphorus and potash fertilization. *Sarhard J. Agric.,* 22: 579-583.Hussein,

Hussein, A. H. A. (2009). Phosphorus use efficiency by two varieties of corn at different phosphorus fertilizer application rates. *Res. J. Appl. Sci*, *4*(2), 85-93.

Jain, P.C. and S.K. Trivedi (2005). Response of chickpea to phosphorus and biofertilizers. *Legume Res.*, 28: 30-33.

Masoo d, T., R. Gul, F. Munsif, F. Jalal and Z. Hussain (2011). Effffect of difffferent phosphorus levels on the yield and yield components of maize. *Sarhad J. Agric.,* 27: 167-170

Muir, J.H. and J.A. Hedge (2002). Corn Response to Phosphorus and Potassium Fertilization at Different Soil-Test Levels. In: Arkansas Soil Fertility Stugies, Slaton, N.A. (Ed.)., Agricultural Experiment Station Research Series 502, *University of Arkansas, Fayetteville, Arkansas, pp:* 60-62.

Negassa, W., Price, R.F., Basir, A., Snapp, S.S. and Kravchenko, A., (2015). Cover crop and tillage systems effect on soil CO2 and N2O fluxes in contrasting topographic positions. *Soil and Tillage Research*, *154*, pp.64-74.

Ngigi S (2003). Review of irrigation development in Kenya. International Water Management Institute Colombo Sri Lanka 35-37.Omar, A.E.A., 92014). Effect of FYM and phosphorus fertilization on yield and its component of maize, Asian J.Crop Sci., 6: 15-26.

Pre-extension Demonstration of Soil test based NPS Fertilizer Recommendation under lime pplication for Bread Wheat (Triticum aestivum L.) in Horo Distric of Horo Guduru Wollega Zone, Oromia Region, Ethiopia

Mintesinot Dessalegn*, Chaltu Regassa, Temesgen Chimdessa, Chalsissa Takale, Firaol Gemada. and Olifan Fikadu

Oromia Agricultural Research Institute, Nekemte Soil Research Center P.O. Box 587, Nekemte

*Corresponding Author: mintesinot12@gmail.com

Abstract

Wheat is a major crop produced in Ethiopian highlands and in particular in the study area, which is a staple food crop. Soil nutrient depletion restrains agricultural crop production and economic growth. A major challenge is recommendations on the amount and type of fertilizers to be applied at the country level and in the study area. A Soil test based phosphorous calibration study was conducted on bread wheat for three consecutive years for the determination of the values of critical level phosphorus (10 ppm) and phosphorus requirement factor (11.03 kg/ha) in Horo District. This District was selected purposely based on potential Bread wheat production. Due to Ethiopia having been beginning to use NPS fertilizer recently, the optimum NPS fertilizer rate for bread wheat production was determined in Horo District. To have confidence in technology diffusion to end users; a Pre-extension demonstration of soil test based NPS fertilizer recommended rate for bread wheat was accomplished in the Horo district with the objective of participatory demonstration of this technology under farmers' conditions in 2020/21cropping season. The treatments were blanket recommendation and Soil test Crop response based NPS fertilizer recommendation (100% Pc from NPS and Nitrogen 46 kg/ ha recommended) . The analysis of variance indicated the highest grain yield (4110 kg/ha) was obtained from the application of Soil Test based NPS fertilizer recommendation (STBFR) whereas the lowest grain yield 3322.67 kg/ha from the blanket fertilizer recommendation. The economic analysis also revealed that the maximum net benefit 87089.40 EB was obtained from STBFR. Soil test based NPS fertilizer recommendation was economically feasible and the highest MRR and net income were obtained from soil test based fertilizer recommendation. Therefore, 100% Pc from NPS and Nitrogen 46 kg/ ha fertilizer rate was recommended for bread wheat production and productivity of the study area. Further scaling up/out the technology to reach more produced in the same soil type and agro ecology in particularly Eastern Wollega Zone and Horo district.

Keywords: *Bread Wheat, Demonstration, NPS, Pre-extension and Soil Test Based.*

Introduction

Soil fertility is one of the biggest challenges in Ethiopia. Soil nutrient depletion restrains agricultural crop production and economic growth. In Ethiopia, fertilizer use has focused mainly on only nitrogen and phosphorous in almost all cultivated crops. Such an unbalanced application of plant nutrients may aggravate the depletion of other important nutrients in the soils. Continuous cropping, high proportions of cereals in the cropping system, and the application of suboptimal levels of mineral fertilizers aggravate the decline in soil fertility (Tanner *et al*., 1992; Hailu *et al*., 1991; Workneh and Mwangi, 1992). Fertilizer consumption in Ethiopia was still below 20 kg ha^- (Croppenstedt *et al.*, 2003; FAO, 2004; Yirga and Hassan, 2013).Only 30 to 40% of Ethiopian smallholder farmers use fertilizer, and those that do only apply 37 to 40 kg on average per hectare, which is significantly below the recommended rates (MoA, 2012). Environmentally sound and economically profitable fertilizer application rates must be of paramount importance for sustainable crop production.

Thus it is vital to search for alternative nutrient sources. A Soil test based phosphorus calibration study was conducted in the Horo district on bread wheat for three consecutive years. Due to Ethiopia begun to use NPS fertilizer as a compound recently, the found of the study changed/converted to NPS rate determination using two consecutive years experimental trial. From the experiment, optimum NPS rate for bread wheat production in the district was determined. Pre extension demonstration activity was conducted before further popularization to evaluate and create awareness in the community. NPS fertilizer recommendation for the study area cannot be achieved without farmers' participation. To have confidential technology dissemination to end users, the economic visibility and acceptance of the technology, decided to demonstrate it in the same area to achieve the following objective.
To demonstrate and popularize optimum NPS fertilizer rate recommendation for bread wheat production through participatory farmers research group in the Horo District.

Materials and Methods

Description of the Study Areas

Horo is situated at latitude: 1,042,726N to 1,091,814N; Longitude 270,000 E to 316,199 E and an altitude ranging from 1449-3147 m above sea level; in Horo Guduru Wollega Zone of the Oromia regional state, Ethiopia (Figure 1.). The terrain is generally undulating to rolling plains. The area is characterized by a mono-modal rainfall pattern. The mean monthly rainfall ranges from 12.8 to 343.8 mm, and the mean monthly temperature is 17.23 to 22.9°C. The major soil types are generally described as Nitisols (FAO. 1990).

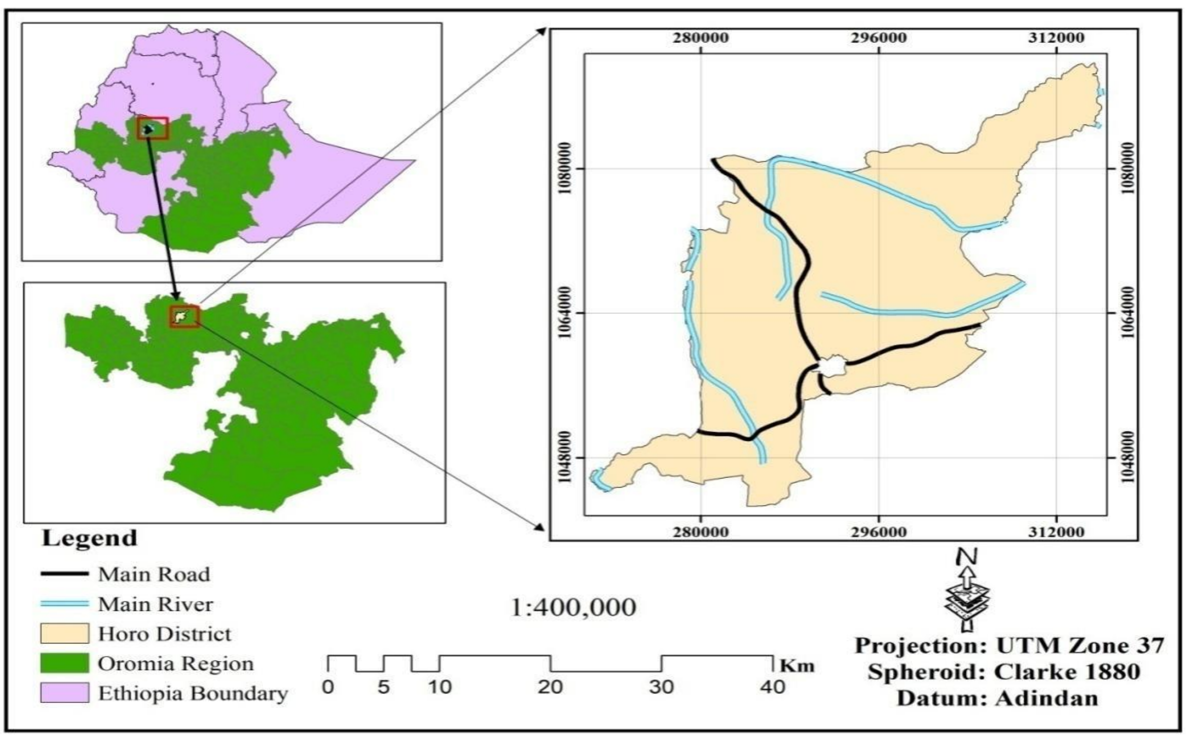


Figure 1: Location map of Horo District, Oromia, Ethiopia

Methodology
The study was conducted on farmers' areas over the Horo District. Soil samples were collected from the fields of selected farmers. To begin with, composite soil samples were made in the zigzag method from 20 farmers who arrive and analyzed for, soil pH and available P, in assemble to be familiar with the level of the desired parameters within the soil to choose cultivate land for the actual experiment. Based on the level of soil initial Phosphorus level; 5 cultivate lands were chosen. Three farmers research groups each consisting of 15(fifteen) members were established purposely based on the will of actors. The groups trained on the concept of FRG and the activities they are going to perform. DAs, Stakeholders and a multidisciplinary team of researchers will join the FRG (agronomist, Soil scientist, socio economist and extensions) all actors will come up with ground rules and regulations. The demonstration site were laid out in simple adjacent plots (10mx10m).

Phosphorus addition was based on the initial phosphorus content of the soil and phosphorous critical level determined in the study area for bread wheat. Available phosphorus in the soil was tested in our soil laboratory. Optimum NPS rates determined during the study was compared with blanket recommendation/farmers practice and control/without fertilizer. All agronomic/crop management practices and variety was secured with previous experiment/study. Improved Bread wheat variety Dendea used with a rate of 150 kg/ha seed with 20 cm inter row spacing were sown in the study area. The collected soil samples were analyzed for the parameters of pH (H2O) within the suspension of a 1:2.5 soil to water proportion using a pH meter and Available P was determined by the Olsen's strategy using a spectrophotometer (Olsen *et.al.*, 1954).

Demonstration Procedures and Management
The experimental was conducted on five farmers' fields across the district in three representative productive Peasant associations. The demonstration treatments were established adjacent plots of 10 m x 10 m (100 m^2) each replicated over five farmers. Amount of Phosphorus applied based on initial Phosphorus content of the soil. Available Phosphorus in the soil was tested and P recommendation rate was given according to the formula. Application of Phosphorus in kg/ha = (P critical – P initial)*P requirement factor. Financially ideal N (46 kg/ha), critical level phosphorus (10 ppm) and phosphorus requirement factor (11.03 kg/ha) for bread wheat production within the district were picked up and recommended during the calibration study phosphorous as stated by (Chimdessa and Takale, 2020); whereas 100% Pc from NPS and Nitrogen 46 kg/ ha recommended by Nekemte soil research center to the study area for bread wheat production as recommended by Takale, *et.al*,. (2021) in the district. Improved Bread wheat variety Dendea used with a rate of 150 kg/ha seed with 20 cm inter row spacing were sown in the study area. Phosphorus applied at planting while, urea by split during planting and after planting 20 days top dressed with the rate of 46N Kg/ha as recommended (Chimdessa and Takale, 2020; Takale, *et.al*, 2021). The treatment arrangements;

Blanket fertilizer recommendation (BFR)
Soil Test based fertilizer recommendation "100% Pc from NPS and Nitrogen 46 kg/ ha" STBFR

Data Management and Analysis
All agronomic and soil data which will be collected will be properly managed using the EXCEL computer software. The collected data will be subjected to the analysis of variance using the SAS.

Result and Discussion

Soil reaction (pH) and available phosphorus; whereas soil pH (H_2O) of the soil samples collected before planting were ranged from (4.78 -6.01) with mean values 5.49 (Table1). Accordingly, the soils were strongly to moderately acidic range in reaction (Tekalign, 1991). This is might be happened due to persistent cultivation and long-term application of inorganic fertilizers driven to low soil pH in the study area. This result agreed with the finding of (Chimdessa and Takale, 2020). The most extreme and least values of available P were 8.53 and 2.7 ppm, respectively (Table 1). Available phosphorus of most tests drop under low category according to the basic level set by Karltun *et.al.* 2013). generally, the available P status of the soils within the consider area are low, even below the basic level representative that soil P inadequacy. This appears it does require for external application of phosphorus fertilizer sources for great crop development and yield obtained.

Table 1. Selective Soil chemical properties of Horo District

Experiment sites	**pH (H2O)**	**Exch.A (cmol(+)/Kg)**	**Av.P (ppm)**
1	5.34	1.34	8.53
2	5.42	2.09	5.83
3	4.78	0.37	2.70
4	6.01	2.18	7.98
5	5.92	0.85	6.68
Mean	5.49	1.37	6.34
Min	4.78	0.37	2.7
Max	6.01	2.18	8.53
Std Dev	0.50	0.78	2.30

Min= Minimum Value, Max= Maximum Value, Std Dev= Standard deviation Value, Exch.A= Exchangeable acidity, Av.P= Available phosphorous

Yield Performance of the Demonstrated Technology

The yield obtained from the demonstration sites revealed that the maximum grain yield wheat (4110kg/ha) obtained from the application of soil test based Phosphorus fertilizer recommendation (STBFR) and optimum Nitrogen recommended, While grain yield of 3322.67 kg/ha obtained from blanket recommendation. The results of this believe are reliable with discoveries of who detailed that the highest grain yield was recorded under application of soil testing based fertilizer applied (Dejene. 2020). Average biomass and grain yield (kg/ha) as affected by the treatment (Figure 3).

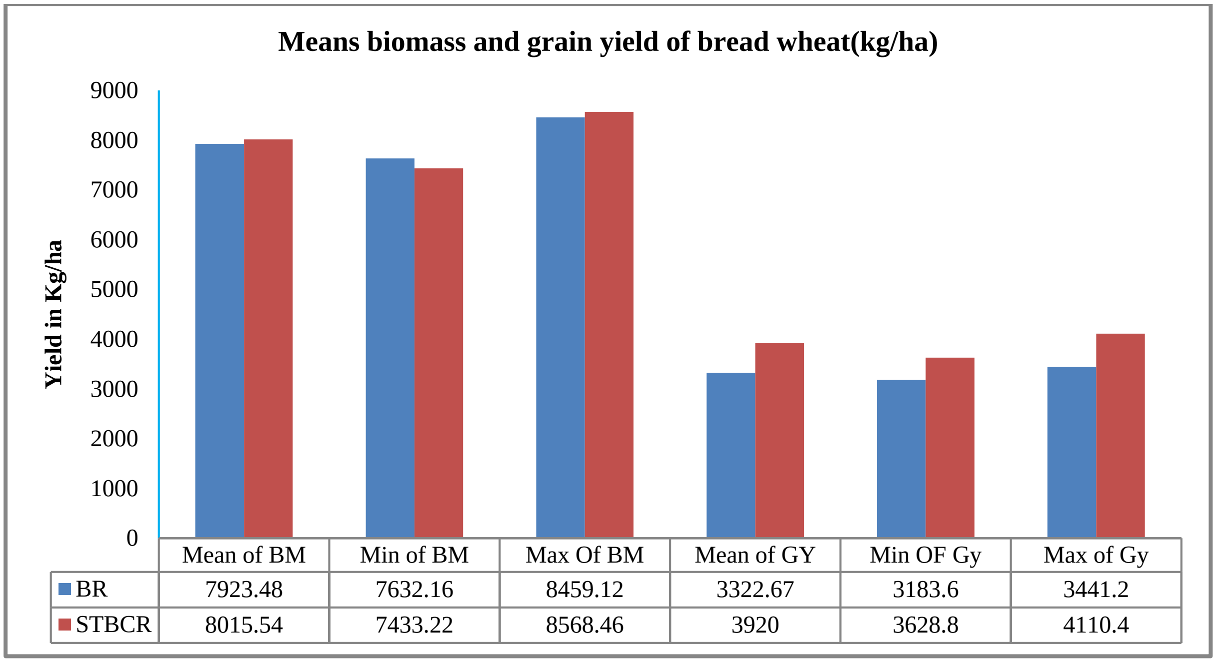


Figure 3: Mean biomass and bread wheat grain yield kg/ha at Horo District.

The data available on figure 4 showed high of mean grain yield at study area due to availability of plant nutrients differences under treatments. This finding indicating the effect essentiality of balanced fertilizer applied.

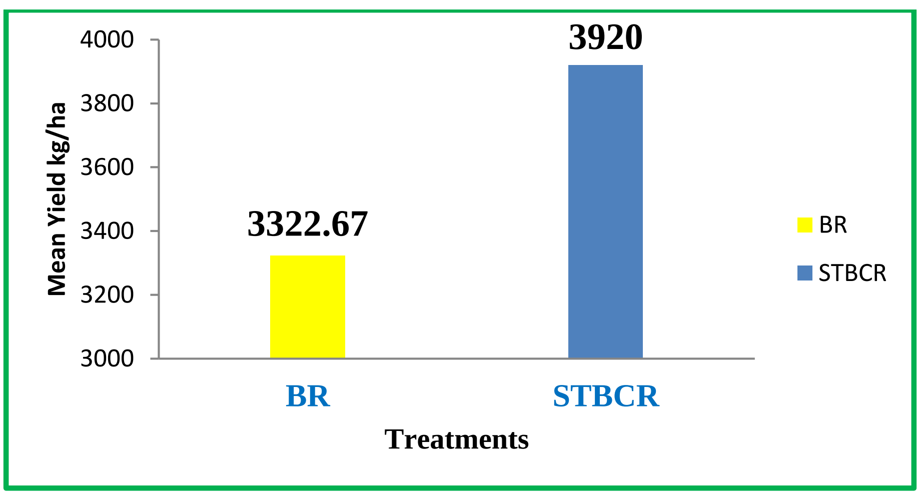


Figure 4: Mean grain yield of bread wheat (kg/ha) of the experimental site of study area

Yield Advantage

$$\text{Yield advantage } \% = \left(\text{Mean Yield of STBFR } \left(\frac{\text{Kg}}{\text{ha}}\right) - \text{aan Yield of STBFR} \frac{\text{Kg}}{\text{ha}}\right) * \text{aan} \Big/ \text{Mean Yield of BR Kg/ha}$$

Yield advantage of STBFR over with blanket recommendation fertilizer rate %= (3920-3322.67)*100/3322.67=17.98%. It's revealed that the yield advantage of the soil test based phosphorus fertilizer recommendation with that of blanket recommendation is 17.98 %.

Conclusion and Recommendations

A pre-extension demonstration activity was conducted at Horo District; Oromia for demonstrating soil test based wheat response phosphorus fertilizer recommendation through FREGs. Thus, popularization of the demonstrated soil test based wheat response NPS fertilizer rate should be made on different extension/promotional events in order to create high demand. This finding confirmed that (100% Pc from NPS + 46 kg/ha N fertilizer rate recommended) was economically feasible and led to the maximum yields of bread wheat in Horo District. Wheat bread yield grain performance of soil test based NPS fertilizer recommendation was still shows potential over blanket NPS fertilizer recommendation. This study revealed that the yield advantage of the soil test based phosphorus fertilizer recommendation with that of blanket recommendation is 17.98 %. Despite this detail, the average yield obtain from soil test based NPS fertilizer recommendation was higher than that of blanket NPS fertilizer recommendation. Soil test based NPS fertilizer recommendation was led to the maximum yields of bread wheat in Horo District. Therefore, soil test based NPS fertilizer rate recommended (100% Pc from NPS + 46 kg/ha N fertilizer rate recommended) was selected and recommended for further per-scaling up activity on wider plot (at least 0.25ha per farmer) in the participant district and to similar soil type and agro-ecologies of the zonal.

Acknowledgments
We are very grateful to the Oromia Agricultural Research Institute, and Nekemte Soil research center, for their generous financial support. Indeed, without their help, we wouldn't have been able to complete this critical project. I am sincerely thankful our Laboratory technicians, experts of Horo district Agricultural office, DA's and farmers for their assistance, and finally, I hope to continue to count on their support in the future.

Reference

Chimdessa, T., & Takele, C. (2020). Verification of Soil Test Based Phosphorous Calibration Study for Bread Wheat (*Triticum aestivum* L.) Production in Horo District, Oromia Regional State, Ethiopia. *Advances in Biochemistry*, *8*(3), 52.

Dejene Getahun, Dereje Girma, Abreham Feyisa, Ajema Lemma, Lello Dejene (2020). Verification of Soil Test Crop Response Based Phosphorus Recommendation on Bread Wheat (Triticum Aestivum L.) in Yaya Gulele District of North Shewa Zone, Oromia. *International Journal of Applied Agricultural Sciences*. 6(3), pp. 52-56

Karltun, E., Lemenih, M., & Tolera, M. (2013). Comparing farmers'perception of soil fertility change with soil properties and crop performance in beseku, Ethiopia. *Land Degradation & Development*, *24*(3), 228-235.

Olsen, S. R. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate* (No. 939). US Department of Agriculture.

Tadesse, T., Haque, I., & Aduayi, E. A. (1991). Soil, plant, water, fertilizer, animal manure and compost analysis manual. *ILCA/PSD Working Document (ILCA).*

Pre-extension Demonstration of NPS Fertilizer Rate Based on Phosphorus Calibration Study for Teff (*Eragrostis tef* (Zucc.) Trotter) at Guduru District, Western Oromia Region, Ethiopia

Temesgen Chimdessa*, Chalsissa Takale, Chaltu Regassa, Nafirom Negassa, Mintesinot Dessalegn, Firaol Gemada and Amanuel Tadase.
Nekemte Soil Research Center P.O. Box 587, Nekemte
***Corresponding Author Email**: temesgenchimdessa468@gmail.com

Abstract
On farm demonstration of NPS fertilizer determined based on P critical level for Teff crop was carried out in Guduru District in 2021/22 main cropping season to demonstrate and popularize the technology through Farmers' Research Group (FRG) approach. Accordingly, Seven sites were selected across the District purposely and four FRGs; were organized. Composite soil samples were collected and initial soil pH, phosphorus and exchangeable acidity were analyzed for all sites. The demonstration treatments were established on adjacent plots each with an area of 10 m x 10 m (100 m^2), replicated three times. Due to security problems, the two sites were not managed and harvested. Therefore the data were summarized from five sites. The highest mean grain yield of 2157.30Kg ha^{-1} was obtained from the application Optimum NPS fertilizer rate determined (75% of Pc from NPS) with an extra 18.41 and 53.3 % yield advantage over the blanket recommendation and without fertilizer application, respectively. Partial budget analysis of the demonstration revealed that the maximum net benefit of (73,350.1 birr ha^{-1}) was obtained from 75% of Pc from NPS fertilizer (Optimum NPS rate determined based on P critical level) while the minimum net benefit of 28,099.6 ETB ha^{-1} was obtained from Without fertilizer application. Thus the NPS fertilizer rate determined based on Phosphorus critical level and phosphorus requirement factor should be wider popularized and scaled out in the study area.

Kewords: Calibration, Demonstration, NPS and Teff

Introduction

Teff (Eragrostis tef (Zucc.) Trotter)is an ancient tropical cereal that has its center of origin and diversity in the northern Ethiopian highlands from where it is believed to have been domesticated (Demissie, 2001). It is an interesting grain used for centuries as the principal ingredient of the Ethiopian population diet. The principal meal in which Teff is used is called ("*Injera*") a big flat bread or pancake, that is eaten alone or with any kind of meats, vegetables and sauces (Dijkstra *et al.*, 2008) It is reported to have a higher content of iron, calcium, phosphorus, copper, and thiamine compared to other grains like wheat, barley, and sorghum (Mohammed *et al.*, 2009). It is also reported to be free of gliadin (Spaenij *et al.*, 2005) and could be suitable for use in the diet of patients suffering with celiac disease (Hopman *et al.*, 2008). Teff proteins are not gluten in nature.

But its productivity is hampered by low and declining soil fertility resulting in the loss of essential plant nutrients such as phosphorus which is one of the most limiting nutrients. Soil fertility is one of the biggest challenges in Ethiopia. Continuous cropping, high proportions of cereals in the cropping system, and the application of sub-optimal levels of mineral fertilizers aggravate the decline in soil fertility (Tanner *et al.*, 1992; Hailu *et al.*, 1991; Workneh and Mwangi, 1992).Fertilizer consumption in Ethiopia was still below 20 kg ha^{-1} (Croppenstedt *et al.*, 2003; FAO, 2004; Yirga and Hassan, 2013).Also, fertilizer use has focused mainly on only nitrogen and phosphorous in almost all cultivated crops. It is supplemented in crop production with blanket recommendations without considering agro-ecology, environmental effects, spatial, and temporal soil fertility variations, hence this method is inefficient economically by increasing production costs and environmental hazards. Such an unbalanced application of plant nutrients may aggravate the depletion of other important nutrients in soils.

It is vital to search for alternative nutrient sources that environmentally sound and economically profitable fertilizer application rates are of paramount importance for sustainable crop production. Thus soil test based phosphorus calibration study was conducted in Guduru district on Teff for three consecutive years. Due to Ethiopia begun to use NPS fertilizer as a compound recently, the foundation of the study changed/converted to NPS rate determination using two consecutive years an experimental trial. From the experiment, the optimum NPS rate for Teff production in the district was determined. This fertilizer (NPS) recommendation cannot be achieved without farmers' involvement. To have confidential on technology dissemination to end users, the economic visibility and acceptance of the technology, we decided to demonstrate it at the same area to achieve the following objective/s.

Objective/s:

- To demonstrate , evaluate the technology and create awareness farming community
- To among farmers about the technology generated

Materials and Methods

Description of the Study Area

The experiment was conducted on farmer's field in Guduru district in Horo Guduru Wollega Zone of Oromia Region, Ethiopia. Guduru is situated at an altitude ranging from 878 – 2448 m above sea level; latitude: 9^{0}16'55" N to 10^{0} 02'31" N; Longitude: 37^{0}12'42" E to 37^{0}42'45" E. (Figure 1). The terrain is generally undulating to rolling plains. The mean monthly rainfall ranges from 10.43 mm to 344.7 mm, and mean monthly temperature is 16.11^{0}C to 19.11^{o}C. The major soil types are generally described as Nitisols (FAO, 2014).

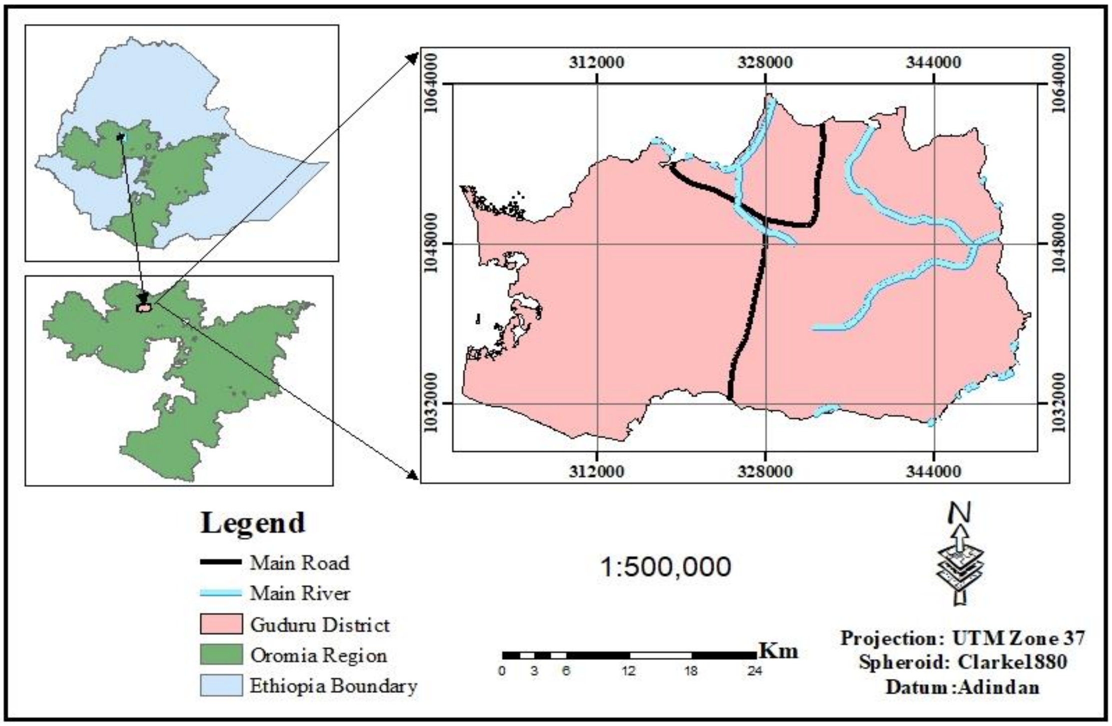


Figure 1: Location of the study area map

Approach Used: The study was conducted in 2021/22 during the main cropping seasons at Guduru district, Horo Guduru Wollega Zone, Oromia region. The study was conducted on purposely selected a farmers' fields in the district. It was done on seven (7) farmers' field. But due to the security problem around two sites, the data was collected and summarized from five (5) sites.

The experiment was laid out in simple observation plot (10mx10m). For this experiment, *"Guduru"* teff variety was used as test crop. Recommended seed rate was used 15kg ha^{-1} for row planting and seeds were drilled at 20 cm spacing (Berhe *et al.*, 2011). Composite soil samples were collected from different farmers field of the district by using zigzag method. Selected soil chemical analysis was done for available phosphorus, pH and exchangeable acidity using the standard laboratory procedure.

Phosphorus addition was based on initial phosphorus content of the soil. All selected soil parameters were done in Nekemte soil laboratory. Optimum rates of NPS determined (75% Pc in NPS with 46 kg N ha^{-1}) during the study was compared with blanket recommendations and control/ without fertilizer. Nitrogen fertilizers in the form of urea were used according to the recommended optimum rate of 46 kg N ha^{-1} during determined phosphorous critical in the district. All agronomic/crop management practices were secured with previous experiment/study.

TSP and NPS fertilizers were applied in full dose during planting while nitrogen was applied in split (1/3 during planting and the rest at 30 days after planting) to avoid losses through leaching and volatilization. Habtegebriel and Singh (2006) reported that nitrogen should be applied in split for optimum nutrient use efficiency of teff for all the treatments except the control.

FRG Establishment and Advisory services

The FRG member farmers were selected based on their lands suitable and sufficient to accommodate the trials, willingness to be held as member and share innovations to other farmers. Selection of farmers was done with the collaboration of development agents and district experts. Then the selected farmers were grouped in to Farmers Research Group (FRG) considering gender issues (women, men and youth). The trial was done in four kebeles. In each kebeles, one FRG units comprising of 15 farmers and one experimental field was established with the rest of farmers were being participant farmers. Although formal training for the stake holder was difficult due to security problem in the district; advisory services were continuously given for all FRG members from the land preparation up to the end.

Data collected and analysis

Furthermore, during the different growth stages of the crop, all the necessary agronomic practices and other management practices were carried out as per the recommendation. All agronomic and soil data were properly managed using the EXCEL computer software. The collected data were subjected to the analysis of variance using the SAS software 9.0 versions.

Result and Discussion

Soil chemical properties of the experimental sites

Selected soil characteristics of the experimental soil are presented (Table 1). Soil pH value ranges from 4.58 to 6.00 with a mean value 5.33 before planting (Table 1). It indicated that it was strong acidic which (EthioSiS 2014). The soil available P values ranged between 1.53 to 588 mg kg^{-1} soils with a mean value 4.98 mg kg^{-1} soil in the study area (Table 1). Available P content of the soil were ranged from very low (<5mg kg^{-1}) to low (5-9mg kg^{-1}) according to cottenie (1980) rating.

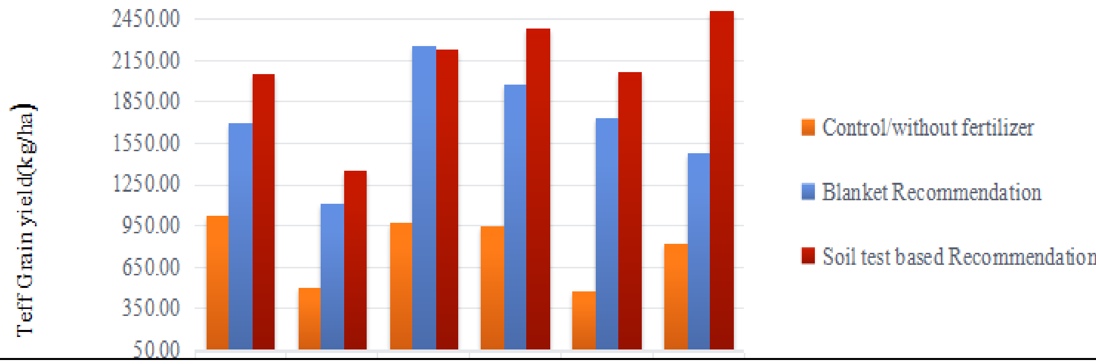
Table 1. Soil chemical characteristics of the experimental field before sowing

Sites	**pH (H2O)**	**Av.P (ppm)**	**Ex.A (cmol(+)/Kg)**
1	4.58	4.20	1.66
2	5.11	1.53	1.07
3	5.04	3.06	0.62
4	5.31	5.70	0.41
5	5.94	5.88	1.38

Figure 1. Photos taken during harvesting

Yield Performance of the Demonstrated Technology

The agronomic data and the crop performance observed were collected and analyzed. The yield obtained from the demonstration sites revealed that the maximum grain yield (2157.30kg/ha) of the teff obtained from the soil test based NPS fertilizer rate recommendation with Recommended N (75 % Pc from NPS + 46kg/ha N). While the minimum grain yield (671.40 kg/ha) of the crop was gained from control plot. The mean grain yield of 2096.00, 1707.64 and 787.73 kg ha^{-1} were gained from the application of soil test based NPS fertilizer rate determined with recommended N, blanket recommendation and control respectively.



Trt#	Mean	Std. Dev.	Min.	Max.
	1530.46	590.967	671.40	2157.30
Control/Without Fertilizer	787.73	190.296	671.40	1007.33
Blanket Recommendation	1707.64	55.642	1649.17	1759.93
Soil Test based recommendation	2096.00	57.776	2042.55	2157.30

Figure 2. Means and Descriptive Statistics for teff grain yield (kg/ha) in the study area

Conclusion and Recommendation

A Pre-extension demonstration activity was conducted at Guduru district, Horo Guduru Wollega Zone, Oromia Region. The main objective of the study were to demonstrate and evaluate the recommended optimum NPS fertilizer rate to farming community and to create awareness among farmers about the technology generated. It was done on purposely selected farmers' field. But Due to security problem, field day was not conducted; Soil test crop response based NPS fertilizer with recommended N (75% Pc from NPS + Rec. N) application in Guduru district gave consistently high grain yield(2157.30kg/ha) for teff production. Therefore, it should be wider popularized and scaled out.

Acknowledgement

Authors' special thanks to the Oromia Agricultural Research Institute for providing financial support funding. Laboratory technicians, former and current technical staffs of Nekemte Soil Research Laboratory Center, who took part in laboratory analyses and field trials, are gratefully acknowledged. Moreover, we like to forward thank to financial staffs of Nekemte Soil Research Center.

References

Agricultural Transformation Agency (ATA). 2014. "Soil Fertility Status and Fertilizer Recommendation Atlas for Tigray Regional State, Ethiopia," Addis Ababa.

Agricultural Transformation Agency (ATA). 2014. Transforming the use of fertilizer in Ethiopia: Launching the national fertilizer blending program; February 12, 2013.

Assefa K, Chanyalew S and Metaferia G. 2013. Conventional and molecular tef breeding. In: Assefa K., Chanyalew, S and Tadele, Z. (eds.) Achievements and Prospects of Tef Improvement, Proceedings of the Second International Workshop. pp 31-49. November 7-9, 2013, Debre Zeit, Ethiopia.

Balock AW, Soomro AM and Javed MA. 2002. Optimum plant density for high yield in rice (Oryza sativa L.). Asian Journal of Plant Science. 1(1): 25-27.

Berhe T, Gebretsadik Z, Edwards S and Araya H. 2011. Boosting Tef Productivity Using Improved Agronomic Practices and Appropriate Fertilizer. In: Achievements and Prospects of Tef Improvement. Proceedings of the Second International Workshop, November 7–9, 20.

Central Statistic Authority (CSA). 2013. Agricultural Sample Survey: report on Area and production of major Crops (Private peasant holdings ‘‘meher’’ season), Volume I Addis Abeba, Ethiopia.

CIMMYT, 1988. From Agronomic data to farmer recommendation: An economics training manual. Completely revised edition, Mexico, D.F.

Cottenie, A. 1980. Soil and plant testing as a basis of fertilizer recommendations. FAO soil bulletin 38/2. Food and Agriculture Organization of the United Nations, Rome.

FAO (Food and Agriculture Organization). 2014. Guidelines for International soil classification system for naming soils and creating legends for soil maps, Update 2015. Food and Agriculture Organization of the United Nations Rome, 2015, Rome. 70p.

Habtegebrial K and Singh BR. 2006. Effects of timing of nitrogen and sulphur fertilizers on yield, nitrogen, and sulphur contents of tef (Eragrostis tef (Zucc.) Trotter). Nutr Cycl Agroecosyst 75:213–222.

Mitiku Melaku. 2008. Effects of seeding and nitrogen rates on yield and yield components of tef [Eragrostis tef (Zucc.) at Adet, Northern western Ethiopia. M. Sc. Thesis, Haramaya University. pp. 18-34.

Refissa L. 2012. Effects of sowing methods and fertilizer types on yield and yield components of Tef [Eragrostis tef (zucc.) trotter] at Guduru Woreda, western Oromia, Ethiopia.

The Response of Faba Bean (Vicia faba L.) to Different Strains of Rhizobium Biofertilizer (Rhizobium leguminosarum) at Horro District, Western Oromia, Ethiopia

Olifan Fikadu,Chalsisa Tekele,Temesgen Chimdessa
Nekemte Soil Research Center, Oromia Agriculture Research Institute, Oromia, Ethiopia
Cooresponding Author: Olifan2007@gmail.com

Abstract
*Among the major pulse crop produced in Ethiopia, Faba bean is widely produced in the highlands and midlands of Ethiopia. In the poor agricultural systems of Ethiopia, many farmers of the country could not use chemical fertilizers in the production of faba bean because of its escalating cost. In addition, only using chemical fertilizer has many side effects on human health and the environment. Therefore instead of chemical fertilizer (urea), farmers can use the cost effective and environmentally sound option biological Nitrogen Fixing (BNF) Rhizobial biofertilizer. This study, therefore, conducted to evaluate the effective strain of Rhizobial bio fertilizer for the production of faba bean in 2021 at Horro district, Oromia Region, Ethiopia. The results from this experiment showed, a significantly ($P \leq 0.05$) difference among the treatments on weight of biomass and grain yields. The both maximum Biomass yield (*10,507.9*Kg/ha) and grain yield (3587.73Kg/ha) were gained from the treatment of 0.5Kg/ha of EAL-1017 and 50kg ha^{-1} of NPS. Therefore this experiment gave the conclusion of using Rhizobial bio fertilizer strain of FB-EAL 1017 (0.5Kg/ha) with NPS (50 Kg/ha) enhances the production of faba bean comparing to other strains at the district.*

Keywords: Rhizobial Strains, Biofertilizer, Pulse crops, Faba bean, Rhizobium Leguminasarum

Introduction

Faba bean *(Vicia faba* L.*)* is the most popular annual pulse crops at the level of the world. Faba bean is the major human foods in many country including Ethiopia, China, Egypt, Mediterranean region and parts of Latin America. In addition, Faba bean used to serve ecosystem by offering renewable inputs like nitrogen to legume plants and soil through its unique activity known as biological N_2 fixation, and a diversification of cropping system (Jensen *et al*., 2010). Faba bean is one of the major pulse crops widely produced in the highlands of Ethiopia. It is an annual crop grown by subsistence farmers, during the cool main rainy season (June to September) and used as the source of dietary protein to the majority of population in the country (Jida and Assefa, 2014). Faba bean occupies about 28% of the total land area under pulse crops in the country (CSA, 2015). In the poor agricultural systems of Ethiopia, many farmers of the country could not use chemical fertilizers in the production of Faba bean and other pulse crops.

Traditionally farmers' usepulse crops as restorer of soil fertility subsequently after cereal crops (Jida and Assefa, 2012). So to bring the solution to the challenges of sustainable agriculture for Sub-Saharan Africa, farmers have to depend on traditional knowledge to improve management of diverse on-farm resources and integration among various farm enterprises (Dey *et al*., 2010). The escalating costs and environmental impacts of using chemical fertilizer is global concern now a day.

Using of alternatives N fertilizers must be urgently sought to bring sustainability in agriculture. Biological nitrogen fixation (BNF) is a microbiological process which converts atmospheric nitrogen into a plantusable form. Nitrogen-fixing systems offer an economically attractive and ecologically sound means of reducing external inputs and improving internal resources. Symbiotic systems such as that of legumes and *Rhizobium* can be a major source of N in most cropping systems (Bohlool *et a.,l* 1992). Through Biological nitrogen fixation (BNF), the reduction of dinitrogen can be occurred from the air to ammonia by a large number of species of free-living and symbiotic microbes called diazotrophs.

BNFpresent an inexpensive and environmentally sound, sustainable approach to crop production and co nstitutes one of the most important Plant Growth Promotion (PGP) scenarios (De Bruijn *et al.,* 2015). Rhizosphere soil is the top layer of soil around plants' root which has large diversity of microbial organisms, which caused plant growth promoting activity. The plant growth promoting rhizobacteria (PGPR) colonize roots, enhance root branching, rooting number and increase growth through direct and indirect mechanisms. PGPR modified root architecture by production of phytohormones, siderophores, HCN, Nitrogen fixation and Phosphate solubilization mechanisms. PGPR also modify root functioning, improve plant nutrition and influence the physiology of the whole plant. N-fixers and P-solubilizers play key role in plant growth and yield of various crops.

However, the PGPR also play very crucial role to maintain the soil fertility and health (Kumar *et al.,* 2015). Rhizobial bio fertilizer is the mixture of substance which has latent microorganisms that can be applied to seeds, plant surfaces, or soil, and colonize the rhizosphere and promotes growth by increasing the supply or availability of primary nutrients to the host plant. Bio-fertilizers gives nutrients to legume plants through the natural processes of nitrogen fixation, solubilizing phosphorus, and stimulating plant growth through the synthesis of growth promoting substances. Inoculating of legume crops with latent rhizobial bio fertilizershas been approved to enhances the yield and yield components of legumes while maintaining soil health (Siczek and Lipiec, 2016). It is also believed to be eco-friendly practices used for improvement of N fixation resulted in increased shoot growth, number of pods and grain yield of faba bean. In Ethiopia, many researches has been done on rhizobiology for more than three decades and significant progresses were also achieved in the country (Amanuel *et al*., 2000 and Gebresamuel *et al*., 2015) are the few one among the Studies of rhizobium inoculation and fertilizer treatment on growth and production of pulse crops Ethiopia. However, most of the works had limitations in addressing all agro ecologies of Ethiopia and using the effective strain to different edaphic conditions. Additionally there was no research conducted in the study area on the evaluation of the effective strains of rhizobial biofertilizer in the production of Faba bean. The objective of this study was therefore, to evaluate the effect of different strains of Rhizobium biofertilizer in the production of Faba bean and to select the effective strain of rhizobial biofertilizer in the study area to enhance yield and yield components of Faba bean.

Materials and Methods

Description of the Study Area

Location, Agro Climate and Soil Type of the District

The study was conducted in 2021/2022 at Horro District. The district is located Horro,Guduru Wollagga Zone, Oromia Regional state, Ethiopia. Shambuu, which is the capital town of the zone and the district itself, is *located* 314 km away from *Addis Ababa*. It lies at an altitude range of 1800 to 2835 m.a.s.l., latitude

1,042726N to 1,091814N and longitude 270,000E to 316,199 E. The area has one long rainy season extending from March to mid-October with mean annual precipitation of about 1800 mm and the district's mean monthly rainfall is 12.8 to 343.8mm. The mean of monthly temperatures is between 17.2C^0 to 22.90 C^0. Horro district consists of 37.89% highland, 54.75% mid altitude and 7.86% lowland.The season is divided into three: the main rainy season (June-October), dry season (November-February) and short rainy season (March-May). The soil type of the district is nitisols.

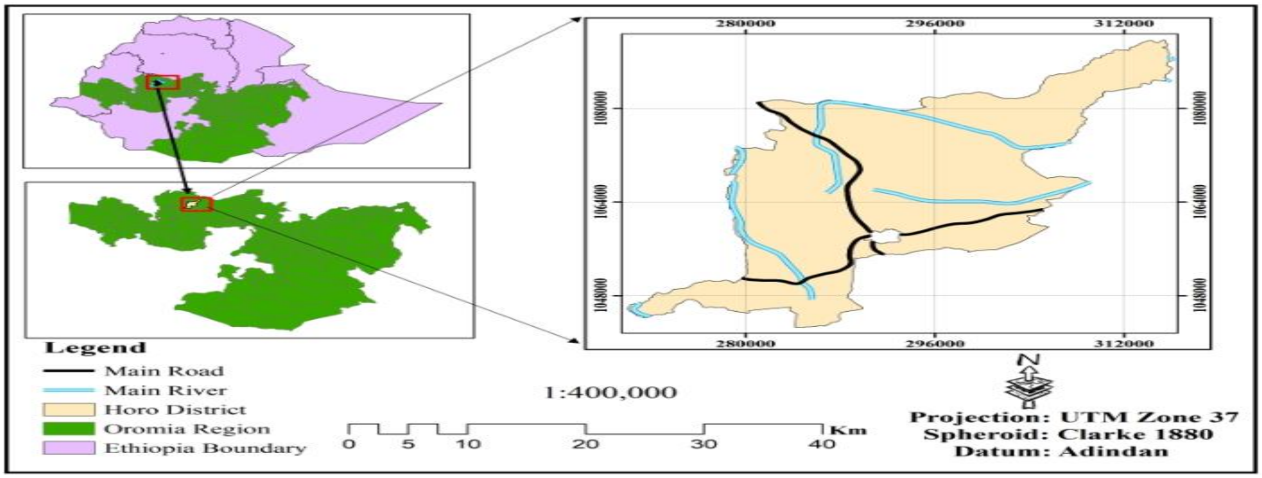


Figure1.*Location map of Horro District.*

Site Selection

Sites and farmers were selected in collaboration with key informant farmers, DAs, and the districts' agriculture and natural resource officers. The target sites were selected based on the high potential Faba bean producing kebele of the district and access of the road and the farm also selected depending on the willingness of the sites owner's farmers to accept the technology. Total of 8 farmers were selected from the district and the experiment was conducted on eight farmer's sites.

Materials and Methodology

The crop used in the experiment was Faba bean Welki variety (EH96049-2) that is well adapted and efficiently perform in the district.

Treatments

The followings are the three *Rhizobium leguminosarum* Strains and control that used as treatment during the conduction of the experiment.

Control (without both chemical fertilizer and bacterial strain).
Strain 1 (faba bean strain EAL-1017) + 50 Kg NPS/ha.
Strain 2 (faba bean strain EAL-1018) + 50 Kg NPS/ha.
Strain 3 (faba bean strain EAL-1035) + 50 Kg NPS/ha.

Treatment and Experimental Design

The lands have been prepared using Oxen plough (three times ploughed) before planting. The four treatments were replicated three times. The experimental plots have an area of 9 square meter (3*3) m^2 plot size. Treatments has been combined and laid out in randomized complete block design (RCBD) and assigned randomly to the experimental units (plots) within blocks. 0.5Kg/ha *Rhizobium leguminosarum* strains of bio fertilizer has been applied and mixed with the seed under shadow to protect the rhizobium from direct sunlight. The inoculated seed were planted first then the application of 50KgNPS/ha was followed.

Data Collection Methods

Number Nodule per Plant

Nodules are found the plant roots and they have been collected by digging of the soil around the plant roots. Among the whole plants in the plots three plants of Faba bean are randomly selected to be uprooted at their flowering stage for nodule collection parameter. The soil has been dig out using a hand hoe and the roots of the plant and soils has been excavated using spade. The excavated roots of plants were washed thoroughly by water in washing buckets to make the nodules free from the soil. Then the Nodules were collected in plastic bag for counting. Then the total number of nodules of each three plants in the plot were counted and registered as the number of nodule per plant with the specific treatment.

Plant Height Parameter

The data of plant height was recorded by selecting three plants in the plot randomly and measured by using measuring meters at physiological maturity stage. The average of measured height of three plants was recorded as plant height.

The Parameter of Pods per Plant

To collect the data of pod per plants, five plants were randomly selected and harvested from the rows of each plots. The pods has been collected and counted by separating them from each other. Then the average number of the five plants pod was recorded as number of pods per plant.

Seed Number per Pod

To collect the data of seeds per pod, the five plants randomly selected and harvested from the rows of each plots have been used by counting the number of grain/seed in the pod. To record the data of seed per pod, the total number of seed on the single plant has been divided by the total number of the pod on the same plant and finally the mean value was recorded as the seed per pod.

The Parameters of Biomass Yield, Grain Yield and Hundred-Grain Weight

To collect the data of above ground dry biomass, five plants were harvested nearest to the ground at the maturity stage of the plants from each plot. Then the plants were put in the open air to be dried and finally weighed to measure above ground plant biomass yield. The Grain yield parameter was recorded by measuring the weight of the grain yield of the five plants harvested from each plots and then the weight has been converted to yield per plot and yield per hectare. The grain yield was adjusted to 10% moisture content. Then hundred grains were selected randomly and counted from each treatment and weighed in gram with a digital balance and reported as hundred seed-weights.

The Procedures of Soil Sampling and Analysis

Disturbed surface soil samples has been taken by using an auger at the depth of (0-20cm) from the experimental sites by two way diagonal soil sample taking method. The soil sample has been taken and analyzed to determine the physic-chemical properties of the soil**.** The collected samples were mixed well and dried in an open air then sieved to pass through a 2 mm sieve for the analysis of soil pH, available P, cation exchange capacity (CEC), to determine total N and organic carbon. The soil was pulverized further to pass through a 0.5 mm sieve. The analyses were carried out by the soil laboratory of Nekemte soil research center using standard methods and procedures. Soil pH was determined using a digital pH metre at 1: 2.5 soils to water ratio (FAO, 2009). The other soil analyzing parameter was organic carbon. OC was analyzed by using the Walkey and Black oxidation method (Sertus *et al*., 2000).

The texture was tested by using hydrometer method (FAO, 2009). The Micro-Kjeldhal method was used to estimate the Total N content (Horneck *et al*., 2011). The available P was extracted with a 0.5 M NaHCO3 solution (Olsen *et al*., 1954). CEC was determined by extracting the soil samples utilizing ammonium acetate (1 M NH4OAc, pH 7.0) and then by washed again with ethanol (98%) to rinse the left ammonium (NH_4^+) ions. The adsorbed NH_4^+ in the soil was displaced with sodium chloride and then determined by steam distillation and titration using 0.1 M NaOH (Hesse, *et al*., 1972).

Analysis of the Statistics

The ANOVA analysis was done by using the general linear model (GLM) methods packed in the SAS statistical software version 9.20 (SAS 2008). Least Significance Difference test (LSD) held at 5% probability level and Means were separated using fisher's protected.

Results and Discussions

Soil Analysis Results

As it is indicated in Table1, the soil data of the experimental sites was taken and analyzed and then results of soil analysis were shown in the table below.

Table1. The results of Soil analysis of the experimental Site

Descriptionofthevalues	**Range**	**Mean**
pH(H_2O)	5.31-5.87	5.52
EA(H^++$Al^{3+)}$Cmol$_{(+)}$/Kg	0.41-1.34	0.69
Av.P(ppm)	8.53-37.31	27.51
OC (%)	3.37-4.78	4.05
OM (%)	5.8-8.23	6.98
TN (%)	0.29-0.412	0.349
E.Ca^{2+} (cmol$_{(+)}$/Kg)	10.23-18.94	15.15
E.Mg^{2+} (cmol$_{(+)}$/Kg)	3.75-6.76	5.31
CEC (cmol$_{(+)}$/Kg)	24.36-32.64	28.78

PH=power of Hydrogen, EX.Ac=Exchangeable acidity, Av.P=AvailablePhosphorus,Tot.N=TotalNitrogen,OM=Organicmatter.

The Results of Yield and Yield Related Parameters

The results of combined analysis of variance revealed different results between the treatments on the resul ts of plant height, branches per plant, number of pod per plant, grain yield and biomass of Faba bean with respect to the difference in the treatments.

Nodule Number

The greatest numbers of nodules per plant (54.07) in table 2 were observed with the combined application of mineral fertilizer and inoculants of FB EAL -110+50Kg/ha. However the mean of nodulation in the different treatments were rating (range of 32-54). It was statistically insignificant (p>0.05) and not influenced by any treatment.

Plant Height and Biomass

In this experiment the results of ANOVA analysis did not show significantly ($P \leq 0.05$) difference from the treatments on plant height in Table 2. The highest number of plant height (151.30 m) in table 2 were recorded with the treatment combination of the mineral fertilizer 50Kg/ha NPS and inoculants of rhizobia strain FB-EAL-1035. The lower plant height (144.7m) was recorded with control treatment. However the mean of plant height in the different treatments were rating (Range of144.7-151), the result is insignificant (p>0.05) and not influenced by any treatment. In this study, the results of ANOVA showed significantly ($P \leq 0.05$) difference among the treatments on the yield of biomas s. The maximum Biomass yield (10,507.9Kg/ha) was gained from the combined application of EAL 1017 strain and 50 kg ha−1 NPS, whereas the lowest Biomass yield (8,615Kg/ha) was obtained from the control. This work is in agreed with the study of(Rugheim and Abdelgani, 2012), who showed that inoculation of rhizobial strains with Faba bean combined with Chemical fertilizer can significantly increase Faba bean biomass yield. This results also in line with the finding of (Adissie *et al*., 2020), who indicated that inoculation of rhizobial strains increases biomass yield of Faba bean and stated that the difference in the biomass yield of legume plants when inoculated with rhizobial biofertilizer could be from the additional supply of nitrogen to the plants via the biological nitrogen fixation by the inoculated microorganisms.

Table: 2. Combined effect of rhizobial inoculation and NPS fertilizer on faba bean (nodule number plant−1, Plant height and biomass).

Treatments	Nodule.no/plant	Plant height (cm)	Biomass (Kg ha^{-})
Control	35.73	144.70	8,615^{b}
FBEAL-1017+50Kg/haNPS	37.90	150.53	10,507.9^{a}
FBEAL-1035+50Kg/haNPS	32.33	151.30	9,332.1^{ab}
FBEAL-110+50Kg/haNPS	54.07	149.70	9,442.4^{ab}
Significance	NS	NS	**
LSD(0.05)	23.03	12.84	1,353.3
CV	30.57	4.57	7.59

*EAL=Ethiopian Agricultural Legume; ** =Significant (P≤0.05); LSD: Least significant difference; CV:C oefficient of variation; NS, Non significant; control; (withoutanyfertilizer); ***=highlysignificant.*

Pod per Plant and Seed per Pod

In this experiment the results of ANOVA did not show significantly ($P \leq 0.05$) difference from the treatments on both pod per plant and seed per pod. However the results of ANOVA analysis did not show significantly ($P \leq 0.05$), there were difference from the treatments on both pod per plant and seed per pod. The highest numbers of pod plant^{-1} and seed pod^{-1} (17.15 and 2.96) respectively in table 3 were observed with the combined application of the mineral fertilizer (50Kg/ha NPS) and strain of FB-EAL-1017 and the lower pod per plant and seed per pod (16.8 and 2.81) respectively were recorded with control treatment.

Table 3. The effect of the combination of rhizobial inoculation and NPS fertilizer on faba bean on (Pod plant^{-1}, and Seed pod^{-1}).

Treatments	Pod per plant	Seed per pod
Control	16.85	2.81
FPEAL-1017+50Kg/haNPS	17.15	2.96
FPEAL-1035+50Kg/haNPS	16.81	2.86
FPEAL-110+50Kg/haNPS	16.82	2.82
Significance	NS	NS
LSD(0.05)	0.55	0.182
CV	1.72	3.37

*EAL=Ethiopian Agricultural Legume; ** =Significant (P≤0.05); LSD: Least significant difference; CV:C oefficient of variation; NS, Non significant; control; (withoutanyfertilizer); ***=highlysignificant*

Grain Yield and Hundred Seed Weight

Analysis of variance indicated that, Faba bean grain yield was highly affected by the treatment of Rhizobial strains (FB EAL-1017) and 50Kg/ha NPS and significantly ($P \leq 0.05$) influenced Faba bean grain yield. As it has been indicated in table below, the result clearly shown significant difference among the treatments on 100 seed weight and grain yields. The maximum grain yield (3587.73Kg/ha) was recorded with the treatment combination of 0.5Kg/ha EAL-1017 Rhizobial strain and 50 kg ha−1 NPS, while the least grain yield (2612.27Kg/ha) was obtained from the control. The study is in lined with the finding of (Rugheim, and Abdelgani, 2012), who shown that combined treatment of chemical fertilizer with inoculation of rhizobial strains significantly increased faba bean grain yield and also in agree with the works of (Rifat *et al*., 2008), who stated that when rhizobial inoculation applied by combining with P fertilizers it has had a significant influence on nodule number, shoot dry matter, and grain yield of the faba bean. The highest results of grain yield (3587.73Kg/ha) gained from this experiment with the treatment of 0.5Kg/ha EAL-1017 Rhizobial strain and 50 kg ha−1 NPS is agree with the finding of (Tekle *et al*., 2016) who reported the production potential of faba bean Walki variety is (3,407Kg/ha).The ANOVA result also shown that combined use of 50 kg ha−1 NPS and 0.5 Kg ha−1 FB EAL-1017 Rhizobial strain gave statistically significant difference ($P \leq 0.05$) on 100 seed weight (0.022Kg) over the control as well as the other strains. This result could in agree with the finding of (El-Wakeil and El-Sebai,2009), Who stated that faba bean inoculation with rhizobial strain alone could increase 100 seed weight and the results again in line with the works of (Woldekiros., 2018), which reported that hundred seed weight can be increased by 11.44% when inoculated than un inoculated plants.

Table 4.The effect of the Combination of rhizobial inoculation and NPS fertilizer on Faba bean (Grain yields and 100 seed weight).

Treatments	Grain yield (Kg ha^{-})	Hundred Seed weight (kg)
Control	2,612.27[d]	0.021
FPEAL-1017+50Kg/haNPS	3,587.73[a]	0.022
FPEAL-1035+50Kg/haNPS	2,976.00[b]	0.021
FPEAL-110+50Kg/haNPS	2,810.67[c]	0.020
Significance	***	***
LSD(0.05)	66.036	0.0005
CV	1.17	1.38

*EAL=Ethiopian Agricultural Legume; ** =Significant (P≤0.05); LSD: Least significant difference; CV:c oefficient of variation; NS, Non significant; control; (withoutanyfertilizer); ***= highlysignificant*

Conclusions and Recommendations

In Ethiopia the production of Faba bean is constrained mainly due to the problems of soil fertility and soil acidity especially in western part of the country. To overcome the problems researches has to dig out many ideas to bring a solution. In this activity different rhizobium strains of Biological Nitrogen Fixers (BNF) are involved to examine the remarkable activity of the different rhizobium strains to increase yield and yield components of Faba bean through their nitrogen fixing activities. Accordingly, field experiment gave different results for the different strains on the yields and yield components of Faba bean. The highest grain yield was obtained from FB EAL-1017 strain combined with 50Kg ha^{-1} of NPS. As indicated from the result it has been concluded as, using the combination of organic, bio fertilizer (0.5Kg ha^{-1} FB EAL1017) strain and mineral fertilizers (50 Kg ha^{-1} NPS) can significantly enhance the yield of faba bean.

This technology is a cheap external source of plant nutrition especially for smallholder farmers who cannot afford expensive inorganic fertilizers in addition to its environmentally unfriendly. Therefore depending on the result obtained from the experiment, the technology of using biofertilizer of rhizobium strain called FB-EAL-1017 combined with 50 Kg ha^{-1} NPS has to be pre scaled, the rhizobium strains called FB-EAL-1017 has to be multiplied and its biofertilizer has to be produced in large numbers of sachets and inoculating of Faba bean seeds with 0.5Kg ha^{-1} of Rhizobium strains called FB-EAL-1017 with 50 Kg ha^{-1} NPS were recommended at Horro district and the same soil types and agro ecological zones.

References

Adissie, S., Adgo, E. and Feyisa, T., 2020. Effect of rhizobial inoculants and micronutrients on yield and yield components of faba bean (Vicia faba L.) on vertisol of Wereillu district, South Wollo, Ethiopia. *Cogent Food & Agriculture*, *6*(1), p.1747854.

Amanuel, G., Kühne, R.F., Tanner, D.G. and Vlek, P.L.G., 2000. Biological nitrogen fixation in faba bean (Vicia faba L.) in the Ethiopian highlands as affected by P fertilization and inoculation. *Biology and fertility of soils*, *32*(5), pp.353-359.

Bohlool, B.B., Ladha, J.K., Garrity, D.P. and George, T., 1992. Biological nitrogen fixation for sustainable agriculture: A perspective. *Plant and soil*, *141*(1), pp.1-11.

CSA (Central Statistics Authority).2015.The Federal Democratic Republic of Ethiopia central Statistical report on area and production of major crops (private peasant holding, Meherseason),VolumeI,Stati sticalBulletin532,AddisAbaba,Ethiopia.

De Bruijn, F.J., 2015. Biological nitrogen fixation. In *Principles of plant-microbe interactions* (pp. 215-224). Springer, Cham.

Dey, M.M., Paraguas, F.J., Kambewa, P. and Pemsl, D.E., 2010. The impact of integrated aquaculture–agriculture on small‐scale farms in Southern Malawi. *Agricultural Economics*, *41*(1), pp.67-79.

El-Wakeil, N.E. and El-Sebai, T.N., 2009. Role of biofertilizer on faba bean growth, yield, and its effect on bean aphid and the associated predators. *Archives of Phytopathology and Plant Protection*, *42*(12), pp.1144-1153.

FAO(Food and Agriculture Organization). FASTAT Data base for Production of Pepper. 2009. Available online: http://faostat.fao. org/site/3339/default.aspx (accessed on 15 June 2021).

Gebresamuel, G., Gebremeskel, Y., Gebretsadik, A., Tesfay, G., Legesse, D., Elias, E., van Beek, C., van Kekem, A. and Diro, M., 2015. 19. FABA BEAN YIELD RESPONSE TO RHIZOBIUM INOCULATION AND NP FERTILIZER APPLICATION: EXPERIENCE FROM SOUTHERN TIGRAY, ETHIOPIA. *Experiences and Challenges*, p.176.

Genetu, G., Yli-Halla, M., Asrat, M. and Alemayehu, M., 2021. Rhizobium Inoculation and Chemical Fertilisation Improve Faba Bean Yield and Yield Components in Northwestern Ethiopia. *Agriculture*, *11*(7), p.678.

Hesse, P.R. A., 1972. Text Book of Soil Chemical Analysis; John Murray Limited: London, UK, 1972; p. 470.

Horneck, D.A.; Sullivan, D.M.; Owen, J.S.; Hart, J.M.,2011.SoilTestInterpretationGuideEC1478; Oregon State University: Corvallis, OR, USA, 2011; p. 12.

Jensen,E.S.,Peoples,M.B. and Hauggaard Nielsen,H.,2010.Faba bean in cropping systems .*Field crops research*,*115*(3),pp.203-216.

Jida, M and Assefa,F.,2014.Effects of acidity on growth and symbiotic performance of Rhizobium legumi nosarumbv.vicia estrains isolated from Faba bean producing areas of Ethiopia.*Science*,*Technologya ndArtsResearchJournal*,*3*(2),pp.26-33.

Kubure TE, Raghavaih CV, Hamza I (2016). Production potentials of Faba bean (Vacia faba.L) Genotypes in relation to plant Densities and Phosphorus Nutrition on Vertisols of central Highlands of West Showa zone, Ethiopia, East Africa. Adv Crop sci Tech 4:214.doi:10.4172/2329-8863.1000214

Kumar, A., Bahadur, I., Maurya, B.R., Raghuwanshi, R., Meena, V.S., Singh, D.K. and Dixit, J., 2015. Does a plant growth promoting rhizobacteria enhance agricultural sustainability. *J Pure Appl Microbiol*, *9*(1), pp.715-724.

Mulissa Jida and Fassil Assefa. 2012. Phenotypic diversity and plant growth promoting characteristics of Mesorhizobium species isolated from faba bean (Cicer arietinum L.) growing areas of Ethiopia. African Journal of Biotechnology 11: 7483-7493.

Olsen, S.R.; Cole, C.V.; Watanabe, F.S.; Dean, L.A. Estimation of Phosphorus in Soils by Extraction with Sodium Bicarbonate; Circular 939; USDA: Washington, DC, USA, 1954; p. 19

Rifat, H.; Ali, S.; Siddique, M.; Chatha, T. Biological nitrogen fixation of summer legumes and their residual effects on subsequent rain fed wheat yield. Pak. J. Bot. 2008, 40, 711–722.

Rugheim, A.M.E. and Abdelgani, M.E., 2012. Effects of microbial and chemical fertilization on yield and seed quality of faba bean (Vicia faba).

Sertus,S.;Bekel,T.Procedures for Soil andPlantAnalysis;TechnicalPaper74;NationalSoilResearchCenter: Addis Ababa,Ethiopia, 2000; p. 110

Siczek, A. and Lipiec, J., 2016. Impact of faba bean-seed rhizobial inoculation on microbial activity in the rhizosphere soil during growing season. *International Journal of Molecular Sciences*, *17*(5), p.784.

Woldekiros, B., 2018. Response of faba bean (vicia faba l.) to rhizobium inoculation and potassium fertilizer rates at Alicho Wuriro Highland, Southern Ethiopia. *Int J Res Agri For*, *5*(5), pp.43-47.

Verification of soil test crop response based calibrated phosphorous for Bread Wheat production in Sinana District of Bale Zone, Oromia Region, Southeastern Ethiopia

Mulugeta Eshetu*, Regassa Gosa, Tesfaye Ketema and Girma Getachew
Sinana Agricultural Research Center, P. O. Box 208, Bale-Robe, Ethiopia
***Corresponding author**: mulugeteshetu@gmail.com (Mulugeta Eshetu)

Abstract
*On-farm verification trial of soil test crop response based phosphorus recommendation for bread wheat was conducted in Sinana District of Bale highland, Oromia Region Southeastern Ethiopia in 2022 bona (July to December)) cropping season using recommended nitrogen rate (46 N kgha-1), P critical (5.24 ppm) and P-requirement factor (22).The verification experiment was conducted to verify P critical and P-requirement factor for bread wheat production. Three treatments were used: control (without fertilizer), blanket recommendation and soil test crop response based on phosphorus recommendation using improved bread wheat dambel variety 10m*10m plot size at seven sites using farmers' replications. Soil samples before planting and agronomic data were taken and analyzed using standard laboratory procedure and R software 4.1.1 version program, respectively. The results of analyzed soil samples and agronomic data indicated that the soil pH (H_2O) of the study area was moderately to slightly acidic with the value ranging from* 6.02 to 6.27 *and the available phosphorus content was varied from* 1.15 to 3.17 mg/kg *which is categories under very low class. The statistical analysis indicated that there was a significant difference ($p \leq 0.05$) between in yield and yield components bread wheat due to the treatment effects. Accordingly, the highest bread wheat grain yield (6414.67kgha^{-1}) was obtained from a soil test based fertilizer recommendation with an economically feasible and acceptable marginal rate of return (5073.46%) which is greater than the acceptable minimum rate of return. Therefore, site specific soil test based crop response fertilizer recommendation based on optimum N (46 kg/ha), Pc (5.22 ppm) and Pf (22) for bread wheat production were demonstrated. Based on this finding, further determination and demonstration of the adjusted NPS fertilizer rate based on calibrated phosphorus for bread wheat production should be recommended.*

Keywords: Blanket recommendation, Soil test based fertilizer recommendation, optimum nitrogen, P critical, P-and requirement factor and bread wheat.

Introduction

Ethiopia is one of the largest wheat producers in Sub-Saharan Africa (SSA) with a yearly estimated production of 4.6 million tons on 1.69 million hectares of land in 2017/18 (CSA, 2018) yield per hectare. The average wheat productivity in SSA is 1.7 tons ha-1 (FAOSTAT, 2015), nearly 50% below the world average majorly due to low soil fertility status and other management practices. Most Ethiopian soils are deficient in nutrients, especially nitrogen and phosphorus, and fertilizer application has significantly increased the yields of crops (Tekalign *et al*., 2001). In particular, nitrogen (N) and Phosphorus (P) fertilizer are the main crop production limit factor that declines from time to time due to soil fertility level decline for many reasons. In Ethiopia, particularly in the study area, low soil fertility due to removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residues from farmlands, low or absence of integrated organic and inorganic fertilizer use and lack of a proper crop rotation program is the bottleneck for sustainable optimum crop production.

The proper management of soil fertility is a crucial role in improving agricultural crop production and soil productivity on a sustainable basis and assuring food security both at regional and household levels in the country. Hence, to step up the productivity of wheat crop production, soil-based crop response fertilization is essential. In order to overcome the problem of the application of Urea and DAP fertilizers in the form of blanket recommendations for long years, regardless of considering the physical and chemical properties of the soil as well as not taking into account climatic conditions and soil fertility level, site-specific fertilizer rates recommendations were conducted.

Additionally, blanket fertilizer application may lead farmers to above the recommendations or majorly below the recommended rate due to high prices and others factors. This method of fertilizer application results in declines in crop production, soil productivity, and economy and also damages the environment (Meryl *et al*., 2015). Therefore, site-specific nutrient management aims to optimize the supply of soil nutrients over time and space to match the requirements of crops through the key principles of fertilizers at the right rate, right time, and in the right place have a great role (Bruulselma *et al*., 2012).

Soil testing is the most reliable tool for making good economic and environmental decisions about applying fertilizers. Accordingly, Sinana Agricultural Research Center, Soil fertility Improvement Research Team has conducted soil test-based phosphorus calibration studies in Sinana District for bread wheat production from 2019 -2021 cropping season and optimum nitrogen rate (46 N kgha-1), P critical (5.24 ppm) and P-requirement factor (22) were determined (Mulugeta et al., 2022). Thus, before disseminating, demonstrating and scaling up this technology, it should be verified on the farmer's field and develop a user guideline for bread wheat production areas in the district (Mulugeta et al., 2022). Therefore, the study was initiated with the objectives to verify phosphorus critical and phosphorus requirement factors for bread wheat production in Sinana District, Bale Zone, Oromia Region Southeastern, Ethiopia.

Material and Methods

Descriptions of the study area

The study was conducted in Sinana District which is one of the Bale highlands Oromia Regional State, Southeastern Ethiopia. This District is bordered by Goro District in the east, Dinsho District in west, Agarfa and Gassera in the north and Goba District in northeast. Sinana district is located about 460 km from the capital city of Addis Ababa. Geographically, Sinana District is located at 6° 47' 30"to 7° 22' 0" N and 39° 55' 0" to 40° 21' 0" E. Topographically, the area consists of gently undulating plain with altitude 1700 to 3100 above mean sea level (masl).

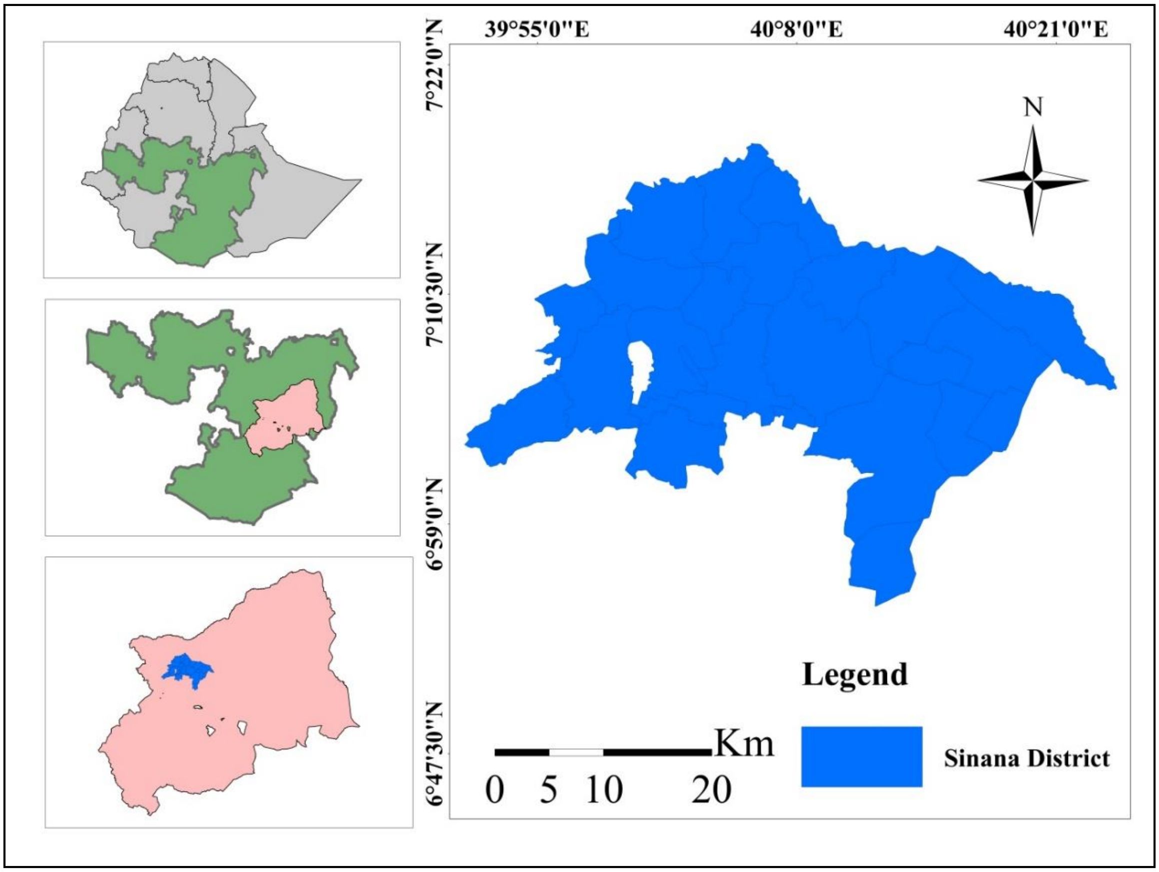


Figure 1. Map the study site

Climate and agro-ecology

The rainfall patterns of the area are a bimodal distribution having SH2 (humid, sub-humid to cool mild highland) agroecology. The area is characterized by annual rainfall between 453 mm and 1130 mm. The temperature maximum ranged from 21.9 to 23.5°C while the minimum varied from 6.8 to 10.1°C. Agriculture is the main economic activity in the district, with the major sources of their livelihood income mainly crop cultivation. Major crops grown in the district include wheat, barley, faba bean, field pea, and others.

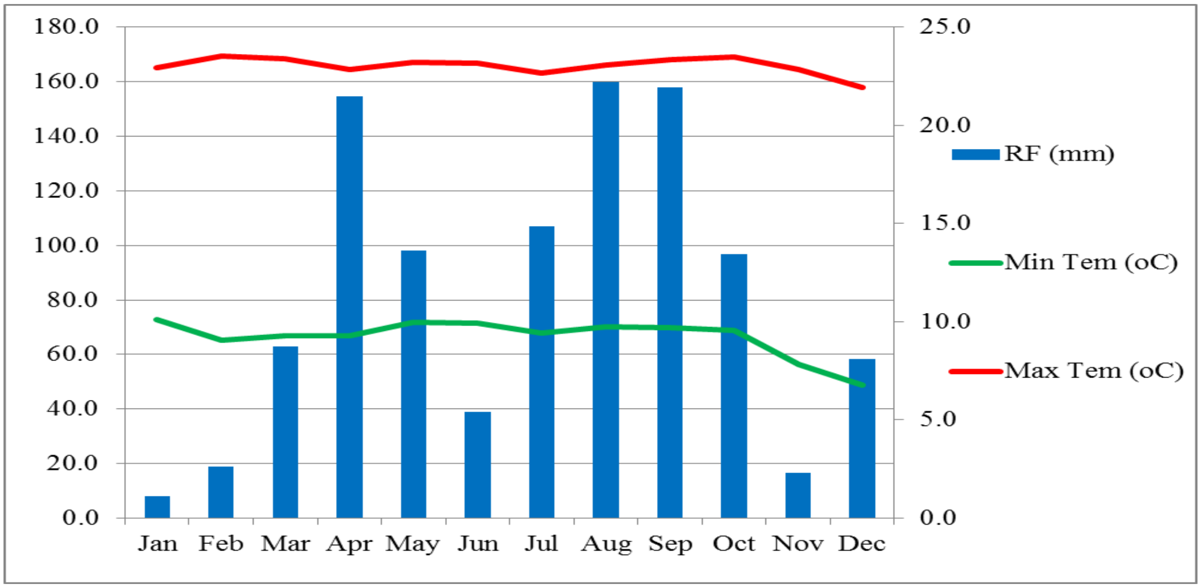


Figure 2. Mean monthly rain fall (mm), Max and Min Temperature (°C) of Sinana District.

Experimental design and layout

The experiment was conducted on 7 (seven) farmers' fields in the 2022 main cropping season for one year. The experimental field was arranged with a total of 3 treatments viz control (without fertilizer), blanket recommendation, and soil-test based P fertilizer recommendation with optimum nitrogen rate (46kgha^{-1}). Fertilizer sources for N and P urea and TSP, respectively, with 150kgha^{-1} improved bread wheat dambel variety in plot size was 10 m*10 m (100m^2) were used.

Soil Sampling, Preparation and laboratory Analysis

Soil samples at 0- 20 cm depth were taken from the experimental sites before planting using auger sampling points and composites were prepared. The composite soil samples were labeled with necessary information then air dried and crushed using a mortar and pestle to pass through a 2 mm mesh sieve for most soil physicochemical properties. The initially available phosphorus below critical concentration determined for the district was selected to conduct the experiment. The analyses were conducted following standard laboratory procedures at Sinana Agricultural Research Center Soil Laboratory.

Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). Finally, the textural class of the soil was assigned using USDA textural triangle classification system (USDA, 1987). The pH of the soil was measured in the supernatant suspension of a 1:2.5 soil-to-water ratio using a pH meter (Rhoades, 1982). (Walkley, 1934) the method was used for the determination of organic carbon. Total nitrogen was determined using the Kjeldahl method as described by (Bremner and Mulveny, 1982). Available P was determined following the Olsen method Olsen (1954) using ascorbic acid as a reducing agent. Then Phosphorus fertilizer requirement was calculated for each farmer by using the formula:

Phosphorus fertilizer rate (kg/ha) = (Pc-Pi)*Pf;

Where, **Pc**-phosphorus critical level **5.24 ppm, Pi-** Initial available phosphorus, **Pf-**phosphorus requirement factor **22** for Sinana District.

Agronomic Data Collection

Agronomic data were collected on the yield and yield components such as plant height, numbers of productive tillers, seed per spike, above-ground biomass yield; grain yield, and thousand kernel weight were taken and then finally subjected to standard statistical analysis. The Least Significant Difference (LSD) at 5% probability level test was used for mean separation for significant treatments.

Statistical Analysis

The collected food barely yields and yield component data were subjected to analysis of variance (ANOVA) using R software version 4.1.1. Significant differences among treatment means were separated by least significant differences (LSD) at a 5% level of probability and using a linear correlation coefficient matrix. Based on these, interpretations were made following the procedure described by (Gomez K.A. and Gomez, A. A. 1984).

Partial Budget Analysis

A partial budget analysis was performed to determine the economic feasibility of the treatments. Partial budget, dominance, marginal, and rate of marginal return analysis were used. The average yield was adjusted downwards to reflect the difference between the experimental plot yield and the yield farmers will expect from the same treatment. The average grain yield was also adjusted by reducing 10% to minimize the overestimation of yield when yield of a small plot was converted to a hectare basis. The average open market price (Birr/kg) of bread wheat, urea (N) fertilizers were considered for analysis. The minimum acceptable rate of return (MARR) was 100% (CIMMYT, 1988), which is suggested to be realistic. This enables making farmer recommendations from marginal analysis.

Result and Discussion

Selected soils physicochemical properties

The results of soil particle size distributions ranged from 14 - 26%, 16 - 36%, and 38 – 66% for sand, silt, and clay content, respectively. As the rate suggested by Hazelton and Murphy (2007) is low to moderate for both sand and silt content, whereas moderate to very high for percent clay content. According to the USDA soil textural class triangle, all soils of the experimental site were clay textural class (Table 1).

The pH (pH_H2O) varied from 6.02 to 6.27 as indicated (Table 1). As per the pH ratings suggested by Jones (2003) pH in the soil-water ratio was rated as slightly acidic media. The values of soil organic matter (OM) ranged from 1.49 to 2.08% (Table 2). As per the ratings of Tekalign (1991) OM contents for soils of the experimental sites are rated in the low to moderate class. The values of total nitrogen (TN) content varied from 0.10 to 0.16% rated as low to moderate as ratings suggested by (Landon, 1991). The value of available phosphorus (Av. P) ranged from 1.15 to 3.17 mg/kg (Table 2). As the rate established for soils determined by the Olsen method phosphorus was rated as very low (Cottenie, 1980). The very low categories of these major soils plant nutrients might be due to leaching, continues cereal-based monocropping, limited inputs of organic and inorganic sources fertilizers, nutrient fixation and loss as a result of soil erosions. Generally, the pH of the experimental site soil was within the normal range for crop production whereas phosphorus and nitrogen are at a critical level so it demands great attention.

Table 1. Selected soils physicochemical properties of the experimental sites of Sinana District

Site Name	Sand (%)	Silt (%)	Clay (%)	Textural class	pH (H_2O)	OM (%)	TN (%)	Av.P (mg/kg)
1	14	20	66	clay	6.11	1.55	0.11	2.09
2	18	16	66	clay	6.27	2.05	0.13	1.15
3	18	24	58	clay	6.02	2.08	0. 10	3.17
4	14	24	62	clay	6.09	1.75	0.15	2.33
5	26	36	38	clay	6.14	2.26	0.16	2.33
6	18	32	50	clay	6.08	1.85	0.14	1.62
7	14	32	54	clay	6.12	1.49	0.13	2.02

Where: OM = soil organic matter, TN = Total nitrogen, Av. P = available phosphorus

Response of Bread Wheat yield and yield components

The statistical analysis of all agronomic data collected indicated that there was a significant difference ($p \leq 0.05$) between different fertilizer recommendations on bread wheat yield and yield components. Accordingly, the highest yield components of bread wheat, namely plant height, spike length, seed per spike, number of tillers, biomass, and thousand kernel weight were obtained from soil test-based crop response fertilizer recommendation followed by blanket recommendation, while the lowest from the control (without fertilizer) (Table 2). The responses on bread wheat grain yield revealed that the highest (6414.67 $kgha^{-1}$) and the lowest (2311.67 $kgha^{-1}$) grain yield were recorded from soil test-based crop response fertilizer recommendation and control, respectively. This result confirmed with the findings of Gidena (2016); Dejene et al (2020); Temesgen and Chalsissa (2020) and Mulugeta *et al* (2022) who reported that soil test-based site-specific optimum fertilizer recommended results the highest grain yield over blanket recommendation.

Table 2. Response of bread wheat production to verification of soil test crop response based Calibrated in Sinana District

Treatment	PH (cm)	SL (cm)	SPS	NT	BM (kg/plot)	GY (Kg/ha)	TKW (g)
Control	80.53^{c}	3.71^{c}	29.63^{c}	2.58^{b}	62.93^{c}	2311.67^{c}	32.53
BK	88.33^{b}	6.30^{b}	37.70^{b}	3.57^{b}	92.16^{b}	3636.33^{b}	34.58
STBFR	98.60^{a}	9.46^{a}	47.15^{a}	5.05^{a}	119.23^{a}	6414.67^{a}	36.63
Mean	89.16	6.49	38.16	3.73	91.44	4120.89	34.58
LSD (0.05%)	7.41	0.80	5.21	1.28	13.51	226.60	NS
CV (%)	6.75	10.07	11.10	27.80	12.01	7.66	10.74

Where: BK = blanket recommendation, STBFR = soil test based crop response fertilizer recommendation, PH = plant height; SL = Spike length, SPS = seed per spike, NT = Number of productive tiller, BM = above ground biomass, GY = Grain yield, TKW = thousand kernel weight

Economic analysis

Based on this result, the partial budget analysis indicated that the soil test based P recommendation is economically feasible for bread wheat production in the district. Accordingly, the use of soil test based crop response phosphorus recommendation is advisable having net benefit (170296.09 ETB) with acceptable MRR (5073.46 %) for bread wheat production at the Sinana district.

Table 3. Partial budget analysis for verification of soil test crop response based Calibrated phosphorous for bread wheat production in Sinana District

Treatment	UnGY (Kg/ha)	AGY ($Kgha^{-1}$)	GB ($Birrha^{-1}$)	TVC ($Birrha^{-1}$)	NB ($Birrha^{-1}$)	MRR (%)
Control	2311.67	2080.50	62415.09	0.00	62415.09	0
BK	3636.33	3272.70	98180.91	1450.00	96730.91	2366.61
STBFR	6414.67	5773.20	173196.09	2900.00	170296.09	5073.46

Where; BK = blanket recommendation, STBFR = soil test based crop response fertilizer recommendation, UnGY = unadjusted Grain yield; AGY = Adjusted Grain Yield; GB = Gross benefit, TVC =Total variable cost; NB = Net benefit; MRR = Marginal rate of return

Farmer perception

The experiment was ranked based on the farmer preference perception and selection criteria (Table 4). Accordingly 55 farmers were used to select and evaluate based on his own knowledge, experience and innovations the verification trials at maturity stage.

Table 4. Farmer's perception and selection criteria

Treatments	Rank	Reason for selection (criteria)
Control	3rd	
BK	2nd	
STBFR	1st (100%)	Highest seed per spike, spike length, plant height, more productive tiller, good standing and expected high grain yield.

Where; BK = blanket recommendation, STBFR = soil test based crop response fertilizer recommendation

Conclusion and Recommendations

Soil test crop response based on fertilizer recommendation significantly increased the yield and yield components of bread wheat than a blanket recommendation for Sinana District. The results of the current study revealed the verification trial of recommended nitrogen rate (46 N kgha-1), Pc (critical level) (5.24) and phosphorus requirement factor Pf (22). The highest bread wheat grain yield ($6414.67kgha^{-1}$) with an economically feasible and acceptable marginal rate of return (5073.46%) which is greater than the acceptable minimum rate was obtained from a soil test based fertilizer recommendation. Therefore, determined optimum nitrogen (46 kg/ha), Pc (5.24) and Pf (22) should be advisable for bread wheat production in Sinana district and similar soil types and agroecology. Based on this finding, further determination and demonstration of the adjusted NPS fertilizer rate based on calibrated phosphorus for bread wheat production should be recommended.

References

Bouyoucos, G. J., 1962. Hydrometer method improved for making particle size analyses of soils 1. *Agronomy journal*, 54 (5): 464-465.

Bremner JL and Mulveny CS., 1982. Nitrogen Total, In: AL Page (ed). Methods of Soil Analysis, Part Two, Chemical and Microbiological properties, 2nd ed. Am. Soc. Agron. Wisconsin pp. 595-624.

CIMMYT. 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition, Mexico, DF.,79 pp.

Cottenie, A., 1980. Soil and plant testing as a basis of fertilizer recommendations. FAO soil bulletin 38/2. Food and Agricultural Organization of the United Nations, Rome.

Gomez, K.A. and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research. 2nd ed. John Wiley and Sons, New York, USA.P. 680.

Hazelton, P. and Murphy, B. 2007. Interpreting Soil Test Results: What Do All the Numbers Mean? 2nd Edition. CSIRO Publishing.

Jones, J. Benton. 2003. Agronomic Hand Book: Management of crops, soils and their fertility. CRC Press, Washington, USA.

Landon, J. R., 1991. Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Sub Tropics. Longman Scientific and Technical, Essex, New York, USA, 474p.

Mulugeta Eshetu, Daniel Abegeja, Regassa Gosa, Tesfaye Ketama, Girma Getachew, Tilahun Chibsa. Soil Test Based Crop Response Phosphorus Calibration Study for Bread Wheat Production in Sinana District of Bale Zone, Southeastern Ethiopia. International Journal of Science and Qualitative Analysis. Vol. 8, No. 1, 2022, pp. 1-12. doi: 10.11648/j.ijsqa.20220801.11.

Mulugeta Eshetu, Shure Sebboka, Tilahun Chibsa, Chala Chimdessa, Negash Bedasso. Optimization of Fertilizer Recommendations for Bread Wheat at Sinana District of Bale Zone, Southeastern Oromia, Ethiopia. International Journal of Science and Qualitative Analysis. Vol. 3, No. 6, 2017, pp. 55-60. doi: 10.11648/j.ijsqa.20170306.11.

Olsen, S. R., Cole, C. V., Watanabe, F. S., and Dean, L. A. 1954. Estimation of available phosphorous in soils by extraction with Sodium Bicarbonate. *USDA Circular*, 939: 1-19.

Rhoades JD .1982. Solubale salts. In: Page AL, Millere RH and Page DT (eds) Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties, pp 167–180. Madison, WI: American Society of Agronomy.

Tekalign Tadesse. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working DocumentNo. 13. International Livestock Research Center for Africa, Addis Ababa.

USDA (United States Department of Agriculture). 1987. Soil Mechanics Level I-Module 3: USDA Textural Classification Study Guide. National Employee Development Staff, Soil Conservation Service, USDA.

Walkley, A, Black, I. A, 1934. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37: 29-37.

Verification of soil test crop response based calibrated phosphorous for Food Barely production in Sinana District of Bale Zone, Oromia Region, Southeastern Ethiopia

Mulugeta Eshetu*, Regassa Gosa, Tesfaye Ketema and Girma Getachew

Sinana Agricultural Research Center, Soil Fertility Improvement, P. O. Box 208, Bale-Robe, Ethiopia
*Corresponding author: mulugeteshetu@gmail.com (Mulugeta Eshetu)

Abstract

*On-farm verification trial of soil test crop response based phosphorus recommendation for food barely was conducted in Sinana District of Bale highland, Oromia Region Southeastern Ethiopia in 2022 bona (July to December)) cropping season using recommended nitrogen rate (46 N kgha^{-1}), P critical (4.60ppm) and P-requirement factor (20).The verification experiment was conducted to verify P critical and P-requirement factor for food barely production. Three treatments were used, control (without fertilizer), blanket recommendation and soil test crop response based phosphorus recommendation using improved food barely Adoshe variety 10m*10m plot size at seven site using farmers as replications. Soil sample before planting and agronomic data were taken and analyzed using standard laboratory procedure and R software 4.1.1 version program, respectively. The soils sample analysis shows that it varied from 6. 03 to 6.25, 1.68 to 2.62 % and ranged from 1.01 to 3.30 mg/kg for soil pH (pH_H_2O), OM and available phosphorus, respectively. The statistical analysis for agronomic data indicated that, there was a significant difference ($p \leq 0.05$) among different fertilizer recommendation on yield and yield components of food barely. Accordingly, the height grain yield (5682.43kg/ha) with economically optimum and feasible for food barely production were obtained from the application of site specific soil test based fertilizer recommendation. Therefore, site specific soil test based crop response fertilizer recommendation based determined optimum N (46 kg/ha), Pc (4.60 ppm) and Pf (20) for food barely production were demonstrated. Based on this finding further determination and demonstration of the adjusted NPS fertilizer rate based on calibrated phosphorus for food barely production should be recommended.*

Keywords: Blanket recommendation, Soil test based fertilizer recommendation, optimum nitrogen, P critical, P-and requirement factor and food barely.

Introduction

Ethiopia is one of the largest food barely producer in the Sub-Saharan Africa (SSA) with yearly estimated production of 4.6 million tons on 1.69 million hectares of land in 2017/18 (CSA, 2018) yield per hectare. The average food barely productivity in SSA is 1.7 tons ha-1 (FAOSTAT, 2015), nearly 50% below the world average majorly due to low soil fertility status and other management practices. Most Ethiopian soils are deficit in nutrients, especially nitrogen and phosphorus and fertilizer application has significantly increased yields of crops (Tekalign *et al*., 2001). Particularly, nitrogen (N) and Phosphorus (P) fertilizer those the main crop production limit factor become decline from time to time due to soil fertility level decline due to many reasons.

In Ethiopia, particularly in the study area low soil fertility due to removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residues from farmlands, low or absence of integrated organic and inorganic fertilizer use and lack of proper crop rotation program the bottleneck for sustainable optimum crop production. Barley is one of the most important cereal crops in the world, ranking fourth in production area next to wheat, maize and rice (USDA, 2017). However; the barley yields were influenced by different factors which is varies in spatial and temporary. Soil fertility status is dynamic and variable from locality to locality do that it is difficult to end up with a blanket recommendation these low yields of food barely due to low fertilizer application.

Barely producing areas mainly located in the highlands which is susceptible to severe soil erosion, poor soil fertility, low pH, particularly deficiency of nitrogen and phosphorus which is the main factor that severely reduces the yield of barely (Mesfin and Zemach ,2015). Barley is very sensitive to insufficient nitrogen and very responsive to nitrogen fertilization (Ketema and Mulatu,2018) . The food barley yield was low due to due to most of the farmers in the area do not use fertilizer and few others use very much below the recommended rate (Lake and Bezabih ,2018). The proper management of soil fertility is crucial role for improving agricultural crop production and soils productivity on sustainable basis and assuring food security both at regional and household levels in the country. Hence, in order to step up the productivity of food barely crop production, soil test based crop response fertilization is very essential. In order to overcome the problem of the application of Urea and DAP fertilizers in the form blanket recommendations for long years, regardless of considering physical and chemical properties of the soil as well as does not taken in to account climatic condition and soil fertility level site specific soil test based fertilizer recommendation were conducted.

Additionally, blanket fertilizer application may lead farmers to over fertilizer application or majorly below fertilizer recommendation due to high price and others factors. This method of fertilizer application results crop production, soil productivity and economically decline also damage the environment (Meryl *et al.*, 2015). Therefore, site specific nutrient management aims to optimize the supply of soil nutrients over time and space to match the requirements of crops through the key principles of fertilizers at right rate, right time and right place great role (Bruulselma *et al.,* 2012). Soil testing is the most reliable tool for making good economic and environmental decisions about applying fertilizers.

Accordingly, Sinana Agricultural Research Center, Soil fertility Improvement Research Team has conducted soil test based phosphorus calibration studies in Sinana District for food barely production from 2019 -2021 cropping season and optimum nitrogen rate (46 N kgha^{-1}), P critical (4.60 ppm) and P-requirement factor (20) were determined (Mulugeta *et al.,* 2022). Thus before disseminate, demonstrate and scale up these technologies it should be verified on farmer's field and develop user guide line for food barely production areas in the district (Mulugeta *et al.,* 2022).Therefore, the study was initiated with the objectives to verify critical phosphorus and phosphorus requirement factor for food barely production in Sinana District, Bale Zone, Oromia Region Southeastern, Ethiopia.

Material and Methods

Descriptions of the Study Area

The study was conducted in Sinana District which is one of the Bale highlands Oromia Regional State, Southeastern Ethiopia. This District is bordered by Goro District in the east, Dinsho District in west, Agarfa and Gassera in the north and Goba District in northeast. Sinana district is located about 460 km from the capital city of Addis Ababa. Geographically, Sinana District is located at 6° 47' 30"to 7° 22' 0" N and 39° 55' 0" to 40° 21' 0" E. Topographically, the area consists of gently undulating plain with altitude 1700 to 3100 above mean sea level (masl).

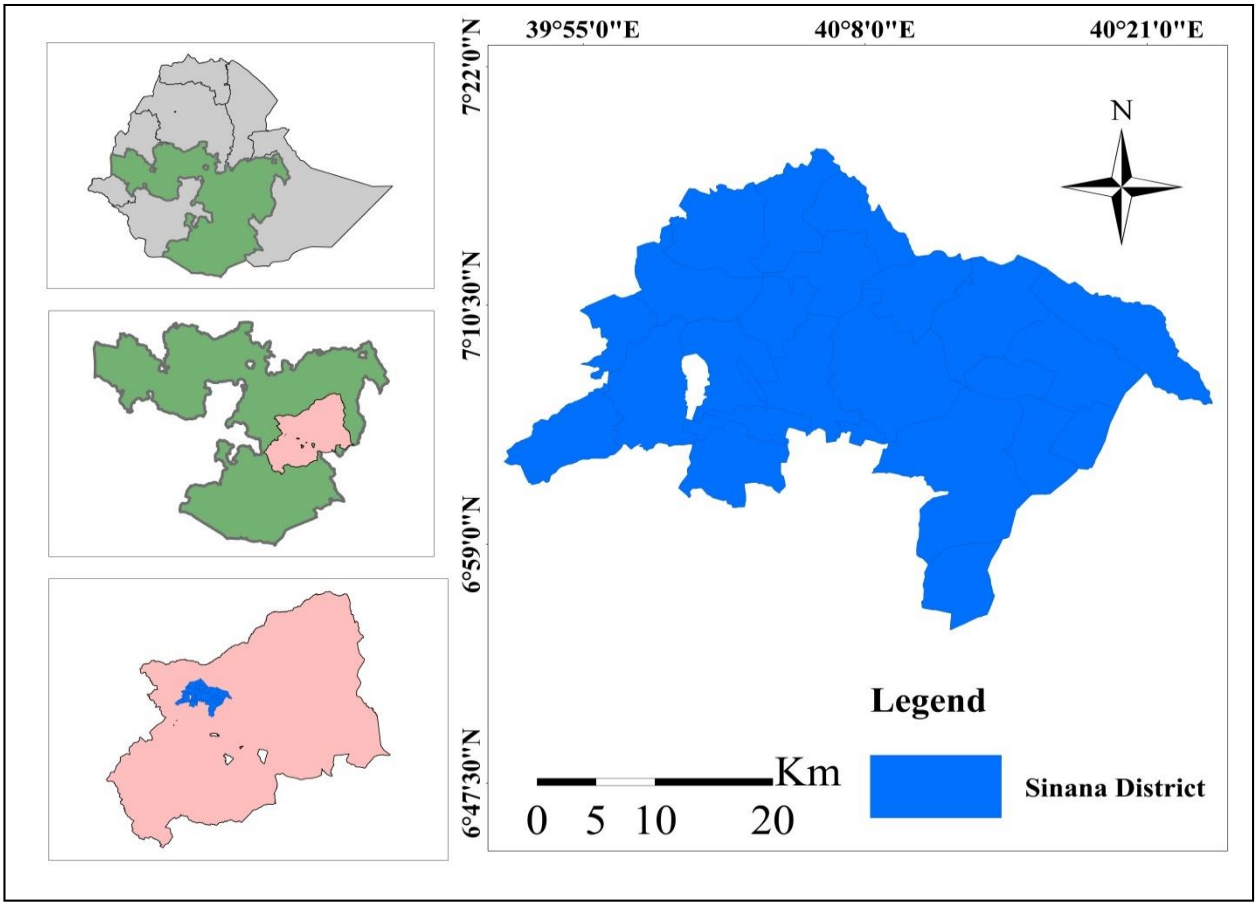


Figure 1. Map the study site

Climate and agro-ecology

The rainfall patterns of the area are a bimodal distribution having SH2 (humid, sub-humid to cool mild highland) agroecology. The area is characterized by annual rainfall between 453 mm and 1130 mm. The temperature maximum ranged from 21.9 to 23.5°C while the minimum varied from 6.8 to 10.1°C. Agriculture is the main economic activity in the district, with the major sources of their livelihood income mainly crop cultivation. Major crops grown in the district include wheat, barley, faba bean, field pea, and others.

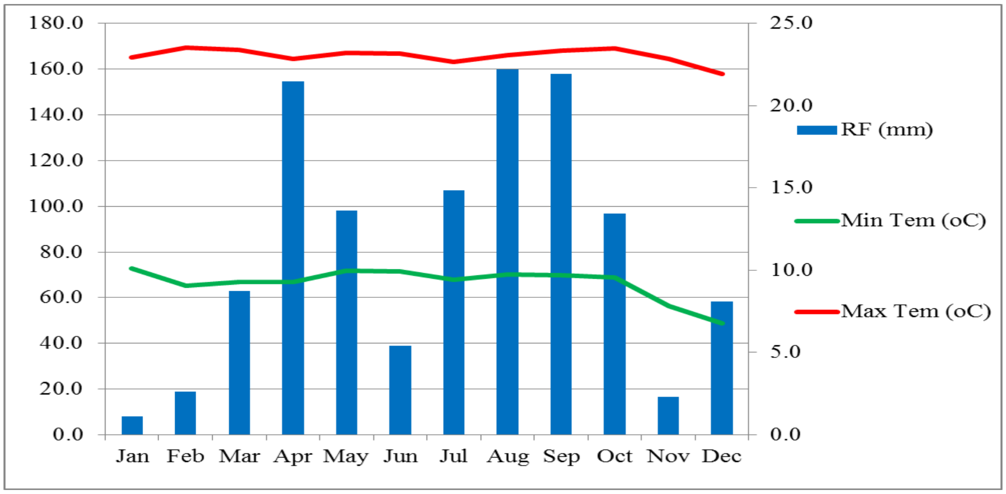


Figure 2. Mean monthly rain fall (mm), Max and Min Temperature (°C) of Sinana District.

Experimental design and layout

The experiment was conducted on 7 (seven) farmers' fields in the 2022 main cropping season for one year. The experimental field was arranged with a total of 3 treatments viz control (without fertilizer), blanket recommendation, and soil-test based P fertilizer recommendation with optimum nitrogen rate (46 kg ha^{-1}). Fertilizer sources for N and P urea and TSP, respectively; with 125 $kgha^{-1}$ improved food barely Adoshe variety in plot size was 10m*10m (100 m^2) were used.

Soil Sampling, Preparation and laboratory Analysis

Soil samples at 0- 20 cm depth were taken from the experimental sites before planting using auger sampling points and composites were prepared. The composite soil samples were labeled with necessary information then air dried and crushed using a mortar and pestle to pass through a 2 mm mesh sieve for most soil physicochemical properties. The initially available phosphorus below critical concentration determined for the district was selected to conduct the experiment. The analyses were conducted following standard laboratory procedures at Sinana Agricultural Research Center Soil Laboratory.

Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). Finally, the textural class of the soil was assigned using USDA textural triangle classification system (USDA, 1987). The pH of the soil was measured in the supernatant suspension of a 1:2.5 soil-to-water ratio using a pH meter (Rhoades, 1982). (Walkley, 1934) the method was used for the determination of organic carbon. Total nitrogen was determined using the Kjeldahl method as described by (Bremner and Mulveny, 1982). Available P was determined following the Olsen method Olsen (1954) using ascorbic acid as a reducing agent. Then Phosphorus fertilizer requirement was calculated for each farmer by using the formula:

Phosphorus fertilizer rate (kg/ha) = (Pc-Pi)*Pf;

Where, **Pc-**phosphorus critical level **4.60 ppm, Pi-** Initial available phosphorus, **Pf-**phosphorus requirement factor **20 mg/kg** for Sinana District.

Agronomic Data Collection

Agronomic data were collected on the yield and yield components such as plant height, numbers of productive tillers, seed per spike, above-ground biomass yield; grain yield, and thousand kernel weight were taken and then finally subjected to standard statistical analysis. The Least Significant Difference (LSD) at 5% probability level test was used for mean separation for significant treatments.

Statistical Analysis

The collected food barely yields and yield component data were subjected to analysis of variance (ANOVA) using R software version 4.1.1. Significant differences among treatment means were separated by least significant differences (LSD) at a 5% level of probability and using a linear correlation coefficient matrix. Based on these, interpretations were made following the procedure described by (Gomez and Gomez, 1984).

Partial Budget Analysis

A partial budget analysis was performed to determine the economic feasibility of the treatments. Partial budget, dominance, marginal, and rate of marginal return analysis were used. The average yield was adjusted downwards to reflect the difference between the experimental plot yield and the yield farmers will expect from the same treatment. The average grain yield was also adjusted by reducing 10% to minimize the overestimation of yield when yield of a small plot was converted to a hectare basis. The average open market price (Birr/kg) of food barely, urea (N) fertilizers were considered for analysis. The minimum acceptable rate of return (MARR) was 100% (CIMMYT, 1988), which is suggested to be realistic. This enables making farmer recommendations from marginal analysis.

Result and Discussion

Selected soils chemical properties before Planting

The pH (pH_H_2O) values of soil of watershed varied from 6. 03 to 6.25 as indicated (Table 2). As per the pH ratings suggested by Jones (2003) for pH in soil-water ratio were rated slightly acidic media. The values of soil organic matter (OM) were ranged from 1.68 to 2.62 % (Table 2). As per the ratings of Tekalign (1991) OM contents for soils of the experimental sites rated into low to moderate class. The values of available phosphorus (Av. P) ranged from 1.01 to 3.30 mg/kg which rated very low based on the critical values as determined by the Olsen method established by (Cottenie, 1980). The very low categories of these major soils plant nutrients might be due to leaching, continues cereal based monocropping, low or limited inputs of organic and inorganic sources fertilizers, nutrient fixation and loss as a results of soil erosions.

Table 2. Selected soils physicochemical properties status of experimental sites of Sinana District

Site Name	pH (H_2O)	OM (%)	Av. P (mg/kg)
1	6.06	1.68	2.29
2	6.25	2.18	1.01
3	6.03	1.94	2.85
4	6.11	1.88	2.51
5	6.2	2.39	2.30
6	6.08	2.22	1.82
7	6.14	2.62	3.30

Where: OM = soil organic matter, Av. P = available phosphorus

Response of Food barely yield and yield components

The statistical analysis of all agronomic data collected indicated that there was a significant difference ($p \leq 0.05$) between different fertilizer recommendations on bread wheat yield and yield components. Accordingly, the highest yield components of food barely, namely plant height, spike length, seed per spike, number of tillers, biomass, and thousand kernel weight were obtained from soil test-based crop response fertilizer recommendation followed by blanket recommendation, while the lowest from the control (without fertilizer) (Table 2). The responses on food barely grain yield revealed that the highest (5682.43 $kgha^{-1}$) and the lowest (2033.00 $kgha^{-1}$) grain yield were recorded from soil test-based crop response fertilizer recommendation and control, respectively. This result confirmed with the findings of Gidena (2016); Dejene *et al* (2020); Temesgen and Chalsissa (2020) and Mulugeta et al (2022) who reported that soil test-based site-specific optimum fertilizer recommended results the highest grain yield over blanket recommendation.

Table 2. Response of food barley production to verification of soil test crop response based Calibrated in Sinana District

Treatments	PH (cm)	SL (cm)	SPS	NT	BM (kg/plot)	GY (kg/ha)	TKW (g)
Control	69.4^{c}	3.41^{c}	34.71^{c}	1.97^{c}	45.73^{b}	2033.00^{c}	31.49^{c}
BK	82.6^{b}	5.05^{b}	44.63^{b}	3.69^{b}	65.21^{ab}	3410.14^{b}	33.86^{b}
STBFR	98.0^{a}	6.87^{a}	55.46^{a}	5.94^{a}	84.96^{a}	5682.43^{a}	36.19^{a}
Mean	83.33	5.11	44.93	3.87	65.30	3708.52	33.85
LSD $_{(0.05\%)}$	9.61	0.76	4.01	0.99	21.70	306.40	2.32
CV (%)	10.27	13.31	7.94	22.74	29.59	7.50	6.11

Where: BK = blanket recommendation, STBFR = soil test based crop response fertilizer recommendation, PH = plant height; SL = Spike length, SPS = seed per spike, NT = Number of productive tiller, BM = above ground biomass, GY = Grain yield, TKW = thousand kernel weight

Economic analysis

Based on this result, the partial budget analysis indicated that the soil test based P recommendation is economically feasible for food barely production in the district. Accordingly, the use of soil test based crop response phosphorus recommendation is advisable having net benefit (150525.61 ETB) with acceptable MRR (4131.16%) for food barely production at the Sinana district.

Table 3. Partial budget analysis for verification of soil test crop response based Calibrated phosphorous for food barely production in Sinana District

Treatment	UnGY ($Kgha^{-1}$)	AGY ($Kgha^{-1}$)	GB ($Birrha^{-1}$)	TVC ($Birrha^{-1}$)	NB ($Birrha^{-1}$)	MRR (%)
Control	2033	1829.7	54891	0	54891	0
BK	3410.14	3069.126	92073.78	1450	90623.78	2464.33
STBFR	5682.43	5114.187	153425.61	2900	150525.61	4131.16

Where BK = blanket recommendation, STBFR = soil test based crop response fertilizer recommendation, UnGY = unadjusted Grain yield; AGY = Adjusted Grain Yield; GB = Gross benefit, TVC =Total variable cost; NB = Net benefit; MRR = Marginal rate of return

Farmer Perception

The experiment was ranked based on the farmer preference perception and selection criteria (Table 4). Accordingly 55 farmers were used to select and evaluate based on his own knowledge, experience and innovations the verification trials at maturity stage.

Table 4. Farmer's perception and selection criteria

Treatments	Rank	Reason for selection (criteria)
Control	3rd	
BK	2nd	
STBFR	1st (100%)	Highest seed per spike, spike length, plant height, more productive tiller, good standing and expected high grain yield.

Where; BK = blanket recommendation, STBFR = soil test based crop response fertilizer recommendation

Conclusion and Recommendations

Soil test crop response based on fertilizer recommendation significantly increased the yield and yield components of food barely than a blanket recommendation for Sinana District. The results of the current study revealed the verification trial of recommended nitrogen rate (46 N $kgha^{-1}$), Pc (critical level) (4.60) and phosphorus requirement factor Pf (20). The highest grain yield (5682.43 $kgha^{-1}$) with an economically feasible and acceptable marginal rate of return (4131.16 %) was obtained from a soil test based fertilizer recommendation. Therefore, determined optimum nitrogen (46 kg/ha), Pc (4.60) and Pf (20) should be advisable for food barely production in Sinana district and similar soil types and agroecology. Based on this finding, further determination and demonstration of the adjusted NPS fertilizer rate based on calibrated phosphorus for food barely production should be recommended.

References

Bouyoucos, G. J., 1962. Hydrometer method improved for making particle size analyses of soils 1. *Agronomy journal*, 54 (5): 464-465.

Bremner JL and Mulveny CS., 1982. Nitrogen Total, In: AL Page (ed). Methods of Soil Analysis, Part Two, Chemical and Microbiological properties, 2nd ed. Am. Soc. Agron. Wisconsin pp. 595-624.

CIMMYT. 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition, Mexico, DF.,79 pp.

Cottenie, A., 1980. Soil and plant testing as a basis of fertilizer recommendations. FAO soil bulletin 38/2. Food and Agricultural Organization of the United Nations, Rome.

Gomez, K.A. and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research. 2nd ed. John Wiley and Sons, New York, USA.P. 680.

Hazelton, P. and Murphy, B. 2007. Interpreting Soil Test Results: What Do All the Numbers Mean? 2nd Edition. CSIRO Publishing.

Jones, J. Benton. 2003. Agronomic Hand Book: Management of crops, soils and their fertility. CRC Press, Washington, USA.

Landon, J. R., 1991. Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Sub Tropics. Longman Scientific and Technical, Essex, New York, USA, 474p.

Mulugeta Eshetu, Daniel Abegeja, Regassa Gosa, Tesfaye Ketama, Girma Getachew, Tilahun Chibsa. Soil Test Based Crop Response Phosphorus Calibration Study for Food barely Production in Sinana District of Bale Zone, Southeastern Ethiopia. International Journal of Science and Qualitative Analysis. Vol. 8, No. 1, 2022, pp. 1-12. doi: 10.11648/j.ijsqa.20220801.11.

Mulugeta Eshetu, Shure Sebboka, Tilahun Chibsa, Chala Chimdessa, Negash Bedasso. Optimization of Fertilizer Recommendations for Food barely at Sinana District of Bale Zone, Southeastern Oromia, Ethiopia. International Journal of Science and Qualitative Analysis. Vol. 3, No. 6, 2017, pp. 55-60. doi: 10.11648/j.ijsqa.20170306.11.

Olsen, S. R., Cole, C. V., Watanabe, F. S., and Dean, L. A. 1954. Estimation of available phosphorous in soils by extraction with Sodium Bicarbonate. *USDA Circular*, 939: 1-19.

Rhoades JD .1982. Solubale salts. In: Page AL, Millere RH and Page DT (eds) Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties, pp 167–180. Madison, WI: American Society of Agronomy.

Tekalign Tadesse. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working DocumentNo. 13. International Livestock Research Center for Africa, Addis Ababa.

USDA (United States Department of Agriculture). 1987. Soil Mechanics Level I-Module 3: USDA Textural Classification Study Guide. National Employee Development Staff, Soil Conservation Service, USDA.

Walkley, A, Black, I. A, 1934. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37: 29-37.

Ketema Niguse and Mulatu Kassaye. 2018. Response of Food Barley (Hordeum vulgare L.) Varieties to Rates of Nitrogen Fertilizer in Limo District, Hadiya Zone, Southern Ethiopia. *Journal of Natural Sciences Research*, 8 (15), 17–31.

Lake Mekonnen and Bezabih W/kiros. 2018. Response of Food Barley (*Hordeum Vulgare* L.) to Various Levels of P Fertilizer. *International Journal of Research in Agriculture and Forestry,* 5 (2), 21-26.

Mesfin Kassa and Zemach Sorsa. 2015. Effect of Nitrogen and Phosphorus Fertilizer Rates on Yield and Yield Components of Barley (Hordeum Vugarae L.) Varieties at Damot Gale District, Wolaita Zone, Ethiopia. *American Journal of Agriculture and Forestry*, 3 (6), 271-275.

USDA (United States Department of Agriculture). 2017. National Agricultural Statistics Services Barley: Area, yield, and production, by State and United States, 2014–2016.

Participatory Integrated Low-cost Measures Gully Rehabilitation and reclamation for sustainable land management in Ilasa watershed of Goba distinct Bale zone

Mulugeta Eshetu*, Daniel Abegeja; Tesfaye Ketama, Girma Getachow and Regassa Gosa
Sinana Agricultural Research Center, P. O. Box 208, Bale-Robe, Ethiopia.
Corresponding author, Mulugeta Eshetu, E-mail mulugeteshetu@gmail.com

Abstract
Gully erosion is a serious threat to the society and environment of the study, primarily caused by surface runoff and dramatically accelerated due to rugged topography and human induced factors. In the study area soil erosion and gulley expansion is among the most challenging and continuous environmental problems in highland of Bale particularly in Ilasa Watershed of Goba District. The study was conducted to evaluate Participatory Integrated Low-cost measures Gully Rehabilitation and reclamation for sustainable land management in Ilasa watershed of Goba distinct Bale zone. Therefore, the studied conducted with the objective to working with local communities to ensure, lower costs for gully reclamation, and enhance the effectiveness of gully rehabilitation measures. In order to reduce the gulley severity different local available materials were integrated with physical gulley rehabilitation and treatment structures. Additionally for the effectiveness of the structures different gully morphological characterizations were conducted and reshaping was conducted. The results obtained from measurement and observation indicated that, the study area was considered as moderate to severely degraded area according to the classifications of gullies morphologies. Priority to reclaiming and restoring of gullies morphological characterization, perception data collection, low cost local available materials determination and slope based implement structure could brought significantly reduce sediment losses. Gully reshaping, Check dam supported with cut off drain constructed at gully heads toward downstream more effective in reclaiming and preventing expansion and development of another gullies branch and sediment loss. Participatory working with local communities to reclaim gullies could help change farmers perception and uses of low cost gully enhance the effectiveness of gully rehabilitation measures which supports farmers implement at early stages. Further study on alternative gulley rehabilitation through discharge monitoring and sediments loss in the watershed from different perspectives is advisable to sustainably satisfy the benefits of the community and viability of natural resources.

Key words: Soil erosion, gulley morphologies; low cost and rehabilitation

Introduction

Soil erosion by water threatened the food security and environmental protection of the globe (Lieskovsky and Kenderessy, 2014). The watershed attributes extreme soil erosion, high runoff and the highest rainfall intensity (Belayneh *et al*., 2019; Fazzini *et al*., 2015). Soil erosions in the form of rill; sheet and gulley are among the hazardous form of erosion causes loss of thousands hectares of cultivated lands abandoned in the country (Belayneh *et al*., 2020). Mitigating soil erosion through proper soil and water conservation (SWC) measures should be a priority to ensure sustainable land uses, particularly on sloping lands subjected to cultivate. In Ethiopia, different SWC measures are implemented in different parts of the centuries (Mukai *et al*., 2021).

Integrated watershed management is a method of continuous restoration, growth and efficient use of available natural resources in a watershed, and a multidisciplinary approach to soil depletion pause (Mekonen and Fekadu, 2015). Studies showed that the implemented integrated watershed interventions increased infiltration and decreased runoff production (Taye *et al*., 2013); improved soil fertility (Nyssen *et al*., 2007) and improved vegetation regeneration (Mekuria *et al*., 2007); improved soil fertility (Nyssen *et al*., 2007); improved vegetation regeneration and soil build-ups (Etsay *et al*., 2019); improved groundwater (Nyssen *et al*., 2010). Investments in soil and water conservation (SWC) practices enhance crop production, food security and house hold income (Adgo *et al*., 2013). Therefore, the studied conducted with the objective to working with local communities to ensure, lower costs for gully reclamation, and enhance the effectiveness of gully rehabilitation measures.

Material and Methods

Description of the study area

The study was conducted at Goba Districts in Ilasa watershed which is situated 25 km away from Goba town of Bale zone of Southeastern Ethiopia Where soil erosion; gully formation and loss of agricultural land are a serious problem for production and productivities in this area. Ilasa Watershed located between in northern or the lower part of watershed bounded by Walti Magida kebele on the southern or upper part of watershed bounded by Barbare district, on the western part of watershed which is bounded by Walti Qubsa kebele and in eastern part of watershed bounded by wacho Misirge. Geogrphically, Ilasa watershed is located. Geographically, the study district is located at 6°57′30″ to 7°0′30″ North and 40°3′ 30″ to 40°6′0″ East and covering the total area of 506 ha having an elevation ranges from 2462 to 2991 amsl (Figure 1).

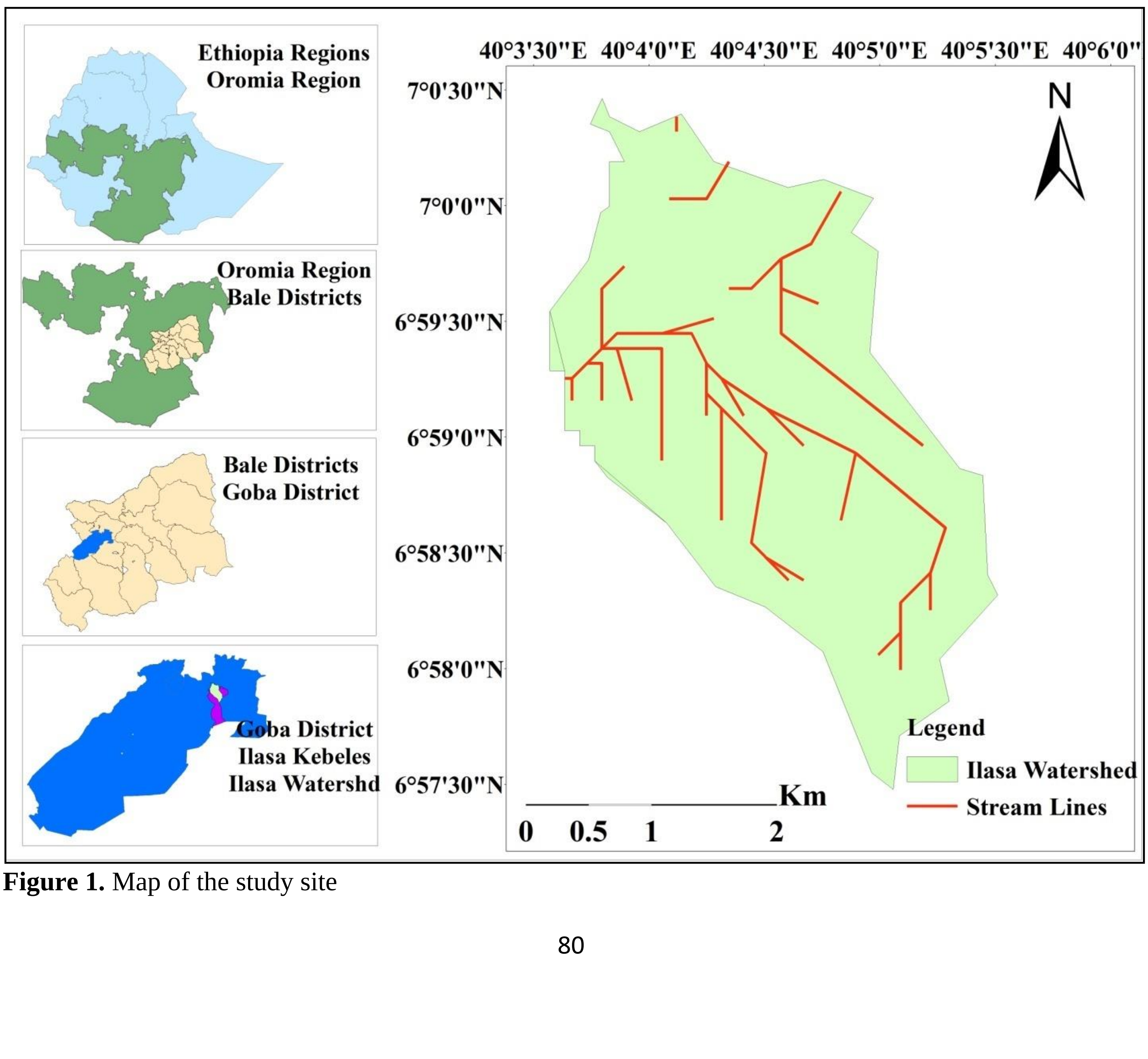


Figure 1. Map of the study site

Topography and Slope Characteristic of Ilasa Watershed

The effects of topography on land degradation depends on the effects of slope steepens and slope length. The ground flat slope is important when considering overall transportation of soil particles. The size and shape of the drainage area and generally its slope major affect runoff rate and velocity (Mulugeta *et al*., 2017). The slope classification based on recommendation for SWC structure implantation and layout given by Lakew *et al* (2005) categorized into five (5) classes namely; flat or almost flat (0 – 3 %) , gently sloping (3 – 8%), sloping (8 – 15%), moderately steep (15 – 30 %) and steep (30 – 50%) as indicated figure 2.

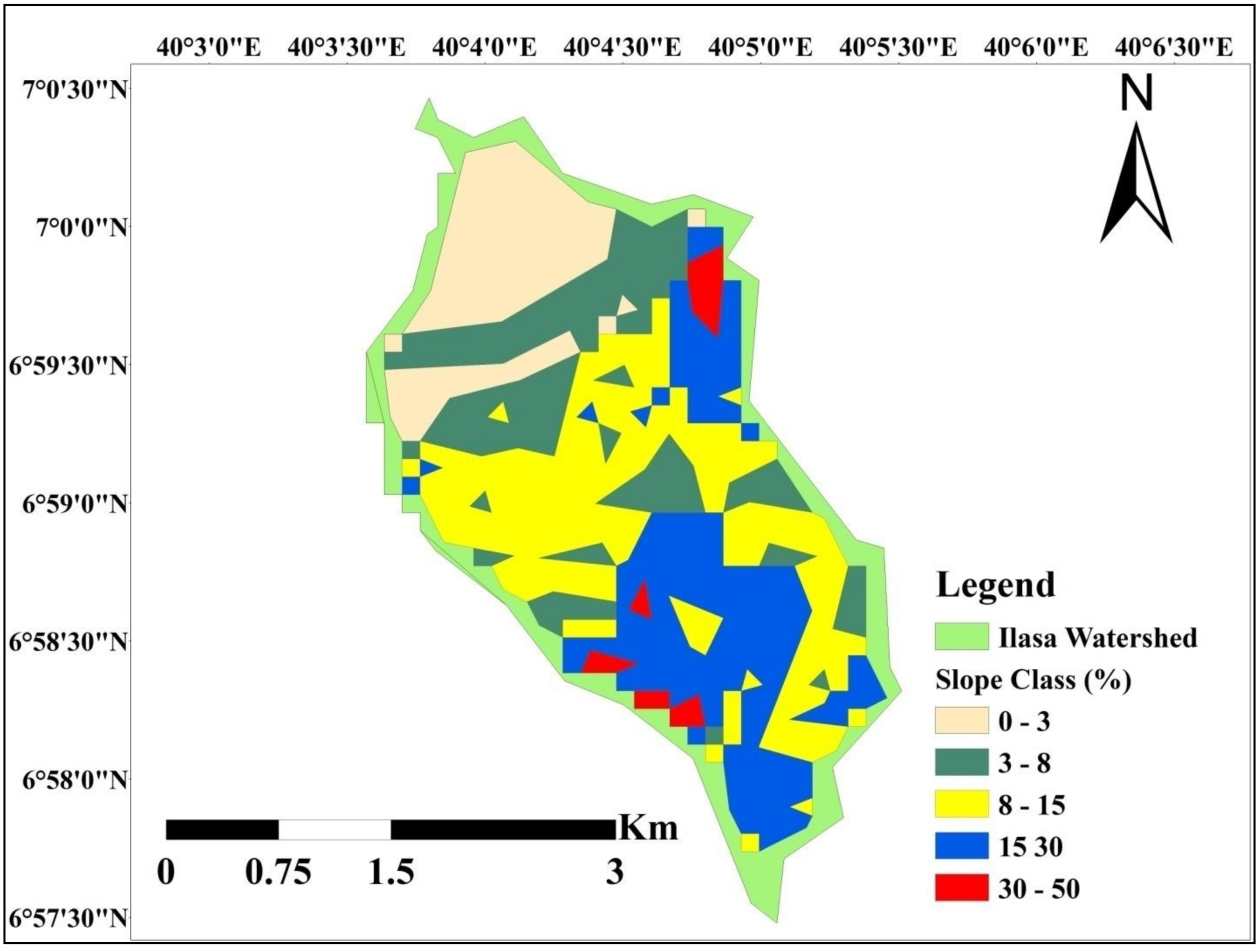


Figure 2. Slope Classes of Ilasa Watershed

Climate

As a part of Bale zone, Ilasa watershed of Goba District has two types of rainfall seasons. The long rainy season extends from March to April with high rain fall during June, July and August.

The second rainy season of rain fall regime is influenced by equatorial westerly and easterly winds with rainfall during spring and autumn. Accordingly; the average monthly climate characterize of the watershed 22.64^{o}C; 8.58^{o}C and 195.69 mm; maximum temperature; minimum temperature and rainfall; respectively.

Soil and vegetation

The major soil types are Chromic, Pellic Vertisols and Luvisols. Vegetation coverage great contribution in interception rainfall, keeping sediment loss and manage interception rainfall, keeping sediment loss and manage soil fertility. Juniperus procera, Eucalyptus, Olea europace, Hagenia Abyssnica, cordial africana, cuppressus and other shrub as well as bush encouragement are grown in the area. However most on the indigenous tree exposed to deforestation for fire wood, construction and agricultural expansion (Mulugeta *et al*., 2017).

Community Participation; Approach and Activities Innervations

The local communities' involvements in watershed management activities through mobilizing through awareness creation; training; labor payment in the form of incentive; FRG and watershed use associations organizing, materials used for SWC measures such as wood and gabion providing which support critical to programme success.

Gullies Morphologies Sampling and Analysis

Gully depth and width were measured at the head cut, at 50% of gully length and at the lower side of each gully, while each gully slope was considered. Physical characteristics (gully head cut shape and gully stage) of each gully and primary causes of gully initiation as well as mitigation measures were recorded. A total of 22 gully samples were randomly at three slope categories upper, middle and lower slope position. Finally, the classical descriptive statistics was used to give an insight into the relationship between each gully morphological parameter.

Gully reclamation approach and Mode of Conducted

The base of the gully heads were excavated to get a stable ground for the constructed gullies reclamation and rehabilitation structures. Gullies at the head were shaped into 45 degree inclination without disturbing the side banks using different local available materials. Participatory integrated watershed approach were adopted to ensure local communities involvement through financial and technical support also capacities building, awareness created to easily manage the tested gully rehabilitation measures.

Layout and construction of Gulley intervention measures

In these works Lakew *et al* (2005) and Ministry of Agriculture (2016) guidelines for were adopted in addition to considering slope and soil types. Generally; some constructed soil and water conservation structures in Ilasa watershed were described as follows.

Gully reshaping and filling: Gully wall reshaping is cutting off steep slopes of active gully flanks in to gentle slope (Minimum at 45% slope), up to two-third of the total depth of the gully and constructing small trenches along contours.

Check-dams were constructed across the gully bed to stop channel/bed erosion. By reducing the original gradient of the gully channel, check-dams diminish the velocity of water flow of runoff and the erosive power of runoff.

Cut-off Drain: were constructed follows the SWC measures minimum standard such as gradient: 0, 5 –1% max without scour checks. From 1 to 2% with scour checks; shape: Parabolic or trapezoidal; embankment: minimum 0,5 m top width, all slopes cut to grade of 1 to 1; scour checks (for gradients 1 – 2%).

Stone Check-dam: were constructed follows the SWC measures minimum standard such as spacing estimated on the safe side using S (spacing) m = Height (m) x 1,2/ Gradient (in decimals) ;Side key: 0,7-1 m inside gully sides, Bottom key & foundation: 0,5m depth x width of check dam ;Height: min 1m and max 1,5 m excluding foundation; Base width: min 1,5 and max 3,5 m.



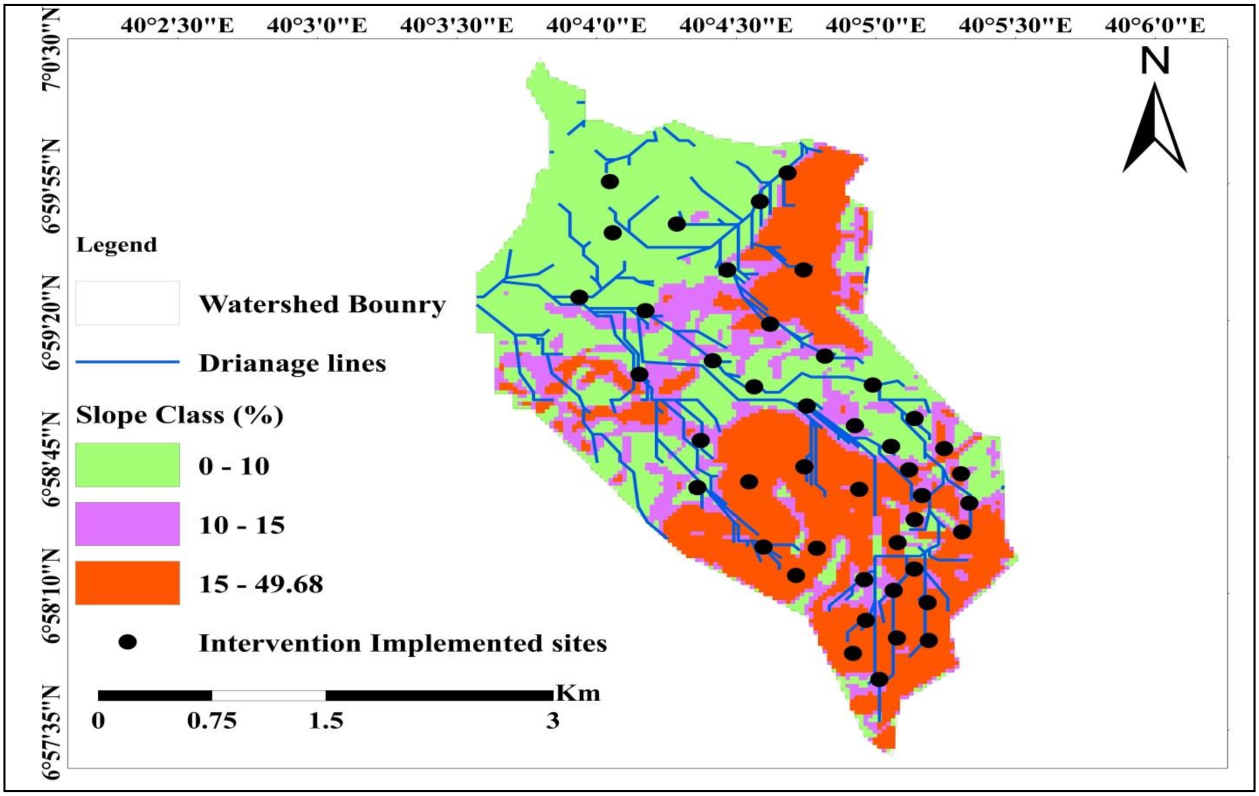



Figure 3. Interventions implemented points

Results and Discussions

Characteristics of Gullies Morphology at Ilasa watershed

Gully classes based on Depth

Gully classification system is based on depth describes small, medium and large gullies as per the standards commonly used in many soil and water conservation manuals. Therefore based on gully depth gullies were classified as small gully (< 1.5 m), medium gully (1.5 to 3 m) and large gully (> 3 m) (Thomas, 1997).

Table 1. Gulley morphology characterization at Ilasa watershed

Gulley Class	Min (m)	Max (m)	Average(m)	StdDev
Small gully	0.05	1.30	0.73	0.44
Medium Gully	1.80	2.22	1.97	0.18
Large gully	3.60	8.00	5.38	1.88

Gully length

In Ilasa sub watershed, the minimum and maximum gullies length were 210 m and 600 m respectively with the mean of 356.68 m and standard deviation of 122.46 (Table 2). As indicated in table 2, the mean value of gully top width was estimated to be 5.20 m and 4.69 m with the standard deviation 4.64 and 4.61 for top width and bottom width; respectively.

Gully surface area

The total surface area occupied by gullies in Ilasa sub watershed showed big variation in which the minimum (0.05 m^2), and maximum (15.73 m^2) with a mean values 15.73 m^2 and standard deviation 24.07 (Table 2). This shows that the gullies in the area great wide variation in their most gully morphological parameters.

Table 2. Statistical description of gullies morphologies at Ilasa watershed

Gullies Morphology	N	Min (m)	Max (m)	Mean	Std. Error	Std. Deviation
Length (m)	22	210	600	356.68	26.11	122.46
Depth (m)	22	0.05	8.00	2.22	0.48	2.26
Top Width (m)	22	0.50	21.00	5.20	0.99	4.64
Bottom Width (m)	22	0.48	20.48	4.69	0.98	4.61
Gully surface area (m^2)	22	0.050	96.00	15.73	5.13	24.07

Training and awareness creation

Finally, our study brought a change in farmers' perception regarding the possibility of reclaiming gullies using low cost local available materials. The major idea before the gulley intervention measures implemented farmers in the study area believed that "the formed gullies are beyond our capacities, untreated with local available materials and it is impossible to stop the formation and development of gullies." However, after the implementation of this study in collaboration with local communities, experts and development agent were convinced of the possibility of reclaiming gullies and converting them to productive land. Awareness creation, strength capacity building; improving community participations great role in sustainable integrated watershed management for rural communities on integrating crops, livestock and natural resource management technologies particularly for Ilasa watershed of Goba district in area sever soil erosion and land degradation problems (Mulugeta *et al*.,2017).

The study gives more attention to training and discussion with different stakeholders on the practical and technical training as well as experience sharing of model practices to ensure participatory sustainable natural resource management at Ilasa watershed. Based on this, a totally of, 473 participants involved in the watershed management capacity building program among these 306 and 167 were male and female household; respectively (Table 1). This approach created the positive efforts among farmers in which perceived benefits of SWC measures as socioeconomic pillars, motivate farmers to participate in watershed management, skill enhancement of households, encourage women role and linkages on these intervention works.

Table 1. Training and capacity building on gullies at Ilasa watershed of Goba Districts

Years	Experts		DA	Farmers		Total
	M	F	M	M	F	
2016	3	1	2	30	17	53
2017	4	1	4	140	60	209
2018	2	1	2	50	40	95
2019	1	-	3	50	50	104
2020	3	1	2	30	26	62
2021	2	1	1	50	46	100
Total	**15**	**5**	**14**	**350**	**239**	**623**

Figure 3. Picture during community based participation rehabilitation work at Ilasa watershed.

Table 4. Soil chemical properties before and after interventions

Site	Before intervention		After Intervention	
	OM (%)	TN (%)	OM (%)	TN (%)
1	1.18	0.06	4.87	0.24
2	1.24	0.06	3.26	0.16
3	1.65	0.08	3.46	0.17
4	1.11	0.06	3.40	0.17
5	1.31	0.07	3.53	0.18

Figure 2. Status of land degration and gulley severist at Ilasa watershed before intevation

Figure 6. Ilasa watershed status after innervations

Conclusion and recommendations

The results obtained from measurement and observation indicated that, the study area was considered as moderate to severely degraded area according to the classifications of gullies morphologies. Priority to reclaiming and restoring of gullies morphological characterization, perception data collection, low cost local available materials determination and slope based implement structure could brought significantly reduce sediment losses. Gully reshaping, Check dam supported with cut off drain constructed at gully heads toward downstream more effective in reclaiming and preventing expansion and development of another gullies branch and sediment loss. Participatory working with local communities to reclaim gullies could help change farmers perception and uses of low cost gully enhance the effectiveness of gully rehabilitation measures which supports farmers implement at early stages.

References

Adgo,E.,Teshome,A.,andMati,B.(2013).Impacts of long-term soil and water conservation on agricultural productivity: the case of Anjenie watershed, Ethiopia. *Agric. Water Manag.* 117, 55–61.

Bafe Betela and Kebede Wolka.2021. Evaluating soil erosion and factors determining farmers' adoption and management of physical soil and water conservation measures in Bachire watershed, southwest Ethiopia. *Environmental Challenges* 5 ; 100348.

Belayneh M, Yirgu T, Tsegaye D. 2019. Potential soil erosion estimation and area prioritization for better conservation planning in Gumara watershed using RUSLE and GIS techniques'. Environmental Systems Research 8(1): 1-17.

Belayneh, M., Yirgu, T., Tsegaye, D., 2020. Current extent, temporal trends, and rates of gully erosion in the Gumara watershed, Northwestern Ethiopia. Global Ecol. Conserv. 24, e01255.

Borrelli, P., Robinson, D.A., Fleischer, L.R., Lugato, E., Ballabio, C., Alewell, C., Meusburger, C.K., Modugno, S., Schutt, B., Ferro, V., Bagarello, V., Oost, K.V., Montanarella, L., Panagos, P., 2017. An assessment of the global impact of 21st century land use change on soil erosion. Nat. Commun. 8 (1), 1–13.

FAO, 2019. Soil erosion: the Greatest Challenge to Sustainable Soil Management. Food and Agriculture of Organization of the United Nations, Rome .

Fazzini M, Bisci C, Billi P. 2015. The climate of Ethiopia. In: Billi P (ed) Landscapes and Landforms of Ethiopia. World geomorphologic landscapes. Springer, Dordrecht.

Haregeweyn, N., Tsunekawa, A., Nyssen, J., Poesen, J., Tsubo, M., Meshesha, D.T., Schütt, B., Adgo, E., Tegegne, F., 2015. Soil erosion and conservation in Ethiopia. Progr. Phys. Geogr. Earth Environ. 39, 750–774.

Heri-Kazi, A.B., Bielders, C.L., 2021. Cropland characteristics and extent of soil loss by rill and gully erosion in smallholder farms in the KIVU highlands, D.R. Congo. Geoderma Reg. 26, e00404.

Karamage, F., Zhang, C., Liu, T., Maganda, A., Isabwe, A., 2017. Soil erosion risk assess- ment in Uganda. Forests 8 (52), 1–20.

Lakew Desta, Carucci, V., Asrat Wendem-Ageňehu and Yitayew Abebe (eds). 2005. Community Based Participatory Watershed Development: A Guideline. Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia.

Lieskovsky J, Kenderessy P. 2014. Modelling the effect of vegetation cover and different tillage practices on soil erosion in vineyards: a case study in Vrable (Slovakia) using WATEM/SEDEM. Land degradation and Development 25(3): 288-296.

Mukai, S., Billi, P., Haregeweyn, N., Hordofa, T., 2021. Long-term effectiveness of in- digenous and introduced soil and water conservation measures in soil loss and slope gradient reductions in the semi-arid Ethiopian lowlands. Geoderma 382, 114757.

Mulugeta Eshetu, Negash Bedasso, Shure Seboka, Chala Chimdessa and Tilahun Chibsa, Abduraman Hussen. 2017. Multiplication and Distribution of Vetiver Grass (*Vetiveria zizanioides*) for Soil and

Water Conservation Measures in the Highland of Bale Zone, Southeastern Ethiopia. *American-Eurasian J. Agric. and Environ. Sci.*, 17 (6): 514-518.

Mulugeta Eshetu, Shure Sebboka and Falmata Gezachew. 2017. Assessment, Resources Characterization and Mapping of Ilasa Watershed in the Case of Goba Distinct in Highland of Bale Zone, Southeastern Ethiopia. *American-Eurasian J. Agric. & Environ. Sci*., 17 (6): 499-513.

Walle J, Jantiene E, Baartman M, Luuk F, Ritsema C J (2018) Participatory assessment of soil erosion severity and performance of mitigation measures using stakeholder workshops in Koga catchment, Ethiopia: *J Environ Manag*, 207: 230-242.

Wubie MA, Assen M. 2020. Effects of land cover changes and slope gradient on soil quality in the Gumara watershed, Lake Tana basin of North West Ethiopia. Modeling Earth Systems and Environment 6(1): 85-97.

Zenebe A, Bezaye G, Demeke N, Mowo J, Kidist H (2013) Farmers' Preference for Soil and Water Conservation Practices in Central Highlands of Ethiopia. *J Afri Crop Scie,* 21: 781-790.

Zimale FA, Tilahun SA, Tebebu TY, Guzman CD, Hoang L, Schneiderman EM, Langendoen EJ, Steenhuis TS. 2017. Improving watershed management practices in humid regions. Hydrological processes 31(18):3294-3301.

Integrated Use of Geospatial Technique and RUSLE Model for Spatial Soil Erosion Severity Analysis, Classification and Mapping for Selected Watershed of Bale Highland, Southeastern Ethiopia

Mulugeta Eshetu*, Tesfaye Ketema, Regassa Gosa and Girma Getachew
Sinana Agricultural Research Center, P. O. Box 208, Bale-Robe, Ethiopia
*Corresponding author: mulugeteshetu@gmail.com

Abstract
Soil erosion in the form of water induced one of the major cause of land degradation in humid and sub humid highlands of Ethiopia. This problem is a serious threat agricultural sustainability which is one of the bottlenecked for food security. In this regard, quantitative analysis of soil erosion and its spatial variation plays a decisive role for better evidence and priority based implementation of soil and water conservation measures. Despite the fact there is very limited or not yet conducted and documented site specific scientifically quantified soil erosion severity and identified priority area for soil and water conservation measures implementation. Thus, this study aimed to estimate the spatial soil erosion severity analysis, classification and mapping for selected Watershed of Bale Highland of Southeastern Ethiopia using geospatial technique and RUSLE Model. After laboratory analysis and processing various input datasets in ArcGIS and ERDAS imagine software, the required six RUSLE model input parameters: soil erosivity (R), slope length and steepness (LS), land cover (C), soil erodibility (K) and land management practice (P) were prepared for the Model. The final images for the model were resampled using nearest resample method to keep the images' resolution uniformity, and then the annual rate of soil erosion was computed using the revised universal soil loss equation (RUSLE) model in Map Algebra, Arc GIS 10.3 software. Based on this analysis, the amount of soil loss 38.22% and 42.57 % subjected to very sever soil loss categories for Sinana and Goba watershed, respectively. The mean annual soil loss were 191.54 $tha^{-1}yr^{-1}$ for Sinana watershed whereas for Goba watershed 180.97 $tha^{-1}yr^{-1}$. In both watersheds the soil loss higher than the maximum tolerable soil loss according in Ethiopia conditions. The GIS and remote sensing techniques, RUSLE model can serve as a tool for deriving strategies for effective planning and implementation of various management and conservation practices for the given watershed. This study recommended prioritized sub watershed for interventions starting in the order of sub watershed 1,3,5,7,4,2, and 6;respectively for Sinana watershed whereas 3,2,4,7,5,8,1 and 6; respectively for Goba watershed. It can be recommended this soil erosion severity assessment and mapping support as to identify high erosion prone areas, baseline information for planning and management interventions to rehabilitate degraded areas and minimize future soil erosion in the watershed.

Key Words: Soil erosion, soil loss, GIS, RUSLE model, and priority for intervention

Introduction

Fertile soil is an essential input for agricultural production particularly; in a country agricultural are the back bone of the economy and the livelihoods of the majority of the population like Ethiopia. The degradation of natural soil fertility in Ethiopia often results decline in soil productivity and crop production which final challenges for country socioeconomic and food security. Among the reason for soil fertility decline soil erosion the common one particularly in the highland agroecology were population and cultivation on the steep slope is high. Soil erosion is a multifaceted and predominant global land degradation process which leads to decline in agricultural productivity and crop production (Angassa 2014 and Haregeweyn *et al*., 2015). Soil erosion not only descent soil quality and productivity due to its on-site impacts but also has far reaching off-site impacts such as deposition of sediments and associated pollution of downstream (Haregeweyn *et al*., 2017). However, the extent and magnitude varies from one place to others depending on the farming practices, type and susceptibility of the soils to erosion, local climate, Topography setting of the area (Monsieurs *et al*., 2015).

Soil erosion has a relation with the agricultural practice that brings negative impact on the environmental problems, and has become a risk to maintain agricultural production so this accelerated soil erosion needs a great attention because it has a negative impact (Belayneh *et al.*, 2019 and Endalamaw *et al.*, 2021). About 40% of all erosion in Ethiopia is caused by the wrong installation of soil and water conservation practices (Gete *et al*., 2014). This implies that there is a need to characterize and classify the given watershed related to soil erosion that support timely information for decision makers and land managers that plan the correct soil conservation planning. The reliable and updated information on watershed soil erosion is an essential prerequisite for prioritization of watershed as well as formulation of appropriate management programs, which are key components for sustainable development. Soil loss is the results of natural process and more accelerated by anthropogenic activities in which taking away of soil particles by the agents of soil erosion and deposits them somewhere else. There are several man induced impacts which accelerate soil erosion, some of which are deforestation, overgrazing and improper land use like cropping pattern and cultivation along the slope (Morgan and Nearing, 2016).

Watershed prioritization is the ranking of different sub watersheds according to the order for intervention according soil erosion and levels of land degradation. Haregeweyn *et al* (2017) and Zerihun *et al* (2018) conducted soil loss in Ethiopian highlands and stated that soil erosion induced by water is the major problem for agricultural productivity and sustainability. Thus implies that soil erosion is the one among factors that affect rural livelihoods through, decline production and productivity, aggravating poverty and food insecurity. Currently, geospatial technique (remote sensing and GIS) and RUSLE model have effective tools to overcome most of the problems of land and water resources planning and management rather than conventional methods of data process (Ganasri and Ramesh 2016 and Arabameri *et al*., 2020).

Therefore, understand the erosion process and their interaction the information on soil loss is essential to plan and prioritize treatments of the watershed. Assessments and mapping soil erosion susceptible area also helps to understand soil conservation and ecosystem management mechanisms in the watershed (Negese *et al*., 2021). In the study area soil erosion and nutrient loss is the major problem this implies that site-specific, accurate and detailed information on trends and status of soil erosion successful conservation planning and other management's options. Hence, investigating soil loss rates and identification of erosion prone areas is very important to protect the area from further damage. However, despite the facts on Sinana and Goba watersheds very limited information and documented materials considering soil nutrient loss, identification of severely affected areas by soil erosion, prioritized and recommend compatible SWC using GIS and RUSLE model. Therefore, this study was initiated with the objective to estimate rates of soil loss and identify soil erosion severity areas and develop soil loss severity map then prioritize areas for specific soil conservation plans using GIS and RUSLE model.

Materials and Methods

Description of the study area

Based on soil erosion severity and levels of soil loss 7 (seven) and 8 (eight) sub-watersheds were selected from sinana and Goba respectively (Figure, 1).

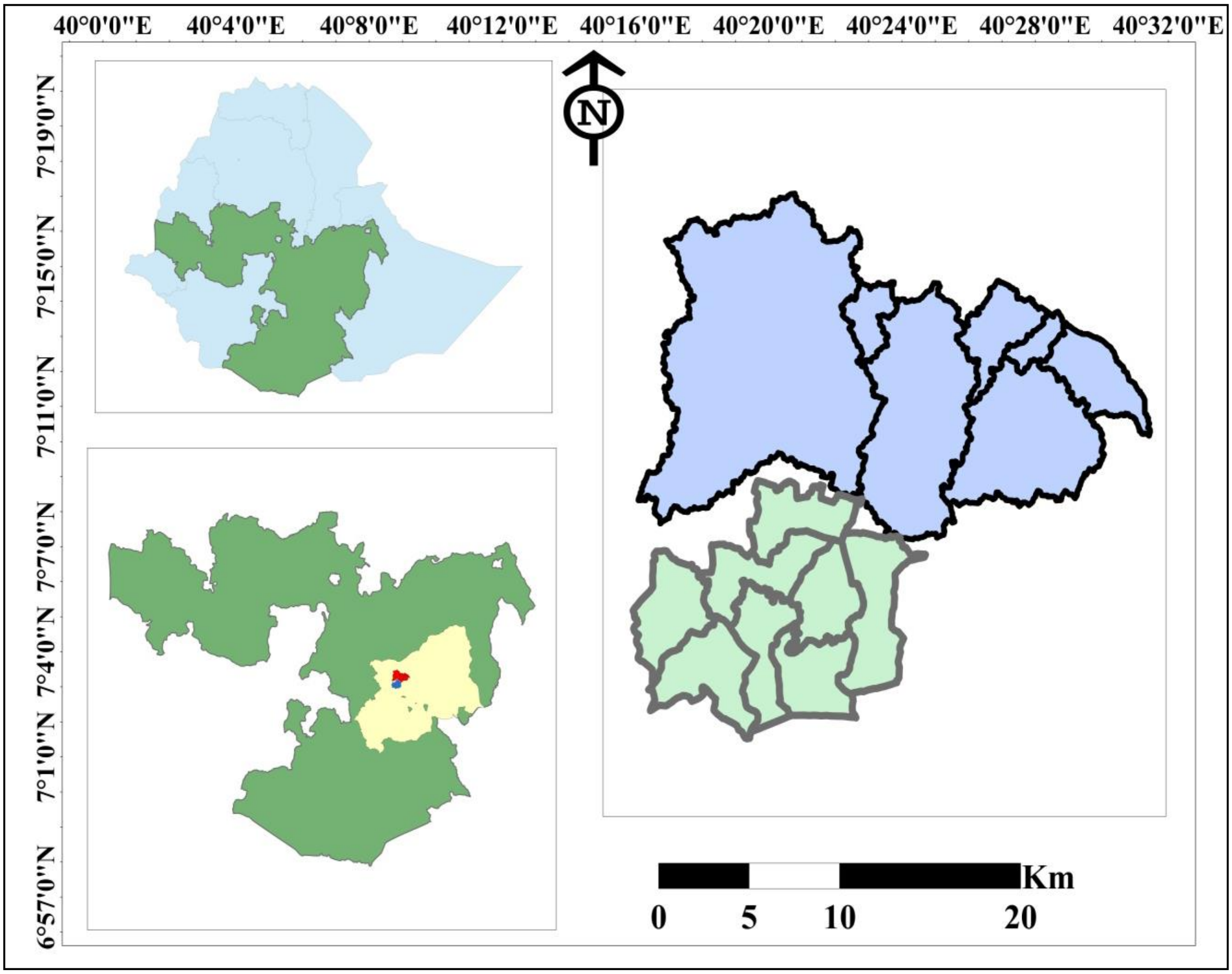


Figure 1. Map of the studied watershed

Table 1.Descriptions of the selected watershed

District Name	No. Watershed	Watershed Names	Watershed categories	Area (ha)
Sinana	**7**	Alage	Sub Watershed 1	31341.60
		Heseberera	Sub Watershed 2	1627.75
		Salka	Sub Watershed 3	12940.30
		Hisu	Sub Watershed 4	2891.90
		Gamora	Sub Watershed 5	9690.49
		Welteiweyib	Sub Watershed 6	992.50
		Welteiarjo	Sub Watershed 7	3432.02
Goba	**8**	Aloshe	Sub Watershed 1	3595.50
		Weltie	Sub Watershed 2	3479.87
		Ashuta	Sub Watershed 3	3114.25
		Wacho	Sub Watershed 4	3111.71
		WeltieWacho	Sub Watershed 5	4601.97
		Wajitu	Sub Watershed 6	3411.98
		Ilasa	Sub Watershed 7	3268.87
		Kubsa	Sub Watershed 8	4097.94

Data type and sources

The soil erosion process is a complicated system controlled by a multitude of factors comprising soil characteristics, local climatic conditions, nature of terrain features, ground cover, land use types, conservation practices, and interaction between them. Different data were collected from many sources including field inspection. Most input factor of RUSLE model were estimated using selected parameters such as land use, slope, management, RF and others according to the Ethiopian. For each factor considered in the RUSLE model, a respective file was built in the GIS environment and finally merged together in the model to generate final map that indicates soil loss rate of the area. The input thematic data included rainfall, soil units, slopes and land use/cover was determined.

Data Processing and RUSLE factor generation

The above mentioned factors were generated using remote sensing as well as field derived information and further integrated in a GIS environment according to the following methodology to estimate soil erosion in the present study (Figure 2). The various RUSLE factor maps were generated in a digital GIS environment using Arc GIS 10.3 and ERDAS Imagine 2015, and the associated GIS packages. These factor maps were integrated employing RUSLE model to compute annual soil erosion rates and its severity.

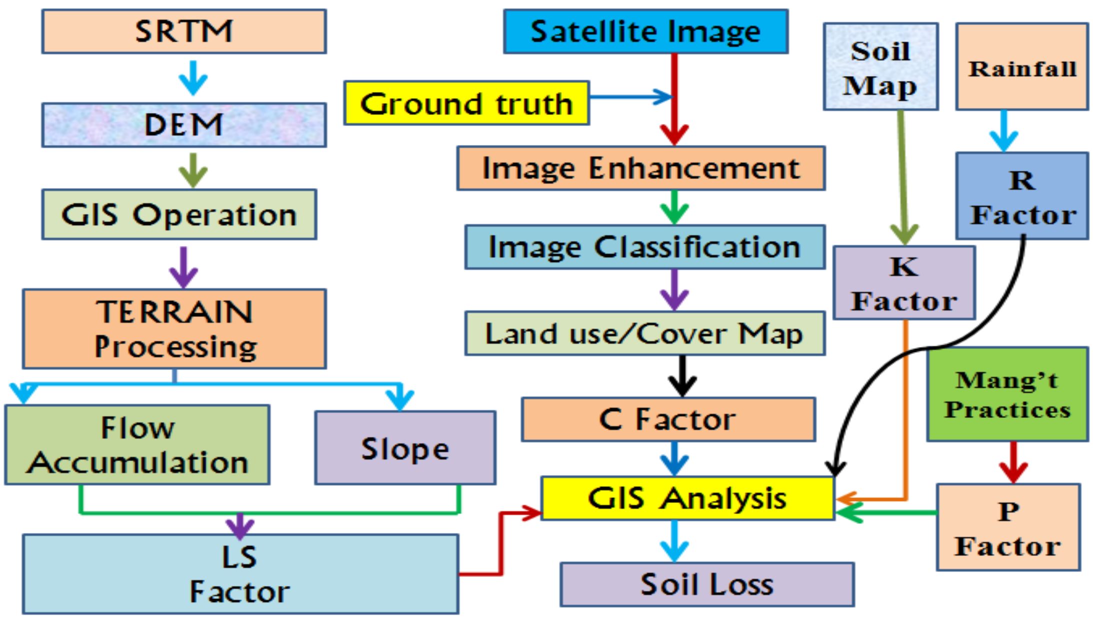


Figure 2. Procedures of RUSLE implementation in GIS

Methods of Data Analysis

Soil Erosion Model

Though soil erosion is harmful land degradation and sedimentation persist throughout the geologic time scales, the circumstance is bothered in recent times with man's expanding mediations with the natural environment. Thus, estimation of soil erosion has become a basic issue and remains being one of the real research topics at various spatial and temporal scales using proper model (Ganasri and Ramesh, 2016). There are a wide variety of models used to estimate soil erosion over many years worldwide (Morgan, 2009; Farhan and Nawaiseh, 2015). There have been a number of studies published that apply RUSLE model to estimate and predict soil loss rate worldwide (Ganasri and Ramesh, 2016). RUSLE model, Coupled with GIS and RS, has also been widely applied and tested by many researchers to estimate soil erosion potentials in the highlands of Ethiopian (Woldemariam *et al*., 2018). These studies supported the existing literature that indicates the efficacy of RUSLE model to adequately estimate soil loss rate in a wide range of environments.

However, the model only addresses rill and inter-rill erosion induced by the impacts of raindrops and surface runoff without accounting for other forms of erosion such as gully development and sliding of lands (Renard *et al*., 1997). Some of the reasons for the selection the model includes its less data requirements, free and readily availability of the required of data sets; its relative simplicity to apply and its compatibility with remote sensing and GIS inputs in computer interface (Farhan and Nawaiseh, 2015). Moreover, most of the input parameters of the model are calibrated for the Ethiopian context (Hurni, 1985). RUSLE models to assess rate and patterns of soil loss in other parts of the Ethiopian highlands also used (Tamene *et al.*, 2017).

Description for Inputs RUSLE Model and Methods of Analysis

Rainfall Erosivity Factor

Rainfall erosivity factor (R factor) describes the erosivity of rainfall at a particular location based on the rainfall amount and intensity on soil erosion (Prasannakumar et *al*., 2012; Wischmeier and Smith, 1978 and Koirala *et al*., 2019). Different empirical equations such as Hurni, (1985); Renard, Foster, Wessies and Porter, (1994) have been developed that estimate R factor for the given areas. The R factor is the product of kinetic energy of rainstorm and its maximum 30-min intensity (I30) (Wischmeier and Smith, 1978and Yin *et al*., 2017). However, due to the lack of rainfall kinetic energy and rainfall intensity (I30) data for the study area Hurni's empirical equation Hurni, (1985) for Ethiopian condition was adopted to compute R factor values for the selected watershed (equation 1).Similarly, this equation was also adopted by different authors in Ethiopia (Belayneh*et al*., 2019; Ayalew and Selassie, 2015; Tesfaye *et al*., 2018; Gelagayand Minale, 2016).

Bale zone monthly precipitation data for the period 1998-2021 were collected from nearby meteorological station, national meteorological agency and NASA Power data access view to calculate the rainfall erosivity Factor (R factor). Then mean annual rainfall were interpolated by inverse distance weighted (IDW) with the help of ArcGIS 10.3 environment with a cell size of 30 m and clipped using with watershed boundary shapefile to generate a continuous rainfall map of the watershed. IDW interpolation techniques has been preferred as geo-statistical spatial interpolation methods because it is easy to generate relatively accurate rainfall erosivity information from known sample points to the points of unknown values at a closer distance than those located far. Moreover, it is favored with the assumption that it enables quick interpolation of the required data from grid based irregularly spaced samples (Li and Heap, 2008). A similar approach was adopted to compute the R factor in Ethiopia (Bewket and Teferi, 2009).

$$\mathbf{R = -8.12 + 0.562P}$$ **... (**Equation 1)

Where R is the rainfall erosivity factor (MJ mmha^{-1}h^{-1}) and P is the mean annual rainfall (mm).

Soil erodibility factor

The soil erodibility factor (K factor) factor reflects the effect of soil properties and profile characteristics on soil loss (Molla and Sisheber, 2017 and Pham *et al*., 2018).It is the measure of the potential susceptibility of soil to the detachment and transport by rainfall and runoff. The main soil properties influencing the *K* factor are soil texture, organic matter, soil structure, and permeability of the soil profile (Ettazarini*et al*., 2017; Haregeweyn*et al*., 2017; Mollaand Sisheber, 2017; Ayalew and Selassie, 2015; Saha, 2018; Koirala *et al*., 2019 and Mohammed *et al*., 2020).Therefore, to developed soil map of the watershed soil samples were taken with the supports of GPS points at a depth of 20 cm considering the enter watershed representativeness.

Then soil samples were air dry at room temperature, grind and sieved finally analysis using standard laboratory procedure; respectively at Sinana Agricultural Research Center, Soil Team Laboratory. Similarly, Byizigiro *et al*, (2020) consider the topsoil layer to calculate K Factor because it is affected directly by the raindrop energ*y*.The equation provided by reference used to estimate the soil loss (Kouli, *et al*., 2009).

$$\mathbf{K\,factor} = \boldsymbol{f}\mathbf{Sand} * \boldsymbol{f}\mathbf{Clay} * \boldsymbol{f}\mathbf{OrgC} * \boldsymbol{f}\mathbf{Silt} * \mathbf{0.1317}$$ **.......................... (Equation 2)**

$$\boldsymbol{f}\mathbf{Sand} = (\mathbf{0.2} + \mathbf{0.3} * \mathbf{exp}[-\mathbf{0.256} * \mathbf{mSand} * \left(\mathbf{1} - \frac{\mathbf{mSilt}}{\mathbf{100}}\right)])$$ .... (Equation 3)

$$\boldsymbol{f}\mathbf{Clay} = \left(\frac{\mathbf{mSilt}}{\mathbf{mClay+mSilt}}\right)\mathbf{0.3}$$ .... (Equation 4)

$$\boldsymbol{f}\mathbf{OrgC} = \left(\frac{\mathbf{1-0.0256*OrgC}}{\mathbf{OrgC+exp[3.72-2.95*OrgC]}}\right)$$ .... (Equation 5)

$$\boldsymbol{f}\mathbf{Silt} = \left(\frac{\mathbf{1-0.7\,(1-\frac{mSand}{100})}}{\mathbf{(1-\frac{mSand}{100})+exp[-5.51+22.9(1-\frac{mSand}{100})]}}\right)$$ .... (Equation 6)

Where $mSand$ is the proportion (%) of sand content (0.05-2.0 mm diameter particles), $mSilt$ is the proportion (%) of silt content (0.002-0.05 mm diameter particles), $mClay$ is the proportion (%) of clay content (<0.002 mm diameter particles), and $orgc$ is the amount (%) of the organic carbon content of the layer (%).

Topographic Factor

The Topographic factor (LS factor) factor reflects the effect of surface topography or slope length (meter) and slope steepness on the rate of soil erosion by water (Pham *et al*., 2018; Saha, 2018; Koirala *et al*., 2019 and Liu *et al*., 2015). After the slope (degree) map of the watershed was derived from 30 m spatial resolutions DEM (digital elevation model) using the Spatial Analyst extension in ArcGIS 10.3 environment the LS factor was estimated using the equation suggested by (Moore and Burch, 1986 and Engel, 2005) (equation). This equation is also adopted in different studies Ayalew and Selassie (2015); Prasannakumar *et al* (2012); Tesfaye *et al* (2018); Gelagayand Minale (2016); Belasriand Lakhouili(2016) and Nurhussen and Desale (2021)for *LS* factor calculation. The specific effects of topography on soil erosion are estimated by the dimension less LS factor as the product of the slope length (L) and slope steepness (S) constituents converging onto a point of interest, such as a farm field or a cell on a GIS raster grid.

$$\mathbf{LS} = \mathbf{Pow}\left(\text{“}\mathbf{flowacc}\text{”} * \frac{\mathbf{[cell\ resolution]}}{\mathbf{22.13*0.4}}\right) * \frac{\mathbf{Power(Sin(\text{“}sloperasterdeg\text{”}*0.01745))}}{\mathbf{(0.0896,1.4)*1.4}}$$ **......... (Equation 7)**

Crop and Management

Crop and management factor(C factor) indicates and determines the ratio of soil erosion from land cropped under specific conditions; how natural vegetation or crop cover reduces rainfall energy and overflows or intercepts rainfall energy and increases infiltration. It t is the second most important factor next to topography and rainfall erosivity that controls soil erosion risk. Several authors Yesuph *et al* (2019); Pham *et al* (2018) and Saha (2018) stated that c factor is the soil erosion from specific land management or surface cover. It is the ratio of soil loss from land covered by vegetation to the corresponding loss from continuous fallow (Gashaw *et al*., 2017 and Prasannakumar *et al*., 2012). The *C*-factor value ranges between 0 (very strong cover effects) and 1 (no cover present and the surface treated as barren land) (Molla and Sisheber, 2017 and Pham *et al*., 2018). Finally, after the LULC of the selected watershed were conducted the C factor values were assigned according to standard assigned by different authors (Table 2).

Table 2. Land use/cover, area coverage and published C-values

LUC type	C-value	Source
Forest land	0.001	Hurni (1985); Zerihun*et al.* (2018)
Shrub land	0.014	Hurni (1985); Gessesse et al. (2015); Moges and Bhat (2017)
Cultivated land	0.25	Hurni (1985); Haile and Fetene (2012)
Grass land	0.05	Hurni (1985); Haile and Fetene (2012)
Built-up area	0.05	Moges and Bhat (2017)
Bare land	0.45	Byizigiro*et al*., 2020
Settlement	1.0	Kalambukattu and Kumar, 2017
River	0.00	Kalambukattu and Kumar, 2017

Support and conservation practice (P) Factor

Support and conservation practice (P factor) refers to the effects of conservation practices in reducing the quantity and rate of runoff and the amount of soil erosion (Ayalew and Selassie, 2015; Wischmeier and Smith, 1978 and Koirala *et al*., 2019). The P factor refers to the effects of land conservation practices in minimizing the quantity and rate of rainfall-runoff and soil erosion. The P factor value can be determined by the type of conservation measure implemented Belayneh *et al* (2019) and the value is always between 0 and 1, where the value 0 indicates a good erosion-resistant facility made by man, and the value 1 indicates the absence of an erosion resistant facility (Saha,2018 and Koirala *et al*., 2019). In the selected watershed due to little information or lack of permanent management practices the P factor in this study was calculated using an alternative method through the combination of slope and LULC data for as proposed by (Wischmeier and Smith, 1978) as indicated in table 3. Similarly, the method was adopted by (Belayneh*et al*., 2019; Ayalew and Selassie, 2015; Wischmeier and Smith, 1978; Gelagay and Minale, 2016) to determine P factor value.

Table 3.Land management factor (P) values

Land-use type	Slope	P factor	References
Agricultural land	0–5	0.1	(Wischmeier and Smith, 1978; Hurni,1985; Bewket and Teferi, 2009; Gelagay and Minale, 2016; Mesfin and Dereje , 2021)
	5–10	0.12	
	10–20	0.14	
	20–30	0.19	
	30–50	0.25	
	50–100	0.33	
Other Land	All	1.00	

Soil Loss Analysis

The overall methodology involved the use of the RUSLE were summarized in figure 1 conceptual framework. Annual soil loss rate was determined by multiplying the respective RUSLE factor values interactively using "Spatial Analyst Tool Map Algebra Raster Calculator" in ArcGIS 10.3 environment as shown equation 4 adopted from the recommendations of Hurni (1985). Soil loss potential of the watershed was then categorized into different severity classes following FAO and UEP (1984) guide line. Finally, all the maps were geo-referenced with Universal Transverse Mercator (UTM) coordinate system.

$\mathbf{A = LS * R * K * C * P}$ **…………………………………………….. (Equation 8)**

Where:

A is the annual soil loss (metric tons ha^{-1} $year^{-1}$);
R is the rainfall erosivity factor [MJ mm h^{-1} ha^{-1} $year^{-1}$];
K is soil erodibility factor [metric tons ha^{-1} MJ^{-1} mm^{-1}];
LS = slope length factor (dimensionless);
C island cover and management factor (dimensionless) and
P is conservation practice factor (dimensionless).

RESULTS AND DISCUSSION

Determinates factors for Soil Loss

Rainfall Erosivity (R) Factor

The soil loss due to soil erosion severity closely related contribution of rain to runoff; intensity and frequency of the rainfall through the detaching power of raindrops striking the soil surface. The results of R factor maps for selected ranged 683.187 to 769.11 MJmm $ha^{-1}year^{-1}$ and 1316.64 to 1379.95 for Sinana and Goba watershed, respectively (Figure 3). Based on the value relativity R factor for Goba watershed higher than Sinana watershed might be due to steep slope and other factors. The significant variation in R factor value in both watersheds might be due to greatly influenced by the volume, intensity, duration and pattern of rainfall that quantify the amount and rate of the resulting runoff. The greater the intensity and duration of the rain storm, the higher R factor and a possible reason for higher surface runoff (Ashiagbor *et al*., 2013; Farhan *et al*., 2013; Gizachew and Mersha, 2015; Habtamu *et al.*, 2020). Areas with low R factor indicate low slope or flat land, high infiltration and less vulnerable to erosion whereas as high R factor value shows more vulnerable to erosion due to steep slope, area received high amount of rainfall and absence or limited surface covers. Therefore, the R factor value revealed both watershed required surface management, covers and proper soil and water conservation measures.

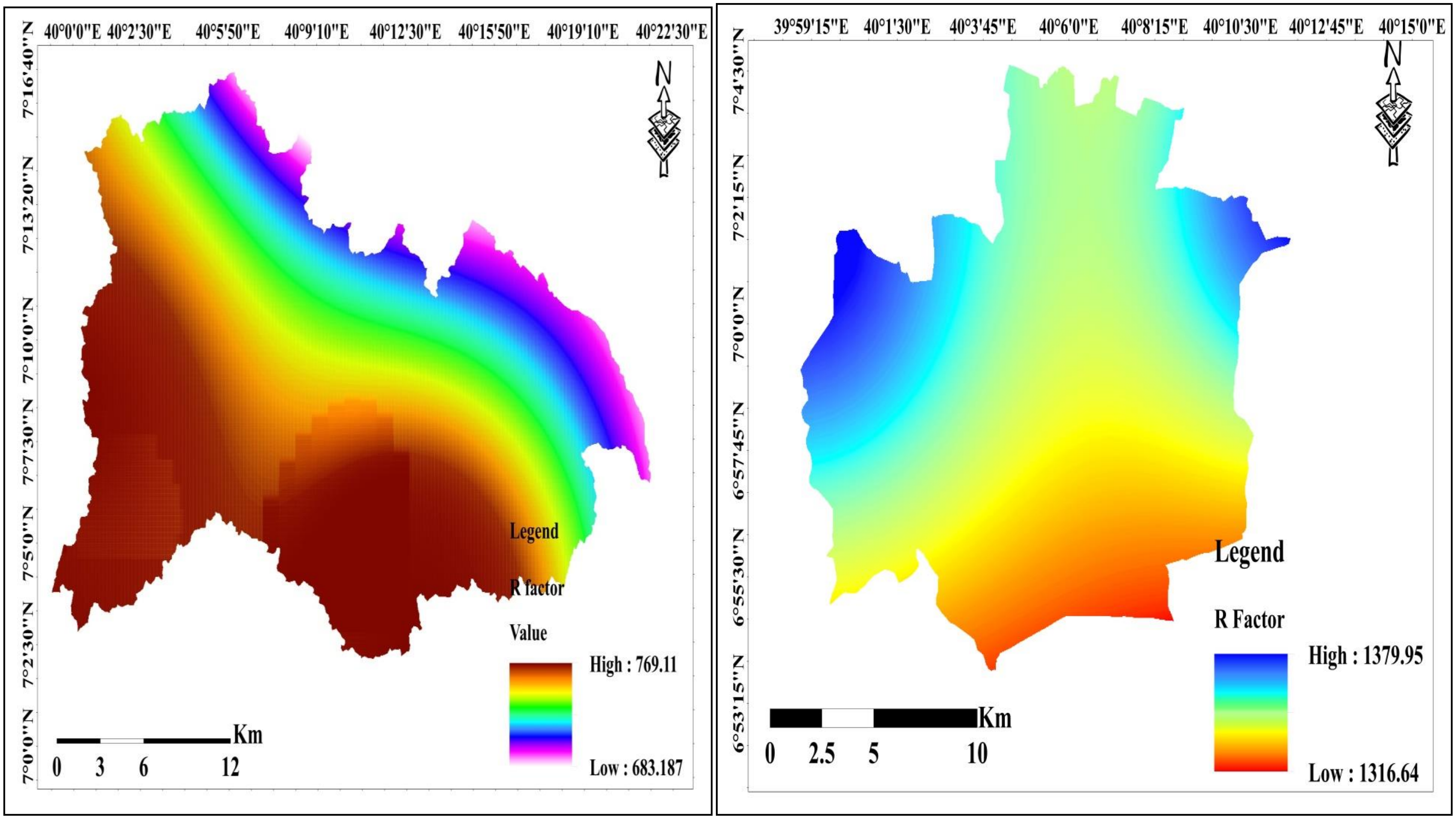


Figure 3. R factor Maps of selected Sinana and Goba Watershed

Soil Erodibility Factor

The results of the current study revealed that soil erodibility (K factor) values was varied from 0.221 to 3.22 Mgh MJ^{-1} mm^{-1} while 1.21 to 2.46 Mgh MJ^{-1} mm^{-1} for Sinana and Goba watershed, respectively (Figure 4). Thus the significant difference in soil erodibility K might be due to the difference in soil types, amount of organic matter contents, soil particle size distribution and also variations in soils color of the area. This highest and lowest k factor value indicates more vulnerable and less vulnerable soil type to erosion, respectively. Soils having high clay contents like vertisols tend to have low K values in terms of texture in which the higher the K-factor value the more the soil vulnerable to erosion that subsequently results the higher soil loss under a given while the low K-factor values mostly preferred since ideally low soil loss (Yongsik, 2014 and Habtamu *et al*, 2020).

Thus result the high k-factor value indicates more vulnerable soil type to soil erosion and the smaller value shows less vulnerable soil type to erosion (Estifanos, 2014). The K factor is rated on a scale from 0 to 1, where 0 refers to soils with least susceptibility to erosion and 1refers to soils which are highly susceptible to erosion by water. Generally, soils become of low erodibility if the silt content is low, regardless of corresponding high content in the sand and clay fractions (Mhangara *et al*., 2012 and Farhan *et al*., 2013). The K factor is influenced by intrinsic soil properties related such as: percent silt (0.002 - 0.1 mm), percent sand (0.1 - 2 mm), percent organic matter, soil structure and permeability (Farhan *et al*., 2013).

The erodibility of a soil is an expression of its inherent resistance to particle detachment and transport by rainfall in which the high k-factor value indicates more vulnerable soil type to soil erosion (Farhan *et al*., 2013, Gizachew and Mersha, 2015, Yongsik, 2014, and Habtamu *et al*, 2020). It is determined by the cohesive force between the soil particles, and may vary depending on the presence or absence of plant cover, the soil's water content and the development of its structure (Gizachew and Mersha, 2015). Erodibility depends essentially on the amount of organic matter in the soil, the texture of the soil, the structure of the surface horizon and permeability (Gizachew and Mersha, 2015).

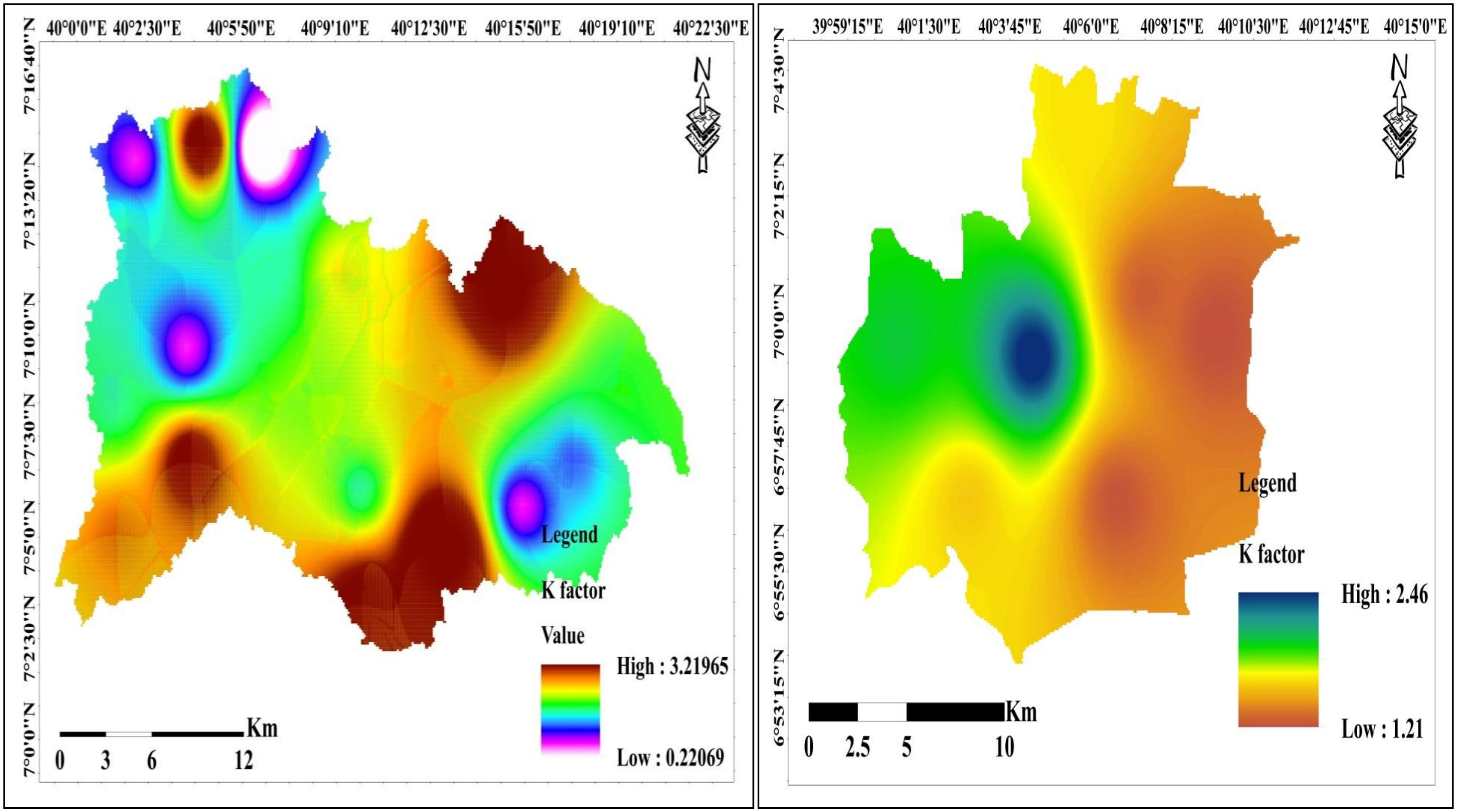


Figure 4. K factor Maps of selected Sinana and Goba Watershed

Slope Length and Slope Steepness (LS) Factor

The result modified (LS) factor map shows that the value was ranged from 0-25.71 and 0.18.91 for Sinana and Goba; respectively. As the slope length L increases, the total soil loss and soil erosion per unit increase; as a result of progressive accumulation of runoff in the down slope. As the slope steepness increases, the soil erosion also increases as a result of increasing the velocity and erosivity of runoff (Farhan *et al*., 2013). The total erosion or sediment yield from a watershed depends not only on slope length but on steepness also. LS factor expresses the effect of local topography on soil erosion rate, combining effects of both slope length (L) and slope steepness (S) (Kalambukattu and Kumar, 2017). The high values may be due to the highly dissected terrain and abrupt slope changes near the drainage channels. The various researchers' studies unanimously agreed that higher LS factor values are observed in hilly and gully area as well as mountainous areas with very steep topography and these areas are prone to sever erosion, due to topography (Ashiagbor *et al*., 2013, Sun *et al*., 2014 and Kalambukattu and Kumar, 2017).

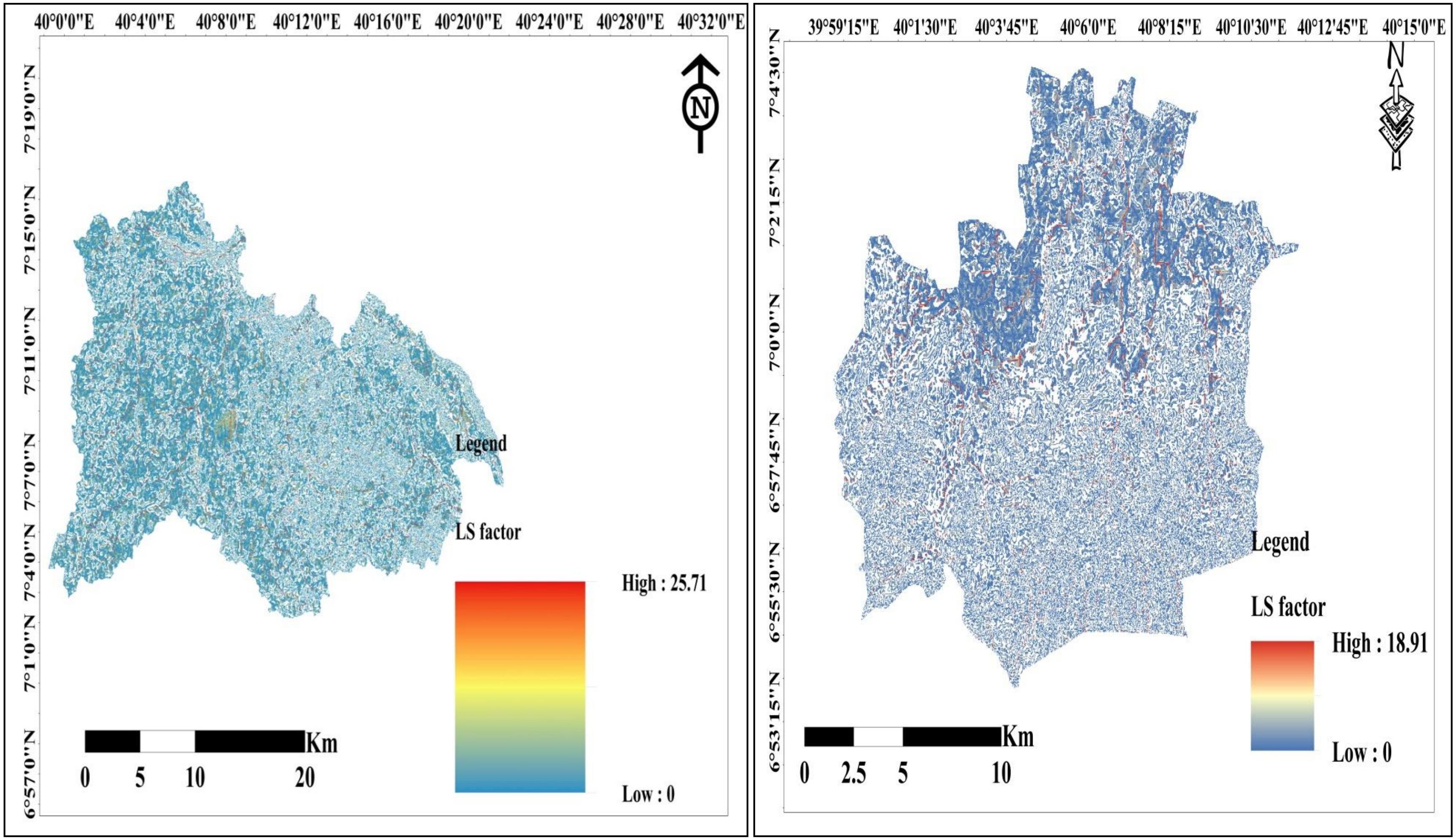


Figure 5. LS factor Maps of selected Sinana and Goba Watershed

Crop Management Factor

Based on the analysis the crop management factor (C factor) value of both the selected watershed namely, Sinana and Goba watershed were ranged between 0 to 1 (Figure 6). Accordingly, the high C factor value was assigned to cultivated land due to relatively highly exposed to erosion than other land use type. In line with this finding Habtamu *et al (*2020) reported the high C factor value in cultivated land while lowest value in grazing and forest land. The crop management factor (C) expresses the effect of cropping and management practices on the soil erosion rate and is considered the second major factor (after topography) controlling soil erosion.

The increase in the C factor indicates a decrease in exposed soil, and thus an increase in potential soil loss (Farhan *et al*., 2013). The C factor measures the combined effect of cropping and management practices in agricultural system and the effect of ground cover, tree canopy and grass covers in reducing soil loss in non-agricultural condition (Gizachew and Mersha, 2015). Higher values of C factor indicate no cover effect and soil loss comparable to that from bare soil, while lower C means a very good vegetation cover effect and less soil loss comparable to bare soil and hence less or negligible erosion (Kalambukattu and Kumar, 2017).

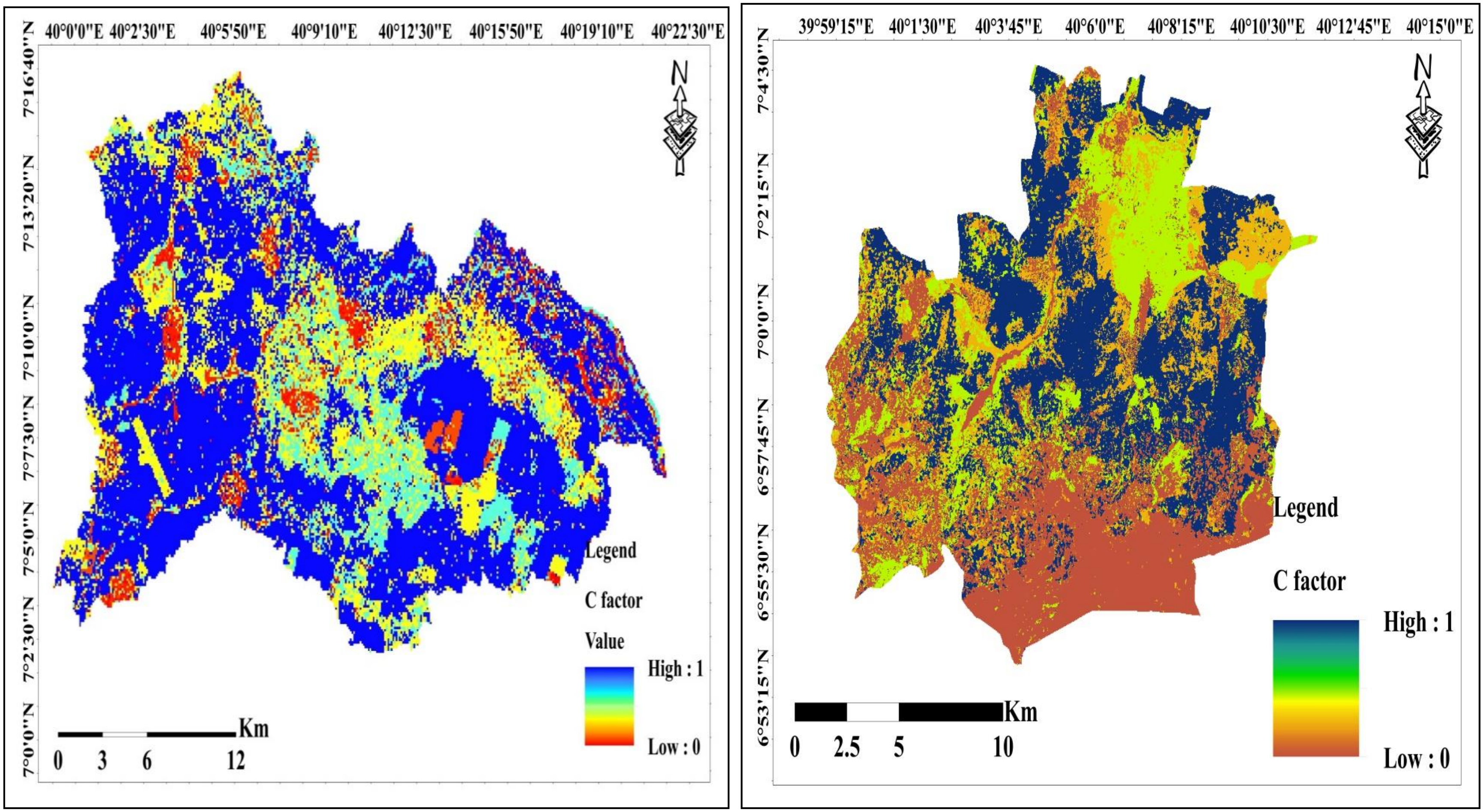
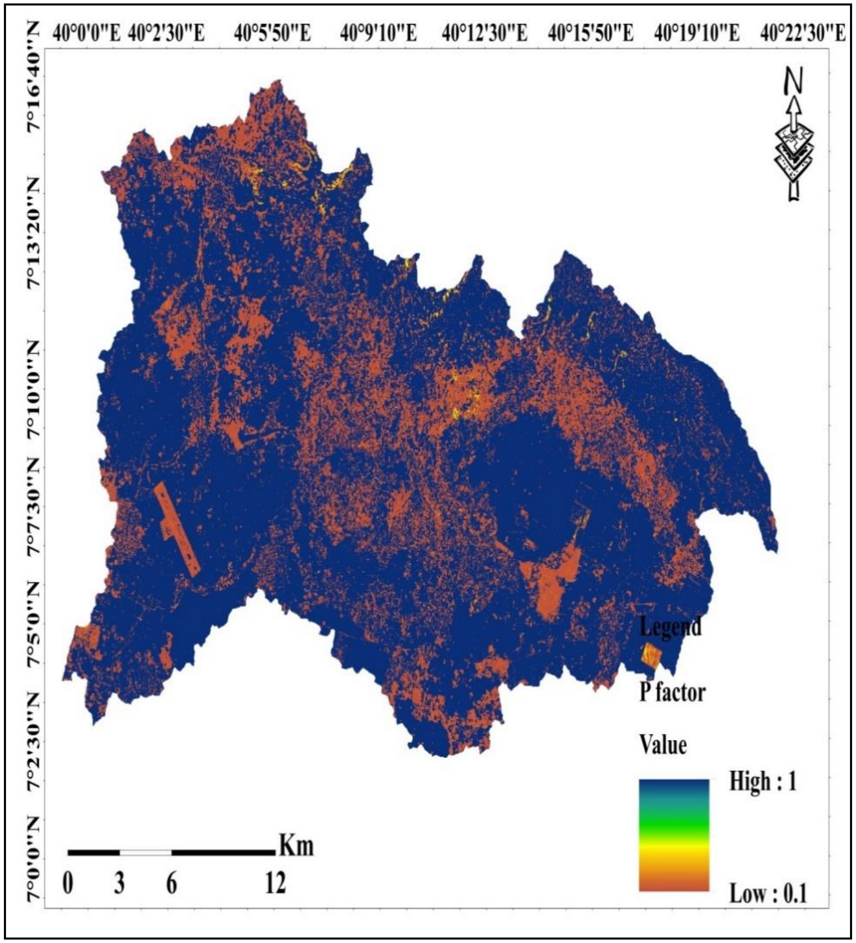


Figure 6. C factor Maps of selected Sinana and Goba Watershed

Conservation Practice Factor (P)

The results for the P factor classified into six slope class classes for agricultural land and one class for other land uses and a total of seven class shows that it ranged from 0.1 to 1 and 0.55 to 1 for Sinana and Goba watershed; respectively (Figure 7). Thus means the higher the P factor and the lower P factor was indicate higher ratio of soil loss and the lower soil loss ratio, respectively. Habtamu *et al (*2020) also reported the similar trends of P factor values with soil loss categories for the given area or selected watershed. Thus means good management practices or any conservation measures can change the slope of the land effect soil erosion particularly reduce soil erosion and improve soils fertility of the watershed. Conservation practice factor (P) in the RUSLE model expresses the effect of conservation practices that reduce the amount and rate of water runoff, which reduce erosion. It is the ratio of soil loss with a specific support practice on croplands to the corresponding loss with slope-parallel tillage (Wischmeier and Smith, 1978; Rabia, 2012 and Farhan *et al*., 2013).



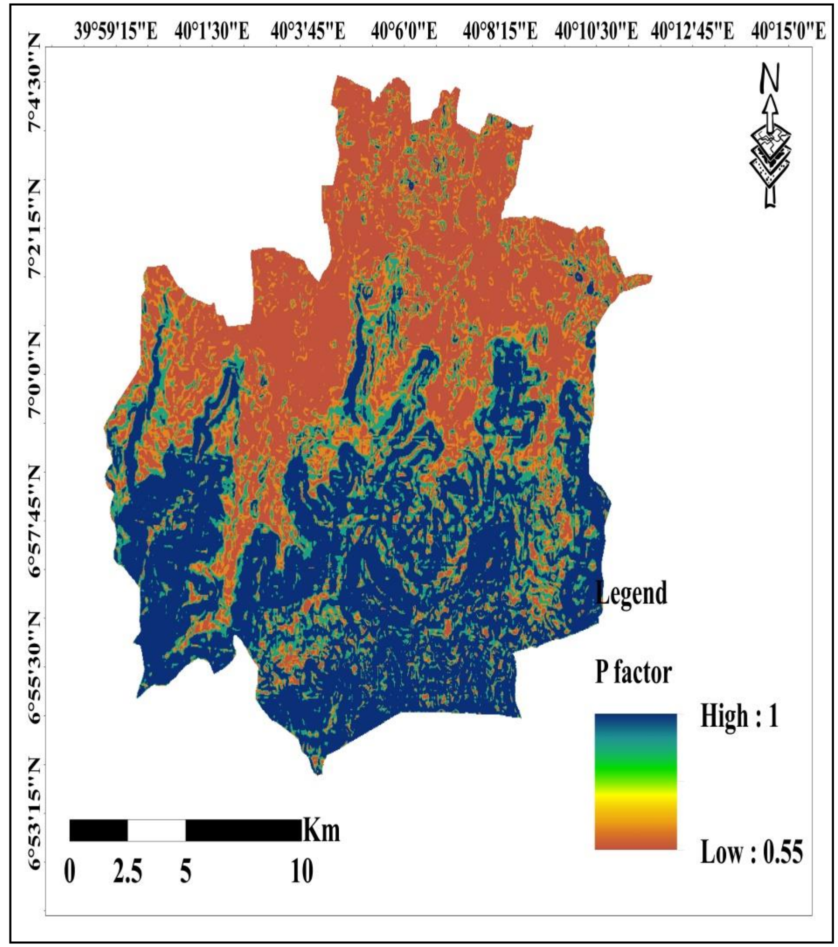


Figure 7. P factor Maps of selected Sinana and Goba Watershed

Soil loss and Erosion Severity

The selected watershed was classified into 7 sub-watersheds for sinana while 8 sub watershed for Goba and their vulnerability classes were identified (Figure 7). According the results in which 38.22% and 42.57 % subjected to very sever soil loss categories for Sinana and Goba watershed, respectively (Table 4). Identification of more risky sub-watersheds was basic for selection of prior-focus areas for conservation planning (Gashaw *et al*., 2017 and Woldemariam *et al*., 2018). The result showed that there was greater variability of soil erosion not only in pixel basis but also among sub-watersheds (Table 3 and Figure 5). The annual soil loss minimum (0 $tha^{-1}yr^{-1}$) and maximum (26957.85 $tha^{-1}yr^{-1}$) with mean values of 191.54 $tha^{-1}yr^{-1}$ and standard deviation 713.06 $tha^{-1}yr^{-1}$ was recorded for Sinana watershed (Table 5). Goba watershed annual soil loss map shows that minimum (0 $tha^{-1}yr^{-1}$) and maximum (20152.61 $tha^{-1}yr^{-1}$) with mean values of 180.97 $tha^{-1}yr^{-1}$ and standard deviation 598.37 $tha^{-1}yr^{-1}$ was obtained (Table 5). In both watersheds the soil loss higher than the maximum tolerable soil loss according Hurni (1985) and Hurni (1983) in Ethiopia conditions. These results supported with the finding of Estifanos (2014) who reported that the annual soil loss of the highlands of Ethiopia ranges from 1248 –23400 million $tha^{-1}yr^{-1}$ from pasture, ranges and cultivated fields.

Table 4. Soil loss severity extent for both selected watershed

	Sinana Watershed		**Goba watershed**	
Soil Loss	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**
Very slight	17932.20	45.36	7108.25	44.68
Slight	3202.78	8.10	792.97	4.98
Moderate	1866.09	4.72	632.65	3.98
Severe	1421.98	3.60	602.52	3.79
Very severe	15111.71	38.22	6772.28	42.57

Table 5. Total annual soil loss characteristics for both selected watershed

Descriptive	**Sinana watershed**	**Goba watershed**
Minimum	0	0
Maximum	269757.85	20152.61
Mean	191.54	180.97
Standard deviation	713.06	589.37

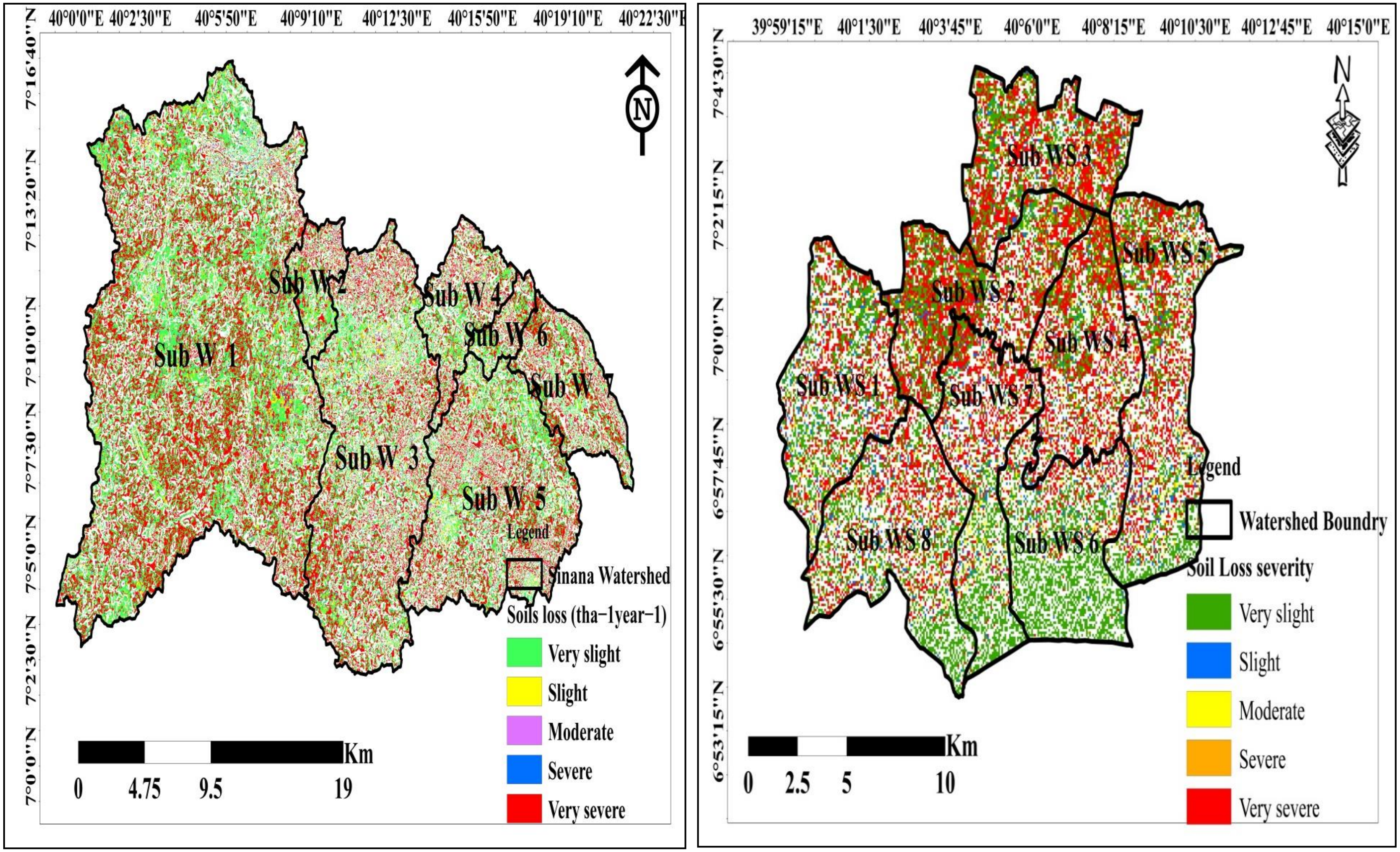


Figure 1. Soil loss severity status Maps within selected Sinana and Goba Watershed

Conclusion and recommendation

The results of this study was to quantify soil loss and prioritize the watershed on the basis of soil loss severity by using geospatial technique (GIS and RS) and RUSEL model for Sinana and Goba watersheds. This the soil loss map categorized into severity class important for the prioritization of sub watersheds into conservation priority plan for management of the watershed. The integrated use of geospatial technique (GIS and RS) and RUSEL model become valuable tools to estimate soil loss rate in a watershed. The parameters soil erosivity (R), slope length and steepness (LS), land cover (C), soil erodibility (K) and land management practice (P) were used in RUSLE model. Based on this analysis, the amount of soil loss 38.22% and 42.57 % subjected to very sever soil loss categories for Sinana and Goba watershed, respectively. The mean annual soil loss were 191.54 tha^{-1}yr^{-1} for Sinana watershed whereas for Goba watershed 180.97 tha^{-1}yr^{-1}. In both watersheds the soil loss higher than the maximum tolerable soil loss according in Ethiopia conditions.

The recommended prioritized sub watershed for decision makers and integrated watershed management should be planned for implementation, starting in the order of sub watershed 1,3,5,7,4,2, and 6 ;respectively for Sinana watershed whereas 3,2,4,7,5,8,1 and 6; respectively for Goba watershed. This implies prioritization of the sub watersheds for planning, development, management and conservation of the natural resources supports for their sustainable development. Based on the result of the study, the sub watersheds which have fallen under high, very high and sever severity classes need immediate attention in their order of implement conservation structure according to their slope class. It can be recommended this soil erosion severity assessment and mapping support as to identify high erosion prone areas, baseline information for planning and management interventions to rehabilitate degraded areas and minimize future soil erosion in the watershed.

References

Arabameri, A., Tiefenbacher, J. P., Blaschke, T., Pradhan, B., and Tien Bui, D. J. R. S. 2020. Morphometric analysis for soil erosion susceptibility mapping using novel gis-based ensemble model. 12(5), 874.

Ashiagbor, G., Forkuo, E.K., Laari, P. and Aabeyir, R., 2013. Modeling soil erosion using RUSLE and GIS tools. *Int J Remote Sens Geosci*, *2*(4),1-17.

Belayneh, M., Yirgu, T., and Tsegaye, D. 2019. Potential soil erosion estimation and area prioritization for better conservation planning in Gumara watershed using RUSLE and GIS techniques". *Environmental Systems Research, 8*(1), 20.

Endalamaw, N. T., Moges, M. A., Kebede, Y. S., Alehegn, B. M., and Sinshaw, B. G. J. E. C. 2021. Potential soil loss estimation for conservation planning, upper Blue Nile Basin, Ethiopia. 5, 100224.

Estifanos Abera.2014. *Assessment of micro-watershed vulnerability for soil erosion in Ribb watershed using GIS and remote sensing* (Doctoral dissertation, Mekelle University).

Farhan, Y., Zregat, D. and Farhan, I., 2013. Spatial estimation of soil erosion risk using RUSLE approach, RS, and GIS techniques: a case study of Kufranja watershed, Northern Jordan. *Journal of Water Resource and Protection*, *5*(12), 1247.

Gizachew Tiruneh and Mersha Ayalew, 2015. Soil Loss Estimation Using Geographic Information System In Enfraz Watershed For Soil Conservation Planning In Highlands Of Ethiopia. *Int. J. Agril. Res. Innov. and Tech. 5 (2): 21-30.*

Haregeweyn, N., Tsunekawa, A., Poesen, J., Tsubo, M., Meshesha, D. T., Fenta, A. A., and Adgo, E. 2017. Comprehensive assessment of soil erosion risk for better land use planning in river basin.

Hurni, H. 1983. Soil erosion and soil formation in agricultural ecosystems in Ethiopia and Northern Thailand. Mountain research and development.

Hurni, H., 1985. Erosion-productivity-conservation systems in Ethiopia. IV. International

Conference on Soil Conservation, Venezuela, 20.
Kalambukattu, J. and Kumar, S., 2017. Modelling soil erosion risk in a mountainous watershed of Mid-Himalaya by integrating RUSLE model with GIS. *Eurasian Journal of Soil Science*, *6*(2), 92-105.
Mhangara, P., Kakembo, V. and Lim, K.J., 2012. Soil erosion risk assessment of the Keiskamma catchment, South Africa using GIS and remote sensing. *Environmental Earth Sciences*, *65*(7), pp.2087-2102.
Morgan, R. P. C., and Nearing, M. 2016. Handbook of erosion modelling: John Wiley and Sons. Mosbahi, M., Benabdallah, S., and Boussema, M. R. J. A. J. o. G. (2013). Assessment of soil erosion risk using SWAT model. 6(10), 4011-4019.
Negese, A., Fekadu, E., and Getnet, H. 2021. Potential Soil Loss Estimation and Erosion-Prone Area Prioritization Using RUSLE, GIS, and Remote Sensing in Chereti Watershed, Northeastern Ethiopia. *Air, Soil and Water Research*, *14*, 1178622120985814.
Rabia, A.H., 2012, June. Mapping soil erosion risk using RUSLE, GIS and remote sensing techniques. In *The 4th international congress of ECSSS, EUROSOIL, Bari, Italy* (pp. 1-15).
Wischmeier, W.H. and Smith, D.D., 1978. *Predicting rainfall erosion losses: a guide to conservation planning* (No. 537). Department of Agriculture, Science and Education Administration.

Determination of NPS Fertilizer Rates Based on Calibrated Phosphorus for Maize in Darimu District, Western Oromia

Dagne Chimdessa, Gedefa Sori, Garoma Firdissa and Bati Dube
Bedele Agricultural Research Center, P.O.Box-167, Buno Bedele Zone, Bedele
*Corresponding author: dagnechim@gmail.com

Abstract
Sufficient soil nutrients are very important for achieving optimal crop production. The aim of this study was to determine optimum NPS fertilizer rate to achieve optimal maize yield. The trial was conducted on twelve farmers' fields in 2020 and 2021 in Darimu district, western Oromia. The experimental design was completely randomized block design in three replications. The treatments were five rates of P critical levels (Pc) (0, 25, 50, 75 and 100 %) calculated from NPS fertilizer and the previously recommended 100% Pc calculated from DAP fertilizer was included as check were tried on hybrid maize (BH 661) for yield and yield component. Results showed that all Pc rates significantly increased the plant above ground bio mass, grains yield, and thousand grain weights and hasten maturity of hybrid maize over control. Phosphorus critical level at the rate of 100% Pc from NPS gave maximum biomass yield (28816.6 kgha^{-1}), grain yield (7660.5 kgha^{-1}) and thousand grain weight (416.6 g) followed by 100% Pc from DAP, while a partial budget analysis result also revealed that fertilizer application rate of 100% Pc from NPS offered net return of (83664.4 ETB ha^{-1}) followed closely by 100% Pc from DAP (75115.0 ETB ha^{-1}) which were substantially greater than the rest of the fertilizer treatments. .Hence, the fertilizer application rate of 100% Pc from NPS and DAP fertilizers appear the most appropriate for intensification of maize production in. Darimu district.

Key Words: BH 661, Nitrogen, NPS, P-critical level, Phosphorus, Sulfur

Introduction

A decline in soil fertility implies either decline in the levels of some important soil properties such as soil organic carbon, pH, cation exchange capacity (CEC), and plant nutrients or increment of the other to the level of toxicity. In the broadest sense, soil fertility decline includes nutrient depletion (large removal than addition of nutrients), nutrient mining (large removal of nutrients and no inputs) (Abdenna *et al., 2014*)

Inorganic fertilizers have been the important tools to overcome soil fertility problems and they are also responsible for a large part of the food production increases worldwide (Sanchez and Leakey, 1997). It has been estimated that at least 30 to 50% of crop yield increment is attributable to application of commercial fertilizers (Stewart *etal*,.2005); Vlek , 1990). Like in other developing countries, information on soil fertility status is not adequate to meet the requirement of agricultural development programs, rational fertilizer promotions and recommendations based on actual limiting nutrients for a given crop in Ethiopia. The prevailing blanket fertilizer rate recommendation throughout the country on all soil types and agro ecological zone justifies the existence of little information on the fertility status of Ethiopia's soils.

Low soil fertility is highly affects the growth and development of maize as compared to other crops. As a result, it is often said "maize speaks" implying that maize cannot produce maximum yields unless sufficient nutrients are available (Delorite and Ahlgren, 1967). When the soil does not supply sufficient nutrients for normal plant growth application of supplemental nutrients are required. The proper application rates of plant nutrients are determined by knowledge about the nutrient requirement of the crop and the nutrient supplying power of the soil (Foth and Ellis, 1997). Application of inorganic fertilizer containing nitrogen and phosphorus has long been started in Ethiopia. On the other hand, Sulfur could be one of the most likely limiting nutrients in Ethiopia soils (Duke and Reisenauer,1992). Understanding the combined effect of NPS fertilizer rather than NP fertilizer is very important. However, there is no information so far on the importance of NPS fertilizer for maize production in Darimu district of Buno Bedele Zone. Therefore, the objective of this experiment was to determine NPS fertilizer rate based on calibrated phosphorus on yield and yield components of maize in Darimu district.

Materials and Methods

Description of the Study Area

The study was conducted for two consecutive years during 2020 and 2021 main cropping seasons in the district of Darimu at twelve farmers' fields in the west of Ethiopia. Darimu is located at $08^{0}37'00''$ to $08^{0}38'09''$ N latitude and $035^{0}\,24'27''$ to $035^{0}25'40''$E longitude. The mean annual rainfall and temperatures of the district is ranged from 792 to 1192 mm, 18 C^{o} to $31C^{0}$, respectively. Altitude ranged from 700 to 1800 masl. The predominant soil type in Southwest and Western Ethiopia in general and the study area in particular, is Nitisols according to the (FAO, 2001) soil classification system. Its vernacular name is "*Biyyee Diimmaa*" meaning red soil. On the average, the soil is deep and relatively highly weathered well drained, clay in texture and strongly to moderately acidic in reaction. Nitisols are highly weathered soils in the warm and humid areas of the west and southwest Ethiopia (Mesfin, 1998).

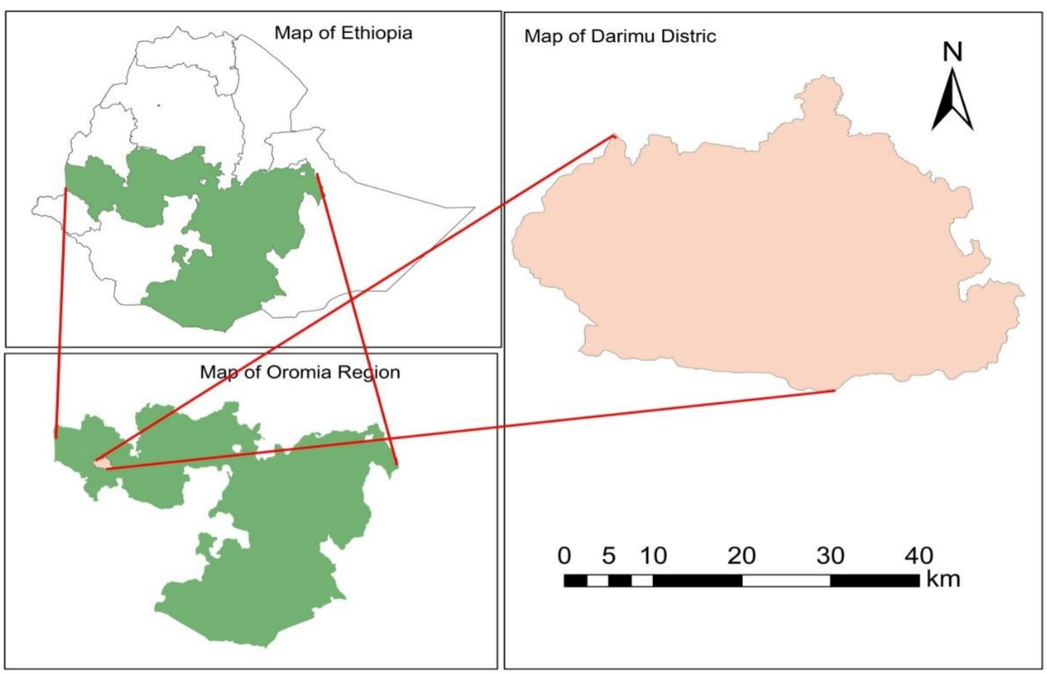


Figure 1. Map of the study area (Darimu district)

Soil Sampling and Analysis

Composite surface soil samples (0-20) cm depth were collected from twelve experimental sites before planting to analyze soil pH (H_2O), exchangeable acidity, available P, (%OC) and CEC. The collected soil samples were prepared and analyzed following standard laboratory procedures at soil analysis laboratory of, Bedele Agricultural Research Center. Accordingly, the soils were characterized as strongly acidic in reaction ranged from (4.4 to 5.3), low available Phosphorus ranged from (0.7 to 1.9 ppm), low organic carbon ranged from (2.0 to 3.3 %), low TN and low to moderate CEC ranged from (10.01 to 21.6)(cmol$^{(+)}$/kg soil) (Table 1).

Table 1: Soil data before planting in Darimu district

Sites	pH (H_2O)	Exch.A (cmol $^{(+)}$/kg soil)	Av. P (ppm)	OC (%)	TN (%)	CEC (cmol $^{(+)}$/kg soil)
1	5.0	0.3	1.9	3.2	0.2	16.0
2	4.7	0.6	0.8	3.3	0.2	15.1
3	4.7	0.6	0.9	2.6	0.3	15.5
4	5.1	0.3	0.9	2.0	0.1	21.6
5	4.4	1.2	1.0	2.4	0.2	17.7
6	5.0	0.3	1.7	2.6	0.2	15.0
7	4.9	0.1	0.8	2.4	0.2	13.0
8	4.4	0.9	1.5	2.9	0.1	15.0
9	4.8	0.2	1.8	2.6	0.2	16.0
10	4.9	0.2	0.9	2.1	0.1	16.5
11	5.1	0.1	0.8	3.1	0.1	10.1
12	5.3	0.1	0.7	2.7	0.2	16.5

Av. P=Available Phosphorus = CEC= Cation Exchange Capacity, OC= Organic Carbon, P=Phosphorus, TN= Total Nitrogen

Treatments, Experimental Design and Procedures

The treatments consisted of five (0, 25, 50, 75 and 100 %) P critical levels (Pc) calculated from NPS fertilizer and one previously recommended P critical level (100% Pc) calculated from DAP was included ,which was used as check, that means the total number of treatment were six. The experiment was laid out in RCBD with three replications. The gross plot size was 12m^2 (3m x4m). BH (661) maize variety was used as a test crop. Phosphorus rate was calculated and applied according to the formula, P (kg ha^{-1}) = (Pc – Po)*Pf, where Pc= Phosphorus critical level, Po = initial soil Phosphorus in the soil and Pf= Phosphorus requirement factor. Recommended N (138 kg N ha^{-1}) determined during Phosphorus calibration study for maize in the district was used. The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times. Full dose of phosphorous as per the treatment and one-half of N was applied at sowing. The remaining one-half of N was top dressed at 35 days after planting in the form of urea. The field was kept free of weeds by hand weeding during the period of the experiment. All other recommended agronomic management practices disease and insect pest control was done. Finally, days to 50% tassling, grain yield, biomass yield and thousand kernal weight were collected. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD.

Economic Analysis

Costs that vary among treatments were also assessed using the CIMMYT partial budget analysis (CIMMYT, 1988). The cost of NPS, DAP,UREA, the cost of labor required for the application of fertilizer, and cost for threshing were estimated by assessing the current local market prices. The price of NPS (1548.87ETB 100 kg-^{1}), DAP (1997.00ETB 100 kg-^{1}), UREA (1394.00ETB 100 kg-^{1}), daily labors (35 ETB per one person day based on governments' current scale in the study area) and the cost of maize threshing (1 ETB kg$^{-1)}$) were considered to get the total cost that vary among the treatments. Time elapsed during fertilizer application for some plots of each treatment was recorded to calculate daily labor required for one hectare. One person per day was estimated based on eight working hours per day. Maize grain yield was valued at an average field price of 20 ETB kg^{-1}. However, other non-varied costs were not included since all agronomic managements were equally and uniformly applied to each experimental plot. Before calculating gross revenue, maize grain yields obtained from each experimental plot were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price that farmers receive for the sale of the crop. The net benefit was also calculated as per standard manual (CIMMYT, 1988).

Results and Discussion

The data (Table 2) showed significant differences among different treatments for days to Tassling. Minimum days to Tassling (86.3 days) was recorded in maize plants fertilized with 100% Pc from DAP fertilizer followed by 100% Pc from NPS (83.6 days) with non-significant difference. The data also showed significant effect among different treatments for above ground biomass. Non significant and maximum above ground biomasses (28816.0 and 26948.0) kgha^{-1} were obtained from maize plants fertilized with 100% Pc from NPS and DAP fertilizers, respectively. The results are in conformity with that of (Dagne *etal.,* 2020) who observed the significant effect of NPS fertilizer on maize yield and yield component. The highest maize grain yield (7660.5 kgha^{-1}) was recorded for the treatment fertilized with 100% Pc from NPS fertilizer followed by 100% Pc from DAP fertilizer (7055.6 kgha^{-1}) while, the lowest(1537.0 kgha^{-1}) was recorded for control plot. NPS rates also significantly affected maize grain yield (Table 2). The results are in conformity with (Benti, 1993) who stated that, although adoption of new varieties especially maize hybrid is moving fast in Ethiopia, fertilizer management techniques need to supplement the existing potential of the varieties. Significant differences were also observed among different treatments in thousand kernal weight. Maximum thousand kernal weight (416.6 g) was obtained in 100% Pc from NPS fertilizer against minimum (328.3 g) in case of control plot. These results are in accordance with that of (Maqsood *et al.,* 2001*)* who also observed an increase in thousand kernal weight with increase in NP application.

Table 2: Mean days to tassling, biomass yield, grain yield and thousand grain weight of maize in Darimu district in 2020 and 2021 cropping seasons

Treatments	DT (days)	BMY (kgha^{-1})	GY (kgha^{-1})	TGW (g)
Without fertilizer	91.1^{a}	7523.0^{e}	1537.0^{f}	328.3^{c}
25% Pc from NPS +Rec N	88.2^{b}	13519.0^{d}	3024.3^{e}	372.7^{b}
50% Pc from NPS +Rec N	86.6^{c}	19892.0^{c}	4681.7^{d}	395.5^{ab}
75% Pc from NPS +Rec N	86.5^{c}	23183.0^{b}	5646.6^{c}	400.0^{a}
100% Pc from NPS+Rec N	86.6^{c}	28816.0^{a}	7660.5^{a}	416.6^{a}
100% Pc from DAP+Rec N	86.3^{c}	26948.0^{a}	7055.6^{b}	405.1^{a}
Mean	87.56	19980.0	4934.2	386.4
CV (%)	3.8	22.2	22.2	14.2
LSD	1.5	2062.3	510.0	25.6

BMY= Biomass Yield, DAP=Di ammonium Phosphate, CV= Coefficient of variation, DT= Days to Tassling, GY= Grain Yield ,NPS= Nitrogen, Phosphorus and Sulfur, Pc= Phosphorus critical level, Rec N= Recommended Nitrogen,TGW= Thousand

Economic Analysis

The economic analysis of maize in relation to nutrient management practices is presented in (Table 3). The total variable cost ranged between 3212 ETB to 20135 ETB ha^{-1}.The gross returns oscillated between 20749 ETB and 103416 ETB ha^{-1} for different treatments. Application of 100% Pc from NPS offered net return of 83664 ETB ha^{-1} followed closely by 100% Pc from DAP (75115 ETB ha^{-1}) which were substantially greater than the rest of the fertilizer treatments (Table 3). The least net return of 17537 ETB ha^{-1} was received from unfertilized plot, elucidating the importance of NPS DAP fertilizers in enhancing the net return.

Table 3: Partial budget analysis for treatment applied for maize

Treatments	Av.GY (Kgha^{-1})	Adj.GY (Kgha^{-1})	TVC (Birr)	Gross benefit (Birr)	Net benefit (Birr)
Without fertilizer	1537.0	1383.3	3212.0	20749.5	17537.5
25% Pc from NPS + Rec N	3024.3	2721.8	10356.7	40827.0	30470.3
50% Pc from NPS + Rec N	4681.7	4213.5	15385.7	63202.5	47816.8
75% Pc from NPS + Rec N	5646.6	5081.9	17084.6	76228.5	59143.9
100%Pc from NPS + Rec N	7660.5	6894.4	19751.6	103416.0	83664.4
100%Pc from DAP + Rec N	7055.6	6350.0	20135.0	95250.0	75115.0

Adj.GY=Adjusted Grain Yield to 10%, Av.GY=Average Grain Yield. , TVC= Total Variable Cost

Conclusion and Recommendation

Information on soil fertility status and crop response to different soil fertility management is very important to come up with sustainable crop production**.** Accordingly, the study confirmed the role of NPS fertilizer in increasing growth and grain yield in maize production. The results conclude that maximum grain yield and the highest net benefits were recorded for 100% Pc from NPS and DAP fertilizers, whereas the lowest were recorded for the treatment without fertilizer. Accordingly these fertilizers increased maize productivity in the study area; which indicated that maize productivity in the study sites were reduced due to high demand for external nutrient inputs. Therefore, maize growers in Darimu district are advised to use either100% Pc from NPS or DAP fertilizers for higher yield.

Acknowledgement

We acknowledged IQQO for granting research fund and technical advise

References

Abdenna Deressa, WakeneNegassa, FiteGetaneh and KefyalewNegisho. 2014. Optimum NP Fertilizers Rate For WheatProduction on Alfisols of Arjo and ShambuHighlands, Western Ethiopia.journal of environment and human,1: 2.

Benti Tolessa, 1993.The need and objective of the 1st National Maize Workshop. *In:* Proceedings of the 1st National Maize Workshop of Ethiopia. 5-7 May, 1992, IAR and IMWI C, Addis Ababa, Ethiopia

CIMMYT (International Maize and Wheat Improvement Center), 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, DF. 79p

Dagne Chimdessa, Gedefa Sori, Dechassa Mengistu and Amanuel Kajela, 2020. Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Maize in Dabo Hana District, Western Oromia. pp. 55- 69. Proceedings of Review Workshop on Completed Research Activities of Natural Resource Research Directorate Held at Batu Fishery and Other Aquatic Life Research Center, Batu, Ethiopia, 23-27 December 2020.

Delorite, R.J. and H. L. Ahlgren,1967. Crop Production.(3rded). Prentice Hall, Inc., Englewood Cliffs, NewJersey.

Duke and Reisenauer, 1992. Roles and requirements of sulfur in plant nutrition. Sulfur in agriculture. In: Tabatabai MA (Ed.). Agronomy Monograph No. 27, ASA, Madison; 1986.

FAO (Food and Agriculture Organization), 2001. Lecture notes on the major soils of the world. Driessen, P., J. Deckers, and F. Nachtergaele, (Eds.). Food and Agricultural Organizations, Rome, Italy. 334p.

Foth, H.D. and B. G. Ellis, 1997. Soil Fertility, (2nded). Lewis Publishers, Boca Raton,Florida.290p.

Maqsood, M., A. M. Abid, A. Iqbal and M. I. Hussain. 2001. Effect of variable rate of nitrogen and phosphorus on growth and yield of maize (golden). Online J. Biol. Sci. 1 (1):19-20.

Mesfin Abebe, 1998. Nature and management of Ethiopian soils. Alemaya University, Ethiopia. 272p.

Sanchez, A. P. and R.B. Leakey, 1997. Land use transformation in Africa: threedeterminantsfor balancingfood security with natural resource utilization. *AgronJ.* 7:15-23.

Stewart, W.M., D.W. Dibb, A.E. Johnston and T.J. Smyth, 2005. The contribution of commercial fertilizer nutrients to food production. *Agron J.* 97: 1-6.

Vlek, P.L., 1990. The role of fertilizers in sustaining agriculture in sub-Saharan Africa. *Fert. Res.J.* 26:327- 339.

Determination of NPS Fertilizer Rates Based on Calibrated Phosphorus for Bread wheat in Gechi District, Western Oromia

*Dagne Chimdessa, Gedefa Sori, Garoma Firdissa and Bati Dube *
Bedele Agricultural Research Center, P.O.Box-167, Buno Bedele Zone, Bedele
*Corresponding author: dagnechim@gmail.com

Abstract
Determination of NPS fertilizer rates was studied on farmer's fields in Gechi district, west Oromia, Ethiopia. Five rates of Phosphorus critical level (Pc) (0, 25, 50, 75 and 100 %) calculated from NPS fertilizer and previously recommended 100% Pc calculated from DAP fertilizer was included as check were tried on bread wheat (king bird variety) for yield and yield component. The results of this experiment revealed that application of NPS fertilizer has significantly increased biomass and grain yields of bread wheat compared to unfertilized control plot, indicating insufficient soil N, P and S nutrient contents for optimum production of bread wheat indicating positive interaction among these nutrient elements. In all cases, maximum biomass (13550 $kgha^{-1}$) and grain (4220.0 $kgha^{-1}$) yields of bread wheat were obtained with treatment involving at *Phosphorus critical level at the rate of 100% Pc from NPS followed by 100% Pc from DAP with none significant difference, while a partial budget analysis result also revealed that 100% Pc from NPS produced net benefit of (59700.0 ETB ha^{-1}) while DAP gave (48542.1 ETB ha^{-1}). Thus these treatments are found to be economically feasible treatments for bread wheat production in the study area, Gechi district.*

Key Words: Bread wheat, Nitrogen, NPS, P-critical level, Phosphorus, Sulfur

Introduction

Declining soil fertility is one of the major factors that account for low productivity of wheat in Ethiopia (Birhan *etal*.,2016; Tamene *etal*., 2017). Declining soil fertility which is caused by soil erosion, continuous cropping of same land year after year, deforestation, inadequate replenishment of nutrients lost through different pathways through application of organic and inorganic fertilizers are the main challenge not only to wheat production but also to the production of all crops (Birhan *etal*.,2016 ; Van Beek *etal*.,2016) . It is an issue of great concern in Ethiopia as soil nutrient depletion is becoming severe and severe with time since little efforts are being made to reverse the problem.

In an effort to overcome declining soil fertility challenge and thereby improve crop productivity including wheat, application of inorganic fertilizer containing nitrogen (*N*) and phosphorus (*P*) has long been started in Ethiopia. However, crop yield gain due to *N* and *P* fertilizer application is declining over time despite steady increases in fertilizer consumption in Ethiopia (IFPRI, 2010). Declining crop yield responses to *N* and *P* fertilizers is attributed to decreasing soil organic matter (SOM) content (IFPRI, 2010). Moreover, depletion of other nutrients in addition to *N* and *P* could be additional factor for decreasing response of crops to N and P fertilizers (Wassie and Tekalign, 2013). Sulfur (*S*) could be one of the most likely limiting nutrients in Ethiopia soils. It is a building block of protein and a key ingredient in the formation of chlorophyll (Duke and Reisenauer,1992). It has been reported that *S*-deficient plants exhibits reduced plant height and stunted growth, reduced tillers, spikelets and delayed maturity (Aulakh and Chhibba,1992 ; Kumar *etal*, 2012). Sulfur-deficient plants are shown to be less resistance under stress conditions (Dobermann and Fairhurst , 2000).

In this regards, emerging research evidences are showing that sulfur (*S*) is one of the nutrients becoming deficient in some Ethiopian soils limiting crop production. According to (Assefa, 2016) studied the response of wheat to *S* application on 18 sites located in Arsi, East Shewa and West Shewa and reported that wheat significantly responded to *S* fertilizer application and soils of responding sites had *S* content below critical level (11–13 mg $kg^{-1}SO4^{-2}$-S) for optimum production. Similarly, (Kiros and Singh, 2009) studied the effect of sulfur on two varieties of wheat and found that *S* application significantly increased grain yield.

Bread wheat crop has high yield potential in Gechi district. Despite its high yield potential, it is giving low yields because of improper fertilizer management practices due to lack of appropriate information on N, P and S nutrient elements management. Therefore, this experiment was designed to determine NPS fertilizer rate based on calibrated phosphorus on yield components and yield of bread wheat in Gechi district.

Materials and Methods

Description of the Study Area

Geographically, the study area (Gechi district) is located in Oromia National Regional State, western Ethiopia, at 08º24'40.0"to 08º25'12.0"N and 036 º25'61.0" to 036 º33'20.0" E with altitude ranging from 1013 to 2390 masl (Fig 1).The long-term weather information at nearby study area (Ethiopian Metrology Agency Bedele District Branch) indicated that a uni-modal rainfall pattern with average annual rain fall of 1945 mm. The rainy season covers April to October and the maximum rainfall is received in the months of June, July and August. The minimum and maximum annual air temperatures are 12.9 and 25.8°C, respectively, The predominant soil type in Southwest and Western Ethiopia in general and the study area in particular, is Nitisols according to the (FAO, 2001) soil classification system. Its vernacular name is "*Biyyee Diimmaa*" meaning red soil. On the average, the soil is deep and relatively highly weathered, well drained, clay in texture and strongly to moderately acidic in reaction. Nitisols are highly weathered soils in the warm and humid areas of the west and southwest Ethiopia (Mesfin, 1998)

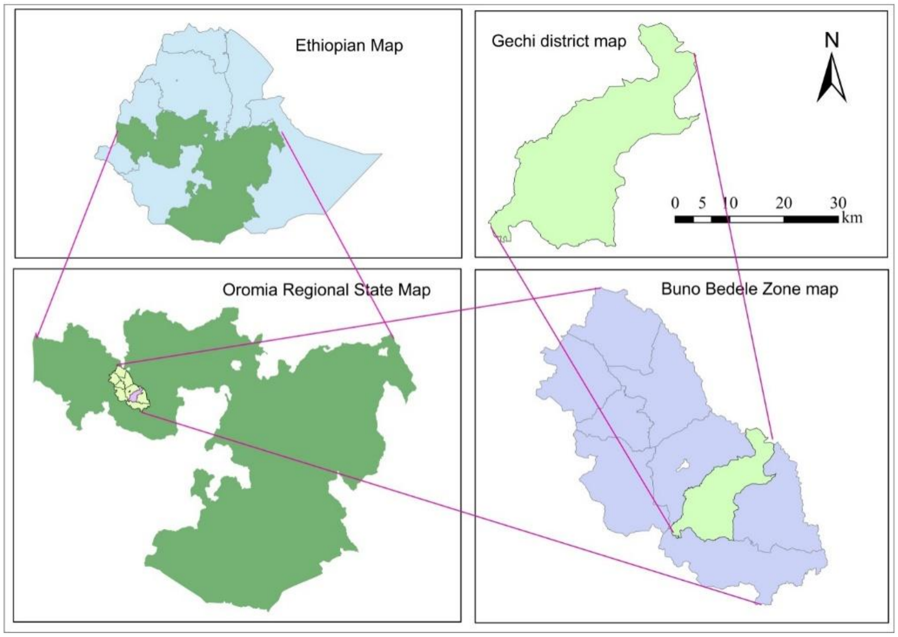


Figure 1. Map of the study area (Gechi district)

Soil Sampling and Analysis

Pre-planting soil analyses data of selected physicochemical properties of samples collected from experimental location at Gechi district were belonging to clay textural class, acidic in reaction. The SOM, available P and TN content of soils were in low categories.

Treatments, Dand Experimental Procedures

The treatments consisted of five (0, 25, 50, 75 and 100 %) P critical levels (Pc) calculated from NPS fertilizer and one previously recommended P critical level (100% Pc) calculated from DAP fertilizer was included, which was used as check, that means the total number of treatment were six. The experiment was laid out in RCBD design with three replications. The test crop, wheat variety, kingbird was sown in a unit plot size of 3×4 m with row spacing of 20 cm apart at a seed rate of 150 kg ha^{-1}. Phosphorus rate was calculated and applied according to the formula, P (kg ha^{-1}) = (Pc – Po)*Pf, where Pc= Phosphorus critical level, Po = initial soil Phosphorus in the soil and Pf= Phosphorus requirement factor. Recommended N (92 kg N ha^{-1}) determined during Phosphorus calibration study for bread wheat in the district was used. The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times, and treated with lime for soil pH less than 5.5, and the amount of lime needed per hectare was calculated based on exchangeable acidity. Full dose of phosphorous as per the treatment and one-half of N was applied at sowing. The remaining one-half of N was top dressed at 35 days after planting in the form of urea. The field was kept free of weeds by hand weeding during the period of the experiment. All other recommended agronomic management practices disease and insect pest control was done. Finally, plant height, days to 50% heading, grain and biomass yields were collected. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD.

Economic Analysis

Costs that vary among treatments were also assessed using the CIMMYT partial budget analysis (CIMMYT, 1988). The cost of NPS, DAP,UREA, the cost of labor required for the application of fertilizer, and cost for threshing were estimated by assessing the current local market prices. The price of NPS (1548.87ETB 100 kg-^{1}), DAP (1997.00ETB 100 kg-^{1}), UREA (1394.00ETB 100 kg-^{1}), daily labors (35 ETB per one person day based on governments' current scale in the study area) and the cost of bread wheat threshing (1 ETB kg$^{-1)}$) were considered to get the total cost that vary among the treatments. Time elapsed during fertilizer application for some plots of each treatment was recorded to calculate daily labor required for one hectare. One person per day was estimated based on eight working hours per day. Bread wheat grain yield was valued at an average field price of 20 ETB kg$^{-1;}$ however, other non-varied costs were not included since all agronomic managements were equally and uniformly applied to each experimental plot. Before calculating gross revenue, bread wheat grain yields obtained from each experimental plot were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price that farmers receive for the sale of the crop. The net benefit was also calculated as per standard manual (CIMMYT, 1988).

Results and Discussion

Effects of *NPS* on Yield and Yield Components of Bread Wheat

There were significant differences among different treatments for plant height. Maximum plant height (72.8cm) was recorded in bread wheat plants fertilized with 75% Pc from NPS fertilizer followed by 50% Pc from NPS (72.5 cm) with non-significant difference. The results are in conformity with (Ashfaq, 2004). Days to heading showed non-significant difference except unfertilized plot. The data also showed significant effect among different treatments for above ground biomass. Non significant and maximum above ground biomasses (28816.0 and 26948.0) kgha^{-1} were obtained from bread wheat plants fertilized with 100% Pc from NPS and DAP fertilizers, respectively. Significant effect of NPS fertilizer rate application on bread wheat grain yields was observed. Maximum grain yield (4220.0 kgha^{-1}) was recorded for the plot fertilized with 100% Pc from NPS fertilizer followed by 100% Pc from DAP fertilizer (3648.3 kgha^{-1}) with non-significant difference. The minimum bread wheat grain yield (827.5 kgha^{-1}) was recorded in case of control plot. These results are in accordance with that of (Wassie and Shiferaw, 2011) nutrient mining due to sub optimal fertilizer use coupled with unbalanced fertilizer use favored the emergence of multi nutrient deficiency in Ethiopian soils resulted in stagnant crop production

Table 2: Mean plant height, days to heading, bio mass yield and grain yield of bread wheat in Gechi district

Treatments	PLH (cm)	DH (days)	BMY ($kgha^{-1}$)	GY ($kgha^{-1}$)
Without fertilizer	44. 3^{c}	66.2^{a}	4775^{d}	827.5^{d}
25% Pc from NPS +Rec N	59.8^{b}	63.4^{b}	8433^{c}	1440.8^{d}
50% Pc from NPS +Rec N	72.5^{a}	62.5^{b}	10217^{c}	2670.0^{c}
75% Pc from NPS +Rec N	72.8^{a}	62.0^{b}	10717^{bc}	3269.2^{bc}
100% Pc from NPS+Rec N	70.6^{a}	62.5^{b}	13550^{a}	4220.0^{a}
100% Pc from DAP+Rec N	71.9^{a}	62.0^{b}	13000^{ab}	3648.3^{ab}
Mean	65.3	63.2	10115.2	2679.3
CV (%)	14.4	3.9	32.3	34.9
LSD	6.8	1.8	2377.7	679.6

BMY= Bio Mass Yield, DAP=Di Ammonium Phosphate, CV= Coefficient of Variation, DH= Days to Heading, GY= Grain Yield ,LSD= Least Significant Differences, NPS= Nitrogen, Phosphorus and Sulfur, Pc= Phosphorus critical level, PLH= Plant Height, Rec N= Recommended Nitrogen,

Economic analysis

The economic analysis of bread wheat in relation to nutrient management practices is presented in (Table 3). The total variable cost ranged between 2544 ETB to 17128 ETB ha^{-1}. The gross return oscillated between 14896 ETB and 75960 ETB ha^{-1} for different treatments. Application of 100% Pc from NPS offered net return of 59700 ETB ha^{-1} followed by 100% Pc from DAP (48542 ETB ha^{-1}) which were substantially greater than the rest of the fertilizer treatments (Table 3). The least net return of 12352 ETB ha^{-1} was received from unfertilized plot, elucidating the importance of NPS and DAP fertilizers in enhancing the net return.

Table 3: Partial budget analysis for treatment applied for bread wheat in Gechi district

Treatments	Av.GY ($Kgha^{-1}$)	Adj.GY ($Kgha^{-1}$)	TVC Birr	Gross benefit Birr	Net benefit Birr
Without fertilizer	827.5	744.8	2544.0	14896.0	12352.0
25% Pc from NPS+Rec N	1440.8	1296.7	6632.0	25934.0	19301.8
50% Pc from NPS+Rec N	2670.0	2403.0	11878.0	48060.0	36181.9
75% Pc from NPS+Rec N	3269.2	2942.3	14077.0	58846.0	44769.0
100%Pc from NPS+Rec N	4220.0	3798.0	16260.0	75960.0	59700.0
100%Pc from DAP+ Rec N	3648.3	3283.5	17128.0	65670.0	48542.1

Adj.GY=Adjusted Grain Yield, Av.GY=Average Grain Yield. TVC= Total Variable Cost

Conclusion and recommendation

The results of this experiment revealed that application of N, P and S (100% Pc from NPS) fertilizer has significantly increased yield component, grain and biomass yield of bread wheat compared to DAP fertilizer, indicating insufficient soil P and S content for optimum production of bread wheat. In all cases, optimum grain and biomass yield of bread wheat were obtained with treatment involving at 100% Pc from NPS and DAP fertilizers. Similarly, partial budget analysis result also confirm it. 100% Pc from both NPS and DAP fertilizers found to be economically feasible treatments for bread wheat production in the study area of the district.

Acknowledgement

We acknowledged IQQO for granting research fund and technical advise

References

Assefa, 2016 Sulphur status of soils and wheat plants in three representative areas of the central highlands of Ethiopia. PhD. Dissertation, University of agriculture. Morogoro, Tanzania; 2016.

Ashfaq, 2004. Influence of different Rates of Nitrogen and Phosphorus on Growth and Yield of Two Maize Varieties. M.Sc.(Hons.) Thesis, Deptt. Agron, Univ. Agric., Faisalabad, Pakistan.

Aulakh and Chhibba, 1992. Sulfur in soils and response of crops to its application in Punjab. Pakistan Fert News. 1992;37:33–5.

Birhan A, Sofiya K, Temesgen D, Kassu T, Mihreteab H. 2016. Soil fertility management studies on wheat in Ethiopia: a review. Eth J Nat Res. 2016;16:1–23.

CIMMYT (International Maize and Wheat Improvement Center), 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, DF. 79p

Dobermann and Fairhurst. 2000. Nutrient disorder and nutrient management. Handbook Series. Potash and Phosphate Institute of Canada and IRRI; 2000.

Duke and Reisenauer, 1992. Roles and requirements of sulfur in plant nutrition. Sulfur in agriculture. In: Tabatabai MA (Ed.). Agronomy Monograph No. 27, ASA, Madison; 1986.

FAO (Food and Agriculture Organization), 2001. Lecture notes on the major soils of the world. Driessen, P., J. Deckers, and F. Nachtergaele, (Eds.). Food and Agricultural Organizations, Rome, Italy. 334p.

IFPRI. 2010. Fertilizers and soil fertility potential in Ethiopia: Constraint and opportunities for enhancing the system. IFPRI, Washington DC; 2010.

Kiros and Singh, 2009. Response of wheat cultivars to N and S for crop yield, nitrogen use efficiency and protein quality in the semiarid region. J Plant Nutri. 2009;32:1768–87

Kumar R, Singh VK, Sharma RP, Kumar A, Singh G. 2012 Impact of nitrogen, phosphorus, potash and sulphur on productivity of rice-wheat system in sub-humid region. J Agric Phys. 2012;12:84–8.

Maqsood, M., R. Ali, N. Nawaz and N. Yousaf. 2000. Effect of NPK application in different proportion on the growth and yield of spring maize. Pak. J. Biol. Sci. 3(2): 356-357.

Mesfin Abebe, 1998. Nature and management of Ethiopian soils. Alemaya University, Ethiopia. 272p.

Tamene L, Amede T, Kihara J, Tibebe D, Schulz S, 2017. A review of soil fertility management and crop response to fertilizer application in Ethiopia: towards development of site- and context-specific fertilizer recommendation. CIAT Publication No. 443. International Center for Tropical Agriculture (CIAT), Addis Ababa, Ethiopia. 2017; p. 86

Van Beek CL, Elias E, Yihenew GS, Heesmans H, Tsegaye A, Feyisa H, Tolla M, Melmuye M, Gebremeskel Y, Mengist S. 2016. Soil nutrient balances under diverse agro- ecological settings in Ethiopia. Nutri Cycl Agroeco. 2016.

Wassie H. and Shiferaw B (2011). Response of irish potato (Solanumtuberosum) to the application of potassium at acidic soils of Chencha, Southern Ethiopia. International Journal of Agricultural Biology 13:595-598.

Wassie and Tekalign, 2013. The effect of potassium on the yields of potato and wheat grown on the acidic soils of Chencha and HagereSelam in Southern Ethiopia. International Potash Institute, e-ifc 2013, No. 35.

Verification of Soil Test Crop Response Based Phosphorous Recommendation for Tef in Dega District, Western Oromia

Dagne Chimdessa, Gedefa Sori and Bati Dube
Bedele Agricultural Research Center, P.O.Box-167, Buno Bedele Zone, Bedele
*Corresponding author: dagnechim@gmail.com

Abstract

On-farm verification trial of soil test crop response based calibrated phosphorus was conducted on the soils of strongly acidic in reaction and low in available Phosphorus at Dega district of Buno Bedele Zone of Oromia, during the main cropping season of 2021. The aims of the study was to verify Phosphorus critical level (4.0 ppm) and requirement factor(11.71) as well as nitrogen rate (46 kg N ha^{-1}) for tef (Dursi variety) for the district. The treatments were control (without fertilizer) (T1).blanket recommendation(T2) and soil test crop response based phosphorus recommendation (STCRBPR)(T3).The experimental design was RCBD and replicated over nine farmers fields. The Plot size was 10m by 10m for each treatment. The results of the study were revealed significant differences in tef plant height, biomass and grain yields.The maximum biomass (6231.1 kg ha^{-1}) grain (1794.4 kg ha^{-1}) yields were recorded from the application of STBCRPR (soil test crop response based phosphorus recommendation), whereas the lowest biomass(3294.3kgha^{-1}) grain(800.0 kg ha^{-1})were recorded from un fertilized plot, while a partial budget analysis result also revealed that STCRBPR produced the highest net benefit. Therefore, statistical and partial budget analysis signifies economical feasibility of determined nitrogen (46 kg N ha^{-1}), P-critical level (4.0 ppm) and P- requirement factor (11.71) for tef. Thus, farmers in Dega district should be advised to use soil test crop response based phosphorus recommendation to increase the productivity of tef.

Key words: *P*-critical level, P- requirement factor, *soil test crop response based phosphorus recommendation (STCRBPR),*

Introduction

Soil Phosphorus occurs as inorganic and organic forms and their relative distribution could vary with climate, vegetation, parent material and soil management practices (Samadi and Gilks, 1998). The plant available forms of phosphorus are limited primarily to solution HPO_4^{-2} and $H_2PO_4^-$, with the dominant form determined by the soil pH. In soils with pH values greater than 7.0 the HPO_4^{-2} form predominates, while in soils with pH between 4.3 and 7.0, the $H_2PO_4^-$form predominates. Regardless of the form, the concentration of soluble P in soil solution is very low (Hodges, 2009). Organic compounds in soils increased P availability by the formation of organophosphate complexes that are more easily assimilated by plants and anions replacement of $H_2PO_4^-$ on adsorption site and the coating of Fe and Al particles by humus to form a protective cover and thus reduce P-adsorption (Tisdale *et al*., 1995). In acid soils, Al and iron (Fe) are more soluble and make phosphorus less available. In alkaline soils, P is converted to insoluble forms of calcium phosphates, which are also not readily available to plants. Therefore, it is essential to maintain the reaction of the soil around pH 7 so that the chemical and biological conditions become optimum for plant growth (Seetharaman *et al*. 1994).

Highly weathered nitisols contain high Fe and Al oxides and hydrous oxides, whereas available P content is very low (Mesfin, 1998). It is also reported that moderate to high phosphate fixation occurs in Nitisols. The contents and distribution of different forms of P vary with varying degree of management, soil type, parent material and degree of weathering (Sharply and Smith, 1983). Soil OM also influences P availability to crops directly by contributing to P pools (Clark *et al.,* 1998).The results of several studies conducted on the status of P in Ethiopian soils (Tekalign and Haque, 1987) indicated that most of the soils studied require addition of P fertilizer for profitable crop growth. It is one of the most important essential nutrients required to increase crop yield. Consequently, lack of phosphorus is as important as lack of nitrogen in limiting crop performance. According to the soil fertility map made over 150 districts, Ethiopian soil lacks about seven nutrients (N, P, K, S, Cu, Zn and B) (EthioSIS, 2013). Based on the EthioSIS (Ethiopian soil information system) soil analysis report of 2013 the study area lack sulfur in addition to the low level of Phosphorus. It is essential that the results of soil tests could be calibrated or correlated against crop responses from applications of plant nutrients in question as it is the ultimate measure of fertilization program. An accurate soil test interpretation requires knowledge of the relationship between the amount of a nutrient extracted by a given soil test and the amount of plant nutrients that should be added to achieve optimum yield for each crop.

Ethiopian farmers grow tef due to a number of merits, which are mainly attributed to the socio-economic, cultural and agronomic benefits (Seyfu, 1993). Tef has more food value than the major grains such as wheat, barley and maize. Tef grain contains 14-15% proteins, 11-33 mg iron, 100-150 mg calcium, and rich in potassium and phosphorus nutrients (National Academy Press, 1996). Regardless of its importance, productivity of tef is low in the country. This is mainly because of low soil fertility and severe organic matter depletion aggravated by low rate of chemical fertilizer application.

In order to give solution to this problem; sound soil test calibration is essential for successful fertilizer program and crop production (Abaidioo *et al*., 2000). Having this concept soil test based phosphorus calibration study was conducted for tef in the area. Based on this experiment, phosphorus critical level (4.0 ppm), requirement factor (11.71) and Nitrogen (46 kg N ha^{1}) were determined for tef production during calibration study for the area. Even though, the experiment was completed further verification trial was needed to have confidence on the significances of determined NP fertilizers over blanket recommendation practiced by farming community. Therefore, the objectives of this research were:

- To Verify P critical level and requirement factor as well as N-fertilizer for tef production in Dega district.
- To compare phosphorus critical level and requirement factor with blanket recommendation fertilizer application and control in Dega district.

Materials and Method

Description of the Study Area

Dega district is located at latitude $08^0$10'41.66" to $08^0$42'45.01"N; Longitude $035^0$59'17.77" to $036^0$14'55.67"E and an altitude ranged from 1810 to 2285 meter above sea level; in Buno Bedele Zone of the Oromia regional state, Ethiopia (Fig.1).The 18 years weather information at nearby study area (Ethiopian Metrology Agency Bedele District Branch) indicated that a uni-modal rainfall pattern with average annual rain fall of 1945 mm. The rainy season covers April to October and the maximum rainfall is received in the months of June, July and August. The minimum and maximum annual air temperatures are 12.9 and 25.8°C, respectively, The predominant soil type in southwest and western Ethiopia in general and the study area in particular, is Nitisols according to the (FAO, 2001) soil classification system. Its vernacular name is "*Biyyee Diimmaa*" meaning red soil. On the average, the soil is deep and relatively highly weathered well drained, clay in texture and strongly to moderately acidic in reaction. Nitisols are highly weathered soils in the warm and humid areas of the west and southwest Ethiopia (Mesfin, 1998)

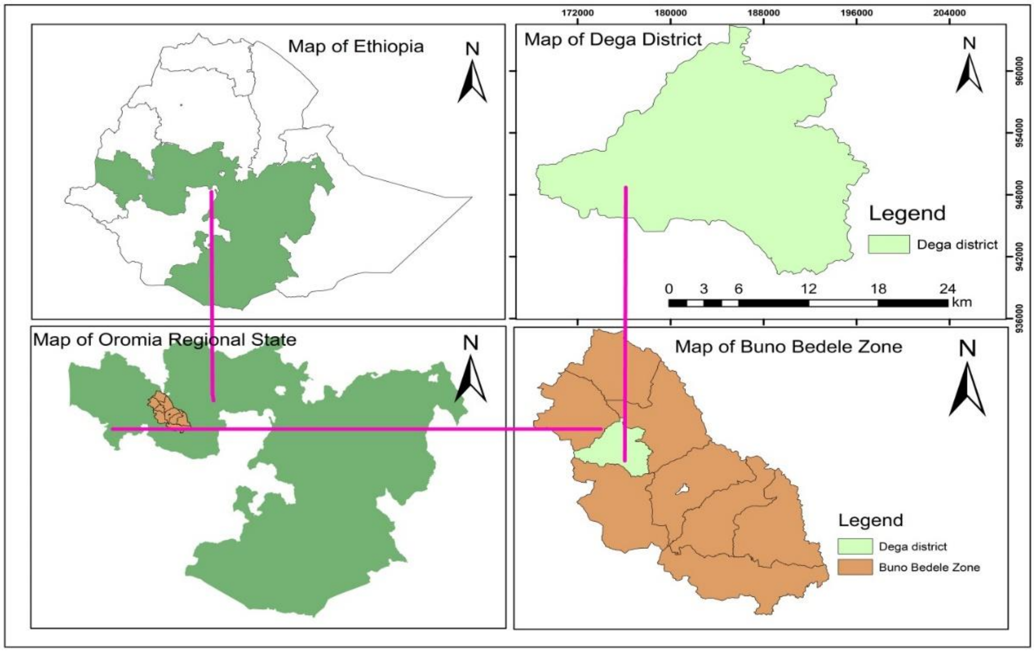


Figure 1. Map of the study area (Dega district)

Soil Sampling and Analysis

Nine farmers' fields were selected purposively based on their willing and initial soil P-value. Composite surface soil samples (0-20) cm depth were collected from each experimental sites before planting to analyze soil pH (H_2O), Exchangeable acidity, available P, (%OC), TN, CEC and textural class. The collected soil samples were prepared and analyzed following standard laboratory procedures at soil analysis laboratory of Bedele Agricultural Research Center. The result indicated that strongly acidic in reaction, low available Phosphorus, low organic carbon, Low TN, low to moderate CEC and clay in texture (Table 1).

Table 1: Soil data before planting in Dega district

Sites	pH (H2O)	Exch.A (cmol(+)/kg soil)	Av. P (ppm)	OC (%)	TN (%)	CEC (cmol (+)/kg soil)
1	4.5	0.9	0.3	3.6	0.2	16.0
2	4.5	0.4	0.8	3.3	0.1	13.0
3	4.0	1.9	0.3	2.0	0.2	11.8
4	5.1	0.1	1.5	2.0	0.1	15.0
5	4.8	0.1	1.5	2.1	0.3	14.5
6	4.9	0.2	0.8	3.1	0.2	17.0
7	4.5	0.9	0.7	2.2	0.1	12.0
8	4.9	0.1	1.5	2.9	0.2	15.5
9	5.1	0.2	2.0	1.8	0.1	8.5

OC= Organic, TN= Total Nitrogen, CEC= Cation Exchange Capacity, P= Phosphorus

Treatments, Experimental Design and Procedures

The treatments consisted of control (without fertilizer) (T1), Blanket recommendation (T2) and STCRBPR (T3), that were arranged in simple adjacent plots and replicated over nine sites. The growth plot size was 10 m by 10 m for each plot. Dursi tef variety which is high yielder as compared to other improved tef varieties in the study areas was used as a test crop. Phosphorus rate was calculated and applied according to the formula, P (kg ha^{-1}) = (Pc – Po)*Pf, where Pc= Phosphorus critical level, Po = initial soil Phosphorus in the soil and Pf= Phosphorus requirement factor. Recommended N (46 kg N ha^{-1}) determined during Phosphorus calibration study for tef was used for soil test. Whereas, 100$kgha^{-1}$ DAP and 50$kgha^{-1}$ UREA were used for farmers' practices. The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times. Full dose of phosphorous as per the treatment and one-third of N was applied at sowing. The remaining two-third of N was top dressed at 35 days after planting in the form of urea. The field was kept free of weeds by hand weeding during the period of the experiment. All other recommended agronomic management practices disease and insect pest control was done. Grain yield data was collected from net plot area. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD.

Economic Analysis

Costs that vary among treatments were also assessed using the CIMMYT partial budget analysis (CIMMYT, 1988). The cost of DAP and UREA, the cost of labor required for the application of fertilizer, and cost for threshing were estimated by assessing the current local market prices. The price of DAP (1997 ETB 100 kg^{-1}), UREA (1394 ETB 100 kg^{-1}), daily labors (35 ETB per one person day based on governments' current scale in the study area) and the cost of tef threshing (1 ETB $kg^{-1)}$) were considered to get the total cost that vary among the treatments. Time elapsed during fertilizer application for some plots of each treatment were recorded to calculate daily labor required for one hectare. One person per day was estimated based on eight working hours per day. Tef yield was valued at an average field price of 30 ETB $kg^{-1,}$. However, other non-varied costs were not included since all agronomic managements were equally and uniformly applied to each experimental plot. Before calculating gross revenue, tef grain yields obtained from each treatment were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price that farmers receive for the sale of the crop. The net benefit was also calculated as per standard manual (CIMMYT, 1988).

Results and Discussion

Significant differences were observed among different treatments in tef plant height. Maximum tef plant height (119.3 cm) was obtained the treatment fertilized by STCRBPR (soil test crop response based phosphorus recommendation) against minimum (71.6 cm) in case of control plot. These results are in accordance with (Ashfaq, 2004).Increased plant height with increasing N level (Maqsood *et al*., 2001). There were also significant differences among treatments in tef biomass and grain yields. The maximum mean biomass yield (6231.1$kgha^{-1}$) and grain yield (1794.4$kgha^{-1}$) were recorded from the application of STCRBPR, whereas the lowest, was recorded from the control plot (Table 2). STCRBPR highly increased tef biomass and grain yields over farmers' practices fertilizer application.

Table 2: Mean plant height, biomass and grain yield for Tef in Dega district in 2021 cropping season

Treatments	PH (cm)	BMY ($kgha^{-1}$)	GY ($kgha^{-1}$)
Without fertilizer	76.1^{c}	3294.3^{c}	800.0^{c}
Blanket Rec.	106.1^{b}	5144.0^{b}	1400.0^{b}
STCRBPR	119.3^{a}	6231.1^{a}	1794.4^{a}
Mean	100.5	4889.8	1331.4
CV (%)	9.8	17.9	19.9
LSD	9.8	878.1	264.8

BMY= Bio Mass Yield, Blanket Rec= Blanket Recommendation, CV= Coefficient of Variation, GY= Grain Yield ,LSD= Least Significant Differences, PH= Plant Height, STCRBPR= Soil Test Crop Response Phosphorus Recommendation

Economic Analysis

The economic analysis of tef in relation to nutrient management practices is presented in (Table 3). The total variable cost ranged between 2145 ETB to 9076 ETB ha-1. The gross return oscillated between 19455 ETB and 39371 ETB ha^{-1} for different treatments. Application of STCRBPR offered net return of 39371 ETB ha^{-1} followed closely by blanket recommendation.(31006 ETB ha^{-1}). The least net return of 19455 ETB ha^{-1} was received from unfertilized control, elucidating the importance of STCRBPR fertilizer in enhancing the net return.

Table 3: Partial budget analysis for treatment applied for Tef in Dega district

Treatments	Av.GY ($kgha^{-1}$)	Adj.GY ($kgha^{-1}$)	TVC (Birr)	Gross benefit (Birr)	Net benefit (Birr)
Without fertilizer	800.0	720.0	2145.0	21600.0	19455.0
Blanket Rec.	1400.0	1260.0	6794.0	37800.0	31006.0
STCRBPR	1794.40	1614.9	9076.0	48447.0	39371.0

Adj.GY=Adjusted Grain Yield, Av.GY=Average Grain Yield., TVC= Total Variable Cost

Conclusion and Recommendation

Appropriate fertilization practices based on actual limiting of nutrients and crop requirement for a given crop is economic and judicious use of fertilizers for sustainable crop production. According to this study STCRBPR would be promising to grow tef in the study area compared to blanket recommendation. Thus indicated that tef productivity in the study area was increased due to STCRBPR fertilizer application, in which the results of the study revealed that the maximum mean grain yield (1794.4kg ha^{-1}) and biomass yield (6231.1kg ha^{-1}) were recorded for STCRBPR fertilizer application. The highest net benefit was recorded for STCRBPR fertilizer application, whereas the lowest were recorded for the treatment without fertilizer. Therefore, statistical and partial budget analysis signifies economical feasibility of determined nitrogen (46 kg N ha^{-1}), P-critical level (4.0 ppm) and P- requirement factor (11.71) for tef. Thus, farmers in Dega district should be advised to use soil test crop response based phosphorus recommendation to increase the productivity of tef.

Acknowledgement
We acknowledged IQQO for granting research fund and technical advise

References

Ashfaq, M. 2004. Influence of different Rates of Nitrogen and Phosphorus on Growth and Yield of Two Maize Varieties. M.Sc.(Hons.) Thesis, Deptt. Agron, Univ. Agric., Faisalabad, Pakistan.

CIMMYT ,1988. From Agronomic Data to Farmer Recommendation: An Economics Training Manual . Completely Revised edition. Mexico , DF .

Clark, M.S., W.R. Howarth, C. Shennan and M. scow, 1998. Changes in soil chemical properties resulting from organic and low input farming practices. *Agronomy Journal,* 90: 662-671.

EthioSIS (Ethiopian soil information system), 2013. Soil analysis report agricultural agency.

FAO (Food and Agriculture Organization), 2001. Lecture notes on the major soils of the world. Driessen, P., J. Deckers, and F. Nachtergaele, (Eds.). Food and Agricultural Organizations, Rome, Italy. 334p

Hodges, C.S., 2009. Soil Fertility Basics. Nc certified crop advisor training. Soil Science Extension North Carolina State University.

Maqsood, M., A. M. Abid, A. Iqbal and M. I. Hussain. 2001. Effect of variable rate of nitrogen and phosphorus on growth and yield of maize (golden). Online J. Biol. Sci. 1 (1):19-20.

Mesfin Abebe, 1998. Nature and Management of Ethiopian Soils. Alemaya University of Agriculture, Ethiopia. 272p.

National Academy Press,1996. Lost crops of Africa Volume 1, Grains. Bostid National Research Council. National Academy of Sciences. Washington, D.C, USA.

Samadi, A. and R.J. Gilkes, 1998. Forms of phosphorus in virgin and fertilized calcareous soils of western Australia. *Australian Journal of Soil Research,* 36: 585-601.

Seetharaman, S., B.C. Biseas B.K. Tawatia, and N. parasad. 1994. Hand Book on Fertilizer. Seyfu Ketema,1993.Tef[*Eragrostistef(Zucc.)*Trotter].Breeding,GeneticResources, Agronomy,Utilization and Role in Ethiopian Agriculture. Institute of AgriculturalResearch,AddisAbaba,Ethiopia.

Smaling, E.M., 1990. Two scenarios for the sub-Sahara: one leads to disaster. *Cere-Rome J*. 22:19-20 and 23-24.

Tekalign Mamo and I. Haque, 1987. Phosphorous status of some Ethiopia soils. Sorption characteristics. *Plant and Soil*. 102: 261-266.

Tisdale, S.L., W.L. Nelson, J.D. Beaton and J.L. Havlin, 1995. Soil Fertility and Fertilizers. 5th (ed) Macmillan Publishing Company, New York. 684p.

Verification of Soil Test Crop Response Based Phosphorous Recommendation for Bread Wheat in Dega District, Western Oromia

Dagne Chimdessa, Gedefa Sori and Bati Dube
Bedele Agricultural Research Center, P.O.Box-167, Buno Bedele Zone, Bedele
*Corresponding author: dagnechim@gmail.com

Abstract
Verification trial of soil test crop response based calibrated phosphorus was conducted on nine farmers' fields in Dega district of Buno Bedele Zone of Oromia, during the main cropping season of 2021. The aims of the study was to verify Phosphorus critical level (3.8 ppm) and requirement factor(30.28) as well as nitrogen (138 kg N ha^{-1}) for bread wheat (kingbird variety) for the district. The treatments were control (without fertilizer) (T1).blanket recommendation (T2) and soil test crop response based phosphorus recommendation (STCRBPR)(T3).The experimental design was RCBD and replicated over nine farmers fields. The plot size was 10m by 10m for each. The results of the study revealed that significant differences in bread wheat plant height, biomass and grain yields. The maximum biomass (16732.0 kg ha^{-1}) grain (4611.1 kg ha^{-1}) yields were recorded from the fertilizer application of STBCRPR (soil test crop response based phosphorus recommendation), whereas the lowest biomass(3938.0 kgha^{-1}) grain (869.4 kg ha^{-1})were recorded from un fertilized plot, while a partial budget analysis result also revealed that STCRBPR produced the highest net return. Therefore, statistical and partial budget analyses signify economical feasibility of determined nitrogen (138 kg N ha^{-1}), P-critical level (3.8 ppm) and P- requirement factor (30.28) for bread wheat. Thus, farmers in Dega district should be advised to use soil test crop response based phosphorus recommendation to increase the productivity of bread wheat.

Key words: P-critical level, P- requirement factor, soil test crop response based phosphorus recommendation (STCRBPR),

Introduction
For optimum plant growth, nutrients must be available in sufficient and balanced quantities. Soils contain natural reserves of plant nutrients, but these reserves are largely in forms unavailable to plants, and only a minor portion is released each year through biological activity or chemical processes. This release is too slow to compensate for the removal of nutrients by agricultural production and to meet crop requirements. On the other hand, effective nutrient management requires the quantification of crop nutrient requirements and the nutrient-supplying capacity of the soil through soil testing. Nutrients applied in excess of crop requirements increase residual nutrient reserves that, if not utilized or recovered in subsequent crops, may result in offsite transport and contribute to degradation of environmental quality (Sattari, 2012). Degraded soils have low capacity to hold water and external soil nutrients, and, thus, external fertilizers have low returns on degraded soils. The low returns on the degraded soils would force farmers to reduce the already low inorganic fertilizer application, which in turn may contribute to further land degradation (Smaling, 1990).

There are several pathways though which soil fertility contributes to crop production. Directly, soil provides nutrients to crops, and, indirectly, soil affects how easily external inputs are absorbed by the crops (Tiessen *et al*., 1994; Palm *et al*., 2001) as a proxy for soil fertility, Marenya and Barrett (2007) use the carbon content. The soil carbon content is also a proxy for soil organic matter (SOM), which consists of the decayed tissues of plants and animals taken from animal excreta and is increasingly taken as a strong indicator of soil fertility and land degradation because SOM tightly controls many soil properties and major biogeochemical cycles (Ngugi *et al*., 1990; Manlay *et al*., 2007).

Bread wheat has high yield potential in Dega district. Despite its high yield potential, it is giving low yields because of improper fertilizer management practices due to lack of appropriate information on nutrient elements management. In order to give solution to this problem soil test based phosphorus calibration study was conducted for bread wheat in the area. Based on this experiment, phosphorus critical level (3.8 ppm), requirement factor (30.28) and Nitrogen (138 kg N ha^1) were determined. Even though, the experiment was completed further verification trial was needed to have confidence on the significances of determined NP fertilizers over blanket recommendation practiced by farming community. Therefore, the objectives of this research were to;

Verify P ritical level and requirement factor as well as N-fertilizer for bread wheat production in Dega district.

To compare phosphorus critical level and requirement factor with blanket recommendation fertilizer application and control in Dega district.

Materials and Method

Description of the Study Area

Dega district is located at latitude $08^0$10'41.66" to $08^0$42'45.01"N; Longitude $035^0$59'17.77" to $036^0$14'55.67"E and altitude ranged from 1810 to 2285 meter above sea level; in Buno Bedele Zone of the Oromia regional state, Ethiopia (Fig.1).The 18 years weather information at nearby study area (Ethiopian Metrology Agency Bedele District Branch) indicated that a uni-modal rainfall pattern with average annual rain fall of 1945 mm. The rainy season covers April to October and the maximum rainfall is received in the months of June, July and August. The minimum and maximum annual air temperatures are 12.9 and 25.8°C, respectively. The predominant soil type in southwest and western Ethiopia in general and the study area in particular, is Nitisols according to the (FAO, 2001) soil classification system. Its vernacular name is "*Biyyee Diimmaa*" meaning red soil. On the average, the soil is deep and relatively highly weathered well drained, clay in texture and strongly to moderately acidic in reaction. Nitisols are highly weathered soils in the warm and humid areas of the west and southwest Ethiopia (Mesfin, 1998)

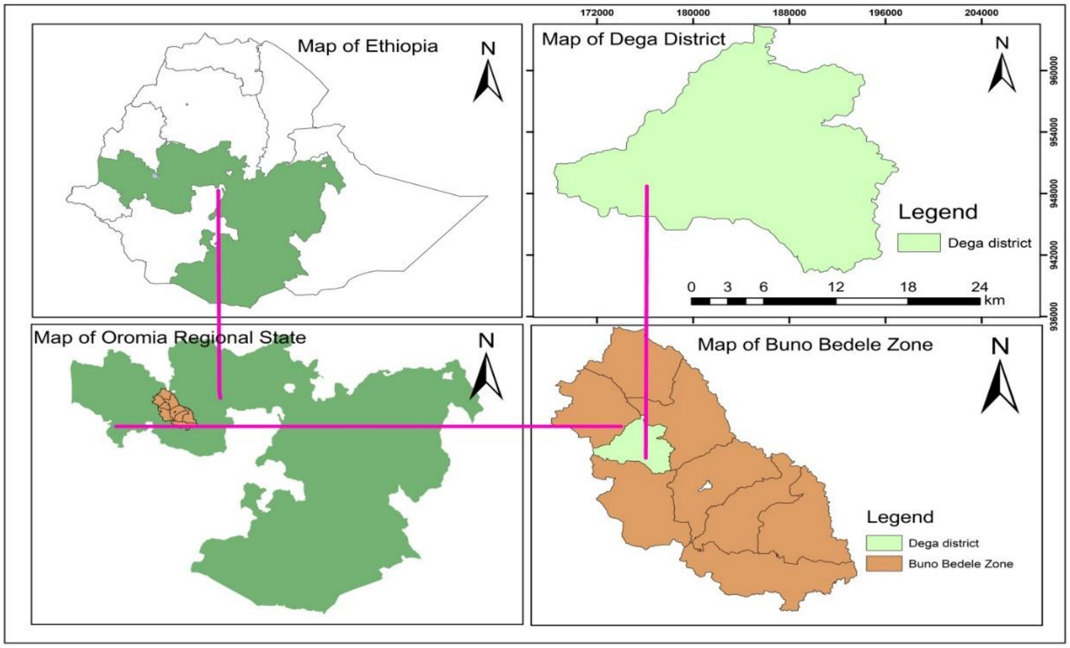


Figure 1. Map of the study area(Dega district)

Soil Sampling and Analysis

Nine farmers' fields were selected purposively based on their willing and initial soil P-value. Composite surface soil samples (0-20) cm depth were collected from each experimental sites before planting to analyze soil pH (H_2O), Exchangeable acidity, available P, (%OC), TN, CEC and textural class. The collected soil samples were prepared and analyzed following standard laboratory procedures at soil analysis laboratory of Bedele Agricultural Research Center. The result indicated that strongly acidic in reaction, low available Phosphorus, low organic carbon, Low TN and low to moderate CEC (Table 1).

Table 1: Soil data before planting in Dega district

Sites	pH (H2O)	Exch.A (cmol(+)/kg soil)	Av. P (ppm)	OC (%)	TN (%)	CEC (cmol (+)/kg soil)
1	4.5	0.8	0.2	3.3	0.2	12.0
2	4.9	0.1	1.5	2.3	0.1	14.2
3	4.8	0.2	1.4	3.7	0.2	13.8
4	4.9	0.1	0.7	2.9	0.2	15.5
5	4.1	1.5	1.0	2.6	0.1	16.0
6	4.1	1.9	0.5	3.3	0.1	12.6
7	4.8	0.1	1.5	2.9	0.2	22.0
8	4.2	1.2	0.2	2.4	0.1	10.5
9	4.2	0.2	2.0	2.3	0.1	17.0

OC= Organic, TN= Total Nitrogen, CEC= Cation Exchange Capacity, P= Phosphorus

Treatments, Experimental Design and Procedures

The treatments consisted of control (without fertilizer)(T1), Blanket recommendation (T2) and STCRBPR (T3), that were arranged in simple adjacent plots and replicated over nine sites. The gross plot size was 10 m by 10 m for each plot. Bread wheat variety (kingbird) was used as a test crop that was planted in rows with spacing of 20 cm between rows. Phosphorus rate was calculated and applied according to the formula, P (kg ha^{-1}) = (Pc – Po)*Pf, where Pc= Phosphorus critical level, Po = initial soil Phosphorus in the soil and Pf= Phosphorus requirement factor. Recommended N (138 kg N ha^{-1}) determined during Phosphorus calibration study for bread wheat was used for soil test. Whereas, 100kgha^{-1} DAP and UREA for each were used for farmers' practices. The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times. Full dose of phosphorous as per the treatment and one-third of N was applied at sowing. The remaining two-third of N was top dressed at 35 days after planting in the form of urea. The field was kept free of weeds by hand weeding during the period of the experiment. All other recommended agronomic management practices disease and insect pest controls were done. Grain yield data was collected from net plot area. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD.

Economic Analysis

Costs that vary among treatments were also assessed using the CIMMYT partial budget analysis (CIMMYT, 1988). The cost of DAP and UREA, the cost of labor required for the application of fertilizer, and cost for threshing were estimated by assessing the current local market prices. The price of DAP (1997 ETB 100 kg^{-1}), UREA (1394 ETB 100 kg^{-1}), daily labors (35 ETB per one person day based on governments' current scale in the study area) and the cost of bread wheat threshing (1 ETB $kg^{-1)}$) were considered to get the total cost that vary among the treatments. Time elapsed during fertilizer application for some plots of each treatment was recorded to calculate daily labor required for one hectare. One person per day was estimated based on eight working hours per day. Bread wheat yield was valued at an average field price of 20 ETB $kg^{-1,}$. However, other non-varied costs were not included since all agronomic managements were equally and uniformly applied to each experimental plot. Before calculating gross revenue, bread wheat grain yields obtained from each treatment were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price that farmers receive for the sale of the crop. The net benefit was also calculated as per standard manual (CIMMYT, 1988).

Results and discussion

Mean Plant Height, Biomass and Grain Yields of Bread Wheat in Dega District in 2021 Cropping Season

The data (Table 1) showed significant differences among different treatments for plant height. Maximum plant height (86.9 cm) was recorded in bread wheat plants fertilized with soil test crop response based phosphorus recommendation (STCRBPR) followed by blanket recommendation (blanket recommendation) (73.8 cm). The results are in conformity with those of (Ayub *et al*., 2002) who observed the significant effect of NP on plant height. Increased pl*a*nt height with optimum N was also observed by (Ashfaq, 2004; Maqsood *et al*., 2000).

There were also significant differences ($P \leq 0.05$) among treatments in bread wheat biomass and grain yields. The maximum mean biomass yield (16732.0 kgha^{-1}) and grain yield (4611.1 kgha^{-1}) were recorded from the application of STCRBPR, whereas the lowest, was recorded from the control plot (Table 2). STCRBPR highly increased bread wheat biomass and grain yields over farmers' practices fertilizer application. This indicated that farmers' practices fertilizer application, which is adopted by farmers' is unbalanced fertilization in the district. Ethiopian farmers use inadequate nutrient inputs, inappropriate quality and inefficient combinations of fertilizers, which in the end prove to be lack of soil fertility restoring inputs and unbalanced nutrient using (Palm *et al.*, 1997). Nutrient mining due to sub optimal fertilizer use coupled with unbalanced fertilizer use favored the emergence of multi nutrient deficiency in Ethiopian soils (Wassie *et al*., 2010; Wassie and Shiferaw, 2011) and resulted in stagnant crop production.

Table 2: Mean plant height, biomass and grain yield for bread wheat in Dega district in 2021 cropping season

Treatments	PH (cm)	BMY (kgha^{-1})	GY (kgha^{-1})
Without fertilizer	51.1^{c}	3938.0^{c}	869.4^{c}
Blanket recommendation	73.8^{b}	9008.0^{b}	2409.7^{b}
STCRBPR	86.9^{a}	16732.0^{a}	4611.1^{a}
Mean	70.6	9892.7	2630.1
CV (%)	7.2	29.7	29.2
LSD	5.0	2941.5	767.4

BMY= Bio Mass Yield, Blanket Rec= Blanket Recommendation, CV= Coefficient of Variation, GY= Grain Yield ,LSD= Least Significant Differences, PH= Plant Height, STCRBPR= Soil Test Crop Response Phosphorus Recommendation

Economic Analysis

The economic analysis of **bread wheat** in relation to nutrient management practices is presented in (Table 3). The total variable cost ranged between 2970 ETB to 19248 ETB ha^{-1}. The gross return oscillated between 15648 ETB and 82998 ETB ha^{-1} for different treatments. Application of STCRBPR offered net return of 63749 ETB ha^{-1} followed by blanket recommendation (32779 ETB ha^{-1}). The least net return of 12678 ETB ha^{-1} was received from unfertilized control, elucidating the importance of STCRBPR fertilizer in enhancing the net return.

Table 3: Partial budget analysis for treatment applied for bread wheat in Dega district

Treatments	Av.GY (kgha^{-1})	Adj.GY (kgha^{-1})	TVC (Birr)	Gross benefit (Birr)	Net benefit (Birr)
Without fertilizer	869.4	782.4	2970.0	15648.0	12678.0
Blanket Rec.	2409.7	2168.7	10594.1	43374.0	32779.9
STCRBPR	4611.1	4149.9	19248.9	82998.0	63749.1

Adj.GY=Adjusted Grain Yield, Av.GY=Average Grain Yield, TVC= Total Variable Cost

Conclusion and Recommendation

Fertilization needs to be rationally used in order to avoid undesirable effects on the sustainability of agricultural production system. Accordingly, verified P-critical level, P requirement factor and N fertilizer signified the economic benefit of soil test crop response based calibrated phosphorus for improved bread wheat in the study area as compared to blanket recommendation. The results of the study revealed that the maximum mean biomass yield (16732.0 ha^{-1}), grain yield (4611.1ha^{-1}) were recorded for STCRBPR, whereas the lowest were recorded for the treatment without fertilizer. Application of STCRBPR had the highest net benefit. Therefore, application of STCRBPR is agronomically and economically feasible for bread wheat production and hence, determined P-critical level (3.8 ppm), P- requirement factor (30.28) and nitrogen fertilizer (138 kg N ha^{-1}) are recommended for bread wheat production in Dega district.

Acknowledgement

We acknowledged IQQO for granting research fund and technical advise

References

Ashfaq, M. 2004. Influence of different Rates of Nitrogen and Phosphorus on Growth and Yield of Two Maize Varieties. M.Sc.(Hons.) Thesis, Deptt. Agron, Univ. Agric., Faisalabad, Pakistan.

Ayub, M., M. A. Nadeem, M. S. Sharar and N. Mahmood. 2002. Response of maize (*Zea mays* L.) fodder to different levels of nitrogen and phosphorus. Asian J. Pl. Sci., 1:352-354.

Mesfin Abebe, 1998. Nature and management of Ethiopian soils. Alemaya University, Ethiopia. 272p.

FAO (Food and Agriculture Organization), 2001. Lecture notes on the major soils of the world. Driessen, P., J. Deckers, and F. Nachtergaele, (Eds.). Food and Agricultural Organizations, Rome, Italy. 334p.

CIMMYT (International Maize and Wheat Improvement Center), 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, DF. 79p

Maqsood, M., R. Ali, N. Nawaz and N. Yousaf. 2000. Effect of NPK application in different proportion on the growth and yield of spring maize. Pak. J. Biol. Sci. 3(2): 356-357.

Manley, R., C. Feller, and M.J. Swift (2007). "Historical evolution of soil organic matter concepts and their relationships with the fertility and sustainability of cropping systems," *Agriculture, Ecosystems and Environment*, 119: 217-233.

Marenya, P.P., and C.B. Barrett (2007). "State-conditional fertilizer yield response on western Kenya farm," Working Paper, Department of Applied Economics and Management, Cornell University, Ithaca, New York.

Ngugi, D.N., P.K. Karau, and W. Nguyo (1990). *East African Agriculture*, 3rd edition, London and Oxford: Macmillan Ltd.

Palm, C. A., Myers, R. J. K., and Nandwa, S. M. (1997). Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. *In* R. J. Buresh, P. A. Sanchez, & F. G. Calhoun (Eds.), *Replenishing soil fertility in Africa* (pp.193-218). Madison, WI, USA: Soil Science Society of America (SSSA).

Palm, C.A., C.N. Gachengo, R.J. Delve, G. Cadisch, and K.E. Giller. (2001). "Organic Inputs for soil Fertility Management in Tropical Agroecosystems: Application of an Organic Resources Databese," *Agriculture, Ecosystems and Environment* 83: 27-42.

Sattari, S.; Bouwmann, A.; Giller, K.and van Ittersum, M. Residual soil phosphorus as the missing piece in the global phosphorus crisis puzzle. Proc. Nat. Acad. Sci. USA **2012**, 109, 6348–6353.

Tiessen, H., E. Cuevas, and P. Chacon (1994). "The Role of Soil Organic Matter in Sustaining Soil Fertility," *Nature* 371: 783-785.

Wassie H. and Shiferaw B (2011). Response of irish potato (Solanumtuberosum) to the application of potassium at acidic soils of Chencha, Southern Ethiopia. International Journal of Agricultural Biology 13:595-598.

Wassie H, Shiferaw B. and Kelsa K (2010). Integrated Soil fertility management options for sustainable crop production: Review of research findings from Southern Regional State of Ethiopia pp. 163-175. In: Improved natural resources management technologies for food security, Poverty eduction and Sustainable

Evaluation of Sorghum and Different Legume Intercropping On Soil Fertility Status, Yield Component, and Yield of Sorghum at Fadis on station, East Hararghe Oromia, Ethiopia

Alemu Tolosa * Robe Elema, Sisay Negash
Fadis Agricultural Research Center, P.O. Box 904 Harar, Ethiopia
Corresponding author: E-mail: alemutolosa2020@gmail.com,

Abstract

Intercropping cereals with legumes has the potential to replenish soil mineral nitrogen through the biological fixation of atmospheric nitrogen. Therefore, a field experiment was conducted at the Fadis Agricultural Research Center in 2021-2022 cropping seasons to evaluate the effects of sorghum-legume intercropping on sorghum yield and yield components, and also to identify which legumes fix the highest amount of nitrogen, reducing the need for nitrogen fertilizers. The experiment was designed using a randomized complete block design (RCBD) with three replicates. The monocropped sorghum had a spacing of 40cm x 15cm, while intercropped sorghum and legumes had a spacing of 75cm x 15cm. Nine treatments were tested; T1 was a sole sorghum crop, T2-T4 were sorghum intercropped with soybean, haricot bean, and cowpea respectively, T5 was sorghum intercropped with mungbean, T6 was a sole soybean crop, and T7-T9 were sole haricot bean, cow pea, and mungbean crops respectively. For this study, the testing crop for intercropping was sorghum (melkam variety), which is adapted to the study area and performs the best there. Legumes crops such as haricot bean (awash 2 varieties), soybean (Boshee variety Awasa 04), mungbean (Rasal variety) and cowpea (9333) were also used. Results showed that the highest sorghum grain yield (3050.2 ha^{-1}) was from soybean + sorghum, followed by sole sorghum (2738.43 ha^{-1}), and the lowest grain yield (2125.1Kg ha^{-1}) was obtained from sorghum intercropped with haricot bean. The highest amount of soil N advantageous after harvesting was 10.1% from sole soybean, followed by sorghum + soybean (0.5%). Economic analysis revealed that the highest net income (87989 ETB ha^{-1}) was obtained from sorghum + soybean, and the lowest net income (26869 ETB ha^{-1}) was from sole cow pea treatment. Thus, sorghum + soybean are recommended for the study area as it fixes higher N and reduces the cost of N fertilizers.

Keywords: Legumes –Sorghum Intercropping, Soil Nutrients (N), Soil Fertility

Introduction

Low soil fertility is an important constraint in agricultural production in Sub Saharan Africa. Legumes can fix nitrogen from the air in leguminous crops can hold promise in this regard. (Alemayehu *et al.*, 2018). However, soil characteristics can be affected positively or negatively by the growth conditions of crops. Intercropping is an agricultural practice of cultivating two or more crops in the same space at the same time (Lithourgidis *et al*., 2011). The authors also define intercropping as an old and the common cropping systems used which targets to match efficiently crop demands to the available growth resources and labour. Yield and nutrient acquisition advantages are frequently found in intercropping systems. However, there are few published reports on soil fertility in intercropping relative to mono cropping (Gong *et al.*, 2019).

The stability under intercropping can be attributed to the partial restoration of diversity that is missed under sole crops. According to this statement, intercropping allows high insurance against crop failure, notably in environments known for heavy weather conditions like frost, flood, drought, and overall provides high financial stability for farmers (Lithourgidis *et al*., 2011).Intercropping can be especially beneficial when a legume and non-legume, often a cereal, are planted together. Because legumes can assimilate N, there is reduced competition for soil N, and the increased residual N is available for a subsequent crop (Searle *et al*., 1981). Cereals tend to be more competitive than legumes for soil inorganic N, indicating that when cereals and legumes are intercropped, the cereal wins the soil N and forces the legume to rely more heavily on N2 fixation (Hauggaard-Nielsen *et al*., 2001).

Moreover, legumes enrich the soil by fixing the atmospheric nitrogen transforming it and other minerals from an inorganic form to forms that are available for uptake by crops (Li x *et al*., 2012). Fixation of atmospheric nitrogen can replace nitrogen fertilization fully or partially. When nitrogen fertilizer is limited, biological nitrogen fixation is the important source of nitrogen in intercropping systems (Fujita *et al.*,1992). In addition, because inorganic fertilizers contributed to ecosystem damage such as nitrate pollution, legumes are grown in intercropping are taken as an alternative and sustainable path to bringing nitrogen in the soil into little input cost and without damage. Furthermore, the green parts and roots of the legume component can decompose and provide nitrogen into the soil where it may be made available to subsequent crops. Specially, under low soil nitrogen conditions the advantages of legumes in an intercrop are greater (Fabio *et al.,* 2017).Legumes broadly are more powerful in increasing the productivity of succeeding cereals. The carryover of nitrogen for succeeding crops may be 60-120 kg in berseem (Trifolum alexadrium), 75kg in cluster bean (Cyamopsis tetragonolobus), 68kg in chickpea (Cicer arietinum), 54-58 kg in groundnut (Arachis hypogea) and 50-51kg in soybean (Glycina max) (Bandyopadhyay *et al*., 2007).

In addition, apart from nitrogen, intercropping legume-cereal can allow acquisition of other nutrients such as phosphorus, potassium, sulphur and micro nutrients. Zhang *et al*., (2015) reported that, maize-soybean intercropping reduced use of N fertilizer per unit of area and enhanced relative biomass of intercropped maize, due to promoted photosynthetic efficiency of border rows and N utilization during symbiotic period. In addition, Ali *et al*., (2015) found that, maize-soybean intercropping increased soil organic carbon content, CEC, N, Ca, Mg and P level after harvesting than sole crops (Wang *et al*., 2014). It encourages high soil fertility maintenance especially where legumes are used as component crop they provide continuous soil cover, which prevents direct impact of raindrops, which causes erosion. Therefore the activity was initiated with objectives of Evaluate sorghum-legume intercropping on sorghum yield and yield components , Evaluate the effect of intercropping sorghum with different legumes crops on soil nutrient status (N) and to identify legumes that fixe higher N.

Objectives

- To evaluate sorghum-legume intercropping on on soil nitrogen, yield and yield components of sorghum
- To identify legumes that fixe higher soil Nitrogen and results optimum yield of sorghum

Materials and Methods

Description of the Study Area:
The study was conducted in the Oromia Region of Ethiopia at the Fedis Agricultural Research Center on-station during the 2021 and 2022 cropping seasons. The experimental site is located at the latitude of

09°07′58.8” N, the longitude of 042◦04′25.8” E, and an altitude of about 1704 m above sea level in Eastern Ethiopia. The mean annual rainfall of the area is 1275mm. The rainy season extends from April to October, and it receives maximum rain from June to August. The amount of rainfall varies between 650 and 750 mm, while the average temperature of the district ranges between 25 and 30°C (Zenna, 2016).

The main sources of income are agriculture (particularly chat and livestock sales), self-employment (firewood sales) and local labor (harvesting and packing chat). Sorghum and maize are grown for home consumption (ACLFE, 2014).

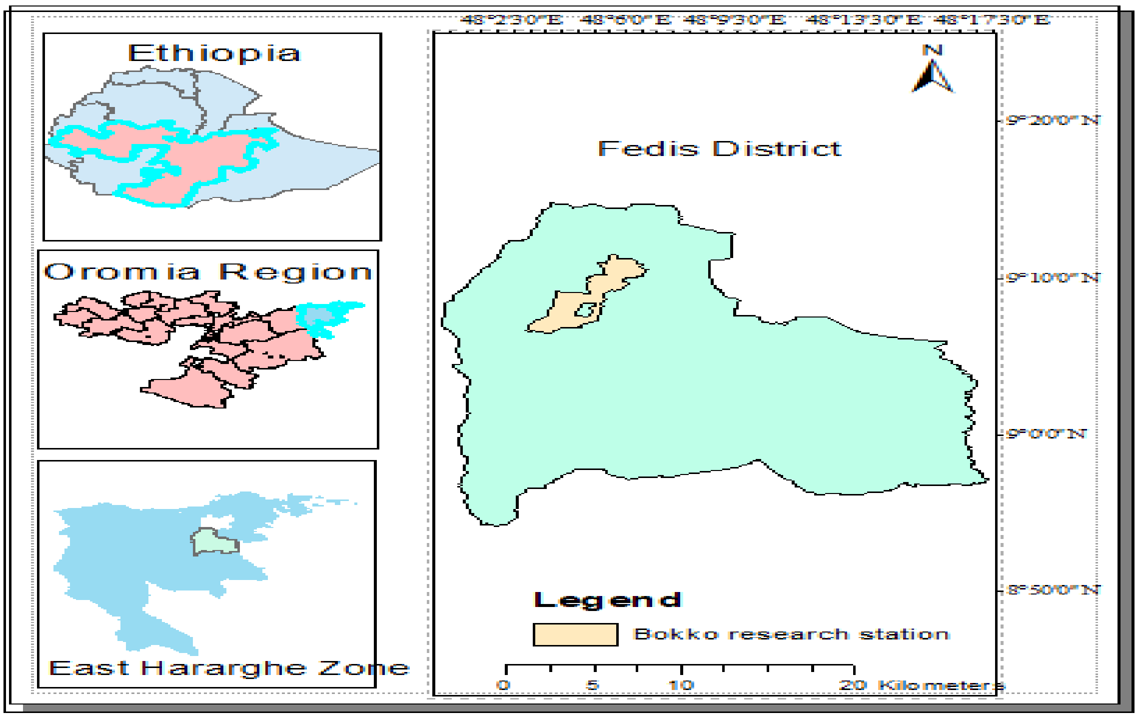


Fig: 1 study area map

Materials

The testing crop for intercropping was sorghum (melkam variety) which is already adapted and still performs best in the study area and legume crops haricot bean(awash 2 variety), soybean (Boshee variety

Awash 04), mungbean (Rasal variety) and cowpea (9333) were used

Experimental Design and Treatments

The Experimental design was laid out as a randomized complete block design (RCBD) with replicate three times. The spacing mono crop different legumes planted at a spacing of 40cm x 15cm, different legume crops intercropped with sorghum: (75cm x 15cm), Mono of sorghum crop: (75cm x 15cm), sorghum intercropped with legumes: (75cm x 15cm). Plot size constructed by 4m * 3m. Gross plot was consists of 3 ridges along 4m long (12 m^2)· The arrangement of intercropping was 1:1 with one row of sorghum intercept by one row of legumes plant.

Land preparation was done manually using traditional implement. The experiments received basal application of NPS at the rate of 150kg ha^{-1} , (Roy *et al*., 2006) . These crops were not sown at the same time and their harvested time were different, but were occupied together the same land area for a significant part of the growing season. The crops were harvested separately and their yields were kept separate. All legumes crops were planted after sorghum plant.

Treatments and Their Description

T1. Sole sorghum
T2. Sorghum intercropping with soybean
T3. Sorghum intercropping with haricot bean
T4. Sorghum intercropping with cow pea
T5. Sorghum intercropping with mungbean
T6. Sole soybean
T7. Sole haricot bean
T 8 .Sole cow pea
T 9 .Sole Mungbea

Soil Sampling and Analysis

Soil Sampling, Preparation and Analysis before Planting and After Harvesting

Prior to the field experimentation disturbed samples were collected. Random disturbed composite soil samples (0-20 cm depth) were collected and a composite soil sample was made. The composite sample was used for soil chemical analysis. The disturbed soil samples were air dried, sieved to pass through a 2 mm sieve, placed in a labeled plastic bag and transported to Batu soil Research Center soil laboratory for analysis and the disturbed composite soil samples were analyzed. After harvesting, the soil samples were collected main plot-wise from each replication from the surface 0-20 cm depth, and composite samples were made for selected soil chemical analysis, and then the soil samples were air dried, sieved to pass through 2 mm sieve, and placed in a labeled plastic bags and submitted to Batu soil research laboratory for soil chemical properties analysis

Soil samples were collected with auger tool using zigzag method at a depth of 0-20cm and then mix different samples of the same site to get one sample which was homogeneous in each site. Before planting and after harvesting soil analysis for each treatment was done in order to ensure the amount of nutrients fixed after harvested in each plot. Five samples (in zigzag pattern) were collected before land preparation and after harvested to form composite soil samples.

Analysis of Agronomic Data

Agronomic data such as plant height, grain yield and biomass yield were collected from each experimental plot. Land equivalent ratio of intercropping system was determined .Total above ground dry biomass yield (kg ha^{-1}) was determined from plants harvested from 12 m^2 of each plot after sun drying for seven days to a constant weight and the result was converted to kilogram per hectare basis.

Data Analysis

The collected data were analysed by using Gens stat15th edition, following standard analysis of variance procedure and the least significant difference (LSD) test at a 5% probability level was used to compare the treatment means and when the analyses of variance indicate the presence of significant differences. For intercropped plots, Land Equivalent Ratio (LER) was calculated to know the total production. The LER were estimated through the following relationship (Willey and Osiru, 1972).

$$\mathrm{LER} = \frac{\mathrm{YMint}}{\mathrm{YMsol}} + \frac{\mathrm{YLint}}{\mathrm{YLsol}}$$

Where: *YMint = Yield of sorghum under intercropping conditions:YMsol = Yield of sorghum under sole crop conditions:YLint = Yield of legume under intercropping conditions:YLsol = Yield of legume under sole crop conditions*

Result and Discussion

Table1: The physical and chemical properties of the experimental site soil, before experimentation, are described in table below

Soil characteristics	Range	Rate	Source
TN%	0.089	Low	Bruce and Rayment (1982)
OC (%)	1.654	Low	Charman and Roper (2000).
pH (1:2.5 H2 O)	6.83	Neutral	Bruce and Rayment (1982)
Av. P(ppm)	1.27	Very low	Holford and Cullis (1985)
CEC(meq/100g)	19.08	Moderate	Hazelton and Murphy (2007)
(Exch.K Cmol(+) /kg soil	1.37	High	J. Landon (1991).
Exch.Mg (meq/100g)	3.00	High	J. Landon (1991).
Exch.Ca (meq/100g)	34.00	High	J. Landon (1991).
EC (Mmhos/cm at 25ºC)	0.12	None saline	(Rhoades et al. 1992)
Texture class	Sandy clay		
Sand%	28		
Silt%	48		
Clay%	24		

Table 2: Effect of intercropped legumes with sorghum on chemical properties of soil

Treatments	P^H 1:2.5	TN%	%OC	Meq/100g		Cmol(+) /kg soil		meq/100g	Mmhos/cm at 25ºC
				Ca	Mg	K	Na	CEC	EC
Sole sorghum	6.83	0.079	1.650	36.5	2.50	1.47	1.11	35.40	0.18
Sorghum+ Soybean	7.12	0.094	1.657	37.5	3.00	1.31	1.06	43.00	0.17
Sorghum+Haricot bean	7.36	0.088	1.661	36.0	3.00		1.00	40.80	0.18
Sorghum+Cow pea	7.45	0.091	1.654	34.0	3.00	1.25	1.09	39.60	0.19
Sorghum + Mungbea	7.57	0.093	1.701	31.0	3.00	1.54	1.04	42.60	0.19
SoleSoybean	6.46	0.11	1.657	32.0	3.00	1.37	1.04	45.20	0.20
Sole Haricot bean	7.15	0.092	1.701	34.0	2.50	1.48	0.95	38.80	0.21
Sole Cow pea	7.78	0.088	1.659	33.5	2.50	1.41	1.13	32.40	0.22
Sole Mungbean	7.95	0.093	1.708	34.0	1.50	1.48	1.13	42.00	0.20

CEC: Cation Exchange Capacity; CV: Coefficient of Variation; pH: Soil reaction; SOC: Soil Organic Carbon; TN: Total Nitrogen; EC: Electrical conductivity; EC = Electrical conductivity; Na: Exchangeable Sodium; K : Exchangeable Potassium; Ca: Exchangeable calcium; Mg: Exchangeable magnesium

Soil Reactions (pH)

The laboratory result of soil chemical parameters on sorghum farms indicated that the sole sorghum and sorghum –legumes intercropped plots showed increases the soil reactions (pH) except sole soybean plot showed a reduction of P^H. Result showed that Soils grown previously with legumes had higher pH value. This resulted support Esekhade and Idoko (2010) reported higher soil pH in legume and cereal intercropping treatments compared to their counterpart under mono cropping culture. Soil pH moved away from strongly acidic to slightly acidic conditions in all plots which received legumes and cereal intercrop (Schoenerberge *et al*., 2002).

The incorporation of legumes as a green manure significantly raised soil pH (Kiiya *et al*., 2010), impacting soil acidification due to carbon (C) and N cycles, as reported by Burle *et al*., (1997). This finding disagree with Uzoh, *et al*., (2019) which states that cultivation of legumes increases acidity by proton release from their roots .The highest pH value was obtained from treatment of sole mungbea followed by Sole cowpea treatment and sorghum intercropped with mungbea pH (7.95, 7.78, and 7.57) respectively (table 2). However sole soybean plots showed a reduction soil pH as compared with soil before experimentation plots (Table 2).The lowest pH value was measured from sole soybean treatment followed by sorghum +soybean and sole sorghum pH value (6.46, 6.83 and 7.12) respectively.

According to Tekalign (1991) rating of soil pH, soils with pH (H_2O) > 8.0 are characterized as strongly alkaline; 7.4-8.0 as moderately alkaline; 6.7-7.3 as neutral, while soils with pH of 6.0-6.6, 5.3-5.9, 4.5-5.2 and < 4.5 are rated as slightly acid, moderately acid, strongly acid and very strongly acid, respectively, in reaction.

Therefore, the soils in experimental plot contain sole mungbea, sole cowpea, sorghum +cowpea, sorghum+mungbea were moderately alkaline, while soils in experimental plot contain sole sorghum, and sole soybean, sole haricot bean, sorghum + Haricot bean and sorghum + soybean were neutral in reaction. This agree the result reported by Schoenerberge *et al*., (2002) Soil pH moved away from strongly acidic to slightly acidic conditions in all plots which received legumes and cereal intercrop

Organic Carbon

The minimum Organic carbon was recorded in soils of the control plot or sole sorghum (1.650%), whereas the maximum organic carbon was recorded in soils of the sole mungbean treatment (1.708%) (Table 2).After the intercropped of the legume with sorghum, the SOM content of soil on all treatments increased, while minimum was recorded on control plots. Organic Carbon increased in the soil after harvesting. Sole mung bean gave higher OC of 1.708% after harvesting compared 1.654% recorded before experiment trial done. This might be due to organic matter decomposed which could increase OC after. Sole sorghum recorded the lowest OC of 1.650 % after harvesting compared to 1.654% obtained before planting in sole crops soil sorghum. The results indicated that a high SOC content was observed in the legumes crop residue or dead roots of legumes decomposition occurred by microorganism. According to (Studdert and Echeverria.,2000) the SOC content in crop rotation systems increased due to the crop residues, root system diversity, and soil biota activity improvement rotation system.

Effect Legumes have revealed remarkable changes in soil chemical characteristics such as total nitrogen (N), pH, and organic carbon. This finding is line with Cong *et al*., (2015), soil organic carbon content in the top 20 cm was 4% higher in intercrops than in sole crops, indicating a difference in carbon sequestration rate

Nitrogen

When compared to that of control (sole sorghum) plot, all plots (legumes) can increase the total nitrogen of the soil than control. Sole soybean gave the highest amount of 1.09% N After harvesting followed by sole sorghum +soybean treatment (0.094%) after harvesting. Sole sorghum treatment gave the lowest soil N of 0.061% after harvesting. Sole soybean showed the highest amount of soil N of 10.1% after harvesting compared to 0.089% recorded before planting followed by sorghum + soybean (0.5%) after harvesting more than 0.061% Before Planting . The legume crops improved soil fertility by increasing total soil N (Nitrogen) and improving P (Phosphorus) and K (Potassium) availability to the subsequent crops. The green parts and roots of the legume component can decompose and provide nitrogen into the soil where it may be made available to subsequent crops. Similarly, Fabio *et al*., (2017) indicated under low soil nitrogen conditions the advantages of legumes in an intercrop are greater. Legumes broadly are more powerful in increasing the productivity of succeeding cereals.

N level recorded in all plots receiving legumes and sorghum intercropped due to legumes fix nitrogen in the soil. .This resulted also agrees with the report of Nweke (2016) that significant N levels were obtained in plots intercropped with legumes. In addition, soil organic N content in the top 20 cm was 11% higher in intercrops than in sole crops, indicating a difference in N sequestration rate between intercrop and sole crop systems of 45 ± 10 kg N ha^{-1} yr^{-1} (Cong et al. (2015).

Cation Exchange Capacity

Measurements of the cation exchange capacity (CEC) show significant changes soil properties. The highest CEC (42.6 meq/100g soil) followed by (42.6 meq/100g soil) were obtained from sole soybean treatment and sorghum +soybean treatment in our study respectively. Whereas minimum CEC has recorded from sole cow pea 32.40 meq/100g soil (Table 2). This finding line with Wang et al. (2015) Soil CEC is reduced by intercropping in some crop combinations. Cation exchange capacity (CEC) values were ranged from 32.2 to 45.4 cmol+/kg .The results indicated the values of exchangeable bases were optimal for crop production it does not mean no need managements.

Yield and Yield Components of sorghum and legumes

Table 3. Combine mean over season

Treatments	GY (kg ha^{-1})		BY(kg ha^{-1})		pH(cm)	
	Sorghum	Legumes	Sorghum	legumes	Sorghum	legumes
Sole sorghum	2738.4[a]		7381		136	
Sorghum + Soya bean	3050.2[a]	1309.4	5635	2738	143.33	54.767
Sorghum +Haricot Bean	2125.1[b]	1091.5	6429	2055.6	171	57.867
Sorghum + Cow pea	2610.6[ab]	1006.5	7540	1800.	133.9	37.3
Sorghum + Mung Bean	2929.4[a]	392.5	7619	1361.1	140.13	39.567
Sole Soya Bean	-	1431.3	-	4805	-	55.9
Sole Haricot Bean	-	2233.3	-	3029.0	-	59.567
Sole Cow Pea	-	1934.6	-	2519.9	-	53.05
Sole Mung Bean	-	759.2	-	1344.4	-	34.85
LSD	507.87	-	NS		NS	
CV (%)	4.87	-	23.2		6.15	

Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher protected LSD test; BY= Biomass yield; GY = Grain yield, PH= Plant Height

Analysis of variance indicated that grain yield of sorghum with legumes intercropping were significantly different at ($P<0.05$), however Biomass not significantly affected by treatments applied or intercropped with legumes. However, there was no significance ($P>0.05$) difference on sorghum yield due to main effect of legume crops during 2021 and 2022 cropping season.

Grain Yield

The highest grain yield (3050.2 ha^{-1}) was resulted from soybean + sorghum followed by sole sorghum (2738.43 ha-1). The results were in line with an experiment performed by Temeche, Degu, *et al*., (2022) reported that Sorghum-mung bean intercropping contributed yield advantage compared to planting a sole crop of Sorghum and a sole crop of mung bean.

Generally, the soybean intercropped with sorghum had higher grain yield of sorghum than plots receiving other treatment. The result indicated Soybean and sorghum intercrop is evidenced in the higher N value obtained in all plots treated with legumes and sorghum when compared to values obtained in sorghum sole crop and pre planting values. This finding was supported by Crews and People (2004) who noted that legumes trapped and fixed N in the soil through their nodules and in that way increased N content of soil. While the lowest grain yield (2125.1Kg ha^{-1}) sorghum intercropped with Haricot bean. Contradictory to the finding Hailu H, *et al*. (2021) report indicated that the highest mean values of sorghum grain yield were recorded from sorghum intercropped with haricot bean.

Biomass : The result that obtained dry biomass and Stover yields of sorghum in Table (3) was not significant among sorghum the treatments. The highest biomass yield was obtained from Treatment sorghum +mungbea (7619kg ha^{-1} when the minimum was obtained from sorghum + soybean (5635 kgha-1) .The reason sorghum biomass yield reduction under intercropping was because the height of sorghum might interactive with the height of soybean. The incremental biomass yield under intercropping of sorghum mungbean may due to incremental of plant height of sorghum moisture conservation and water use efficiency so maximum vegetative growth of the plant's availability for plant growth process including chlorophyll which is responsible for the dark green color of stem and leaves which enhance vigorous vegetative growth.

Thus result similarly with Geren *et al*., (2008), when maize was planted in alternate rows (1:1) with cowpea, comparatively better agronomic growth of component crops led to the highest and dry biomass owing to more number of plants per unit land area but disagreed with the finding of Berhane (2016) intercropping highly significantly affected dry biomass yield of sorghum

Plant Height. It was observed that the plant height of sorghum was not significantly different ($p < 0.05$) level of significance. However, cropping systems (intercropping) were not affected by plant height statistically. The maximum height recorded by sorghum +haricot bean (171 cm). The minimum sorghum plant height obtained from sorghum+ cowpea treatment ((133.9 cm). As the height of sorghum increased, the height of mungbea was decreased due to shading ability and competitions of sorghum crops increased.

Legumes grain yield. Generally sole legumes the higher grain yield compared to intercropped legumes (Table 3). Result showed that among the legumes, treatment sole haricot Bea gave the highest grain yield (22

33.3 kg ha^{-1}) and the lowest was recorded from mungbea intercropped with sorghum treatment (392.5 kg ha^{-1}). Highest yield was due to increasing levels of legumes density. Under these sole haricot bean legumes, increasing bean density improved the interspecies competitive ability of beans. The result Agree with (Nigussie, 2016) reported that maize-common bean intercropping, bean yield reduction of 45 to 56% have been reported from various studies. On the other hand, (Worku 2014) reported a yield reduction of 18% under maize-common bean simultaneous additive intercropping. Differences in the magnitude of yield loss on the associated bean could be attributed to variation in the component densities, time of bean introduction and availability of growth resources.

Legumes Biomass Yield.

The result showed that The maximum dry biomass yield of legumes recorded from sole soybean (4805 kg ha^{-1}) and The minimum dry biomass yield obtained from (1344.4 kg ha^{-1}) followed by sorghum +mungbea(1361 kg ha^{-1}). This increment order of dry biomass yield might be due to the shading and solar radiation entry attributed by sorghum. The increment in dry biomass production of sole cropped soybean might be attributed to seed proportion of legumes characteristic, absence of competition and thus, more dry matter accumulation in stem, branches and leaves matter because of its good vegetative cover to harvest ample solar radiation important for its photosynthesis. This result is in agree with the findings of (Karanja *et al*., 2014) who reported that sole cropped gave higher dry biomass yield than the intercropped. Likewise, (Getachew *et al*., 2013) reported that dry biomass of forage legumes was significantly affected due to sole and intercropping when intercropped with maize. Iqbal *et al*., (2012) conducted a field experiment on the productivity of summer legume forage intercropped with maize the highest dry matter yield (2.039 t ha^{-1}) was obtained from cowpea.

Table 4: Mean Land equivalent ratio under different intercropped legumes with sorghum in fedis district in 2021 and 2022 main cropping seasons

Treatment	Sorghum partial LER			Legumes partial LER			Total LER		
Cropping season	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
Sole sorghum									1
Sorghum + Soya bean	1.42	1.28	0.89	0.91	0.92	0.91	2.33	2.2	1.8
Sorghum+Haricot Bean	1.12	1.08	0.69	0.46	0.46	0.48	1.58	1.54	1.17
Sorghum + Cow pea	1.23	0.95	0.85	0.52	0.53	0.52	1.75	1.48	1.37
Sorghum +Mung Bean	1.29	1.20	0.96	0.51	1.29	0.51	1.8	2.49	1.47
Sole Soya Bean									1
Sole Haricot Bean									1
Sole Cow Pea									1
Sole Mung Bean									1

The effect of intercropping sorghum legume on sorghum yield and yield components was evaluated for two years period. Land equivalent ratio was used to evaluate the intercrop yield in yield relative to the monocropped condition. From the analysis in table above, and Land equivalent ratio (LER) of sorghum intercropped with Soybean, Mung Bea, Haricot bean and cowpea was greater than 1.

The calculated LER for the grain yield of sorghum and Haricot bean was 1.17 while LER for sorghum with cowpea 1.37, sorghum with mungbea 1.47 and sorghum with soybean 1.8 which were higher than 1, which showed the benefits of intercropping. Temeche, Degu, *et al.*, (2022) reported that higher total LER was obtained from sorghum/soybean than to sorghum/cowpea intercropping .According to the finding of JNA *et al*., (2022), *LER* values greater than 1 indicate advantage of intercropping over monoculture. In addition, intercropping favors the growth and yield of the crops reducing weed distribution, paste and disease. In contrast, the lower value of LER below 1 indicates intercropping negatively affects the growth and yield of a crop grown. The highest 64 Gebremichael *et al*., (2019) Effect of sorghum-legume intercropping on yield of sorghum LER was obtained from intercropping sorghum with cowpea. So, intercropping indicated an advantage over sole cropping in the trail time of year. In constrict reported the lower yield under intercropped condition as compared to mono-cropped could be due to the differences in the intercropped condition particularly on growth factors and different crop species, which could better utilize nutrients from soils, compared mono cropped condition (JMM Matusso 2014). Mixtures of sorghum-legume showed advantages in land-use efficiency expressed as LER than monoculture sorghum (Iqbal *et al*., 2018).Areas where intercropping is practiced, crop yield is enhanced simply by growing two or more compatible crops without using costly agricultural inputs.

Economic Analysis

Table 5: Economic Analysis of sorghum inter cropping with Legumes in fedis district

Treatments	Yield Kg-1		Cost		Total cost	Income from		Gross income (birr)	Net income
	Sorghum	legumes	Sorghum	legumes		Sorghum	legumes		
Sole sorghum	2738.4		20		2050	54768	0	54768	52718
Sorghum+Soya bean	3050.2	1309.4	20	25	5750	61004	32735	93739	87989
Sorghum+Haricot Bean	2125.1	1091.5	20	35	8200	42502	38202	80704.5	72504
Sorghum + Cow pea	2610.6	1006.5	20	15	6200	52212	15097	67309.5	61109
Sorghum + Mung Bean	2929.4	392.5	20	40	6550	58588	15700	74288	67738
Sole Soya Bean		1431.3		25	1700		35782	35782.5	34082
Sole Haricot Bean		2233.3		35	4150		78165	78165.5	74015
Sole Cow Pea		1934.6		15	2150		29019	29019	26869
Sole Mung Bean		759.2		40	2500		30368	30368	27868

According to the economic analysis conducted for intercropping legumes with sorghum, the highest net income (87989 ETB ha^{-1}) was obtained from sorghum + soybean treatment while the lowest net income (26869ETB ha^{-1}) was recorded from sole cow pea treatment. The data with looks to sole crop the highest net income (74015.5ETB ha^{-1}) was obtained from sole haricot bean and the lowest net income (26869 ETB ha-1) was recorded from sole cowpea. Thus the net income was higher in intercropping system than sole cropping system. This was in agreement with the findings of (Wondimu, 2013) obtained higher monetary returns from intercropping than sole maize, in maize soybean cropping system. Similarly, (Biruk, 2007 reported that intercropping sorghum with common bean was more advantageous than sole cropping of either common bean or sorghum (Table 5).

Conclusions and Recommendation

Intercropping legumes with sorghum can be a great way to improve soil chemical properties and consequently increase soil productivity. Legumes have a restorative effect in infertile soils, increasing nitrogen levels, and organic carbon, calcium, magnesium, and pH levels. This resulted in higher grain yields of sorghum in all intercropped plots. The land equivalent ratio was higher in plots with sorghum and soybean intercrops than in mung bean, cowpea, and haricot bean intercrops. This suggests that farmers in the research area could enjoy increased income from intercropping sorghum and soybean without sacrificing sorghum yield. Intercropping also reduces the labour and time required for harvesting and other related activities, making it an attractive option for farmers. For these reasons, intercropping sorghum with legumes, particularly sorghum and soybean, is recommended for farmers in the study area and other areas of similar agroecological conditions. It is clear from the data that intercropping legumes with sorghum can have a significant positive effect on soil fertility. In particular, the sole soybean treatment showed the highest increase in total nitrogen of the soil (10.1%) compared to the control (sole sorghum). This indicates that legumes can effectively decompose and provide nitrogen for subsequent crops. Additionally, sole mungbean showed higher Organic Carbon and Potassium after harvesting than other treatments. These results suggest that a variety of legume crops can be beneficial for increasing the fertility of the soil. Furthermore, the economic analysis showed that the highest net income was obtained from the sorghum + soybean treatment, which further highlights the potential of legumes for improving crop yields. Intercropping sorghum and soybean is a great way for farmers in the study area to maximize their net income. The data shows that sole haricot bean had the highest net income at 74015.5ETB ha-1, while sole cowpea had the lowest at 26869 ETB ha^{-1}. Intercropping sorghum and soybean also has the benefit of fixing nitrogen, which reduces the cost of nitrogen fertilizer. Therefore, this combination of crops is an excellent choice for farmers looking to maximize their net income.

Acknowledgement

We would like to express our sincere gratitude to the Oromia Agricultural Research Institute for allocating funds, the Fedis Agricultural Research Centre for funding and logistic support, and the Batu Soil Research Centre for laboratory analysis. We are also thankful to all who participated in the implementation of this research activity. Your contributions have enabled us to carry out this research successfully and we are very appreciative of your efforts.

Reference

Hassan, A. E., & Elasha, E. A. (2007). Intercropping effect using local cowpea on Striga hermonthica (Del.) Benth. control and grain yield of Sorghum bicolor (L.) Moench. *Sudan Journal of Agricultural Research (Sudan)*.

Geren, H., Avcioglu, R., Soya, H., & Kir, B. (2008). Intercropping of corn with cowpea and bean: Biomass yield and silage quality. *African Journal of Biotechnology*, *7*(22).

Wycliffe, W. K., Samuel, M. M., Robert, K. O., & Joseph, G. N. (2010). Effect of incorporation of legumes on selected soil chemical properties and weed growth in a potato cropping system at Timboroa, Kenya. *African Journal of Agricultural Research*, *5*(17), 2392-2398.

Lithourgidis, A. S., Dordas, C. A., Damalas, C. A., & Vlachostergios, D. (2011). Annual intercrops: an alternative pathway for sustainable agriculture. *Australian journal of crop science*, *5*(4), 396-410.

1Li, X., Mu, Y., Cheng, Y., Liu, X., & Nian, H. (2013). Effects of intercropping sugarcane and soybean on growth, rhizosphere soil microbes, nitrogen and phosphorus availability. *Acta Physiologiae Plantarum*, *35*(4), 1113-1119.

JNA, A. (2022). Evaluation of productivity traits of five pigeonpea (Cajanus cajan) varieties in pigeonpea-maize strip intercropping under rainfed condition in Limpopo Province, South Africa. *Research on Crops*, *23*(1).

Phiri, A. T., Njoloma, J. P., Kanyama-Phiri, G. Y., Sieglinde, S., & Lowole, M. W. (2013). Effects of intercropping systems and the application of Tundulu Rock phosphate on groundnut grain yield in Central Malawi. *International Journal of Plant and Animal Sciences*, *1*(1), 011-020.

Temeche, D., Getachew, E., Hailu, G., & Abebe, A. (2022). Effect of Sorghum-Mung Bean Intercropping on Sorghum-Based Cropping System in the Lowlands of North Shewa, Ethiopia. *Advances in Agriculture*, *2022*.

Searle, P. G. E., Comudom, Y., Shedden, D. C., & Nance, R. A. (1981). Effect of maize+ legume intercropping systems and fertilizer nitrogen on crop yielding and residual nitrogen. *Field Crops Research*, *4*, 133-145.

Gong, X., Liu, C., Li, J., Luo, Y., Yang, Q., Zhang, W., ... & Feng, B. (2019). Responses of rhizosphere soil properties, enzyme activities and microbial diversity to intercropping patterns on the Loess Plateau of China. *Soil and Tillage Research*, *195*, 104355.

Wang, Z. G., Bao, X. G., Li, X. F., Jin, X., Zhao, J. H., Sun, J. H., ... & Li, L. (2015). Intercropping maintains soil fertility in terms of chemical properties and enzyme activities on a timescale of one decade. *Plant and Soil*, *391*(1), 265-282.

Adafre, A. N. (2016). Advantages of maize-haricot bean intercropping over sole cropping through competition indices at west Badewacho woreda, Hadiyazone, SNNPR. *Acad. Res. J. Agric. Sci. and Res*, *4*(1), 1-8.

Willey, R. W., & Osiru, D. S. O. (1972). Studies on mixtures of maize and beans (Phaseolus vulgaris) with particular reference to plant population. *The Journal of Agricultural Science*, *79*(3), 517-529.

LIST, E. S. (1998). Natural Resources Conservation Service. *US Department of Agriculture*.

Uzoh, Ifeyinwa Monica, et al. "Legume-maize rotation effect on maize productivity and soil fertility parameters under selected agronomic practices in a sandy loam soil." *Scientific reports* 9.1 (2019): 1-9.

WondimuB.“Evaluation of Soybean Varieties and N Fertilizer Rates on Yield, Yield Components and Productivity of Associated Crops under Maize/Soybean Intercropping at Mechara”, Eastern Ethiopia. M.Sc. Thesis. Haramaya University (2013).

Worku, W. (2014). Sequential intercropping of common bean and mung bean with maize in southern Ethiopia. *Experimental Agriculture*, *50*(1), 90-108.

Alice T. “Adaptability of Soybean [Glycine max (L).Merr.)] Varieties to Irrigat Drainage Sys Eng, Volume 10:5, 2021 Page 8 of 8 Hailu H, et al. Intercropping under Leaf Stripped and Detasselled Maize (Zea mays "L.). M.Sc Thesis”. Zimbabwe University (2007).

Amede, T., Legesse, G., Agegnehu, G., Gashaw, T., Degefu, T., Desta, G., ... & Thorne, P. (2021). Short term fallow and partitioning effects of green manures on wheat systems in East African highlands. *Field Crops Research*, *269*, 108175.

Ghosh, P. K., Bandyopadhyay, K. K., Wanjari, R. H., Manna, M. C., Misra, A. K., Mohanty, M., & Rao, A. S. (2007). Legume effect for enhancing productivity and nutrient use-efficiency in major cropping systems–an Indian perspective: a review. *Journal of Sustainable Agriculture*, *30*(1), 59-86.

Sibhatu, B. (2016). Evaluation of cowpea plant density and nitrogen fertilizer for productivity of sorghum/Cowpea Intercrops at Abergelle, Northern Ethiopia. *Evaluation*, *6*(3).

Biruk, T. (2007). *Effect of planting density and variety of common bean (Phaseolus vulgaris L.) intercropped with sorghum (Sorghum bicolor L.) on performance of the component crops and productivity of the system in South Gonder, Ethiopia* (Doctoral dissertation, M. Sc. Thesis Haramaya University, Ethiopia).

Burle, M. L., Mielniczuk, J., & Focchi, S. (1997). Effect of cropping systems on soil chemical characteristics, with emphasis on soil acidification. *Plant and Soil*, *190*(2), 309-316.

Fujita, K., Ofosu-Budu, K. G., & Ogata, S. (1992). Biological nitrogen fixation in mixed legume-cereal cropping systems. *Plant and soil*, *141*(1), 155-175.

Evaluation of Rhizobium Bio-fertilizer inoculation on yield and yield components of Faba bean (Vicia faba L.) at Jarso District, East Hararghe, Oromia, Ethiopia

Sisay Negash* Robe Elema and Alemu Tolosa
Fedis Agricultural Research Center, P.O. Box 904, Harar, Ethiopia
Corresponding author: E-mail: alemutolosa2020@gmail.com,

Abstract

*The Faba bean is a highly important grain legume grown in the highlands of Ethiopia, yet its production and productivity have been consistently dropping due to soil fertility depletion. In order to increase yield and reduce soil fertility problems, an experiment was conducted to assess the efficacy of Rhizobium strain inoculation on yield and yield components of the Faba bean in Jarso district, Eastern Hararghe, Oromia, Ethiopia. The experiment was conducted over two consecutive 2020-2021 cropping seasons, and consisted of eight treatments: control, recommended NPS, FB 17, FB; EAR 15, FB 18, FB 17 + 50 kg NPS/ha, EAR 15 + 50 kg NPS/ha and FB 18 + 50 kg NPS/ha. The treatments were laid out in a complete randomized block design with three replications, and a Dosha improves the variety of the Faba bean was used for the trial. Results showed that Rhizobium strains inoculation had a significant effect on yield and yield components of the Faba bean, including nodule number. Moreover, the results indicated that the application of Rhizobium strain FB 18 with 50 kg/ha NPS fertilizer can be a viable and beneficial option for Faba bean production in the study area. This is encouraging, and more research should be done to further explore the potential of this approach. It would also be beneficial to isolate indigenous bacteria from the soil to determine if they could be more effective in increasing biomass and yield than the Rhizobium strain FB 18. This could give farmers in the study area an even better option for enhancing their crop productio*n.

Keywords: - Strain, Nitrogen Fixation, Yield, Rhizobium, Soil Fertility.

Introduction

Grain legumes are a primary source of amino acids providing about a third of all dietary protein and second to cereals in providing food for humans worldwide (Kudapa et al., 2013). They are considered a vital crop for achieving food and nutritional security for both poor producers and consumers (Allito et al., 2014). These grain legumes are an important source of dietary protein and daily food supplements for the majority of Ethiopian population.

Faba bean is high- yield pulse crop that's both–economic and ecologic role is very significant; they contain up to 35% of crude protein, approximately 50% of carbohydrate and no more than 15% of crude lipid (Proskina et al., 2016). As a grain legume, it provides cheap and quality protein (lysine) supplement (20-40%) in the cereal- based Ethiopian diet (Nebiyu, 2014). Faba bean is the most important grain legume in the highlands of Ethiopia (1800-3000 m) in terms of area, production, foreign exchange earnings, protein source, soil amelioration and nitrogen provision in cropping systems (Agegnehu, 2018). It occupies 27.34% of the total land area under pulse crops in Ethiopia (1,598,806.51 ha-1) and of the entire Oromia region area under pulse crop production (662,144.90 ha), 32.85% was covered by faba bean (CSA, 2017/18). Net profit ha-1 of faba bean was found to be higher than most other pulses and cereals (Yirga et al., 2010). This attributed to the saving of 150-200 kg ha-1 of N as well as some 20-50 kg in the subsequent crop. Despite its multifaceted benefits the productivity of faba bean, regional production, 23.64qu/ha (CSA, 2017/18), which is remained low compared to its attainable yield >3t/ha (MoA, 2011).

Soil fertility deficiency is the main constraint factor affecting the production and productivity of Pulses crops mainly Faba bean both in terms of quality and quantity. To improve the productivity of faba bean, alleviation of soil fertility depletion through proper fertilizer management is very important along with other agronomic practices. Integrating organic and inorganic fertilizers for tackling soil fertility depletion and sustainably increasing crop yields is the best alternative to avert soil fertility depletion and increase crop productivity (Mahajan et al., 2008, Gete et al., 2010). One of the best organic materials for increasing crops yield is biological nitrogen fixation, especially rhizobia-legumes symbiosis is one of the alternative solutions and the promising technologies which play an important role in reducing the consumption of chemical N-fertilizers, increasing soil fertility, decreasing the production cost, and eliminating the undesirable pollution impact of chemical fertilizers in the environment (Upendra et al., 2013, Livija et al., 2017). Rhizobium inoculants are selected strains of beneficial soil microorganisms cultured in a laboratory and packed in with or without a carrier. They are host-specific, low cost and an environmentally friendly source of nitrogen (EIAR, 2016). Rhizobia inoculants coated on legume seeds before planting enhance growth, yield of legume crops, and provide nitrogen and organic carbon for subsequent or associated crops (Fact sheet, 2016).

Several studies showed that Ethiopian soils harbored symbiotically effective rhizobia, which are tolerant to different stresses such as acidity (Argaw, 2012). Inoculation of Faba bean with effective rhizobial strains can reduce the need of inorganic fertilization to achieve higher crop yield under low soil fertility condition. The inoculation of the legume seed material with active nitrogen fixing bacteria strains before sowing has a significant role for the increase of the legume yield (Woldekiros 2018). Inoculation can improve crop yields in cases where appropriate rhizobia are not present in the soil or the soil contains a significant proportion of ineffective nitrogen-fixing strains. Inoculation of legume seeds with Rhizobium affects soil microbial community and processes, especially in the rhizosphere (Livija et al., 2017). Different leguminous crops require specific Rhizobium species for the formation of effective nodules and N2 fixation and the various strains of Rhizobium species differ in their efficiency of N2 fixation (Aserse, et al,. 2020). The low level of nutrient supply and the lack of effective indigenous Rhizobium populations in soil have limited the faba bean yields (Gorfu, et al., 2012). Thus, the crop should be inoculated with the proper Rhizobium species and strains. Therefore, understanding the impact of rhizobia inoculation and contrasting soil rhizobia on nodulation and Nitrogen fixation in faba bean is crucial to optimize the crop yield, particularly under low fertility soil conditions. Therefore, the general aim of this study was to evaluate the rhizobium strains (biofertilizer) inoculation on growth and yield components of faba bean (Vicia faba L.) at Jarso woreda, East Hararghe zone of Oromia region.

Materials and Method

Descriptions of Study Areas

The study was conducted in Jarso district, which is one of the woreda in the Oromia Region of Ethiopia. Part of the Misran (East) Hararghe Zone, Jarso is bordered on the south by the Harari Region, on the west by Kombolcha, on the north by the city of Dire Dawa, on the east by the Somali Region, and on the southeast by Gursum. The administrative center of this woreda is Ejersa Goro. Geographically found at Latitude: 9° 24' 59.99" N Longitude: 42° 09' 60.00" E and the altitude of this District ranges from 1050 to 3030 meters above sea level.

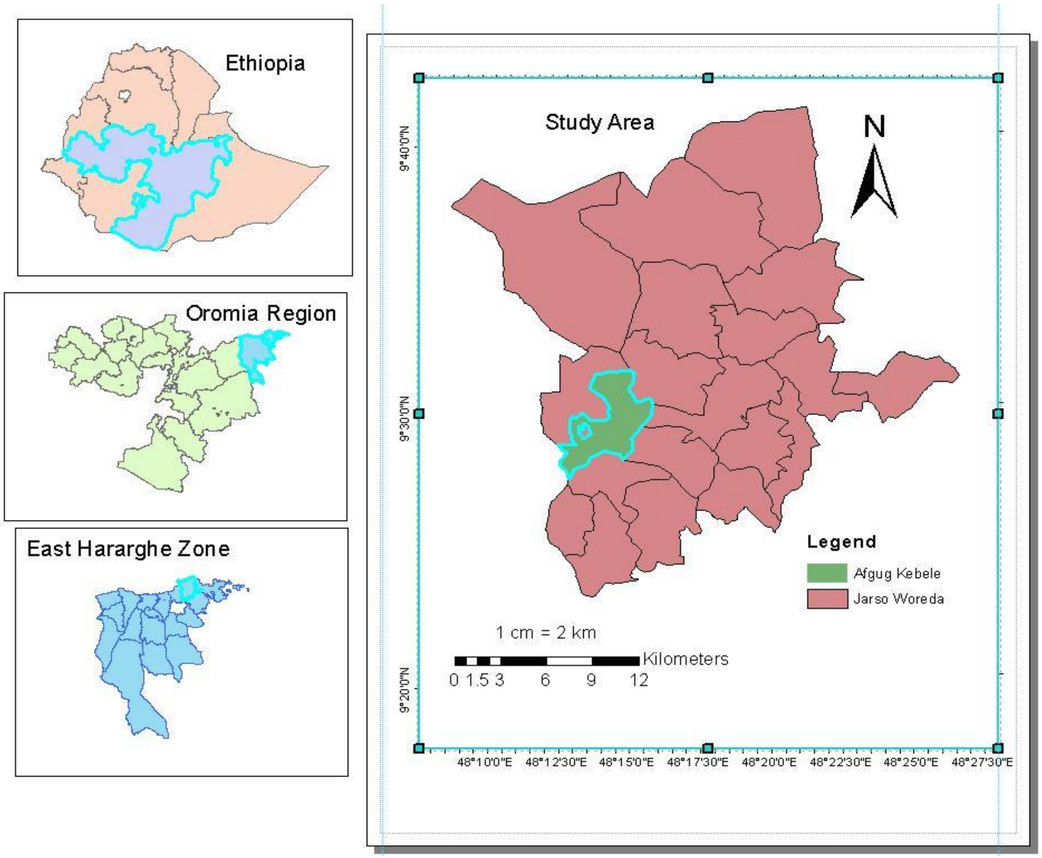


Figure 1. Map of the study area

Experimental Design, Treatments and Procedures

The experimental plots were laid out in a Randomized Completely Block Design (RCBD) with three replications with a plot size of 3m*4m. An improved variety of Faba bean (Dosha) used as testing crop for the experiment.

The treatments were the combination of different type of strain and fertilizer

T1: Absolute control (no fertilizer no strain)

T2: Recommended NP (100kg NPS)

T3: FB; 17

T4: FB; EAR 15

T5: FB 18

T6: FB; 17 + 50 kg NPS

T7: FB; EAR 15+ 50 kg NPS

T8: FB 18+ 50 kg NPS

Treatments were designed based on available strains (bio-fertilizers) solely and with half of recommended NP for economic advantage. TSP was used as a source of P applied in the rows mixed with soil just at time of planting. Improved Faba bean (Dosha) variety with higher yielding during adaptation trial was used for the experiment. The recommended amount of seed (134kg/ha) Were soaked in distilled water for six hours and also the seeds were inoculated with Rhizobia strains (FB1018,FB17,EAR 15) which were received from Holetta Agricultural Research Center. During inoculation of rhizobia strains mixed with sugar by addition of some water in order to facilitate adhesion of the strains to the seed. The seed was dressed with mixed strains and planted immediately. All management practices applied uniformly as per research recommendations for faba bean on each plot. All necessary agronomic and soil data collection done at appropriate crop growth stages following recommended procedures. At the 50% flowering stage, five plants from each treatment uprooted and nodule number were recorded. Soil Sampling and Analysis Before planting, soil samples were collected from the experimental field at a depth of 0 to 20 cm in zigzag manner using an auger and the samples were mixed thoroughly to produce one representative composite sample. After harvesting soil sample were taken from each plot at depth of 0 to 20 cm using auger in a Crisscross movement from five spots and mixed up to one sample based on treatments accordingly (Abera *et al*., 2020). The collected soil sample was air-dried, grounded and analyzed for total N, pH, organic carbon (OC), Organic matter, CEC and texture.

Data Collection

Data for yield and yield components were collected as per the procedures mentioned as follows. Five plants from the central rows of each plot were randomly selected for measuring plant height. Then the average values of these plants were recorded as the plant height of the crop. Nodulation assessments were undertaken at the mid (50%) flowering stage by carefully uprooting five plants randomly from each plot. The plants were separated into shoots and roots. The adhering soil was carefully washed from the roots over a metal sieve. The nodules from each plant were picked and spread on the sieve to drain water from their surface. Nodules were counted and their average will be taken for plots as nodule number per plant. At harvesting time number of pods per plant, number of seeds per pod, hundred seed weight and grain yield, was recorded. For hundred seed weighted sun dried seeds was randomly taken from the seed lots of each plot and then weighed by using sensitive balance.

Data Analysis

The collected data were subjected to analysis of variance (ANOVA) using SAS version 9.1 GLM procedures and Least Significant Difference (LSD) were used to separate means at $p<0.05$ probability levels of significance.

Partial Budget Analysis

Grain yield data were economically evaluated using partial and marginal analysis for the feasibility of fertilizer and strain application. A treatment were considered orthwhileto farmers when it’s minimum acceptable rate of return (MAR) is 100% (CIMMYT, 1988), which is suggested to be realistic. This enables’ to make farmer recommendations from marginal analysis.

Result and Discussion

Soil Analysis Results

Table 1: The soil chemical properties before experiment and after harvest from experimental site

Soil Parameters	Sand (%)	Silt (%)	Clay (%)	Textural Class	pH (H_2O)	TN (%)	OC (%)	Ava. P (mg/kg)	CEC (meq/100g)	EC (Mmhos/cm)
Value	28	23	42	Clay loam	7.3	0.19	0.56	6.7	35.7	0.16

Before application of the experiment, the experimental field characterized for selected soil physical and chemical properties, soil samples were collected from 0-15 cm depth for initial determination of soil textural class, pH, Total Nitrogen, Organic Carbon, Available Phosphorus, Cation exchange capacity and Electrical conductivity parameters (Table 1). The soil of the experimental site has a proportion of 28% sand, 23% silt, and 42% clay; and it classified as clay loam according to the soil triangle texturally. The pH of the experimental site (1:2.5 ratio of soil to water suspension) was 7.3, which implied that the soil of the study site was moderately acidic.

The experimental site has total nitrogen of 0.19% by Keljdal digestion and distillation followed by titration method; which implied that the soil of the experimental site has a medium level of total nitrogen according to Tekalign *et al.*, (1991). The organic carbon of the soil was 0.56%, which rated as very low. The available P content of the experimental site was 6.7 mg kg^{-1} rated as low (Jones, 2003). The CEC of the experimental site was 35.7meq/100g which was rated as high.

Table 2: The mean effect of Rhizobium Strain Inoculation on yield and yield components

No	Treatments	Nodule Number	Plant height(cm)	No of pod/ plant	No of seed/ pod
1	Control	51.6^{b}	78.3^{c}	10.78^{d}	3.2
2	Recommend NP/100 NPS kg/ha	79.67^{ab}	86.1^{bc}	16.4^{bc}	3.06
3	FB 17	85.07^{ab}	95.52^{b}	16.3^{bc}	3
4	FB; EAR 15	81.1^{ab}	88.3^{b}	20.9^{ab}	3.3
5	FB 18	76.6^{ab}	89.3^{b}	16^{c}	3.1
6	FB 17 + 50 kg NPS/ha	79.97^{ab}	92.1^{b}	19.5^{bc}	3
7	EAR 15 + 50 kg NPS/ha	88.67^{ab}	89.4^{b}	16.5^{bc}	3.3
8	FB 18 + 50 kg NPS/ha	105.5^{a}	107.3^{a}	25.4^{a}	3.3
	LSD	37.88	10.42	4.5	NS
	CV (%)	26.7	6.5	15.12	6.36

Nodule Number: Inoculation of Faba bean seed with Rhizobium strain shows the statistical significance difference on the number of fresh nodule per plant at 5% significance level. The highest fresh nodule number per plant (105.5) was recorded from the treatment FB 18 + 50 kg NPS/ha which was in statistical parity with the other all inoculated and recommended fertilizer except control, the lowest nodule number (51.6) per plant was recorded from control treatment. This result indicated that the inoculation of these strains in the study area could be more effective and lack of competition with the existing indigenous bacteria. Similarly, Kebede and Lele (2022) reported that inoculation of rhizobium strain could be more appropriate and competitive than the existing native strains of Faba bean rhizobia. Desta *et al*., (2015) reported that inoculation of Faba bean rhizobium strains significantly increase nodule number per plant. However, in contrary this work with Endalkachew Fekadu *et al*., (2018) reported that Faba bean plants, which, not inoculated with rhizobium, have a higher number of nodule as compared with plants inoculated and received the same treatment. Gedamu *et al*., (2021) also reported that inoculation of Rhizobium strains may best suited as compared to the existing Faba bean rhizobium strains to bust the nodule number.

Plant Height

The results revealed that rhizobium strain inoculation significantly affect the plant height of Faba bean at 5% level of significance. The highest plant height (107.3cm) was recorded from the treatment FB 18 + 50 kg NPS/ha, which have statistical significance difference with the other treatments. The lowest plant height (78.3cm) was recorded from control treatment, which statistical parity with Recommend NP/100 NPS kg/ha treatment. This implies that inoculation of effective rhizobium strain on Faba bean and fertilizer increase the Nitrogen yield of the crops, which increase the height of the plant. This result agreed with the result of Gedamu *et al*. (2021) which affirm that inoculation of rhizobium strains to Faba began supplying additional nitrogen through symbiotic nitrogen fixation and lead to increased plant height. Similarly, (Kebede and Lele 2022) reported that Rhizobium inoculation increases Faba bean growth parameters by increasing nitrogen supply.

The significant increase in plant height in response to the application of Rhizobium inoculation attributed to the increased availability of nitrogen in the soil for uptake by plant roots, which might have sufficiently increased vegetative growth through enhancing cell division and elongation. The increment of plant height due to Rhizobium inoculation might also be due to the sufficient amount of nitrogen fixed by the bacteria which likely resulted in enhanced vegetative growth of the plants (Kutafo and Alemneh,. 2020).

Number of Pods per Plant

A Significant effect of rhizobium inoculation was observed on the number of pods per plant at 5% level of significance. The highest pods per plant (25.4) was recorded from the treatments FB 18 + 50 kg NPS/ha which was in statistical parity with treatments FB; EAR 15. The lowest pods per plant (10.78) were observed on the control treatments, which, was statistically in significant with the all treatments. The result indicates that inoculation rhizobium strain significantly increase number of pod per plat with addition of fertilizer at planting time. Similarly, Bezabih *et al*., (2018) reported that number of pods per plant showed significant response to phosphorus fertilization and Rhizobium inoculation. The result is also in conformity with the finding of Birhanu (2021) who reported that the highest number of pods per plant recorded.

Inoculation of faba bean seeds with Rhizobium strains also had a statistically significant effect on the number of seeds per pod compared to un-inoculated treatment (Kebede and Lele., 2022). According to Gedamu *et al*., (2021) the rhizobia strain could significantly increase the number of pods plant.

Number of Seed per Pod

The result shows that there no significance effect of rhizobium inoculation the number seed per pod at 5% level of significance. The highest seed per pod (recorded from treatment FB; EAR 15, EAR 15 + 50 kg NPS/ha and FB 18 + 50 kg NPS/ha and the lowest seed per pod (3) recorded from treatment FB 17. The result of the present study agrees with that reported by Zerihun and Abera (2014), who showed that the number of seeds per Faba bean pod was not significantly affected by fertilizer rate and rhizobia inoculation. This finding disagree with Gedamu *et al*., (2021) who reported that inoculation of rhizobium strains statistically affected number of seeds /pods as compared to the un-inoculated treatment.

Table 3. Mean effect of Treatments on Yield Components

No	Treatments	Biomass kg/ha	Yield kg/ha	Hundred seed weight
1	Control	5054^{b}	1441.2^{c}	$71.67b^{c}$
2	Recommend NP/100 NPS kg/ha	6481^{ab}	1902.9^{bc}	$74.33b^{c}$
3	FB 17	7050^{ab}	2343.1^{b}	77.3^{ab}
4	FB; EAR 15	6667^{ab}	2278.7^{b}	73^{bc}
5	FB 18	6217^{b}	2053.7^{b}	71.3^{bc}
6	FB 17 + 50 kg NPS/ha	6362^{b}	1994.5^{b}	68.67^{c}
7	EAR 15 + 50 kg NPS/ha	5860^{b}	1935.3^{bc}	$70.33b^{c}$
8	FB 18 + 50 kg NPS/ha	8579^{a}	3016.6^{a}	84.67^{a}
	LSD	2149.5	536.94	8.625
	CV (%)	18.8	13.36	6.63

Biomass

Analysis of variance revealed that different rhizobium strains significantly affect the biomass of Faba bean at 5% level of significance. Treatment with FB 18 + 50 kg NPS/ha score the highest (8579kg/ha) biomass which was statistical parity with Recommend NP/100 NPS kg/ha. FB 17 and FB; EAR 15 treatments, while the lowest biomass (5054kg/ha) was measured from control treatment. Application of FB1018 of Rhizobium strains and 50 kg NPS/ha improves aboveground biomass production by 40.39% as compared with control treatments. The present result have in line agreement with Kutafo and Alemneh, (2020) observe that application of FB1018 of Rhizobium strains alone improves aboveground biomass production by 35.85% as compared with control treatments.

The biomass yield difference obtained from the inoculation of Faba bean rhizobium strains could be from the additional supply of nitrogen through the remarkable biological nitrogen fixation by the inoculated strains and Rhizobium strains inoculation significantly influenced Faba bean biomass weight un-inoculated treatment (Gedamu *et al*., 2021). Similarly, Kebede and Lele (2022) reported that the Difference in biomass yield obtained from the inoculation of Faba bean Rhizobium strains could be from the additional supply of nitrogen through the notable biological nitrogen fixation by the inoculated strains. Effective Rhizobium nodulation contributes to increased Faba bean growth and yield parameters by supplying nitrogen to plants by fixing it from the atmosphere and converting it into plant-available nutrient forms.

Grain Yield

The analysis of variance results showed that the strain, NPS, and the interaction between the two had a significant effect on the grain yield of faba beans at a 5% level of significance. The highest grain yield (3016.6 kg/ha) was seen when FB 18 and 50 kg of NPS were applied together, and this result was statistically different to all other treatments. On the other hand, the lowest grain yield (1441.2 kg/ha) was seen in the control group and this was statistically similar to the results seen in the Recommend NP/100 NPS kg/ha and EAR 15 + 50 kg NPS/ha treatments. The inoculation of faba bean seeds with Rhizobium strains in combination with phosphorus fertilizer increased grain yield by 52.22%.

This result is in agreement with Kutafo and Alemneh (2020), who reported that the application of FB1018 of Rhizobium strains improved grain yield production by 72.6% from the control. The increase in nitrogen levels due to the fixation of atmospheric nitrogen by Rhizobium strains, as well as the application of fertilizer at planting time, are likely to have caused the observed yield improvements. The results of this research consistently demonstrated that faba bean plants inoculated with rhizobia produced a greater seed yield than those left un-inoculated (Abera *et al*., 2015; Reda *et al*., 2016). Moreover, Gedamu *et al*., (2021) established that rhizobia inoculation yielded a significantly higher weight of faba bean biomass than those not inoculated. This difference in biomass yield may be attributable to the nitrogen supplied by the rhizobia strains through their remarkable ability to biologically fix nitrogen. Furthermore, Rhizobium inoculation of faba bean markedly improved its grain yield when compared to not inoculated seed (Abera *et al*., 2015; Bezabih *et al*., 2018).

Hundreds Seed Weight

The result clearly showed a marked difference in terms of hundred seed weight. It was observed that strains significantly affected hundred seeds weight at 5% level of significance. FB 18 + 50 kg NPS/ha contributed maximum hundred seed weight (84.67 gram) which was statistical parity with FB 17 treatment. The lowest hundred seed weight (68.67gm) was recorded from FB 17 + 50 kg NPS/ha treatment which was in statistical parity with the rest treatment except FB 17 and FB 18 + 50 kg NPS/ha treatments. The result indicate that rhizobium strain demonstrate in increment of yield which improve the weight of the seed. Similarly, Endalkachew *et al*., (2016) indicated that hundred seed weight was significantly higher in inoculated treatments in the pot experiment. The weight difference gained from this work could be attributed the effect of the grain filling ability of nitrogen through nitrogen biological fixation (Gedamu *et al*., (2021).

Partial Budget Analysis

The partial budget analysis for marginal rate of return showed that Faba bean rhizobium strains gave acceptable marginal rate of return (i.e., MRR greater than 100%). According to CIMMYT (1988) when there are two and more treatments with MRR greater than 100%, the treatment with greater net benefit should selected for recommendation. Therefore, inoculation of rhizobium strain FB 18 with 50 kg NPS per hectare brought the maximum net benefit 177151 Ethiopian Birr per hectare while possessing MRR of greater than 100% and thus it is economically feasible for Jarso district.

Table 4. Partial budget analysis

SN	Treatment	TVC	adjusted yield	Yield price birr/Kg	Total revenue	Net benefit	Marginal Return
1	Control	1600	1441.2	60	86472	84872	
2	FB18	1920	2053.7	60	123222	121302	11384
3	EAR 15	1940	2278.7	60	136722	134782	67400
4	FB 17	1960	2343.1	60	140586	138626	19220
5	FB 18 + 50 NPS kg/ha	3845	3016.6	6o	180996	177151	2043
6	EAR 15 +50 NPS kg/ha	3865	1925.3	60	115518	111653	
7	FB 17 +50 NPS kg/ha	3885	1994.5	60	119670	115785	206.6
8	RECOM NPS	5450	1902.9	60	114174	108724	

Conclusion and Recommendation

Soil fertility deficiency is the main constraints factor affecting the production and productivity of Pulses crops mainly Faba bean both in terms of quality and quantity. In order to improve the productivity of faba bean, alleviation of soil fertility depletion through proper fertilizer management is very important along with other agronomic practices. The inoculation of the legume seed material with active nitrogen fixing bacteria strains before sowing has a significant role for the increase of the legume yield. Inoculations of rhizobium strain alone and with fertilizer significantly improve yield and yield-related traits of faba bean. As indicated from the result, rhizobium inoculants significantly affected yield and yield components of faba bean at 5% level of significance.

Inoculation of effective rhizobium strain with fertilizer increase the nodule number, plant height, pods per plant, total biomass, grain yield of Faba bean crop. FB 18 strain and applying 50 kg NPS/ha increase biomass and yield 40.39% and 52.22% respectively, as compared to control and the brought the maximum net benefit 177151 Ethiopian Birr. Thus, FB 18 strain with 50 kg NPS/ha recommended in the study district and similar agro ecological zones.

Acknowledgement

We would like to acknowledge Oromia Agricultural Research Institute for financial support provided during whole activity. We also provide thanks to Fedis Agricultural Research Center for providing necessary attention and follow up to conduct the research successfully.

Reference

Abera D; Liben FM; Shimbir T; Balemi T; Erkossa T; Demiss M, Tamene L. 2020. Guideline for Agronomy and Soil Fertility Data Collection in Ethiopia: National Standard. Ethiopian Institute of Agricultural Research (EIAR). Addis Ababa, Ethiopia. 31 p

Agegnehu G (2018). Soil fertility and crop management research on cool-season food legumes in the central highlands of ethiopia. Ethiopian Journal of Agricultural Sciences 28:95-109.

AllitoB.B., Nana Ewusi-Mensah., and AlemnehA.A. 2015. Rhizobia Strain and Host-Legume Interaction Effects on Nitrogen Fixation and Yield of Grain Legume: A Review, Molecular Soil Biology, Vol.6, No.2 1-6 (doi: 10.5376/msb.2015.06.0002)

Anteneh Argaw. 2012. Characterization of rhizobia nodulating faba bean (*Vicia faba* L.) isolated from central Ethiopia. Research Journal of Microbiology 7: 280-296.

Aserse, A.; Markos, D.; Getachew, G.; Yli-Halla, M.; Lindström, K. 2020. Rhizobial inoculation improves drought tolerance, biomass and grain yields of common bean (Phaseolus vulgaris L.) and soybean (Glycine max L.) at Halaba and Boricha in Southern Ethiopia. Arch. Agron. Soil Sci., 66, 488–501.

Batista, L., Irisarri, P., Rebuffo, M., Cuitiño, M.J., Sanjuán, J. and Monza, J. 2015.Nodulation competitiveness as a requisite for improved rhizobial inoculants of *Trifolium pretense*.*BiolFertil Soils*, 51:11-20.

Bezabih Woldekiros. 2018. Response of Faba Bean (*Vicia faba* L.) to Rhizobium Inoculation and Potassium Fertilizer Rates at AlichoWuriro Highland, Southern Ethiopia. International Journal of Research in Agriculture and Forestry, 5(5), pp 43-47.

CIMMYT (International Maize and Wheat Improvement Center). 1998. From agronomic data to farmers recommendations. Economics training manual. Completely revised edition. D. F. Mexico.

CSA (Central Statistics Agency). 2017/2018.The Federal Democratic Republic of Ethiopia Central Statistical Agency agricultural sample survey report on area and production of major crops (private peasant holdings, Meher season), Volume I, Statistical Bulletin 586, Addis Ababa Ethiopia, 2017/18 (2010 E.C.)

Daniel. K.B (2019) Review on: Response of legume crops to Rhizobium Inoculation and Inorganic fertilizers(N,P,K and S) Application in Ethiopia. International journal of research and Innovations in Earth science, volume 6,Issue 4, ISSIN(0nline): 2394-1375

Desta Y, Habtegebrial K, Weldu Y. (2015) Innoculation, Phosphorus and zinc fertilizer rates on nodulation, yield and nutrient uptake of faba bean (Vica faba L.) grown on Calcaric Cambi soil of semiarid Ethiopia. J Soil Sci Enivron Manag.6:9–15.

EIAR (Ethiopian Institute of Agricultural Research) (2016). Rhizobia-based bio-fertilizer manual Ethiopian release lentil varities, (2016). Rust resistant lentil variety Newsletters, seed info. No 50: http: //www.amseed.org/media-center/news/

Fact sheet (2016). The benefit of rhizobium inoculant, Grain research and Development Corporation level 4: east building 4: National circuit Barton act 2600, (www.coretext.com.au.).

Fekadu E, Kibret K, Melese A, Bedadi B. (2018) Yield of Faba bean (Vicia faba L.) as afected by lime, mineral P, farmyard manure, compost and rhizobium in acid soil of Lay Gayint district, northwestern highlands of Ethiopia. Ethiopia: Agriculture and Food Security.

Gedamu, S.A., Tsegaye, E.A. and Beyene, T.F., 2021. Effect of rhizobial inoculants on yield and yield components of faba bean (Vicia fabae L.) on vertisol of Wereillu District, South Wollo, Ethiopia. CABI Agriculture and Bioscience, 2(1), pp.1-10.

Getachew A, Berhane L, Paul NN. 2014. Cropping sequence and nitrogen fertilizer effects on the productivity and quality of malting barley and soil fertility in the Ethiopian highlands. Arch Agron Soil Sci. 2014a. 60(9): 1261- 1275.

Getachew A, VanBeek C, Michael IB. 2014. Influence of integrated soil fertility management in wheat and tef productivity and soil chemical properties in the highland tropical environment. J Soil Sci Plant Nutr, 2014b. 14: 532-545.

Gete Z, Getachew A, Dejene A, Shahidur R. 2010. Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system. IFPRI, Addis Ababa, Ethiopia, 2010. 63.

Godara AS, Gupta US, Singh R. 2012.Effect of integrated nutrient management on herbage, dry fodder yield and quality of oat (*Avena sativa* L.). Forage Research, 2012. 38(1): 59-61.

Gorfu, D.; Mulugeta, W.; Keneni, G. Faba Bean Galls 2012: A New Disease of Faba Bean in Ethiopia; Holeta Agricultural Research Center, Ethiopian Institute of Agricultural Research: Addis Ababa, Ethiopia.

Habtemichial KH, Singh BR, Aune JB. 2007. Wheat response to N fixed by faba bean (*Viciafaba* L.) as affected by sulfur fertilization and rhizobial inoculation in semiarid Northern Ethiopia. J Plant Nutr Soil Sci., 2007, 170: 412-418.

Hailemariam A, Tsigie A (2006). Symbiotic nitrogen fixation research on food legumes in Ethiopia. In: Proceedings of a Workshop on Food and Forage Legumes (Kemal A, Gemechu K, Seid A, Rajendra M, Surendra B, and Khaled M eds). ICARDA, Addis Ababa, Ethiopia. pp. 172-176.

Jones J.B., 2003. Agronomic Handbook: Management of Crops, Soils, and Their Fertility. CRC Press LLC, Boca Raton, FL, USA. pp.482.

Kebede, P.K. and Lele, T.T., 2022. Performance of Rhizobial In-oculants on Yield and Yield Components of Faba Bean in South-ern Ethiopia. *Arch Crop Sci*, *5*(1), pp.126-130.

Kopke U, Nemecek T. 2010. Ecological services of faba bean. Field Crops Res, 2010. 115: 217–233.

Kudapa H., Ramalingam A., Nayakoti S., Chen X., ZhuangW.J., Liang X., Kahl G., Edwards D., and VarshneyR.K. 2013. Functional genomics of study stress responses in crop legumes: progress and prospects, Funct. Plant Biol., 40: 1221-1233.http://dx.doi.org/10.1071/FP13191

Livija Zarina, Ina Alsina, AijaVaivode. 2017. Effectiveness of Rhizobial Strains on the Faba Bean Development and Yield in Soddy Podzolic Soils. Environment.Technology.Resources, 2017. 1: 305-308.

Mahajan A, BhagatRM, Gupta RD. 2008. Integrated nutrient management in sustainable rice-wheat cropping system for food security in India.SAARC J Agric, 2008. 6(2): 29-32.

MoA (Ministry of Agriculture), 2011.Animal and plant health regulation directorate.Crop variety register. Issue No. 14. Addis Ababa, Ethiopia, 2011, pp. 71-73.

Mulas, D., Seco, V., Casquero, P.A., Velázquez, E. and González-Andrés, F. 2015. Inoculation with indigenous Rhizobium strains increases yields of common bean (*Phaseolusvulgaris* L.) in northern Spain, although its efficiency is affected by the tillage system. Symbiosis, 2015, 67: 113-124.

Nebiyu A (2014). Role of faba bean (Vicia faba L.) for intensification of cereal-based cropping systems in the humid highlands of Ethiopia. PhD thesis, Ghent University, Gent, Belgium. p 201.

Proskina L, Cerina S, Zeverte-Rivza S. 2016. Faba beans as an alternative protein source for broiler chicken feed.Proceedings of the 2016 International Conference "Economic Science For Rural Development',41, Jelgava, LLUESAF, 2016. 265-272.

Reda A Abdel-Aziz, Talaat N El-Sebai, Said M BadrEl-Din, and Salah A Abo-Sedera. 2016. Field Application of Bio-Fertilizers Technology on Faba Bean Growth and Yield.Research Journal of Pharmaceutical, Biological and Chemical Sciences7(3)2016 Page No. 2481

Saidi S, Ramírez-Bahena MH, Santillana N, Zuniga D, Alvarez-Martínez E, *et al*. 2014. ***Rhizobium laguerreaesp***. nov.nodulates*Viciafaba* on several continents. Int J SystEvol Microbial, 2014. 64: 242–247.

Siczek A, Lipiec J. 2016. Impact of Faba Bean-Seed Rhizobial Inoculation on Microbial Activity in the Rhizosphere Soil during Growing Season.Int J MolSci, 2016. 17: 784

Tekalign Tadese. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa, Ethiopia.

ToleraAbera, Ernest Semu, TolessaDebele, DagneWegary and Haekoo Kim. 2015. Determination Soil Rhizobium Populations, Intrinsic Antibiotic Resistance, Nodulation and Seed Yield of Faba Bean and Soybean in Western Ethiopia. World Journal of Agricultural Sciences 11 (5) 2015: 311-324, 2015

Upendra MS, Lenssen AW, Barsotti JL.2013. Dry land malt barley yield and quality affected by tillage, cropping sequence, and nitrogen fertilization. Agron J, 2013. 105: 329-340.

Yirga, C, Shahidur R, Befekadu B, Solomon L (2010). Pulses value chain potential in Ethiopia; Constraints and Opportunities for Enhancing Exports. IFPRI, Addis ababa, Ethiopia.pp.32-41.

Zerihun Belay and FassilAssefa. 2011. Symbiotic and phenotypic diversity of Rhizobium leguminosarumbv. viciae from Northern Gondar, Ethiopia. African Journal of Biotechnology 10, 2011: 4372- 4379.

Determination of NPS Fertilizer Rate on Bread Wheat (Triticum Aestivum L.) in Yaya Gullele District of North Shewa Zone, Oromia, Ethiopia

Dereje Girma* Dejene Getahun , Tadele Geremu, Abera Donis and Meron Tolosa
Fitche Agricultural Research Center
*Corresponding author Email: dergrima@gmail.com

Abstract

Inappropriate crop management practices are among the key elements that contributed to the low production of wheat. Moreover, the application of balanced fertilizers and nutrient requirements of the crop is the basis to produce more crop yield from the land under cultivation. Hence, a field experiment was conducted in the 2020 & 2021 main cropping season to determine the NPS fertilizer rate in relative to determined the P-critical and P-requirement factor for wheat and to estimate the economically feasible NPS fertilizer rate for higher yield of wheat in Yaya gulale District. Accordingly the result indicated that, plant height was not significantly (P > 0.05) influenced by the NPS fertilizer rate but spike length, biomass, and grain yield were highly significantly (P < 0.05) affected by the NPS fertilizer rate. The highest plant height (86.72cm), spike length (6.57cm), biomass yield (12163kg ha^{-1}) and grain yield (3327 kg ha^{-1}) of wheat were recorded by the application of 75% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field without fertilizer which was significantly inferior to all other treatments. Furthermore, the economic analysis indicates that, application of NPS fertilizer at the rate of 75% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of wheat was more economically beneficial for the district. In conclusion, farmers and other end users could be advised to use 75% PC from NPS fertilizer rate with recommended nitrogen for wheat production in the district and other areas having similar soil types and agro- ecology.

Keywords: Bread wheat Pc,Pf, NPS fertilizer rate , Recommended Nitrogen, yield

Introduction

Ethiopia is the largest wheat producer in sub-Saharan Africa with about 0.75 million ha of durum and bread wheat (Hailu *et al.*, 1991). Wheat is one of the major cereal crops grown in the Ethiopian highlands, which lie between 6 and 16° N, and 35 and 42° E, at altitudes ranging from 1500 to 3000 m. At present, wheat is produced solely under rain fed conditions. Currently, about 60% of the wheat area is covered by durum and 40% by bread wheat. Wheat is the fifth most important cereal crop both in area and production after Teff, maize, barley and sorghum (Hailu *et al.*, 1991).

Soils in sub-Saharan African (SSA) are degraded with low nutrient availability. This is partly a result of erosion, leaching, and depletion through clearing and cultivation of the land with minimal use of external sources of nutrients (Stoorvogel *et al.*, 1993; Bekunda *et al.*, 1997). The rate of soil fertility decline depends on soil erosion, nutrient removal in harvests, the rate at which nutrients are returned to the soil through the use of both inorganic fertilizer and organic manures, and the rate of mineralization of soil mineral and organic matter nutrients. The economic consequences of soil fertility/nutrient depletion are great with reduced farm production and food security. For the last three decades, Ethiopian agriculture depended solely on imported fertilizer products, only urea and diammonium phosphate (DAP), sources of N and P. However, recently it is perceived that the production of such high protein cereals like wheat and legumes can be limited by the deficiency of S and other nutrients. In Ethiopia, major prone areas to Sulfur deficiency are the central highlands, because of their high crop production, which is driven by high market access in the big towns/cities in the center of the country. Reasons that lead to S deficiency in soils of central high lands include improved use of high analysis fertilizers that contain no S, intensive agriculture that leaves behind little organic matter (OM), and/or complete removal of OM for alternative uses, including farm yard manure (FYM), increased crop yields due to high yielding varieties, resulting in more Sulfur removal, and intensive cropping systems that include legumes and oil crops that mine more Sulfur.

Sulfur is a nutrient most overlooked in Ethiopian agriculture. In Ethiopia, the incidental addition of Sulfur from low analysis sources is nil due to a shift to high analysis fertilizers. It is true that farmers and extensions can indeed aim at increasing crop yields only in quantity by applying significantly higher amounts of NP from urea and DAP. But, in such conditions, failure to supplement Sulfur in balanced fertilizer programs can rapidly deplete available soil reserve leading to hidden Sulfur deficiency. Regardless of its importance, very little research is done on the status of soils and crops, and the available information/data are quite scanty. Furthermore, nitrogen and phosphorus are considered the most deficient nutrients in the soils of Ethiopia (Asnakew *et al.,* 1991). This indicates that nitrogen and phosphorus are the most yield limiting factors of cereals including wheat production in Ethiopia. Soil fertility status also varies within adjacent farms or plots mainly due to preceding individual farmers's soil management practices.

Therefore, developing site specific fertilizer recommendations that consider existing soil nutrient supply and recommend fertilizer based on crop nutrient demand to achieve target yield is required. The site and crop specific fertilizer recommendation is very useful for easy adoption of technologies as it better increases productivity as compared to the blanket recommendation. Site and crop specific recommendation is resulted from solving the real production constraints in the specific area. Since, Ethiopia is moving from blanket recommendations to soil test based fertilizer recommendations, Fitche Agricultural Research Center conducted research to determine critical phosphorus and phosphorus requirement factors for bread wheat in the Yaya Gulale district, North Shewa Zone. However, the effect of the NPS fertilizer rate was not determined for bread wheat in the study area. Thus, based on the determined Pc (23 ppm) and Pf (3.76), optimum NPS fertilizer rate determination was carried out in the study area with the objectives; to determine the NPS fertilizer rate relative to the determined P-critical for bread wheat and estimate the economically feasible NPS fertilizer rate for higher yield of bread wheat in the Yaya Gulale district

Materials and Methods

Description of the Experimental Site

The experiment was conducted in the Yaya Gullele district during the 2012 and 2013 cropping seasons on wheat potential kebeles.The district is located 131 kilometers far from Finfinne in North West direction. The district has a total population of 155,233 with 52 and 48 percent males and females, respectively. The district is located between $09^0$29'30" to $09^0$41'30"N and $38^0$30'00" to $38^0$45'00"E and at an average elevation of 2800 masl. The mean annual rainfall of the area is 1000mm which ranges from 800 to 1200 and bimodal rainfall pattern. The average daily minimum and maximum temperatures of the district are 16 and 20 ^{0}C, respectively.

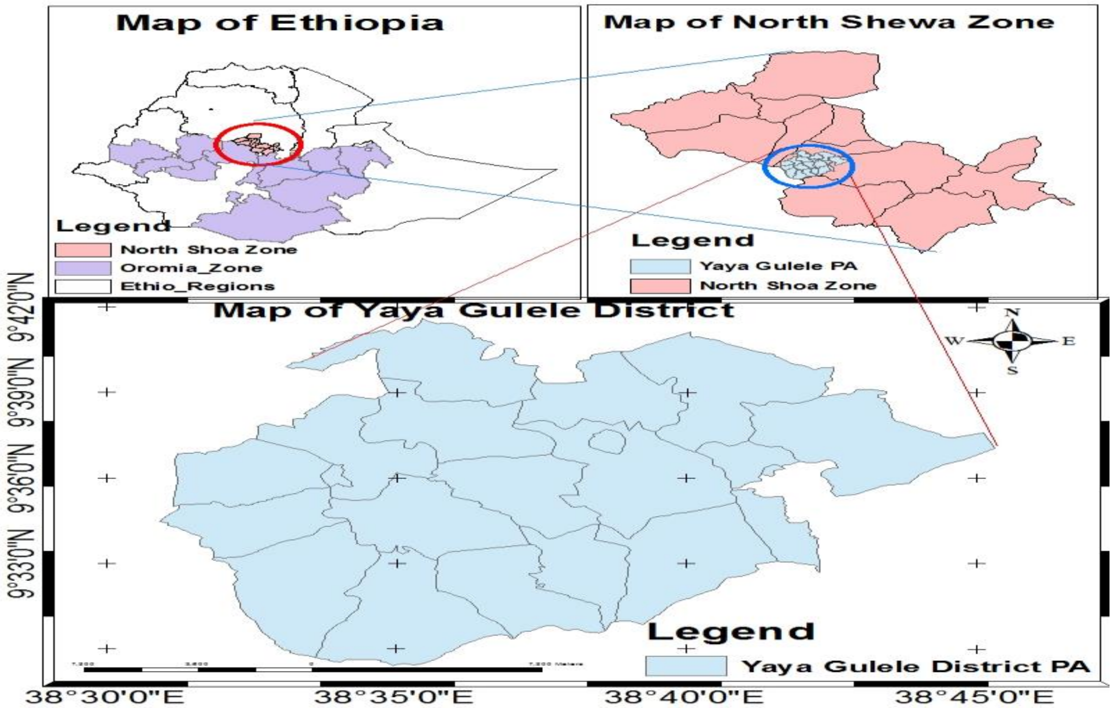


Fig.1 Location map of Yaya Gulele District

Site Selection, Soil Sampling, and Analysis Methods
Wheat production potential kebeles were selected with the office of Agriculture and Natural resource office from Yaya gulale District. Accordingly, the 11 farmer's fields were selected based on their willingness to handle the experimental fields. Before planting, 30(thirty) surface composite soil samples were collected from the farmers' field for analysis at a depth of 0-20 cm in a zig zag method. Soil samples were collected using auger. The collected surface soil samples from the experimental field were air dried, grinded and allowed to pass through 2 mm sieve for further analysis in the laboratory (FAO, 2008).

The collected soil samples were analyzed for the parameters of pH (H_2O) in the suspension of a 1: 2.5 soil to water ratio using a pH meter (Rhoades, 1982). A Organic carbon was determined by Wakley and Black procedure. Organic matter was estimated as organic carbon multiplied by 1.724. Total Nitrogen was determined by the micro Kjeldahl method and available P was determined by Olsen's method using a spectrophotometer (Olsen *et al*., 1954). Then the farmer's field was selected based on the analyzed soil sample results in which the available soil phosphorus below critical phosphorus (Pc) was selected for the experiments.

Experimental Design and Treatments
The experimental field study was arranged with a total of 6 treatments in a randomized complete block design (RCBD) in three replications. The recommended Nitrogen (92 kg ha^{-1}) for the district was used. The gross plot size was 3m*3m and the space between the block and plot was 70cm and 30cm respectively. The required amount of seeds were weighed per plot by considering the recommended rate (150 kg ha^{-1}) of wheat seed per hectare. Urea, NPS, and DAP (Di ammonium Phosphate) were used as a source of nitrogen

and phosphorus containing fertilizers. Uniform field management practices for all plots were conducted. A bread wheat variety (Sanate) was used as a test crop.

The treatment were:

T1=Control (No fertilizer).

T2=25% P-critical in NPS +Recommended Nitrogen
T3=50% P-critical in NPS + Recommended Nitrogen
T4=75% P-critical in NPS + Recommended Nitrogen
T5=100% P-critical in NPS + Recommended Nitrogen
T6=100% P-critical in DAP + Recommended Nitrogen
Note: Where recommended Nitrogen is 92Kg N/ha.

The determined P-critical value (23 ppm) and phosphorous requirement factor (3.76) were used to calculate the rate of phosphorus fertilizer to be applied. Thus, the Phosphorus fertilizer rate was calculated by using the formula given below;

Rate of P-applied= (pc-pi)*pf

Where: Pc: Critical phosphorus concentration; P: Initial available P; Pf: Phosphorus requirement factor which was derived from the calibration study

Data Collected

Wheat grain yields were harvested at the ground level from the net plot area. Then plant height and spike length was measured at harvest. After threshing, grain yield were cleaned and weighed. The total above ground biomass yield for each respective treatment was recorded. Economic data such as production cost (input cost), gross income, and net income based on the current market price of the yield and input was recorded.

Data Analysis

All data recorded and collected were subjected to the procedure of analysis of variance (ANOVA) using GenStat 18th edition software program. The comparisons among treatment means were employed by using of Least Significance Difference (LSD) at a 5% significant level.

Economic Analysis

Partial budget analysis was done to identify economic feasibility. The average open market price (Birr kg^{-1}) of tef, price of fertilizers was used for analysis. For a treatment to be considered a worthwhile option to farmer, the minimum acceptable rate of return (MRR) should be 100 % (CIMMT, 1988), which is suggested to be realistic. This enables to make recommendations from marginal analysis. The Marginal rate of return (MRR) was calculated by using the formula given below;

$$\text{MRR (\%)} = \frac{\text{Net Income From Fertilized Field} - \text{Net Income From Unfertilized Field}}{\text{Total Variable Cost From Fertilizer Application}}$$

Result and Discussions

Status of Soil Chemical Properties of Experimental Site

The pre-sowing composite surface soil sample (0-20 cm) collected from the experimental site was analyzed for some selected soil chemical properties (Table 1). The pre sowing soil analysis showed that the experimental soil has a pH (H_2O) of 5.63 found in moderately acid according to the rating of Tekalign (1991). FAO (2000) reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil is within the range for productive soils. The soil organic carbon and total nitrogen content of 2.2% and 0.2 % were found in medium/ moderate range respectively as ratting of Tekalign (1991). The available phosphorous content of the study area is 8.03ppm found in the medium range as the rating of Olsen *et al*., (1954).

Table 1: Soil status of the experimental site

Site	PH	OC (%)	TN (%)	Av.P (ppm)
1	5.88	1.7	0.15	12.73
2	5.82	2.19	0.19	5.31
3	5.75	2.99	0.26	12.52
4	5.87	2.39	0.21	4.63
5	5.58	2.29	0.2	10.1
6	5.6	2.19	0.19	6.68
7	5.67	2	0.17	4.84
8	5.27	3.89	0.34	6.55
9	5.29	1.2	0.1	14.9
10	5.73	1.6	0.14	8.25
11	5.46	1.5	0.13	1.79
Mean	5.6	2.2	0.2	8.03

Where OC= Organic Carbon, TN= Total Nitrogen, Av P = Available phosphorous

Response of yield and yield component of Wheat to NPS Fertilizer Rate

Plant Height

From the analysis of variance plant height was not significantly influenced due to the effect of NPS fertilizer rate ($p>0.05$). The mean of the tallest plant height of 86.72cm was recorded from the application of 75% PC from NPS with optimum N fertilizers while the shortest plants 57.21cm were recorded from zero plot fertilizer application (Table 2). The result indicated that plant height increased with an increased up to the optimum NPS fertilizer rate based on calibrated phosphorus supplemented by Nitrogen fertilizer. The increment in plant height might be due to an increase in cell elongation and vegetative growth attributed to the different nutrient content of NPS fertilizer and the increase of sulfur content caused a significant increase in wheat root and shoot growth as well as nutrient uptake. In conformity with this result, Tilahun and Tamado, 2019, Abera *et al.*, 2021 and Tigist *et al.*, 2021 reported that increased application of balanced fertilizer significantly increased plant height of wheat.

Spike Length

The result of analysis variance showed that spike length was highly significant ($P < 0.05$) , and affected by the NPS fertilizer rate. The tallest (6.57cm) and the shortest (4.29cm) spike length was recorded from the application of 75% PC from NPS supplemented with optimum N fertilizers and unfertilizer fields respectively (Table 2). The fertilizer application up to 75% PC from NPS an indicate increasing tendency of spike length with optimum nitrogen fertilizer. This might be due to an adequate and balanced nutrient supply especially nitrogen, phosphorus and sulfur available in the formulation of applied NPS fertilizer as in the fact that it has a great role in cell division and grain filling there by it attributes to increased spike length. These results are in agreement with Diriba *et al.*, 2019 reported that spike length was significantly affected by NPS fertilizer rate and the longest spike length was observed at the highest application of fertilizers.

Table **2.** Effects of NPS Fertilizer rate and recommended Nitrogen on yield components of bread wheat

Treatment	pH (cm)	SL (cm)	Biomass kg ha^{-1}	Grain yield kg ha^{-1}
without fertilizer	57.21^{b}	4.29^{e}	4437^{e}	1130^{e}
25% P-critical from NPS +Recommended Nitrogen	76.09^{a}	5.57^{d}	8447 ^{d}	2348^{d}
50% P-critical from NPS+ Recommended Nitrogen	79.44^{a}	5.88^{cd}	9694 ^{c}	2664^{cd}
75% P-critical from NPS +Recommended Nitro	86.72^{a}	6.57^{a}	12163^{a}	3327^{a}
100% P-critical fromNPS+Recommended Nitrogen	84.19^{a}	6.31^{ab}	11463 ^{ab}	3114 ^{ab}
100% P-critical from DAP fertilizer +Recommended Nitrogen	81.66a	6.207bc	10598bc	2911bc
$LSD_{0.05}$	12.04	0.344	912.690	335.9
CV (%)	32.0	12.2	19.9	26.8

Means with the same letter in columns are not significantly different at 5% level of significance's, PH=plant height, SL= Spike length CV=Coefficient of variation, LSD=Least Significance Difference.

Biomass Yield

Biomass yield was significantly ($P < 0.05$) affected by the NPS fertilizer rate. The highest biomass yield 12163 kg ha^{-1} was obtained at an application of 75% P-critical from NPS fertilizer with recommended Nitrogen and the lowest biomass yield of 443 kg ha^{-1} was registered from the control plot (Table 2). The result is consistent with that of Usman *et al.*, 2020, and Diriba *et al.*, 2019 who reported an increase in biomass yield of bread wheat with increased application of balanced fertilizers with nitrogen.

Grain Yield

Grain yield is the result of many complex morphological and physiological processes occurring during the growth and development of crops (Khan *et al.*,2008). The analysis of variance showed that the grain yield of wheat was significantly ($P < 0.05$) influenced by the NPS fertilizer rate. The highest grain yield (3327 kg ha^{-1}) was obtained from the application of 75% P-critical from NPS fertilizer rate supplemented with optimum recommended Nitrogen while the lowest (1130 kg ha^{-1}) grain yield was recorded from the fields without fertilizers. The highest grain yield at the highest rates of NPS and nitrogen might be connected with provision of adequate plant nutrient requirements which results in the induction of more productive tillers that directly correlated with the production of better yields. This result is in agreement with Abera *et al.*, 2021 who reported that, the maximum grain yield of bread wheat was recorded at the highest application of balanced fertilizer .

Economic Analysis

Economic analysis was performed to investigate the economic feasibility of the treatments. The economic analysis showed that the highest net benefit (110941.16 ETB ha^{-1}) was obtained from the application of 75% Pc from NPS with recommended nitrogen, whereas the least net benefit (39550.0ETB ha^{-1}) was obtained from the unfertilized treatment (Table 3). The highest marginal rate of return (MRR) (1297.12 %) obtained from the fertilizer application of 75 % P-critical from NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}). The MRR was indicated that bread wheat producers can get an extra 12.97 ETB for 1.00 ETB investments in the NPS and N fertilizers application on the rates of 75 % P-critical in NPS fertilizer with recommended Nitrogen fertilizer. Therefore, application of NPS fertilizer at the rate of 75 % P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of bread wheat was more economically profitable.

Table 3. Marginal Analysis of Bread Wheat Yield as influenced by NPS Fertilizer Supplemented by Nitrogen Rate

Treatment	Variable Input (Kg ha^{-1})		Unit price(ETB)		TVC	Output (Kg ha^{-1})	Unit price (ETB)	Gross Income (ETB ha^{-1})	Net Income (ETB ha^{-1})	MRR (%)
	DAP/ NPS	Urea	DAP/NPS	Urea						
without fertilizer	0	0	0	0	0	1130	35	39550	39550.0	
25% Pc NPS +N	85	165	1363.7	2476	3839.7	2348	35	82180	78340.3	1010.24
50% Pc NPS +N	170	130	2727.4	1950.79	4678.19	2664	35	93240	88561.81	1047.67
75% Pc NPS +N	254.2	95	4078.26	1425.58	5503.84	3327	35	116445	110941.16	1297.12
100% Pc NPS +N	339.2	60	5441.96	900.37	6342.33	3114	35	108990	102647.67	994.87
100% Pc DAP +N	280	90	4577.75	1350.55	5928.3	2911	35	101885	95956.7	951.48

Where: ETB = Ethiopian Birr, TVC = Total Variable Cost, MRR = Marginal Rate of Return, PC = Critical phosphorus, Rec. N = Recommended Nitrogen

Conclusion and Recommendations

Inappropriate crop management practices are among the key elements that contributed to the low production of wheat. Moreover, the application of balanced fertilizers and nutrient requirements of the crop is the basis to produce more crop yield from the land under cultivation. According to this study the NPS fertilizer rate based on calibrated phosphorus significantly influences the yield and yield component of wheat which is at a promising level to sustain soil fertility and tackle the problems. Therefore, the study was conducted to determine the effect of NPS fertilizer rate in relative to determined critical phosphorus for wheat in Yaya gulale District.

The analysis of variance depicted that, plant height was not significantly (P >0.05) influenced by NPS fertilizer rate while spike length, biomass and grain yield was significantly (P<0.05) affected by NPS fertilizer rate. The highest plant height (86.72cm), spike length (6.57cm), biomass yield (12163kg ha^{-1}) and grain yield (3327 kg ha^{-1}) of wheat were recorded from the application of 75% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field without fertilizer which was significantly inferior to all other treatments. Furthermore, the economic analysis depicted that, application of NPS fertilizer at the rate of 75% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of wheat was more economically beneficial for the districts. Therefore, farmers could be advised to use 75 % PC from NPS fertilizer rate with recommended nitrogen for wheat production in the district. Demonstration and further scale up as well as verification at other district of similar soil type agro-ecology should be pre requisite.

Acknowledgements

We kindly thank the Oromia Agricultural Research institute for financially supporting the study. We are also grateful to Fitche Agricultural Research Center and Agricultural office of the district for facilitating the experiment.

References

Donis, A., Getahun, D., Geremu, T., Girma, D., Feyisa, A., Dejene, L., & Tolosa, M. (2021). Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Yield of Bread Wheat in Wachale District, North Shewa Zone, Oromia, Ethiopia. *American Journal of Plant Biology*, *6*(3), 73-77.

Bekunda, M. A., Bationo, A., & Ssali, H. (1997). Soil fertility management in Africa: A review of selected research trials. *Replenishing soil fertility in Africa*, *51*, 63-79.

CIMMYT Economics Program. (1988). *From Agronomic Data to Farmer Recommendations: An Economics Workbook*. CIMMYT.

Diriba Shiferaw, G., Rut-Duga, D., & Wogayehu, W. (2019). Effects of blended fertilizer rates on bread wheat (Triticum aestivum L.) varieties on growth and yield attributes. *J Ecol & Nat Resour*, *3*(3), 1-13.

FAO, 2000. The State of Food and Agriculture . FAO Agriculture Series. No. 32. Rome, Italy, pp: 353 Fikrineh N, Fiseha T, Shimelis G, Megersa F.,-ZFRRC ,Tilahun F and AbrehamF(2017).Participatory Agricultural Production Constraint Analysis in Oromia .

Gebre-Mariam, H., Tanner, D. G., & Hulluka, M. (1991). *Wheat research in Ethiopia: a historical perspective*. Institute of Agricultural Research

Jansen, J. A., Wortmann, C. S., Stockton, M. A., & Kaizzi, C. K. (2013). Maximizing net returns to financially constrained fertilizer use. *Agronomy Journal*, *105*(3), 573-578.

Jones Jr, J. B., Eck, H. V., & Voss, R. (1990). Plant analysis as an aid in fertilizing corn and grain sorghum. *Soil testing and plant analysis*, *3*, 521-547.

Kaizzi KC and Wortmann CS (2015) Optimizing fertilizer use within an integrated soil fertility management framework: Fertilizer Optimizer Training Manual. http://agronomy.unl.edu/OFRA.

Khan, H. Z., Malik, M. A., & Saleem, M. F. (2008). Effect of rate and source of organic material on the production potential of spring maize (Zea mays L.). *Pak. J. Agric. Sci*, *45*(1), 40-43.

Olsen, S. R. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate* (No. 939). US Department of Agriculture.

Stoorvogel, J. J., Smaling, E. M., & Janssen, B. H. (1993). Calculating soil nutrient balances in Africa at different scales. *Fertilizer research*, *35*(3), 227-235.

Mamo, T., & Haque, I. (1991). Phosphorus status of some Ethiopian soils, II. Forms and distribution of inorganic phosphates and their relation to available phosphorus. *Tropical Agriculture*, *68*(1).

Tesfaye, T., Laekemariam, F., & Habte, A. (2021). Response of bread wheat (Triticum aestivum L.) to potassium (K) and blended NPS fertilizer rates in the nitisols of Southern Ethiopia. *Applied and Environmental Soil Science*, *2021*.

Tilahun, A. I., & Tamado, T. (2019). Growth, yield component and yield response of durum wheat (Triticum turgidum L. var. Durum) to blended NPS fertilizer supplemented with N rates at Arsi Negelle, Central Ethiopia. *African Journal of Plant Science*, *13*(1), 9-20.

Kedir, U., Tana, T., & Worku, W. (2020). Effects of blended (NPSB) fertilizer rates on yield components, yield and grain quality of bread wheat (Triticum Aestivum L.) varieties at Kulumsa, South-Eastern Ethiopia. *International Journal of Research Studies in Biosciences*, *8*(9), 14-27.

Asnakew Wolde-ab, Tekalign Mamo, Mengesha Bekele and Tefera Ajema. 1991. Soil Fertility Management of wheat in Ethiopia. pp. 112-144. In: Hailu Gebre Mariam, Tanner, D.G and Mengestu Hulluka (ed). Wheat Research in Ethiopia historical perspective. IAR/CIMMYT, Addis Ababa

Determination of NPS fertilizer rate on yield and yield component of Teff [Eragrostis tef (Zucc.) Trotter] in Kuyu District North Shewa Zone, Oromia, Ethiopia

Dereje Girma * Tadele Geremu, Dejene Getahun , Abera Donis and Meron Tolosa
Fitche Agricultural Research Center
*Corresponding author Email: dergrima@gmail.com

Abstract

Teff is the main staple food of Ethiopia. It ranks first among cereals in the country in area coverage and second in production volume; however, its productivity is almost stagnant. The Degim Teff variety was sown during the main cropping season of 2020 and 2021 in the kuyu District, Northern Oromia, and Ethiopia. The objective of this study was to determine the NPS fertilizer rate relative to determined P-critical and P-requirement factor for Teff and to estimate the economically feasible NPS fertilizer rate for higher yield of TeFf in kuyu District. Accordingly, the statically analysis of variance showed that, plant height, panicle length, biomass and grain yield were significantly ($P<0.05$) influenced by NPS fertilizer rate with N fertilizer. The highest plant height (83.59 cm), of tef was recorded from the application of 75% P-critical from NPS fertilizer rate with recommended Nitrogen but panicle length (29.05cm), biomass yield (7509 kg ha^{-1}) and grain yield (1635 kg ha^{-1}) of Teff were recorded from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field unfertilized which was significantly inferior to all other treatments. Furthermore, the economic analysis showed that, application of NPS fertilizer at the rate of 100% P-critical from NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of Teff was more economically beneficial for the district. Moreover, farmers and other end users could be advised to use 100% PC from NPS fertilizer rate with recommended nitrogen for Teff production in the district and other area having similar soil type and agro- ecology.

Keywords: NPS fertilizer rate, Nitrogen fertilizer, Teff, yield,

Introduction

In Ethiopia Teff occupies about 3.01 million hectares (27% of the cereal crop area) of land which is more than any other major cereals such as maize (22.7%), sorghum (19%) and wheat (16%) (CSA), 2013). Ethiopian farmers prefer Teff, because the grain and straw bring good prices. Its production area is increasing at unprecedented scale due to increased market demand both in the local and foreign market. Teff is used in Ethiopia to produce the nation's staple dish enjera. Grinding Teff grain into flour and mixing with water results in a spongy type of pancake.

Teff is also used to brew local beer. It has high protein, fiber and complex carbohydrates content, relatively low calorie content, and is gluten free (Berhane *et al.* 2011; ATA 2013c). It accounts for between 11 and 15 percent of all calories consumed in Ethiopia (Berhane *et al*. 2011, ATA 2013c) and provides about 66 percent of daily protein intake (Fufa *et al.* 2011). Almost two thirds of the Ethiopian population use Teff as their daily staple food. It is estimated that per capita consumption grew by 4 percent over the last 5 years (ATA, 2013c). Teff is considered an economically superior good, relatively more consumed by urban and richer consumers (Berhane *et al.*, 2011; Minten *et al.*, 2013). In urban areas, the share of per capita tef consumption in total food expenditure is 23 percent, while in rural area this is only 6 percent. In rural areas, tef is seen as a luxurious grain consumed only by elders or during special occasions. Growth in average incomes and faster urbanization in Ethiopia are likely to increase the demand for Teff over time (Berhane *et al*., 2011). Even though, Ethiopia is a center of origin and diversity of Teff and has the above-mentioned importance and coverage of large area, its productivity is very low to feed the demand of its people and market.

These are due to low soil fertility and suboptimal use of mineral fertilizers In addition to weeds, lack of high yielding cultivars, erratic rainfall distribution in lower altitudes, lodging, water logging, low moisture, and low soil fertility conditions (Fufa, 1998). On the other hand, under conditions where most growth requirements are available and in organic matter rich soils, Application of fertilizers without knowing its fertility status causes yield and fertilizer losses (Tekalign *et al.,* 2001). There are different blanket fertilizer recommendations for various soil types of Ethiopia for Teff cultivation. This is due to its cultivation in different agro ecological zones and soil types, having different fertility status and nutrient content. Thus, 100 kg DAP ha^{-1} and 100 kg urea ha^{-1} were set by the Ministry of Agriculture and Rural Development later (Kenea *et al.,* 2001).

Those blanket recommendations brought generally, an increase in yield of improved cultivars ranging from 1700 to 2200 kg/ha (Seyfu, 1997). Accordingly, the average national yield in the year 2010 reached 1200 kg/ha (CSA, 2010) However, the recommendations do not work for all Production aspects of various soil types of different regions. Soil test based application of plant nutrients helps to realize a higher response ratio: As the nutrients are applied in proportion to the magnitude of the deficiency of a particular nutrient and, Correction of the nutrients imbalance in soil helps to harness the synergistic effects of balanced fertilization location specific fertilizer recommendations are possible for soils of varying fertility, resource conditions of farmers and level of target yield conditions of similar soil classes and environment (Ahmed *et al.,* 2002).

Now a day’s farmers are using those blended fertilizer suggested by Ethio SIS in the area where there are deficient in the soil without any recommendation of crop response to the respective fertilizers. However, the effect of NPS fertilizer rate was not determined for Teff in the study area. Thus, based on the determined Pc (10 ppm) and Pf (3.03), optimum NPS fertilizer rate determination was carried out in the study area with the objectives; to determine NPS fertilizer rate in relative to determined P-critical and P-requirement factor for tef and to estimate the economically feasible NPS fertilizer rate for higher yield of tef in kuyu District.

Material and Methods

Description of the Experimental Site

The study was carried out in Kuyu district North Shewa Zone Oromia. The district is located 42 km from the zonal capital Fiche and 156 km from Finfinne to north direction. Geographical location existed between $9^{0}35$`- $9^{o}49$’N latitude and $38^{o}03$’-$38^{o}31$’E and at an average elevation 2757 meters above sea level. The average annual rainfall ranges from 1,600-1,800 mm, while the average annual temperatures vary between 15^{o}c and 18^{o}c.

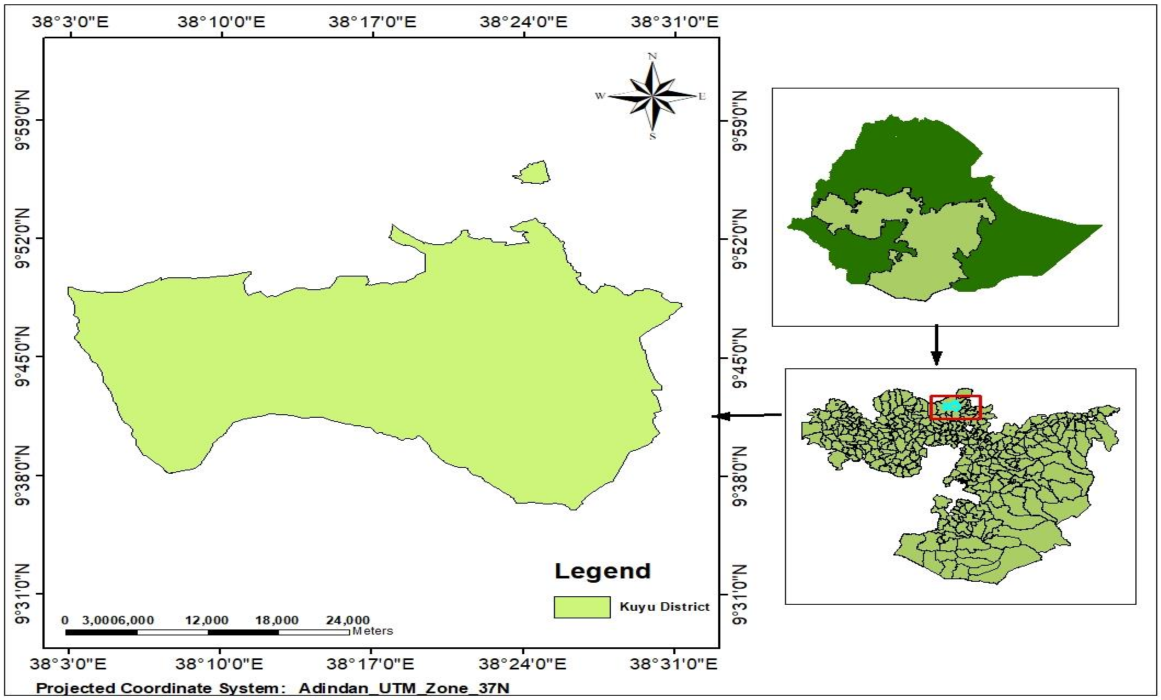


Fig. 1. Map of the study area

Site Selection, Soil Sampling and Analysis Methods

Teff production potential kebeles were selected from the district. Accordingly, the 10 farmer's fields were selected based on their willingness to handle the experimental fields. Before planting, 40 surface composite soil samples were collected for two years from Farmers fields for analysis at a depth of 0-20 cm in a zigzag methods. The collected surface soil samples from the experimental field were air dried, grinded and allowed to pass through a 2 mm sieve for further analysis in the laboratory (FAO, 2008). The collected soil samples were analyzed for the pH (H_2O) in the suspension of a 1:2.5 soil to water ratio using a pH meter (Rhoades, 1982). Organic carbon was determined by Wakley and Black procedure. Organic matter was estimated as organic carbon multiplied by 1.724. Total Nitrogen was determined by the micro Kjeldahl method and available P was determined Olsen's method using a spectrophotometer (Olsen *et al*., 1954). Then the farmer's field was selected based on the analyzed soil sample results in which the available soil phosphorus below critical phosphorus (Pc) was selected for the experiments.

Experimental Design and Treatments

The trial field study was arranged with a total of 6 treatments in a randomized complete block design (RCBD) in three replications. The recommended Nitrogen (92 kg ha^{-1}) for the district was used. The gross plot size was 3m * 3m and the space between block and plot was 70cm and 30cm respectively. The required amount of seeds was weighed per plot by considering the recommended rate of Teff seed per hectare. Urea, NPS, and DAP (Di ammonium Phosphate) was used as a source of Nitrogen and Phosphorus containing fertilizers. Uniform field management practices for all plots were conducted. A Teff variety (Dagim) was used as a test crop.

The treatments were;

T1 = Control (without fertilizers).

T2 = 25% P-critical from NPS fertilizer +Recommended Nitrogen

T3 = 50% P-critical from NPS fertilizer + Recommended Nitrogen

T4 = 75% P-critical from NPS fertilizer + Recommended Nitrogen

T5 = 100% P-critical from NPS fertilizer + Recommended Nitrogen

T6 = 100% P-critical from DAP fertilizer + Recommended Nitrogen

The determined P-critical value (10 ppm) and phosphorous requirement factor (3.03) was used to calculate the rate of phosphorus fertilizer to be applied. Thus, Phosphorus fertilizer rate was calculated by using the formula given below;

Rate of P-applied= (pc-pi)*pf

Where: Pc: Critical phosphorus concentration; P: Initial available P; Pf: Phosphorus requirement factor which was derived from the calibration study

Agronomic Data were Collected Include:

Agronomic data to be collected include: plant height (cm), panicle length (cm), above ground biomass (kg ha-1) and grain yield (kg ha^{-1})

Data Collection

Teff grain yield was harvested at the ground level from the net plot area and weighed for biomass data. Then plant height and panicle length was measured at harvest. After threshing, grain yield were cleaned and weighed. The biomass yield was determined by addition of grain yield and straw yield for each respective treatment. Economic data such as production cost (input cost), gross income and net income based on the current market price of the yield and input was recorded.

Data Analysis

All data recorded and collected were subjected to analysis of variance (ANOVA) using GenStat 18^{th} edition software program. The comparisons among treatment means were employed by using Least Significance Difference (LSD) at 5% significant level.

Result and Discussions

Selected Soil Chemical Properties of the Study Area

The result of the soil analysis indicate that the soil pH , total N, available P and OC of the soil before planting were 5.9, 0.3%, 3.8 ppm and 3.0%, respectively (Table 1). The soil pH of the study site was found in the range of moderately acid Tekalign (1991). According to Tekalign (1991) soils are classified depending on their total N content in percentage (%), as very high (> 0.25). Thus, the soil of the study site has high total N content. Olsen et al. (1954) classified available P content of the range < 5 as low, 5 to 10 as medium and >10 $mg \cdot kg^{-1}$ as high. Thus, the soil of the study site has low P. According to Tekalign (1991) the soil organic carbon content ranges from 0.5% to 1.5%, 1.5% to 3.0 % and > 3.0% are rated as low, medium and high, respectively. Thus, the OC content of the study area considered as medium.

According to these results, clearly justify, the need for the external application of inorganic and organic sources based on the base recommendation for the different crops grown in the area.

Table 1: Soil status of the experimental site

Site	PH	OC(%)	TN(%)	Av.P (pmm)
1	5.51	3.69	0.32	5.99
2	5.51	3.99	0.34	3.31
3	5.69	3.39	0.29	4.63
4	5.55	2.49	0.21	5.74
5	5.87	1.6	0.14	4.55
6	6.36	2.69	0.23	2.37
7	6.02	3.29	0.28	2.15
8	6.31	2.39	0.21	2.66
9	6.08	2.09	0.18	2.02
10	5.65	3.89	0.34	4.28
Mean	5.855	2.951	0.254	3.77

Where OC= Organic Carbon, TN= Total Nitrogen, Av P = Available phosphorous

Effect of NPS Fertilizer Rate on yield and yield component of Teff

Plant Height

The analysis of variance showed that plant height was significantly ($P < 0.05$) influenced by the NPS fertilizer rate (Table 2). The highest plant height (83.59cm) of Teff was recorded from the application of 75% P-critical from NPS fertilizer rate with recommended Nitrogen. The lowest plant height (51.34 cm) was recorded from the field without fertilizer which was significantly inferior to all other treatments (Table 2). The increase in plant height with increasing NPS fertilizer could be attributed due to sufficient supply of nutrient which in turn contributed to increased vegetative growth since nitrogen plays a crucial role in the structure of chlorophyll and P involved in the energy transfer for cellular metabolism.

Panicle Length

A Panicle length is one of the yield that contribute to grain yield. Crops with higher panicle length could have higher grain yield. Panicle length was highly significantly ($P < 0.05$) influenced by the NPS fertilizer rate. The highest Panicle length (29.05cm) of Teff was recorded from the application of 100% P-critical from NPS fertilizer rate with recommended Nitrogen. The lowest Panicle length (19.20 cm) was recorded from the field without fertilizer which was significantly inferior to all other treatments (Table 2). This result is in agreement (Feyera *et al.*, 2014) who report that balanced fertilization application and efficient utilization of nutrient leads to high photosynthetic productivity and accretion of dry matter, eventually increasing panicle /spike length.

Table 2. Effects of NPS Fertilizer rate and recommended Nitrogen on yield and yield components of Teff

Treatment	pH (cm)	PL (cm)	Biomass kg ha^{-1}	Grain yield kg ha^{-1}
without fertilizer	51.34^{d}	19.20 ^{d}	2521 ^{e}	507^{d}
25% P-critical from NPS+ Recommended Nitrogen	74.92 ^{c}	25.55^{c}	5086^{d}	1209^{c}
50% P-critical from NPS+ Recommended Nitrogen	77.14b^{c}	26.16^{c}	5916 ^{c}	1375^{b}
75% P-critical from NPS +Recommended Nitro	83.59 ^{a}	28.75 ^{ab}	7079^{ab}	1548^{a}
100% P-critical from NPS+ Recommended Nitrogen	82.99 ^{a}	29.05^{a}	7509^{a}	1635^{a}
100% P-critical from DAP+ Recommended Nitrogen	80.66^{ab}	27.57^{b}	6808^{b}	1502^{ab}
$LSD_{0.05}$	3.61	1.39	621.28	144.91
CV (%)	9.4	10.5	20.9	21.9

Means with the same letter in columns are not significantly different at 5% level of significance's, PH=plant height, PL= Panicle length CV=Coefficient of variation, LSD=Least Significance Difference.

Biomass Yield

The analysis of variance showed that the biomass yield was significantly ($P < 0.05$) affected by NPS fertilizer rate (Table 2). The highest biomass yield (7509 kg ha^{-1}) was obtained from the application of 100% P-critical from NPS fertilizer rate with recommended Nitrogen and the lowest biomass yield (2521kg ha^{-1}) was obtained from unfertilized plot. The significant increase in biomass yield could be attributed due to the availability of macronutrients and some secondary nutrients formulated with the NPS fertilizer, which could increase the vegetative consequently the biomass yield. Similar significant increase in biomass yield was also observed for different application rate of NPS fertilizers which states that the increased in straw yield was attributed due to the proportional vegetative growth especially plant height (Feyera *et al*.,2014 andWakjira,2018).

Grain Yield

Grain yield was significantly ($P < 0.05$) affected by NPS fertilizer rate. The highest (1635kg ha^{-1}) and the lowest (507 kg ha^{-1}) grain yield was obtained from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen and unfertilized plot respectively (Table 2). Grain yield increased consistently and significantly in response to increasing the rate of NPS fertilizer from nil up to the highest. The increased in grain yield from NPS fertilizer might be facilitated the uptake of other essential nutrients which helps to boost plant growth and yield. This result is in line with Wakjira, 2018 and Desta *et al.*, 2021 who reported that, the maximum of grain yield of Teff was recorded at the highest application of fertilizer rate.

Economic Analysis

Economic analysis indicate that the highest net benefit (72465.2 ETB ha^{-1}) and the highest marginal rate of return (MRR) (1110.46%) was obtained from the fertilizer application of 100% P-critical from NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}). The lowest net benefit (23829ETB ha^{-1}) was obtained from unfertilized plots (Table 3). The MRR indicated that tef producers can get an extra of 11.1 ETB for 1.00 ETB investments in the NPS and N fertilizers application on the rates of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}).Therefore, application of NPS fertilizer at the rate of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of Teff was more economically beneficial and recommended for kuyu District.

Table 3. Marginal Analysis of tef yield as affected by NPS Fertilizer with Nitrogen Rate

	Variable Input (Kg ha^{-1})		Unit price(ETB)		TVC	Output (Kg ha^{-1})	Unit price (ETB)	Gross Income (ETB ha^{-1})	Net Income (ETB ha^{-1})	MRR (%)
Treatment	DAP/ NPS	Urea	DAP/N PS	Urea						
without fertilizer	0	0	0	0	0	507	47	23829	23829	
25% Pc NPS	35	185.55	561.5	2784.4	3345.9	1209	47	56823	53477.1	886.10
50% Pc NPS	70	171.1	1123.0	2567.5	3690.6	1375	47	64625	60934.4	1005.41
75% Pc NPS	105	189.62	1684.6	2845.5	4530.0	1548	47	72756	68226.0	980.06
100%Pc NPS	140	142.19	2246.1	2133.7	4379.8	1635	47	76845	72465.2	1110.46
100%Pc DAP	115.6	154.76	1854.6	2322.3	4177.0	1502	47	70594	66417.0	1019.59

Where: ETB = Ethiopian Birr, TVC = Total Variable Cost, MRR = Marginal Rate of Return, PC = Critical phosphorus, Rec. N = Recommended Nitrogen

Conclusion and Recommendations

Application of balanced NPS and Nitrogen fertilizer rate significantly influenced most of the plant phrenology, growth parameters, yield and yield components of Teff. According to this study NPS fertilizer rate based on calibrated phosphorus significantly influences yield and yield component of Teff which is at promising level to sustain soil fertility and to tackle the problems. Therefore, the study was conducted to determine the effect of NPS fertilizer rate in relative to determined critical phosphorus for Teff in kuyu District.

The statically analysis of variance showed that, plant height, panicle length, biomass and grain yield was significantly ($P<0.05$) influenced by NPS fertilizer rate with N fertilizer. The highest plant height (83.59 cm), of Teff was recorded from the application of 75% P-critical from NPS fertilizer rate with recommended Nitrogen but panicle length (29.05cm), biomass yield (7509 kg ha^{-1}) and grain yield (1635 kg ha^{-1}) of Teff was recorded from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field unfertilized which was significantly inferior to all other treatments. Furthermore, the economic analysis depicted that, application of NPS fertilizer at the rate of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of Teff was more economically beneficial for the district.

Therefore, farmers must be advised to use 100% PC from NPS fertilizer rate with recommended nitrogen for Teff production in the district. Demonstration and further scale up as well as verification at other district of similar soil type agro-ecology should be pre requisite.

Acknowledgements

The authors would like to acknowledge the Oromia Agricultural Research Institute for its financial support of this study. Other thanks also went to Fitche Agricultural Research Center for facilitating the successful completion of the study.

Reference

Central Statistical Agency (CSA) (2010). Federal Democratic Republic of Ethiopia, Central Statistical Agency.

CSA(Central Statistical Authority) (2013). Agricultural Sample Survey: report on Area and production of major Crops (Private peasant holdings ‘‘meher’’ season), Volume I Addis Abeba, Ethiopia

CSA.2012 Central Statistic Authority. Agricultural Sample Survey: report on Area and production of major

D., Haile, W., Lelago, A. and Bibiso, M. (2021) Response of Tef (Eragrostis tef (Zucc.) Trotter) to Balanced Fertilizer in Wolaita Zone, Southern Ethiopia. Journal of Agricultural Chemistry and Environment, 10, 124-142.

Demeke, M., & Di Marcantonio, F. (2013). Analysis of incentives and disincentives for teff in Ethiopia (Technical Notes Series). *Rome: MAFAP, FAO*.

EthioSIS (Ethiopian Soil Information System), 2013.Soil analysis report. Agricultural Transformation Agency (Unpublished)

FAO (Food and Agricultural Organization), 2008. Guide to laboratory establishment for plant nutrient analysis, fertilizer and plant nutrition bulletin 19 Rome Getahun, B., 2003. The food security challenges in Ethiopia. Proceeding of the workshop on challenges and prospects of food security, Aug. 13-15, UNCC, pp: 34-48

Fayera Asefa, A. D., & Mohammed, M. (2014). Evaluation of tef [Eragrostis tef (zuccagni). Trotter] responses to different rates of NPK along with Zn and B in Didessa District, South Western Ethiopia. *World Applied Sciences Journal*, *32*(11), 2245-2249.

Hundera, Fufa. "Variations of morpho-agronomic characters and grain chemical composition of released varieties of tef (Eragrostis tef (Zucc.) Trotter)[Ethiopia]." *Journal of Genetics & Breeding (Italy)* (1998).

Hundera, F., Bechere, E., & Tefera, H. (1999). Interrelationships of grain yield, lodging and agronomic traits in tef, Eragrostis tef. *Tropical science*

Hundera, F., Efrem Bechere and HailuTefera. 1999.Interrelation ships of grain yield, lodging and agronomic

Gomez K.A. and A.A. Gomez. 1984. Statistical procedurefor agricultural research. Second edition.John Wiley and Sons, Inc. New York.

Hailu T, Seyfu K. 2000. Production and importance of tefin Ethiopia Agriculture. In: Tefera H, Belay G, Sorrels M(eds.), Narrowing the Rift: Tef research and development-Proceedings of the international Tef Genetics and improvement, 16-19

Olsen, S. R. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate* (No. 939). US Department of Agriculture.

Rhoades, J. D. (1982). In Methods of Soil Analysis, Part 2. (AL Page. Miller and DR Keeney, Eds.), American Society of Agronomy. *Madison, USA*.
SAS Institute, 2000. SAS User's Guide, Statistics version 8.2 (Ed.).SAS Inst., Cary, NC, USA.traits in tef, Eragrostistef. Tropical Science. 39: 63-69.
Wakjira Tesfahun , 2018.Tef Yield Response to NPS Fertilizer and Methods ofSowing in East Shewa, Ethiopia, *Journal of Natural Sciences Research ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online) Vol.8, No.1*,

Verification of Soil Test Based Crop Response Recommended Pc and Pf for Maize at Ilu Galan District, West Shewa, Oromia

Temesgen Temene*, Mamo Mekonnen, Bayisa Baye, Lemi Gebrekidan and Negash Teshome
*Bako agricultural research center, P.O.Box 03
*Corresponding author email: temetamam1@gmail.com

Abstract

*The on farm verification study was executed to verify the pre-determined optimum amount of nitrogen (110Kg N ha^{-1}), critical Phosphorus (14.5ppm) and phosphorus requirement factor (5.5ppm) for maize production in Iluu Galan district. The experiment was arranged with three treatments (Control, Blanket Recommendation and phosphorus critical value and requirement factor) and laid out with simple adjacent plots and replicated over ten farmer's field during the main cropping season of 20121/22. A gross plot of 10m*10m ($100m^2$) and 1m between plots was used for each treatment. The Composite surface soil samples were collected from the experimental plot (0-20cm depth) before planting and analyzed for pH (H_2O) and initial P level. The result of laboratory analysis showed that the pH (H_2O) of the selected field Ranged from 4.38 to 5.47 and initially available P was ranged from 7.32 to 12.4ppm. Phosphorus fertilizer was applied by using formula "Pa= Pc-Pint)*Pf; where Pa the rate of P fertilizer applied; Pc P concentration; and Pf, P requirement factor). The result of study disclosed that the maximum biomass (12102kg/ha) and grain yield (6335Kg/ha) was obtained from the recommended Pc and Pf respectively. The lowest mean Biomass 3096kg/ha and mean grain yield 819kg/ha was recorded from the control plot. Moreover, economic evaluation undertaken confirmed that soil test based crop response P applied benefited 17.84 EB for every one Birr invested. Hence recommended pc and pf for maize was opted by farmers for produced high yields and obtained high economic return, it is advised to use recommended Pc and Pf for maize production in Ilu Galan District and NPS rate determination will be pre requested in the area.*

Key Words: *phosphorus critical, requirement factor, blanket recommendation, Maize and Ilu Galan*

Introduction

Maize is a major crop for farmers in many parts of the world, and a staple food for many subsistence farmers in the developing world. In Ethiopia, it was ranked second in total area coverage and first in production (CSA, 2019). However, the productivity of maize in high potential maize growing areas of western Oromia is constrained by the decline of soil fertility and alarmingly increased soil acidity due to improper plant nutrient management. Since Maize is a heavy nutrient feeder, it withdraws huge amounts of nutrients from the soil for plant growth. Therefore, fertilizer nutritional requirements for maize are based on expected yields and availability of soil nutrients.

Phosphorus is the most growth and yield limiting nutrient for cereal crops, intensely for maize. Plant requires sufficient supply of P during the first stage of root development and throughout growth for optimum crop production (Grant *et al.,* 2001). P fertilizer is required to plants for synthesis of nucleic acid, early root growth, energy transformation, fruiting and seeding. However, farmers apply too much of a little needed and too little of another plant nutrient which is actually the principal factor limiting plant growth without testing the nutrient status of their agricultural soil and without appropriate fertilizer recommendation.

A blanket type of fertilizer recommendation for the past twenty years in Ethiopia general and in maize belt areas of western Oromia, Ilu Galan district in particular leads to indiscriminate uses of fertilizer and decline in soil fertility and productivity. Blanket fertilizer recommendation leads to Excess or low application of chemical fertilizers, that aggravates stunted growth of plants due to toxicity or deficiency of the essential elements (Kidanemariam and Assen, 2008). As study by Tarfa *et al.*, 2017 illustrated that, low fertilizer use efficiency can result from inappropriate fertilizer recommendations that could account for the limitations and risks affecting resource-poor farmers. The blanket recommendation of 46 kg P_2O_5 for maize in sub-humid, high rain fall and maize belt areas of Ilu Galan did not consider the difference of soil fertility levels of different farmland and availability of P nutrient to specific crop.

On the other hand, the prices of fertilizer over the last two years, have increased twofold to fourfold which is could not be affordable to most of the farming community and increase the cost of crop production. To overcome this bottleneck problem, and to get the most accurate fertilizer recommendation and provide for increased nutrient use efficiency, soil test based crop response P calibration relationship that reflects both crop response and profit response is more important than ever. Making recommended fertilizers (calibration) provides information on how much nutrient should be applied at a given soil test value, optimizing crop growth without excessive waste and ensuring that soil nutrients are applied to plants and also adjust the test to field conditions for individual crops (Seif, 2013). Check the effectiveness of current P recommendations.

To solve such concerned problems, soil research under natural resource directorate of IQQO has designed a local assessment for the soil P critical levels and soil P requirement factor for the major crops of the region. Indeed, soil fertility improvement team of Bako Agricultural Research Center was recommended soil test crop response based phosphorus critical value and phosphorus requirement factor for maize in maize belt areas of Bako (Shiferaw *et al.,* 2018). The result was also verified and preferred by farmers for its high grain yield and high economic return was obtained from soil test crop response based recommended Pc and Pf for maize production in Bako Tibe (Shiferaw *et al.,* 2019). This value of research outcomes was suggested to be verified for similar agro ecology, receive same rainfall mode and similar mode of fertilizer application, in Ilu Galan Districts.

However, the validity of P critical level and P requirement factor obtained for maize production in the area should be verified on varies number of farmer's field before fertilizer recommendation. Therefore, the objective of this experiment was to verify the calibrated P critical and P requirement factor and determined optimum nitrogen fertilizer for maize production and to develop Phosphorus fertilizer recommendation guide line for maize production at the district.

Material and Method

Description of the Study Area

On farm soil test crop response based verification study was conducted in Ilu Galan Districts, West Shewa zone of western Oromia. The experimental area is located at 8° 59' 44" to 9° 0' 41" N latitude and 37° 20' 47" to 37° 17' 22" E longitude, western Oromia, Ethiopia. The average annual rain fall of the area is 1332mm of which 1416mm were received from May to October during 2021 cropping season. The mean annual minimum and maximum temperature of research area was 20°C and 32°C respectively. Soil of the experimental area is characterized by red clay typical Nitisol which is acidic with pH of 5.20 and Cereal monocropping is the most practiced crop production and soil fertility of the area is very low.

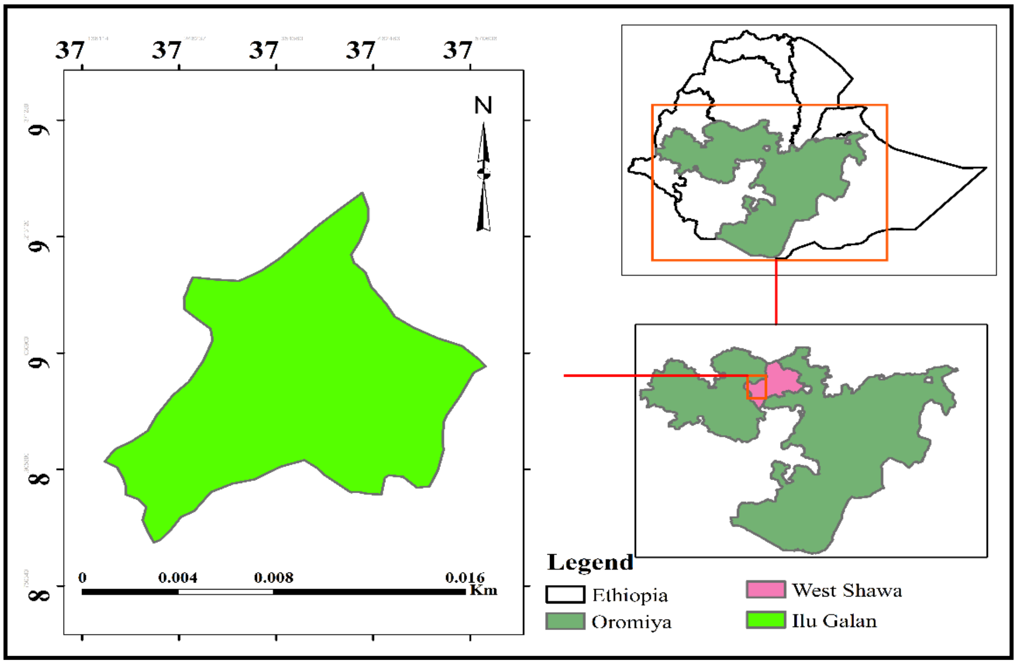


Fig. 1: Location Map of the study area.

Experimental Design and Procedure

The experiment had three treatments (Control, Blanket Recommendation and phosphorus critical value and requirement factor) and laid out with simple adjacent plots and replicated over farmer's field. Based on the P initial value of soil, phosphorus fertilizer was applied by using the designed formula:

Rate of P fertilizer to be applied (Kg P/ha) = $(Pc-P_0)*P_f$ where; Pc= critical P concentration, P_0 = initial P value of soil and Pf = P-requirement factor. From the soil test based phosphorus calibration study carried out for maize in Bako Tibe, 14.5ppm of P critical and 5.5 of Pf was established (Shiferaw *et al.*, 2018). The rates of P fertilizer received by each farmer's field were calculated from the initial soil P value. Blanket recommendation of the area ($46P_2O_5$) and control plot were used for comparison. Maize variety, BH 546 was planted on plot area of 10m*10m ($100m^2$) at the spacing of 75cm between rows and 30cm between plants. All crop management and recommended agronomic practices were undertaken accordingly.

Soil Sampling and Analysis

Composited soil samples were collected from ten farmer's field at depth of 0-20cm before planting and analyzed for pH (H_2O), Ex. Acidity and initial P level for each field. Available Phosphorus was analyzed by following the Bray 2 method (**Bray 1945**). As the laboratory results indicates, PH of the fields were ranged from 4.38 to 5.47 and Available phosphorus ($P_{initial}$) were ranged from 7.32 to 12.4 ppm. Since the pH value of all the selected field scored less than 5.5, lime was applied to the experimental site a month before planting date. The amount of lime needed per hectare was calculated based on exchangeable acidity base by using the formula LR =Ex. Acidity *1.5*1000kg ha^{-1}

Data Collection and Analysis

Total biomass, grain and plant height was collected from a net harvestable experimental plot area of 10m*7.75 (77.5m^2). All data were collected across the location and properly managed by using Microsoft EXCELL. The data were subjected to analysis of variance using SAS version 9.3. Means for the main effects were compared using the means statement with the least significant difference (LSD) test at 5% level.

Economic Analysis

Partial budget analysis was executed and the marginal rate of return was calculated for both soil test based and blanket recommendation and compared with no fertilizer application based on (CIMMYT, 1988). Marginal rate of return calculated as;

$$\textbf{MRR} = \frac{\textbf{Net income from fertilized field – net income from unfertilized field}}{\textbf{Total variable cost from fertilizer application}}$$

The value of maize grain was collected from local market based on local market price during February, 2022. At that time, 1Kg of maize grain valued 16ETB. Fertilizer price of DAP/TSP and Urea were 20.58, 18.4 ETB kg^{-1} respectively at planting time. Other labor cost was similar for all treatments.

Results and Discussion

Biomass and Grain Yield

The result of study disclosed that the maximum biomass (12102kg/ha) and grain yield (6335Kg/ha) was obtained from the recommended Pc and Pf respectively. The lowest mean Biomass 3096kg/ha and mean grain yield 819kg/ha was recorded from the control plot. The results corresponded with a result reported by (Shiferaw *et al.,* 2019) in which a recommended Pc and Pf produced higher biomass and grain yield. Moreover, economic evaluation undertaken confirmed that soil test based crop response P applied benefited 17.84 EB for every one Birr invested.

Table 1: Initial soil PH, available p and calculated p applied on farmer's field before planting in Ilu Galan District during 2021 maize cropping season

No	Farmers /site	pH (H_2O)	Available P(ppm)Bray2 method	P fertilizer applied (P Kg/ha)
1	S1	5.36	10.83	20.185
2	S2	5.47	9.27	28.765
3	S3	5.39	12.04	13.53
4	54	5.2	9.91	25.245
5	S5	5.46	10.37	22.715
6	S6	5.13	7.93	36.135
7	S7	5.12	10.34	22.88
8	S8	5.44	7.32	39.49
9	S9	4.38	9.25	28.875
10	S10	4.76	11.26	17.82
Average		**5.20**	**9.94**	**25.06**

Table 2: Mean maize Biomass yield, Grain yield and HI on the verification of soil test based crop response P requirement factor for maize in Ilu Galan District during 2021 cropping season

Treatment	Biomass yield (Kg ha^{-1})	Adj. Grain yield (kg ha^{-1})	Harvest Index (HI)
Control	3096^{c}	819^{c}	27.3^{c}
Bk	10351^{b}	4603^{b}	44.2^{b}
Pc and P_f	12102^{a}	6335^{a}	52.83^{a}
CV (%)	17.7	17.4	12.8
LSD (5%)	1696.9	767.7	5.97

Bk = blanket recommendation, Pc and Pf = phosphorus critical and requirement factor, CV= Coefficient of Variation, LSD = Least Significance Difference

Table 3: Partial budget analysis for on farm verification of soil test based recommended Pc and Pf for maize in Ilu Galan Districts

Treatment	Urea N(Kg/ha	TSP (P kg/ha)	AGY Kg/ha	GFB(EB/ha)	TVC(EB/ha)	NB(EB/ha)	MRR (%)
Control	0	0	819	13104	0	14742	--
BK	110	100	4603	73648	4082	69566	1343
Recom.Pc and Pf	110	125	6335	101360	4596	96763	1784

ADY= Adjusted Grain Yield, GFB= Gross Field Benefit, TVC= Total variable cost, NB= Net Benefit, MRR= Marginal rate of return, EB= Ethiopian Birr, TSP= Triple super phosphate

Conclusion and Recommendations

Based on the executed field performance evaluation and economic analysis, soil test crop response P ranked 1st on 7 farmers' fields due to growth performance, cob vigor, stalk vigor, and maturity. On the other hand, soil test-based crop response P improved farmers' fertilizer use efficiency and generated 17.84 EB for every one Birr invested. The validity of the P critical level and P requirement factor obtained for maize production has been verified. The recommended Pc and Pf for maize were chosen by farmers because they produced high yields and obtained a high economic return. Therefore, it is advised to use recommended PC and PF for maize production in Ilu Galan District. Soil testing should be encouraged by farmers, and NPS rate determination will be pre requested in the area.

Reference

Beza Shewangizaw, Kenzemed Kassie, Shawl Assefa and Tesfaye Feyisa, 2020. On farm verification of soil test-based phosphorus fertilizer recommendations for bread wheat (*Triticumaestivum* L.) on the vertisols of central highlands of Ethiopia, Cogent Food &Agriculture, 6:1, 1807811, DOI: 10.1080/23311932.2020.1807811.

Bray RH, 1945. Soil-plant relations: II. Balanced fertilizer use through soil tests for potassium and phosphorus. Soil Science 60:463-473.Ethiopia.

CIMMYT, 1988. Farm Agronomic to farmer's recommendation. An Economic Training Manual.Completely revised edition, D.F. Mexico, 51p.

CSA (Central Statistical Agency), 2019. Agricultural sample survey. Report on area and production of major crops (private peasant holdings, meher season). Addis Ababa, Ethiopia.

Getachew Agegnehu, PN Nelson, MI Bird, and C van Beek, 2015. Phosphorus Response and Fertilizer Recommendations for Wheat Grown on Nitisols in the Central Ethiopian Highlands. Communications in Soil Science and Plant Analysis 46, 2411-2424.

Girma Chala. 2016. Soil test phosphorous calibration for potato production on Nitisols of central highlands Ethiopia.Ethiop. J. Sci. Sus. Dev. 120-137.

Grant, C.A., D.N. Flaten, D.J. Tomasiewicz and S.c. Shepppard, 2001. The importance of early season P nutrition.Can, J. Plant Sci. 81; 211-224.

Kidanemariam, A., and Assen, Y., 2008. Recommendation on phosphorus fertilizer based on soil test and response of Tef to nitrogen and phosphorus fertilizers.

Self, J., 2013. “Soil testing”. Fact sheet No. 0.501. Crop/soil series. Colorado state university. USA

Shiferaw Tadesse and Mamo Mekonnen, 2019. On farm Verification of Soil Test Based Crop Response Recommended Pc and Pf for Maize in Bako Tibe and Gobu Sayo Districts of West Shewa and East Wellega Zones In: Kefyalew assefa, Tilahun Chibsa, Bikila Mengistu and Tilahun Geleto, (eds). Proceeding of Review Workshop on Completed Research Activities of Natural Resource Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Oromia, Ethiopia. 07-12 October 2019.

Shiferaw Tadesse, Bayissa Baye and Gemechu Shumi, 2018. Soil Test Crop Response Based Phosphorus Calibration for Maize (Zea mayis L.) Production in the Sub-Humid Areas of Bako. 21-28.pp. In: Kefyalew Assefa, Bikila Mengistu, Geremew Eticha, Kasahun Kitila, Eshetu Ararso and Tilahun Geleto (Eds.). Proceedings of Review Workshop on Completed Research Activities of Natural Resource Directorate held at Adami Tulu Oromia, Ethiopia.

Tarfa, B.D., Yoila, A.I., Kayode, D.C., Lucky, A.U., Shero, I.A., Alhaji, Y.A., Abdu, N., Tawa, A.T., Raymond, B.P., Marinus, U.E., Haratu, D. and Ogbodo, U.O., 2017. Optimizing Fertilizer Use within the Context of Integrated Soil Fertility Management in Nigeria. In: Wortmann, C.S. and Sones, K.R., Eds, Fertilizer use optimization in sub-Saharan Africa, CAB International, Nairobi, 148-163.

Verification of Soil Test Crop Response Based Phosphorus Recommendation for Maize (Zea maize) in Boneya Boshe District, East Wollega Zone, Western Oromia

Negash Teshome*, Lami G/Kidan and Bayisa Baye
Bako Agricultural Research Center, P.O.Box: 03, Bako, Ethiopia
**Corresponding Author email: negashteshome5@gmail.com*

Abstract
*Verification trial of soil test crop response based phosphorus recommendation for maize was conducted in Boneya Boshe district of Western Oromia in 2021 main cropping season. The trial was used to extrapolate verification result formerly conducted at Bako Tibbe and Gobu Sayo Districts on maize as bench mark. P-Critical (14.5) and P-requirement factor (5.5) was used for maize in this district. Three treatments were used, T1 (control), T2 (STBFR), T3 (blanket recommendation) laid out with simple adjacent plots side by side by using improved maize variety (BH-546) and replicated over eleven farmers' fields in the district. The plot size was 10m x 10m (100m^2) for each treatment. The highest mean grain yield (6520 kg/ha) was obtained from soil test crop response based fertilizer recommendation while the lowest mean grain yield (1515.62 kg/ha) was recorded from the control plot. Eventually, Partial budget analysis also indicated that phosphorus critical and requirement factor were economically feasible having net benefit of (*92,900 *Et.Birr) at 2144% MRR. Therefore, Pc and Pf were verified and recommended for farmers of Boneya Boshe district to produce and obtain optimum yield from maize while further scaling up will be expected to popularize the technology to farmers of the study areas and similar agro ecologies.*

Key words: *Blanket Recommendation, Maize (BH-546), P-Critical, P-requirement factor, Soil test based*

Introduction

Ethiopia is endowed with huge potential for agricultural development and cereal crops like maize are widely cultivated across a range of environmental conditions. However, it has been one of the more food insecure countries of the world. Food insecurity in the country is mainly due to inadequate utilization of improved crop production and protection technologies by the predominantly small-scale farmers (CSA, 2010). Since 1952 maize research has been ongoing at deferent capacities to generate and recommend improved technologies for maize production. As a result, maize productivity and production has been increasing over the years. The progress made from the 1950s to 1990s has been documented in the proceedings of the First and Second National Maize Workshops of Ethiopia (Kebede *et al.*, 1993; Mosisa *et al.*, 2002). In the 2000s, eﬀorts have also been made by deterrent stakeholders to enhance maize research, and thus increase maize productivity and production.

Maize is the most important staple in terms of calorie intake in rural Ethiopia. The 2004/5 national survey of consumption expenditure indicated that maize accounted for 16.7 % of the national calorie intake followed by sorghum (14.1 %) and wheat (12.6 %) among the major cereals (Berhane *et al.*, 2011). Compared to the 1960s the share of maize consumption among cereals more than doubled to nearly 30% in the 2000s, whereas the share of teff, a cereal that occupies the largest area of all crops in Ethiopia, declined from more than 30% to about 18% during the same period (Demeke, 2012). The popularity of maize in Ethiopia is partly because of its high value as a food crop as well as the growing demand for the Stover as animal fodder and source of fuel for rural families. Approximately 88 % of maize produced in Ethiopia is consumed as food, both as green and dry grain. Maize for industrial use has also supported growing demand. Very little maize is currently used as feed but this too is changing in order to support a rapidly growing urbanization and poultry industry. Unlike its neighbor, Kenya, which imports a significant share for its consumption needs, Ethiopia has increasingly attained self-sufficiency in maize production since early this decade and even exports some quantities to neighboring countries (e.g., Sudan and Djibouti) in years of surplus production. If production can be significantly expanded, the potential for maize export to all the neighboring countries including Kenya is very high although the national demand is expected to continue to grow in the coming years. There is evidence that the increased productivity and production of maize is also having a significant positive impact on poverty reduction (Dercon *et al.,* 2009; Zeng *et al.,* 2013).

Low soil fertility is one among the major factors limiting maize production and productivity in Western Oromia, Ethiopia (Wakene *et al.,* 2005) inorganic fertilizers are relied upon to improve crop yields and maintain soil fertility; Insufficient use of fertilizers resulting in severe nutrient depletion of soils (Christina, 2002). It is widely believed that economic optimum fertilizer application can only be achieved by developing appropriate fertilizer recommendation. Currently however, there are negligibly site-specific fertilizer recommendations for different soil-crop climatic conditions and none in Boneya Boshe district of Western Oromia. As in all other areas of the country, site specific fertilizer recommendation for maize in Boneya Boshe district is very important since its application is not based on soil test based results. In Gobu Sayo and Bako districts soil test crop response based phosphorus fertilizer recommendation was completed and verification trial was done but not for Boneya Boshe. Boneya Boshe district is adjacent to those districts so, extrapolation of soil test crop response based recommended fertilizer results done for Bako and Gobu Sayo in to Boneya Boshe for its verification is mandatory.

Objective

To verify soil test crop response based recommended Pc and Pf at Bako and Gobu Sayo

Materials and Methods

Description of the Study Area

The trial was conducted in Boneya Boshe district, East Wollega Zone in Western Oromia. The topography of the area is flat and as well as undulating. The elevation of the area is 1645 m.a.s.l. The mean annual rain fall 1500 mm classified in mono-modal rain fall distribution, in the months of June to October**.** The soil of the area is classified as reddish brown.

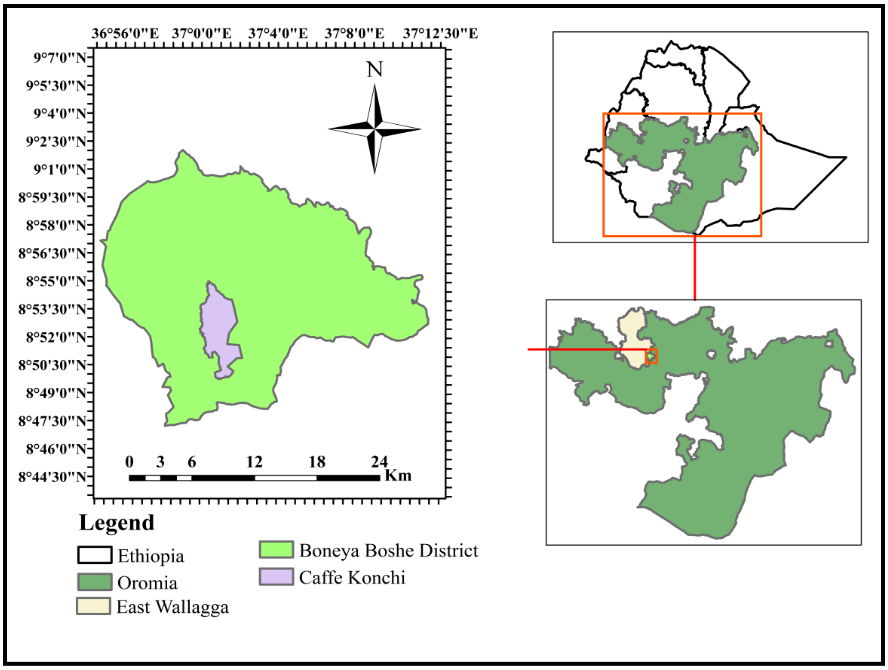


Fig.1: Location map of the study area.

Experimental Design and Procedure

The trial has three treatments Trt1=(control/check), Trt2=blanket recommendations (100kg/ha phosphorous plus 100 kg/ha N from Urea) and Trt3=phosphorus critical values(14.5) and Requirement factor(5.5) laid out with non-designed plots adjacent to each other and replicated over the farmers. Based on the results of phosphorus critical and P factors formerly recommended at Bako and Gobu Sayo districts for maize, this result was decided to be extrapolated to Boneya Boshe district. Where Pc=Critical P concentration (14.5); Po=Initial P values of the site (ppm); Pf= P-requirement factor 5.5. Improved maize variety (BH-546) was used as test material for the trial on plot size of 10mx10m (100m^2) for each treatment by using a seed rate of 25 kgha^{-1}. All crop management activities were applied based on farmers practices of the study area for all treatments.

Rate of fertilizer to be applied (kg P/ha) = (Pc-Po) x Pf

Soil sampling and Analysis

Composite soil samples were collected from eleven (11) sites of the selected farmers' fields at a depth of 0-20 cm before planting to determine initial soil available phosphorous (Po). The soil samples collected were labeled, packed and transported to Bako Agricultural Research Center. Available soil phosphorus was analyzed by Bray II method **(Bray 1945).**

Data Collected and Analysis

Yield data: Grain yield was collected from total plot size of 10mx10m (100m^2) and data was congested analyzed from net plot size of 4mx4m=16m^2 to identify significance between treatments. The data was collected from this net plot size over locations and managed by using Microsoft EXCEL. Eventually, the collected data converted to hectare and it was subjected to the analysis of variance using Gen-Stat computer software 18th edition. Mean separation was implemented using least significance differences (LSD) at 5% level of significance.

Economic Analysis

Economic feasibility study was conducted by calculating the marginal rate of return (MRR) for all treatments (STCRB, Farmers Practices/blanket recommendation/ and for the control) (CIMMIT, 1988). The marginal rate of return was calculated by the following formula.

$$\mathbf{MRR} = \frac{\text{Net income from fertilized field – net income from unfertilized field}}{\text{Total variable cost from fertilizer application}}$$

Results and Discussions

Grain Yield

The analysis of variance showed that significant differences were observed between mean grain yield at $p<001$, (Table.1.).The highest mean grain yield was recorded on soil test based fertilizer recommendation (6520 kg ha^{-1}) but the lowest mean grain yield (1515.62 kg ha^{-1}) was obtained from the control. The result reveled that soil test crop response based fertilizer recommendation is suitable and economical to obtain optimum yield of maize in the study area through the application of fertilizer that plant requires efficiently.

Biomass Yield

The ratio of the amount of biomass produced to the amount of substrate consumed (g biomass/g substrate) is defined as the *biomass yield*, and typically is defined relative to the electron donor used.

$$\text{biomass yield } Y = \frac{\text{g biomass produced}}{\text{g substrate utilized}}$$

Source: Metcalf and Eddy, page 567

Harvest Index

Harvest Index (HI): is the ratio of the amount of element in the grain relative to the amount of the element in the total above ground biomass of the plant, which was estimated as:

$$\mathbf{HI} = \frac{\text{Grain Yield}}{\text{Biomass Yield}}$$

Hundred Seed Weight

Table: 1. Mean Grain Yield and Biomass Yield, Harvest Index and 100 seed weight of Maize as affected by STBFR in Boneya Boshe District (2021)

Treatments	GRY(kg/ha)	BMY(kg/ha)	HI	HSW(g)
Trt1 (Control)	1515.62[c]	4312.50[c]	0.35[b]	20.69[b]
Trt2 (STBFR)	6520.00[a]	13906.25[a]	0.47[a]	27.05[a]
Trt3 (Bk)	4125.94[b]	9750.00[b]	0.42[ab]	25.47[a]
LSD (5%)	1002.278	2146.88	0.131	3.234
CV (%)	23.1	21.5	30.1	10.5

Bk=Blanket Recommendation; STBFR=Soil Test Crop Response Based Fertilizer Recommendation; Means with the same letters are not statistically significant.

Economic Analysis

Total variable cost is a cost incurred due to the application of P fertilizer (both but in separate of soil test based P calibration result and farmers' fertilizer rate) with the assumption of all the costs incurred are being the same for all treatments. Gross income is obtained by multiplying mean grain yield (kg/ha) of each treatment by the price of one kg of the grain. Net income is calculated by subtracting the total variable cost from the gross income. To use the marginal rate of return (MRR) as basis for fertilizer recommendation, the minimum acceptable rate of return (MARR) was set to 100%. The partial budget analysis revealed that soil test based crop response fertilizer recommendation for maize at Boneya Boshe District was acceptable at 2144% MRR **(Table 2**).

Table: 2.Partial budget analysis

Treatment	**Urea** N(kg/ha)	**NPS/TSP** P(kg/ha)	**MGY** (kg/ha)	**TVC(Birr/ha)**	**GFB** (Birr/ha)	**NB(EB/ha)**	**MRR (%)**
Control	0	0	1515.62	850	22734.30	21884.30	-
Bk	100	100	4125.94	3300	61889.09	58589.09	1498
STBFR	200	-	6520.00	4900	97800.00	92900.00	2144

NB: MGY= Mean Grain Yield, TVC=Total Variable Cost, GFB= Gross Field Benefit, NB= Net Benefit, MRR= Marginal Rate of Return

Marginal rate of returns (MRR) were found to be 2144% for soil test based P fertilizer rate and 1498% for farmers practices as indicated in Table 2. The economic analysis showed that the highest net income (92,900.00 birr) was obtained from soil test based P recommendation with marginal rate of return (2144%) which is greater than the minimum rate of return (MRR) 100% (CIMMIT, 1988). Based on this result, partial budget analysis indicated that soil test based P recommendation is economically feasible for maize production in Boneya Boshe District.

Conclusions and Recommendations

From verification of soil test crop based fertilizer recommendation, P-Critical level (14.5) and P-requirement factor (5.5), the economic analysis indicated that the highest net income (92,900 birr) was recorded from soil test crop response based having a marginal rate of return 2144% which is greater than the acceptable minimum rate of return (100%). Accordingly, the highest mean grain yield (6520 kg/ha) was obtained from STBFR to that of farmers practices and the control plots. As a result, soil test crop response based fertilizer recommendation is economically feasible for maize production in the district. Therefore, demonstrating this recommended results of Pc and Pf for wider areas to the farmers followed for adoption of the P recommendation technology to increase maize production and productivity in Boneya Boshe District is pertinent.

Acknowledgements

The Author would like to acknowledge Oromia Agricultural Research Institute (IQQO) for financial support and BARC soil fertility improvement research team and soil laboratory for providing all necessary materials required for the implementation of the experiment.

References

Berhane, G., Paulos, Z., Tafere, K., and Tamru, S., 2011. Food grain consumption and calorie intake patterns in Ethiopia. Addis Ababa: IFPRI.

Bray RH, 1945. Soil-plant relations: II. Balanced fertilizer use through soil tests for potassium and phosphorus. Soil Science 60:463-473.Ethiopia.

CIMMYT, 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, D.F. ISBN 968-6127-18-6.

Demeke, M., 2012. Analysis of incentives and disincentives for maize in Ethiopia. Technical Notes series, MAFAP. Rome: FAO.

Dercon, S., Gilligan, D. O., Hoddinott, J., and Woldehanna, T., 2009. The impact of agricultural extension and roads on poverty and consump-tion growth in fifteen Ethiopian villages. American Journal of Agricultural Economics, 91, 1007–1021.

Huffnagel, H. P., 1961. Agriculture in Ethiopia. Rome: FAO.

McCann, J. C., 2005. Maize and grace: Africa's encounter with a new world crop, 1500–2000. Cambridge: Harvard University Press.

Zeng, D., Alwang, J., Norton, G. W., Shiferaw, B., and Jaleta, M., 2013. Ex-post impacts of improved maize varieties on poverty in Ethiopia.Washington, DC: IFPRI (Unpublished manuscript).

Characterization of Parthenium (Parthenium hysterophorus L.) compost for Major Plant Nutrient Contents at Ginir District of Bale Zone, Oromia Region, South-eastern Ethiopia.

Tesfaye Ketema[1], Mulugeta Eshetu[1], Girma Getachew[1], and Regassa Gosa[1]*
[1]Sinana Agricultural Research Center, P. O. Box 208, Bale-Robe, Ethiopia
Corresponding author: ***tesfayeke33@gmail.com***

Abstract
This Experiment was conducted at Ginir District of Bale Zone, Oromia Region, Southeastern, Ethiopi.therefore this research was conducted with the objectives to characterize the quality, and nutrient contents of compost prepared from parthenium combination with wheat residue and farmyard manure in terms of major plant nutrient. The Parthenium plants were collected before flowering stage and chopped into smaller pieces. Consequently, compost of parthenium were prepared in three categories or treatments viz, Parthenium biomass plus farm yard manure, Parthenium biomass plus crop residue, and Parthenium biomass combination with both farm yard manure and crop residue were used. The major chemical properties such as pH, EC, OC, TN, available P, CEC, exchangeable bases (Ca, Mg, K and Na) and micronutrients (Fe, Mn, Cu and Zn) were analyzed using standard laboratory procedures. Results for nutrient content characterizations. The final laboratory analysis of the prepared and harvested Parthenium compost show that the compost had high in plant nutrients and also significantly varied among the three Parthenium compost preparation procedures. Accordingly, Parthenium compost have multipurpose advantages such as; high nutrient contents, means of weed control, and generally uses of organic fertilizers are environmental sound full.

Keywords: *Nutrients, Parthenium, Parthenium compost**,** Nutrient Quality**.***

Introduction

Parthenium (Parthenium hysterophorus L., Asteraceae) is an aggressive invasive alien weed species native to the America (Kohli et al., 2006) but now widely spread in Asia, Africa and Australia (Evans, 1997). Parthenium weed was first introduced accidentally into Ethiopia in the 1970s. Parthinium was first found in Ethiopia in 1988 at Dire-Dawa in the Eastern Ethiopia and subsequently found near Desse, North-eastern Ethiopia (Seifu, 1990). They are major food-aid distribution centers and it was believed that parthenium weed seeds were imported from subtropical North America as a contaminant of grain food aid during the 1980s famine (Tamado and Milberg, 2000). Afterwards it spreads rapidly in all regions of the country, along roads and railways in grazing areas and arable land strongly affecting crop production, animal and biodiversity (Tefera, 2002). Parthinium is now widely spread in the central rift valley and neighboring localities of Afar Region, East Shoa, Arsi and Bale in southern Ethiopia.

Composting is useful alternative to convert biomass from this species to a useful material that could be used as soil conditioner (Anbalagan and Manivannan, 2012; Jelin and Dhanarajan, 2013). Organic farming involves the use of ecofriendly manures in agriculture. The increased use of chemical fertilizers improved the production but at same time the soil fertility is getting reduced due to inadequate organic matter. To combat this, the use of organic materials is recommended. The compost technology is a promising technique for recycling the weeds and wastes and the resultant product improves the soil fertility and crop production without harming the nature. It is easy to practice, ecologically safe and used to reduce the pollution problems (Yadav, 2015). The practice of compost is at least a century old and now it is receiving worldwide attention as a waste management technique in terms of weeds utilization and reduction in quantity of accumulated wastes (Yadav, 2015). Parthenium weed not only competes with crops and pasture species but it has also been reported as a health hazard to human beings and livestock (Devi, .et al 2014). In the presence of Parthenium the growth and development of crops can be suppressed, and if not controlled. Due to its Aggressive coverage, Bale zone farmers call it ‘Anamalee,’ in Afaan Oromo- meaning ‘Only me’ (Personal Communications). Different authors reported that Parthenium the spread of this species which great influence the agricultural, natural ecosystem production and biodiversity as well as also heath of life (Wabuyele et al., 2014; Ayele et al., 2014 and Kumari et al., 2014). Several studied revealed that Parthenium compost used both as the means of eradicating weed and sources of organic fertilizer i.e. contains two times more N, P and K than Farm Yard uses the nutrient (Ameta et al., 2016; Fitsum et al., 2017).

In spite of enough quantity of various essential macro and micro plant nutrients and huge amount of locally available Parthenium weed, composting of Parthenium is not practiced by farmers in the study area. Additionally, very limited or no scientific studies have been conducted on uses of parthenium as suitable for compost and tried for a better way of eradicating it by utilizing for better crop production. Therefore this studied conducted with the specific

Objectives;

To characterize the quality of compost produced from parthenium

To characterize the nutrient contents of compost prepared from parthenium combination with wheat residue and farmyard manure in terms of major plant nutrient.

Material and Methods

The study was conducted in Ginir District which is one of the Bale highlands Oromia Regional State, Southeastern Ethiopia. Ginir is 519 km away from Addis Ababa; Ginir is located at 07° 15′ N latitude and 40° 66′ E longitude elevation between 1750 and 1986 meters above sea level (figure1). The seasonal rainfall is 531 mm and its mean annual minimum and maximum temperatures are 13.4 and 25.5°C, respectively (Boja & Girma, 2022). The soil type is Vertisol. Ginir experience a mono cropping season (main season) that extends from September to January. The Ginir district is very suitable for the production of cereals but pulse, oil crop and horticultural crops are also produced by farmers.

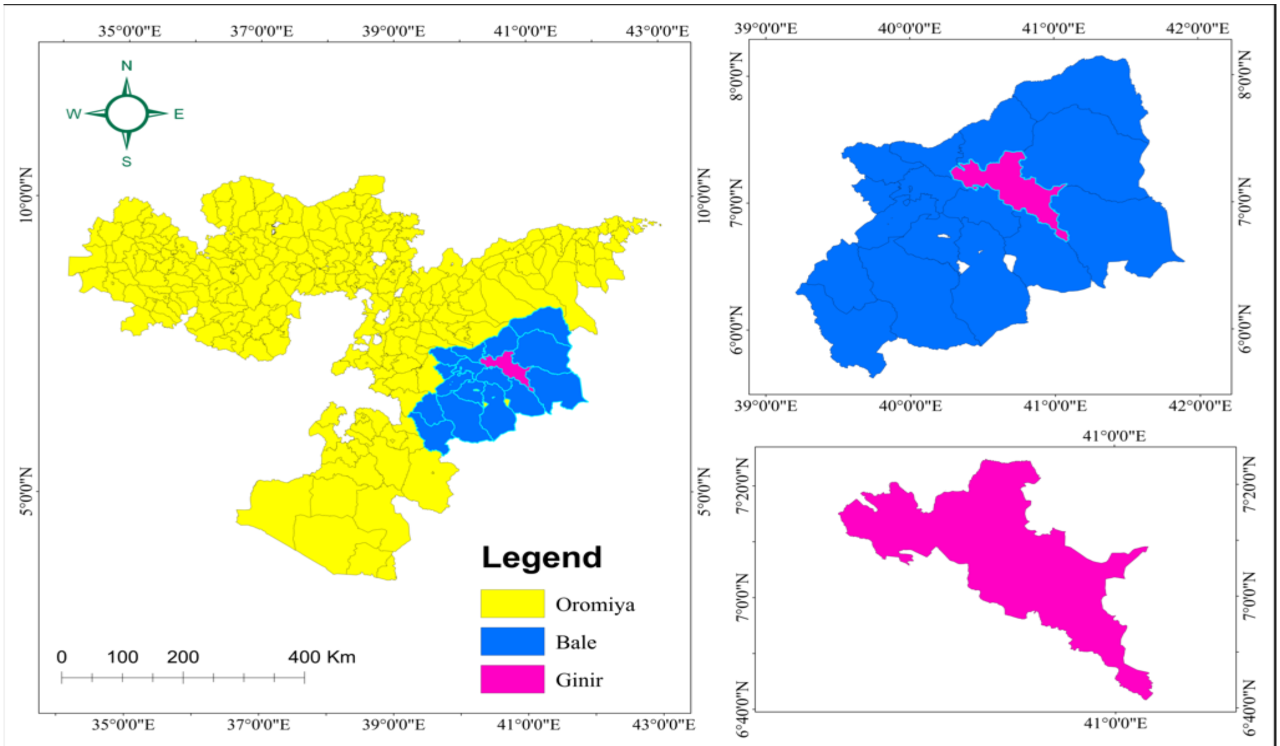


Figure 1.map of study area.

As cite in (Boja etal,.2022) the Central Statistical Agency's population projection, the total population of the district by the year 2021 was estimated to be 203,751 (103,592 males and 100,159 females). The topography of the district falls within the altitudinal range of 1200–2406 m above sea level. According to data from the district agricultural office(2022), the land configuration of the district is categorized as plain, which accounts for approximately 85%, mountain 3%, and rugged and gorge areas account for approximately 12% (i.e., approximately 15% of the area of this district is covered with a valley, gorges, and hills). Similarly, the land use in the district indicates that 30.5% is arable or cultivable, 31.2% is pasture, 35.6% is forest, and the remaining 2.7% is considered swampy, mountainous, or otherwise unusable (GDAO, .2022).

Material Used for Compost Preparation.

Compost was prepared from different substrate materials that were locally available crop residues: Maize, sorghum, haricot bean, wheat straw, teff straw, grasses and the whole mixture of straws and grass as a bedding material. Farmyard manure was added to all substrates in equal amount. The collected Parthenium weed biomass were chopped and added to the pit for compost preparation.

Treatments

T1 = Parthenium biomass plus farm yard manure.
T2 = Parthenium biomass plus crop residue plus farm yard manure
T3 = Parthenium biomass plus farm yard manure plus crop residue

The materials used in this experiment were Parthenium weed biomass, crop residue and farmyard manure that are obtained from experimental site. Parthenium weed were collected during rainy season at early stage before flowering and cut into small pieces having a maximum size less than 2.5 cm. Wheat straws were used as a good source of carbon for maintaining the required C/N ratio in the process. Likewise, other organic wastes such as ash were used so that the waste was utilized and more balanced compost was prepared. Total quantity and combination ratio of materials were used in the formation of compost, Parthenium to wheat straw ratio 1:2.78 while Parthenium: cow dung ratio 1:27.78 was used. The green biomass from the Parthenium weed were freshly picked during compost preparation, to facilitate the composting process all the biomass used were cut into pieces

Compost Preparation

The pit of 1 m × 1 m × 1 m size was prepared at Farmers' home garden. Water was sprinkled in the stacking process to maintain 60 per cent moisture. They were kept under semi aerobic condition and plastered with paste of wheat straw, dung and soil with combined ratio at the top. After one month, a turning was given and the moisture content maintained. In about 45 to 60 days, good quality compost was obtained on optimum temperatures and decomposition rates. The compost unit is constructed with permanent materials for continuous process. The Parthenium biomass were collected before flowering stage and chopped into smaller pieces of 1–2 inch. Mechanically and decomposed with farm wastes and animal wastes for about 60 days. The temperature and moisture were maintained by sprinkling water regularly. After 20 days the materials were mixed. The composting process was carried out for duration of 60 days the pit composting methods were used for compost preparation.

Parthenium Compost Laboratory Analysis

Parthenium Compost samples were collected from each compost pits. The samples were sieved and then analyzed for it's the compost quality at Sinana agricultural research center soil laboratory and at Baatuu soil research laboratory. The pH and EC of compost was measured in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter and electrical conductivity; respectively (Rhoades, 1982). Walkley and Black (1934) method used for the determination of organic carbon. Total nitrogen was determined using the Kjeldahl method as described by Bremner and Mulvaney (1982). Total exchangeable bases ($Ca^{2+,}$ $Mg2^+$, K^+ and Na^+) were conducted for Ca^{2+} and Mg^{2+} were determined by atomic absorption spectrometry (AAS) while K^+ and Na^+ were determined by flame photometer (Okalebo et al., 2002). Cation exchange capacity (CEC) was determined using (Chapman, 1965). A germination test of 100 seeds which were picked from the compost was planted in beds to find out if any of them was viable (Araya et al., 2015).

Results and Discussion

The pH and Electrical Conductivity

The laboratory analysis result revealed that the highest (7.27) and the lowest (7.17) pH value were recorded for obtained Parthenium biomass combination farm yard manure and Parthenium biomass plus animal manure and Parthenium biomass plus wheat straw; respectively (Table 1). This finding is in agreement with Jouquet et al (2013) who stated that the values of pH were ranged from 6.8-8.41 for compost. The study carried by (Spiers and Fietje 2000; Araya etal, 2015) also revealed that the higher pH goes with a higher K level, which was responsible for the high Electrical Conductivity (EC). According to value cited on(Hazelton And Murphy,2007) pH value recorded from Parthenium compost ranged are neutral, this means the application of Parthenium compost does not have impact on soil pH. There was no significant variation of Electrical conductivity (Ec) values between all treatment's groups (Table 1). According to (Santamaria et al, .2001) and (mulugeta etal, .2022) the EC values of Parthenium compost were free from salinity. This increase in EC might be due to the slight increase in Potassium ions (K^+) and other ions as decomposition proceeds. The increase in EC could be due to the release of mineral salts such as phosphates and ammonium ions through the decomposition of organic substances (Huang et al., 2004; Tadele et al, .2020 and mulugeta etal, .2022).

Organic matter, C: N Ratio and Cation Exchange Capacity (CEC)

The analyzed result showed that, relatively the highest mean value of organic matter (37.8%) was recorded under Parthenium compost combine farm yard manure pluss crop residue and the lowest (35.2%) mean values of organic matter was registered from the compost prepared from Parthenium compost pluss farm yard manure (Table 1). According to (Charman and Roper 2000) the status of organic matter in all type Parthenium compost is very high when compared with its availability in garden soil. This finding is in conformity with the study of (Tadele et al, .2020; mulugeta et al, .2022). Result indicates that the lowest (22.9%) was registered under Parthenium compost prepared from Parthenium biomass plus crop residua whiles the highest (24.8) from Parthenium compost combine farm yard manure plus crop residue from (Table 1).This result confirmed with different authors Derib et al (2016) and mulugeta et al (2022) who stated that conventional compost had lowest C: N ratio. According to (Metson 1961) medium C: N ratio was registered from all types of Parthenium compost. Medium C: N ratio below 25 indicates higher rate of mineralization.CEC of Parthenium compost made from all treatment was very high status which was ranged from 34.8 to 53.2cmol+ kg-1. This result is in agreement with the study conducted by Mulugeta et al. (2022) who found that 33.23 to 65.43 cmol+ kg-1 of CEC in conventional compost. The compost prepared from Parthenium plus farm yard manure and crop residue had higher content of EC, OC, NT and CEC. The report by Veena and Shivani (2012) also showed that Parthenium was good for soil and animal feed because of that it is protein rich weed. According to (Metson) cited in (Hazelton and Murphy,2007) CEC value recorded from Parthenium compost ranged from high to very high, this means the application of Parthenium compost increase the capacity of the soil to hold and exchange cations.

Total Nitrogen

The composition of Parthenium weed with respect to major nutrients in the present investigation was estimated as lowest from Parthenium compost plus farm yard manure 0.81 and (0.93%). The highest Nitrogen content was obtained from Parthenium compost combine with farm yard manure plus crop residue. The result is in line with work done by (Biradar etal. 2005; Araya etal, 2015 and Ameta et al., 2016). According to (Bruce and Rayment 1982) value recorded from Parthenium compost range to very high total nitrogen.

Table 1. Organic matter and some macronutrient

Trt	pH-H_2O (1:2.5)	EC (dS/m)	OM (%)	TN (%)	CEC (cmo(+)/kg	C:N
T1	7.17	0.000062	34.5	0.81	34.8	24.8
T2	7.26	0.000056	35.1	0.89	46.2	22.9
T3	7.27	0.000058	36.8	0.93	53.2	23.0

T1 = Parthenium compost + farm yard manure; **T2** = Parthenium compost + crop residue, **T3** = Parthenium compost + farm yard manure + crop residue

Exchangeable Bases (Ca, Mg, K and Na) of Parthenium Compost

The analyzed result showed that the values for exchangeable bases (Ca, Mg, K and Na) were varied from 4.56 to 5.40(cmol (+)/kg), 1.30 to 3.25 (cmol (+)/kg), 1.51to 1.86(cmol (+)/kg) and 0.24 to 0.33(cmol (+)/kg) for Ca, Mg, K and Na; respectively (Table 2). Relatively highest values of exchangeable bases obtained from Parthenium biomass combination with wheat straw and farm yard manure. The compost made from Parthenium biomass plus animal manure and Parthenium biomass plus wheat straw) showed lowest value. This result is in agreement with the finding of Channappagoudar et al (2007). In general, the Parthenium compost obtained using mixed farm yard manure and other crop residue were rich in exchangeable cations than Parthenium compost plus farm yard manure compost. These findings further support the idea of Amir and Fouzia (2011) reported that the exchangeable bases (Ca,Ma,andK)were significantly increased compost made from Parthenium biomass plus farmyard manure to Parthenium compost obtained using mixed farm yard manure. According to (Hazelton and Murphy,2007) very high Ca; high to very high Mg; very low K and very low to low Na registered from Parthenium compost, the individual cations may then be expressed as a percentage of the Effective CEC.

Table 2 Exchangeable Basic cations

Trt	Exchangeable Basic cations (cmol (+)/kg)				PBS(%)
	Ca	Mg	K	Na	
T1	4.56	1.30	1.51	0.24	21.87
T2	4.80	2.00	1.68	0.31	19.1
T3	5.40	3.25	1.86	0.33	20.38

Where T1 = Parthenium compost + farm yard manure; **T2** = Parthenium compost + crop residue, **T3** = Parthenium compost + farm yard manure + crop residue

Conclusions and Recommendations

Parthinium (Parthenium hysterophorus) is now days widely spread almost in all agro ecology and it became major threat in affecting agricultural production and reducing land productivity. The government and different NGOs have been tried a lot of alternatives so far to avoid or reduce its expansion though no significance change is observed yet. Using parthinium weed for composting is a new strategy to maximize the benefit from this weed consequently to reduce its expansion. Compost has good macro and micronutrients when compared to Farm Yard Manure. They help to increase soil fertility and increase the crop yield considerably. Parthenium can be utilized effectively as organic manure by composting there by preventing alarming spread of it. Use of environmentally friendly technologies for sustainable soil productivity and crop production and also means of controlling weeds were identified from the current studied. Parthenium compost prepared from parthenium biomass combination with both farm yard manure and crop residue was better nutrient contents as compared to only compost made from parthenium biomass only. Generally, from the studied point of view creating public awareness especially in farmers’ area about the effect of Parthenium hysterophorus on agricultural productivity, ecosystem as well as on strategies control methods should be recommended. In generally, there is a need for further studies on the rate of application of Parthenium compost and their effect on crop yields and soil physic chemical properties under field condition.

Acknowledgement

The author likes to acknowledge Oromia Agricultural Research Institute for financial support; we would like to express our heartfelt and deep gratitude to staff members of Soil fertility improvement and soil and water conservation research team at Sinana Agricultural research center for their active participation in conducting this experiment. Thanks Batu soil research center for their cooperation by sampling analysis on experiments

References

Ameta SK, Benjamin S, Ameta R, Ameta SC. Vishishta Composting: A Fastest Method and Ecofriendly Recipe forPreparing Compost from Parthenium hysterophorus Weed. J EarthEnviron Health Sci 2016;2:103-8.

Amir Khan and Fouzia Ishaq. 2011. Chemical nutrient analysis of different composts (VermicompostandPitcompost) and their effect on the growth of a vegetative crop Pisumsativum. Asian Journal of Plant Science and Research, 1 (1): 116-130.

Anbalagan M., Manivannan S. (2012): Assessment of impact of invasive weed Parthenium hysterophorus L. mixed with organic supplements on growth and reproduction preference of Lampito mauritii (Kinberg) through vermitechnology. Int. J. Environ. Biol. 2(2): 88-91.

Ayele Shashie, Nigatu, Lisanework., Tana, Tamado., and Adkins, S.W. 2014. Impact of parthenium weed (Parthenium hysterophorus L.) on the above-ground and soil seed bank communities of rangelands in Southeast Ethiopia. Global Science Research Journals. 2(1): 66-78.

Bruce, R. C., and Rayment, G. E. (1982). Analytical methods and interpretations used by the Agricultural Chemistry Branch for Soil and Land Use Surveys. Queensland Department of Primary Industries. Bulletin QB8 (2004), Indooroopilly, Queensland.

Charman, P. E. V., and Roper, M. M. (2007). Soil organic matter. In 'Soils – their properties and management'. 3rd edn. (Eds P. E. V. Charman and B. W. Murphy.)pp. 276–285. (Oxford University Press: Melbourne.)

Derib Kifle, Gemechu Shumi and Abera Degefa. 2017. Characterization of Vermicompost for Major Plant Nutrient Contents and Manuring Value. Journal of Science and Sustainable Development, 5 (2), 97-108.

Devi YN, Dutta BK, Sagolshemcha R, Singh NI. Allelopathic effect of Parthenium hysterophorus L. on growth and productivity of Zea mays L. and its phytochemical screening. Int J Curr Microbiol Appl Sci 2014; 3:837-46.

Ginnir distinct agricultural office2022.

Hailu Araya, Mitiku Haile, Arefayne Asmelash, Sue Edwards, and Tewolde Berhan Gebre Egziabher,2015 Overcoming the Challenge of Parthenium Hysterophorus through Composting Journal of Agricultural Science and Food Technology Vol. 1 (6), pp. 72-77

Jelin J., Dhanarajan M. S. (2013): Comparative physicochemical analysis of degrading Parthenium (Parthenium Hysterophorus) and saw dust by a new approach to accelerate the composting rate. Int. J. Chem. Environ. Biol. Sci. 1(3): 535-537.

Kumari, P., Sahu, P.K., Soni, M.Y. and Awasthi, P. 2014. Impact of Parthenium hysterophorus L. invasion on species diversity of cultivated fields of Bilaspur (C.G.) India. Agricultural Sciences, 5: 754-764.

Metson, A. J. (1961). Methods of chemical analysis for soil survey samples. Soil Bureau Bulletin No. 12,New Zealand Department of Scientific and Industrial Research, pp. 168–175. (Government Printer: Wellington, New Zealand.)

Mulugeta Eshetu, Daniel Abegeja, Tilahun Chibsa, Negash Bedaso.2022 Worm Collection and Characterization of Vermicompost produced using different worm species and waste feeds materials at Sinana on – Station of Bale highland southeastern Ethiopia. International Journal of Environmental and Agriculture Research;8(2)

Njorge, J.M. 1991. Tolerance of Bidens pilosa and Parthenium hysterophorus l. To paraquat (gramaxone) in Kenya coffee. Kenya Coffee: 56: 999 - 1001.

Pam hazlton and bian murphy,2007 interpreting soil test results : what do all the numbers mean? [2nd ed.].CSIRO PUBLISHING

Santamaria R. S, Ferrera C. R, Almaraz S. J. J, Galvis S. A, Barois B. I. 2001. Dynamics and relationships among microorganisms, C-organic and N-total during composting and vermicomposting. Agrociencia-Montecillo, 5 (4), 377-384.

Spiers TM, Fietje G (2000). Green waste compost as a component in soilless growing media. Compost Sci. Util. 8(1): 19-23.

Tadele Geremu, Habtamu Hailu, Alemayhu Diriba. 2020. Evaluation of Nutrient Content of Vermicompost Made from Different Substrates at Mechara Agricultural Research Center on Station, West Hararghe Zone, Oromia, Ethiopia. Ecology and Evolutionary Biology. 5 (4), 125-130.

Tamado T, Milberg P (2000). Weed flora in arable fields of eastern Ethiopia with emphasis on the occurrence of Parthenium hysterophorus. Weed Res. 40: 507-521.

Tefera T (2002). Allelopathic effects of Parthenium hysterophorus extracts on seed germination and seedling growth of Eragrostis tef. J. Agron. Crop Sci.188: 306-310.

Veena BK, Shivani M (2012). Biological utilities of Parthenium hysterophorus. J. Appl. Natural Sci. 4 (1): 137-143.

W`abuyele, E., Lusweti, A., Bisikwa, J., Kyenune, G., Clark, K., Lotter, W.D., McConnachie, A.J. and Wondi, M., 2014. A roadside survey of the invasive weed Parthenium hysterophorus (Asteraceae) in East Africa. Journal of East African Natural History, 103(1), 49-57.

Yadav. 2015 Assessment of different organic supplements for degradation of Parthenium hysterophorus by vermitechnologyJournal of Environmental Health Science & Engineering 13:4.

Soil Test based Crop Response Phosphorus Calibration Study on Teff (Triticum Aestivum L.) in Liban Chukala District, East Shewa Zone, and Oromia, Ethiopia

Tilahun Abera[1*], Tilahun Firomsa[1], Amante Lema[1], Abdurhman Husen, [1] and and Chali Hundesa[1]
Batu Soil Research Center, P. O. Box 59, Batu, Oromia, Ethiopia
Corresponding author: tileabera3@gmail.com

Abstract
Teff productivity is hampered by low and declining soil fertility resulting in loss of essential plant nutrients such as phosphorus which is one of the most limiting nutrients. Therefore, study was conducted on twenty one farmers' field in Liban Chukala District of East Shewa Zone of Oromia, during the main cropping seasons of 2019-2022. The aims of the study was to determine economically optimum rate of nitrogen fertilizer in the first year and the treatments were consisted of factorial combinations of three levels of NPS (0, 100 and 200) kg ha^{-1} with six levels of nitrogen (0, 23, 46, 69 92 and 115) kg ha^{-1} that gave a total of eighteen treatments. However, in the second two consecutive years the experiment was conducted to determine phosphorus critical (Pc) and phosphorus requirement factor (Pf and the treatments were consisted of six levels of phosphorus (0, 10, 20, 30, 40, and 50) kg ha^{-1} combined with single level of nitrogen (69 kg ha^{-1}) that gave a total of seven treatments. The experiments were laid out in randomized complete block design (RCBD) with two replications and the gross plot size was 4 m x 5 m (20 m^2) were used to determine optimum nitrogen in first year and 4m x 5m (20 m^2) and phosphorus critical (Pc) and also harvested from 4m^2 plot areas. The analysis of variance indicated that, grain yield was highly significantly (p <0.01) influenced by the interaction effect of NPS and nitrogen fertilizer rates. The highest (1987 kg ha^{-1}) grain yield was recorded by interaction effect of 200 kg NPS ha^{-1} and 69kg N ha^{-1} while the lowest (903 kg ha^{-1}) grain yield was recorded by control plots. However Biomass yield and Harvest index were significantly (p<0.05) affected by main effect of NPS and Nitrogen fertilizer. The highest (6411 and 6552 kg ha^{-1}) biomass yield were recorded by the highest application of 200Kg NPS and 115 kg Nha^{-1}respectively While the lowest (5100 and 4417 kg ha^{-1}) were recorded by control plots. Moreover, the highest (27.74% and 24.77%) harvest index were also recorded by maximum application of 200Kg NPS ha^{-1} and 115 kg Nha^{-1}respectively.The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of 46 kg N ha^{-1}) is profitable which gave the highest (47834 Birr) net return with acceptable (4532%) marginal rate of return and recommended for farmers in Liban Chukala district. On the other hand the analysis of variance indicated that, biomass yield and grain yield were highly significantly (p <0.01) influenced by soil test based phosphorus fertilizer application. The result indicated that the highest (7046 kg ha^{-1}) biomass and the highest (1734 kg ha^{-1}) grain yield were recorded by 30and 40 kg P ha^{-1} respectively. Moreover, 21ppm phosphorus critical (Pc) and 5.47 ppm phosphorus requirement factor (Pf) were identified for Teff crop production for the farmers of Liban Chukala District.

Key words: - Applied phosphorus, Teff, Cate and Nelson graph, NPS, Nitrogen, Phosphorous critical (Pc) phosphorus requirement factor (Pf), Soil and Yield

Introduction

Tef (Eragrostis tef (Zucc.) Trotter) is a cereal which belongs to the family Poaceae, sub-family Eragrostoideae, tribe Eragrosteae and genus Eragrostis (Costanza 1979). Teff (*Eragrostis tef*) is an ancient tropical cereal that has its center of origin and diversity in the northern Ethiopian highlands from where it is believed to have been domesticated (Demissie 2001).It is an interesting grain used for centuries as the principal ingredient of the Ethiopian population diet. The principal meal in which teff is used is called enjera: a big flat bread or pancake, than is eaten alone or with any kind of meats, vegetables and sauces (Dijkstra *et al*., 2008)

It is reported to have a higher content of iron, calcium, phosphorus, copper, and thiamine compared to other grains like Teff, barley, and sorghum (Mohammed *et al*., 2009). It is also reported to be free of gliadin (Spaenij *et al*., 2005) and could be suitable for use in the diet of patients suffering with celiac disease (Hopman *et al*., 2008). Teff proteins are no gluten in nature. It has high nutritional content including all essential amino acid composition especially lysine, more mineral content (mainly iron, calcium, phosphorus and copper) than other cereal grains. It contains B1 vitamin and is rich in fibre (Dijkstra *et al*., 2008).

But its productivity is hampered by low and declining soil fertility resulting in loss of essential plant nutrients such as phosphorus which is one of the most limiting nutrients; it is supplemented in crop production with blanket recommendation without considering agro-ecology, environmental effects, spatial and temporal soil fertility variations, hence this method is inefficient economically by increasing production costs and environmental hazards. So soil test based crop response and site specific P fertilizer application is important to improve the trend and increase crop yield; dependable and important method to identify the rates required in attaining needed level of plant growth and yield. Therefore, this study was undertaken with the following objectives:

- To determine economically optimum N fertilizer for Teff in Liban Chukala district.
- To determine Phosphorus critical and phosphorus requirement factor for Teff crop.

Materials and Methods

Description of the Experimental Site

The experiment was conducted on a Farmers' field in Liban Chukala district, east Shewa Zone of Oromia regional state in central Ethiopia for three consecutive years (2018 -2022). Liben is one of the wored as in the Oromia Region of Ethiopia. It is part of the East Shewa Zone located in the Great Rift Valley. Mount Zuqualla (2989 m) is also a prominent peak as well as a notable landmark, as the monastery of Saint Gebre Manfas Qeddus is located on it.

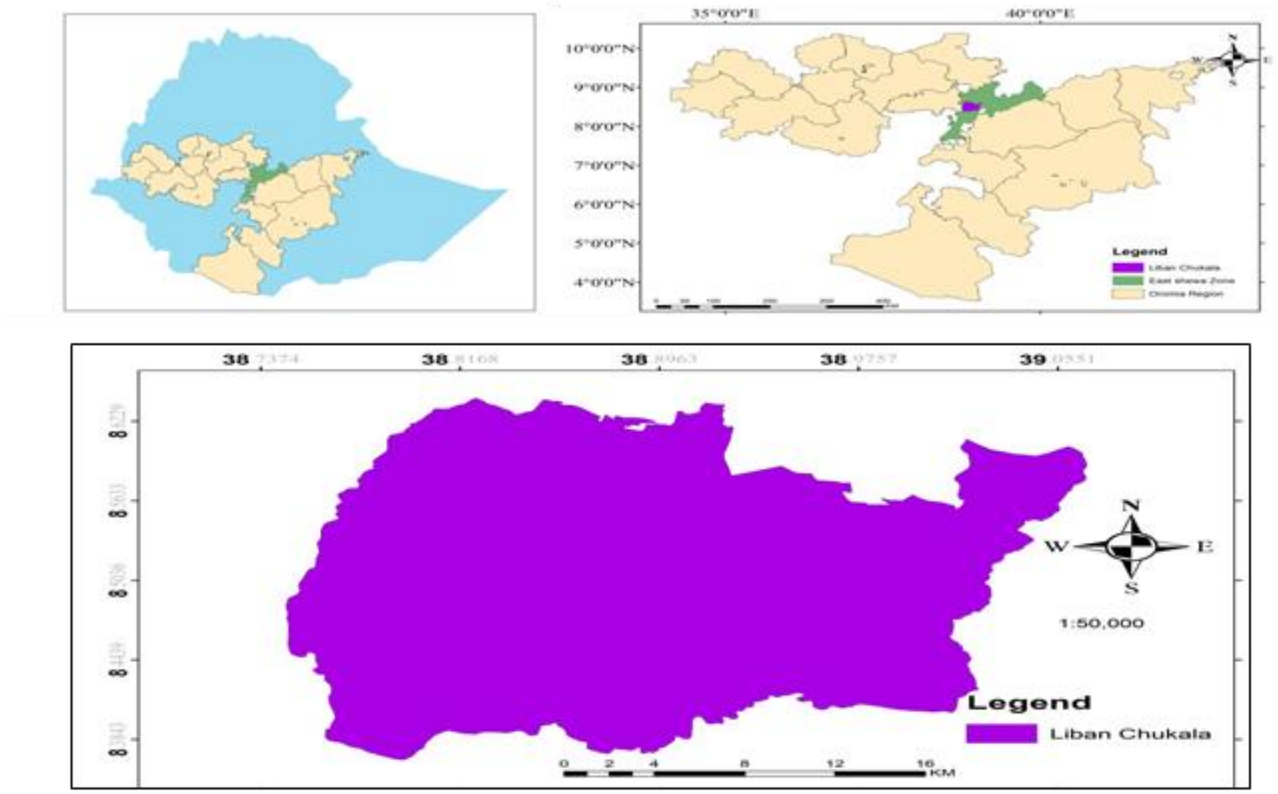


Figure 1. Location map of Liban Chukala District

Experimental Materials

- ✓ Teff variety (Boset) was used for the study area.
- ✓ TSP (46% P_2O_5),
- ✓ NPS (19%N: 38%P_2O_5:7%S) and Urea (46% N) were used

Treatments and Experimental Design

In the first year the experiment was conducted to determine optimum nitrogen rate and the treatments were consisted of factorial combinations of three levels of NPS (0, 100 and 200) kg ha^{-1} with six levels of nitrogen (0, 23, 46, 69 92 and 115) kg ha^{-1} that gave a total of eighteen treatments. However, by using the determined optimum Nitrogen (46 kg ha^{-1}) at first year; phosphorus critical (Pc) and phosphorus requirement factor (Pf) were determined in the second two consecutive years. So the treatments were consisted of six levels of phosphorus (0, 10, 20, 30, 40, and 50) kg ha^{-1} combined with single level of nitrogen (46 kg ha^{-1}) that gave a total of seven treatments. The experiments were laid out in randomized complete block design (RCBD) with two replications and the gross plot size was 4 m x 5 m (20 m^2) were used and also harvested from 4m^2 plot areas.

Management of the Experiment

The experimental fields were prepared following the conventional tillage practice which includes three times plowing before sowing of the crop. As per the specification of the design, a field layout was prepared; the land was leveled and made suitable for crop establishment. Sowing was done in mid-July of 2018, 2019 and 2020 using seed rate of 30 kg ha^{-1}. Full dose of NPS and TSP as per the treatment and one-third of N alone was applied at sowing time. The remaining two-third of N alone was top dressed at the mid-tillering crop stage. While conducting the experiment, others necessary agronomic management practices were carried out uniformly for all treatments.

Data Collection and Measurement
Yield components and Yield Parameters

Aboveground dry biomass yield: The aboveground dry biomass yield was determined from plants harvested from the net plot area after sun drying to a constant weight and expressed in kg ha^{-1}.

Grain yield: The grain yield was taken by harvesting and threshing the grain yield from net plot area. The yield was adjusted to 12.5% moisture content and expressed as yield in kg ha^{-1}.

Harvest index (HI): The harvest index was calculated as ratio of grain yield per plot to total above ground dry biomass yield per plot expressed as percent.

Soil Sample collection and analysis: **-** After 21 day's composite soil samples were collected from each plots by using soil auger from a depth of 0-20cm and analyzed for phosphorus

Determination of Critical P Concentrations
Critical phosphorus concentration is below which there were a response while above phosphorus was not respond. Intensive composite soil samples were collected after 21 days of planting. At this time the applied phosphorus was ready to be utilized by crop. Critical P value (mg/kg)has been determined following the Cate-Nelson graphical method where soil P values were put on the X-axis and the relative grain yield values on the Y-axis.

$$\text{Relative grain Yield \%} = \frac{\text{Yield}}{\text{Maximum Yield}} * 100$$

The Cate-Nelson graphical method was dividing the Y axis and X axis scatter diagram into four quadrants and maximizing the number of points in the positive quadrants while minimizing the number of points in the negative quadrants (Nelson and Anderson, 1977).

Determination of Phosphorus Requirement Factor
Phosphorus requirement factor (Pf) is the amount of Phosphorus in kg needed to raise the soil P by 1ppm. Average of Olsen P-ppm after 21 days of each applied P-treatment and Phosphorus increase over the control were calculated. Finally Pf (phosphorus requirement factor) was determined by the following formula.

$$\mathbf{Pf} = \frac{\mathbf{Kg\ P\ applied}}{\mathbf{\Delta\ Soil\ P}}$$

Statistical Analysis

The data subjected to analysis of variance (ANOVA) as per the experimental design using GenStat (15th edition) software (GenStat, 2012). The Least Significance Difference (LSD) at 5% level of probability was used to determine differences between treatment means.

Partial Budget Analysis

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using this technique were referred to as dominated and un dominated treatments, respectively. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula MRR (%) = $\frac{\text{Change in NB (NBb}-\text{NBa)}}{\text{Change in TCV (TCVb}-\text{TCVa)}} \times 100$

Where NB_a = NB with the immediate lower TCV, NB_b = NB with the next higher TCV, TCV_a = the immediate lower TCV and TCV_b = the next highest TCV.

Result and Discusion

The analysis of variance indicated that crop phenology and yield components of Teff did not significantly ($p < 0.05$) affected by interaction effect of NPS and nitrogen fertilizers (Table 1).

Table 1. Grain Yield of Teff as influenced by interaction effect of NPS and N fertilizers rates.

NPS (kg ha^{-1})	N from Urea (kg ha^{-1})					
	0	23	46	69	92	115
0	903^{e}	1206de	1476^{cd}	1601^{abcd}	1730^{abc}	1730^{abc}
100	1541^{cd}	1951^{ab}	1549^{bcd}	1662^{abc}	1832 ^{abc}	160^{abcd}
200	1870^{abc}	1790^{abc}	1742^{abc}	1987^{a}	1617^{abc}	1475^{cd}
LSD (0.05)	405.1					
CV (%)	11.8					

Means followed by the same letter with in the same column of the respective treatment are not significantly different (P ≤ 0.05) according to fishier Test, NPS= type of fertilizer, , CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant

Grain Yield

The analysis of variance showed that Teff grain yield was significantly ($p< 0.05$) influenced by the interaction effect of NPS and Nitrogen fertilizers (Table 1). Grain yield has been increasing as the rate of NPS and N increased from the lowest rate to the highest application rates. The result showed that, highest (1987 kg ha^{-1}) and the lowest (903 kg ha^{-1}) grain yield were recorded by integrated application level of 200 kg NPS ha^{-1} and 69 kg N ha^{-1} and control plots respectively. The result is consistent with the finding of (Mulugeta and Shiferaw 2017) which recorded the highest (1946.3 kg ha^{-1}) by application of (150 NPS/34.5 N) kg ha^{-1} fertilization.

Biomass Yield

The analysis of variance indicated Biomass was not affected by interaction effect of NPS and nitrogen fertilizer rates. However, it was highly significantly ($p < 0.01$) influenced by the main effect of each NPS and nitrogen fertilizers (Table 1). This result is in line with the result of (Wakjira, 2018) who reported the highest (10.09 tone ha^{-1}) biomass yield by application of (120 kg NPS kg ha^{-1}).

Table 2. Biomass yield and harvest index of Teff as influenced by main effect of NPS fertilizer and N rates.

Treatment (NPS kg ha^{-1})	BM (kg ha^{-1})	HI %
200	6411[a]	27.74[a]
100	6151[a]	27.65[a]
0	5100[b]	29.19[b]
LSD (0.05)	1603.4	6.807
CV (%)	12.9	NS
N (kg ha^{-1})		
115	6552[a]	24.77 [a]
92	6521[a]	26.56 [bc]
69	6281[ab]	28.06 [bc]
46	6002[ab]	27.08 [bc]
23	5552[b]	31.27 [ab]
0	4417[c]	28.12[c]
LSD (0.05)	1603.4	874.4
CV (%)	12.9	12.0

Biomass Yield has been increasing as the rate of NPS and N increased from the lowest rate to the highest application rates. The result showed that, highest (6411 kg ha^{-1}) and (6552 kg ha^{-1}) biomass yield were recorded by the maximum application rate of 200 kg NPS ha^{-1} and 115 kg N ha^{-1} respectively. While nil fertilizer application was recorded the smallest biomass yield per all plots (Table 1).

Partial Budget Analysis

To identify treatments with the optimum return to the farmer's investment, marginal analysis was performed on non-dominated treatments. For a treatment to be considered as worthwhile to farmers (100% marginal rate of return (MRR)) was considered as the minimum acceptable rate of return (CIMMYT, 1988). As indicated in table 3, the partial budget and dominance analysis showed that the highest net benefit 48,770 Birr ha^{-1} was obtained in the treatment that was treated with 150 kg ha^{-1} urea and 200 kg NPS ha^{-1} while the lowest net benefit 23,274 Birr ha^{-1} was obtained in the control treatment.

Table3. Partial budget and marginal analysis for NPS and N rates of teff

NPS	N	AGY	GNB	TVC	NR	MRR %
0	0	776	23,274	-	23,274	
0	23	917	27,513	830	26,683	411
0	46	1,263	37,881	1,360	36,521	1,856
0	69	1,499	44,982	1,890	43,092	297
0	92	1,213	36,396	2,420	33,976	D
0	115	1,460	43,794	2,950	40,844	D
100	0	1,481	44,442	1,754	42,688	1,565

100	23	1,555	46,656	2,284	44,372	325
100	46	1,822	54,648	2,814	47,834	4,532
100	69	1,679	50,382	3,344	47,038	555
100	92	1,565	46,953	3,874	43,079	D
100	115	1,273	38,178	4,404	33,774	D
200	0	1,650	49,491	3,208	46,283	2,108
200	23	1,601	48,033	3,738	44,295	D
200	46	1,686	50,571	4,268	46,303	818
200	69	1,786	53,568	4,798	47,770	3,806
200	92	1,489	44,658	5,328	39,330	D
200	115	1,467	44,010	5,858	38,152	D

Where, NPS cost = 16 Birr kg^{-1}, UREA cost = 14 Birr kg^{-1}of N, NPS, teff price = 30 Birr kg^{-1}, NPS and Urea application cost = 400 Birr ha^{-1}, MRR (%) = Marginal rate of return, D= Dominated treatment.

Determination of Phosphorus Critical Concentration and P-Requirement Factor

The Cate_Nelson graphical method was employed to determine phosphorus critical point for *for Teff crop in Liban Chukala district***.** Accordingly, the phosphorus critical concentration above which the responses of the crop become minimal was 21 ppm for Teff crop production (Fig 1). Phosphorus requirement factor is the amount of p in kg needed to raise the soil p by 1ppm. Moreover, the determination of Pc defined by the Cate Nelson method for the study area was 21 ppm. The soil available phosphorus vs. phosphorus fertilizer of the district was ranges 13.79 and 21.73 ppm for 0 and 50 kg P ha^{-1} respectively. The P requirement factor (Pf), computed from the difference between available soil test P values from plots that received 0-50 kg P ha^{-1}. Where, the Pf of the district were ranges 4.3 to 6.29 and the overall average Pf of all treatments was 5.97 for the study area.

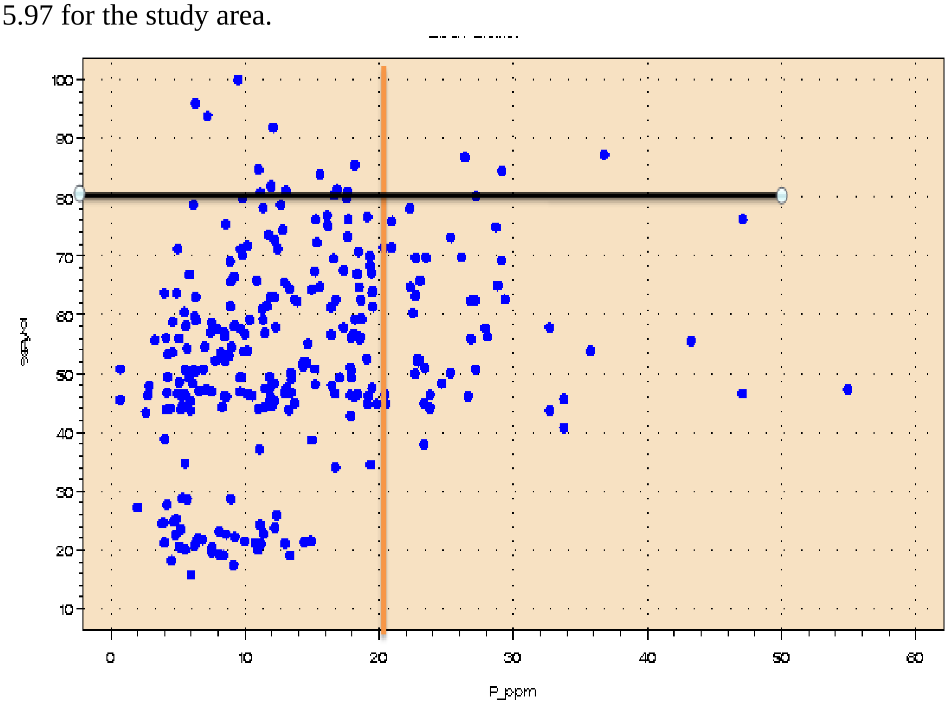


Figure 1. Graph of phosphorus critical concentration for teff production at liban chukala district

Table 4. Phosphorus requirement factor for Teff in Liben Chukala district

Fertilizer treatment kg P ha^{-1}	Olsen - P (ppm)		P increase Over control	*P f kg P^{-1} (ppm)/ Δ P
	Range	Average		
0	5.18 - 35.10	13.79	**0**	**0**
10	5.28 - 28.41	16.11	2.32	4.3
20	5.6 - 40.42	16.67	2.88	6.94
30	4.08 - 42.97	17.08	3.29	9.11
40	2.14 - 53.62	18.13	4.34	9.21
50	3.4 - 53.72	21.73	7.94	6.29
Mean				**5.97**

Harvest Index

The analysis of variance reveals that Harvest index of teff crop was not significantly ($p<0.05$) influenced by the main effect of phosphorus fertilizer application levels (table 5).

Grain and Biomass Yield

Grain yield, biomass yield, and plant height of Teff crop significantly responded ($p<0.01$) to P fertilizer application rate. Thus application of 30 and 40 kg P ha^{-1} gave significantly higher (1734 kg ha^{-1}) grain yield and (7.046 kg ha^{-1}) biomass yield respectively.

Table 5. Effect of NP fertilizer on yield and yield components of Teff at liban chukala district

Treatments		Yld (kg ha^{-1})	Bm (ton ha^{-1})	HI (%)
P (kg ha^{-1})	N (kg ha^{-1})			
0	0	1308^{c}	4.464^{e}	29.30
0	46	1501^{b}	5.932^{d}	25.36
10	46	1701^{a}	6.394^{c}	26.58
20	46	1645^{ab}	6.619^{bc}	24.84
30	46	1734^{a}	6.879^{ab}	25.19
40	46	1649^{ab}	7.046^{a}	23.41
50	46	1633^{ab}	6.960^{ab}	23.47
LSD (0.05)		177.7	0.3913	NS
CV (%)		4.5	2.5	6.1
P – values		0 .011	< .001	0.083

Conclusion and Recommendation

Teff (*Eragrostis tef*) is an ancient tropical cereal that has its center of origin and diversity in the northern Ethiopian highlands from where it is believed to have been domesticated (Demissie 2001. Teff productivity is hampered by low and declining soil fertility resulting in loss of essential plant nutrients such as phosphorus which is one of the most limiting nutrients. Therefore, study was conducted on twenty one farmers' field in Liban Chukala District of East Shewa Zone of Oromia, during the main cropping seasons of 2019-2022. The aims of the study was to determine economically optimum rate of nitrogen fertilizer in the first year and the treatments were consisted of factorial combinations of three levels of NPS (0, 100 and 200) kg ha^{-1} with six levels of nitrogen (0, 23, 46, 69 92 and 115) kg ha^{-1} that gave a total of eighteen treatments. However, in the second two consecutive years the experiment was conducted to determine phosphorus critical (Pc) and phosphorus requirement factor (Pf and the treatments were consisted of six levels of phosphorus (0, 10, 20, 30, 40, and 50) kg ha^{-1} combined with single level of nitrogen (69 kg ha^{-1}) that gave a total of seven treatments. The experiments were laid out in randomized complete block design (RCBD) with two replications and the gross plot size was 4 m x 5 m (20 m^2) were used to determine optimum nitrogen in first year and 4m x 5m (20 m^2) and phosphorus critical (Pc) and also harvested from 4m^2 plot areas. The analysis of variance indicated that, grain yield was highly significantly ($p <0.01$) influenced by the interaction effect of NPS and nitrogen fertilizer rates. The highest (1987 kg ha^{-1}) grain yield was recorded by interaction effect of 200 kg NPS ha^{-1} and 69kg N ha^{-1} while the lowest (903 kg ha^{-1}) grain yield was recorded by control plots. However Biomass yield and Harvest index were significantly ($p<0.05$) affected by main effect of NPS and Nitrogen fertilizer. The highest (6411 and 6552 kg ha^{-1}) biomass yield were recorded by the highest application of 200Kg NPS and 115 kg Nha^{-1}respectively While the lowest (5100 and 4417 kg ha^{-1}) were recorded by control plots. Moreover, the highest (27.74% and 24.77%) harvest index were also recorded by maximum application of 200Kg NPS ha^{-1} and 115 kg Nha^{-1}respectively.The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of 46 kg N ha^{-1}) is profitable which gave the highest (47834 Birr) net return with acceptable (4532%) marginal rate of return and recommended for farmers in Liban Chukala district. On the other hand the analysis of variance indicated that, biomass yield and grain yield were highly significantly ($p <0.01$) influenced by soil test based phosphorus fertilizer application. The result indicated that the highest (7046 kg ha^{-1}) biomass and the highest (1734 kg ha^{-1}) grain yield were recorded by 30and 40 kg P ha^{-1} respectively. Moreover, 21ppm phosphorus critical (Pc) and 5.47 ppm phosphorus requirement factor (Pf) were identified for Teff crop production for the farmers of Liban Chukala District.

Acknowledgement

We kindly thank Oromia Agricultural Research Institute (IQQO) for financial sponsorship and also Batu Soil Research Center (BSRC) for logistic support during conducting the experiment. Also would like to thank all staff members, especially to soil laboratory analysis team for their support and unreserved effort to provide reliable samples analysis data on time. finally our special thank also forwarded to experts of Liban Chukala Agricultural office, DA's and participant farmers for their effective collaboration work voluntarily in this study.

References

Demissie, Abebe. 2001. "Teff Genetic Resources in Ethiopia." *Narrowing the Rift: Tef Research and Development.* Proceedings of the "International Workshop on Tef Genetics and Improvement", Debre Zeit, Ethiopia, 16-19 October 2000. 27-31.

Dijkstra, A., Polman, J., van Wulfften-Palthe, A., Gamboa, P.A. and van Ekris, L., 2008. Survey on the nutritional and health aspects of teff (Eragrostis Tef). *Memorias, red-alfa lagrotech, comunidad europea, cartagena*.

Hopman E, Dekking L, Wuisman ML et al. Teff in the diet of celiac patients in the Netherlands. Scand J Gastroenterol. 2008; 43(3):277-282

Mohammed MIO, Mustafa AI, Osman GAM. Evaluation of wheat breads supplemented with Teff (Eragrostis tef (ZUCC.) Trotter) grain flour. Aust J Crop Sci. 2009; 3(4):207-212

Mulugeta Habte and Shiferaw Boke. 2017. Influence of balanced nutrients on growth performance and yield of Teff (Eragrostis tef (Zucc.)) in the midland of Bensa, Southern Ethiopia. *Journal of Scientific and Innovative Research*, *6*(3), pp.101-103.

Spaenij-Dekking L, Kooy-Winkelaar Y, Koning F. The Ethiopian Cereal Teff in Celiac Disease. N Engl J Med. 2005; 353(16):1748-1749.

Wakjira Tesfahun. 2018. Tef Yield Response to NPS Fertilizer and Methods of Sowing in East Shewa, Ethiopia. *Journal of Agricultural Sciences–Sri Lanka*, *13*(2), pp.162-173.

Yared Tesfaye, Yibekal Alemayehu and Kiya Adare.2020. Effect of blended nps and nitrogen fertilizers rates on yield components and yield of tef (eragrostis tef (zucc.) trotter) at adola district, southern Ethiopia. *International Journal of Current Research* Vol. 12, Issue, 02, pp.10168-10180.

Soil Test based Crop Response Phosphorus Calibration Study on Bread Wheat (Triticum Aestivum L.) in Liban Chukala District, East Shewa Zone, and Oromia, Ethiopia.

Tilahun Abera[1*], Tilahun Firomsa[1], Abdurhman Husen[1] Amante Lema[1], and and Chali Hundesa[1]
Oromia Agricultural Research Institute, Batu Soil Research Center, P. O. Box 59, Batu, Oromia, Ethiopia.
Corresponding author: tileabera3@gmail.com

Abstract

Nutrient mining due to sub optimal fertilizer use in one hand and unbalanced fertilizer uses on other have favored the emergence of multi nutrient deficiency in Ethiopian soils. Therefore, study was conducted on twenty one farmers' field in Liban Chukala District of East Shewa Zone of Oromia, during the main cropping seasons of 2019-2022. The aims of the study was to determine economically optimum rate of nitrogen fertilizer in the first year and the treatments were consisted of factorial combinations of three levels of NPS (0, 100 and 200) kg ha^{-1} with six levels of nitrogen (0, 23, 46, 69 92 and 115) kg ha^{-1} that gave a total of eighteen treatments. However, in the second two consecutive years the experiment was conducted to determine phosphorus critical (Pc) and phosphorus requirement factor (Pf and the treatments were consisted of six levels of phosphorus (0, 10, 20, 30, 40, and 50) kg ha^{-1} combined with single level of nitrogen (69 kg ha^{-1}) that gave a total of seven treatments. The experiments were laid out in randomized complete block design (RCBD) with two replications and the gross plot size was 4 m x 5 m (20 m^2) were used to determine optimum nitrogen in first year and 4m x 5m (20 m^2) and phosphorus critical (Pc) and also harvested from 4m^2 plot areas. The analysis of variance indicated that plant height, thousand kernels weight and harvest index were not significantly ($p<0.05$) influenced by applied NPS and Nitrogen fertilizers. However, biomass yield of bread wheat was significantly ($p<0.05$) affected by the interaction effect of NPS and N applied where, the highest (10584 kg ha^{-1}) biomass yield were recorded by application of 100 kg NPS ha^{-1} and 69 kg N ha^{-1}. On the other hand, the main effect of blended NPS and N significantly ($p<0.05$) influenced, spike length, seed per spike and grain yield. Therefore the maximum (3614 kg ha^{-1}) grain yield and (7.325cm) spike length were recorded by application of 100 kg NPS ha^{-1}. However the highest (39.46) number of seed per spike was recorded by200 NPS kg ha^{-}. Similarly, the highest (3803 kg ha^{-1}) grain yield and (7.367cm) spike length were recorded by application of 92 kg N ha^{-1}. But the highest (42.38) number of seed per spike was recorded by 115 kg N ha^{-1}.The economic analysis also revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of 200 kg NPS ha^{-1} with 69 kg N ha^{-1} were profitable and recommended for farmers in Liban Chukala District and other areas with similar Agro-ecological conditions. On the other hand the analysis of variance indicated that, Plant height, spike length, number of seed per spike, biomass yield and grain yield were highly significantly ($p<0.01$) influenced by soil test based phosphorus fertilizer application. The result indicated that the highest (87.82 cm) plant height, the highest (1013 kg ha^{-1}) biomass and the highest (4517 kg ha^{-1}) grain yield were recorded by 40 kg P ha^{-1}. Moreover, 23ppm phosphorus critical (Pc) and 9.86ppm phosphorus requirement factor (Pf) were identified for bread wheat production for the farmers of Liban Chukala District.

Key words: - Applied phosphorus, bread wheat, Cate and Nelson graph, NPS, Nitrogen, Phosphorous critical (Pc) phosphorus requirement factor (Pf), Soil and Yield

Introduction

Wheat is a type of cereal crops cultivated for its grain and used worldwide as staple food. The many species of wheat together make up the genus Triticum; the most widely grown is common wheat (Triticum *aestivum*) (James, 2014). Ethiopia is also one of the largest wheat producers in Sub-Saharan Africa and approximately 80% of the wheat area is planted to bread wheat (Asfaw *et al*. 2013). In Ethiopia wheat is mainly grown in the highlands, which lie between 6 and 16° N latitude and 35 and 42° E longitude, at altitudes ranging from 1500 to 2800 m above sea level and mean minimum temperatures of 6°C to 11°C. In Arsi, Bale and Shewa Zones, the soil, moisture and disease conditions within the range of 1900-2300m altitude zone are favorable for the production of early and intermediate maturing varieties of bread wheat. This is estimated to comprise 25% of the total wheat production area, while the remaining 75% falls in the 2300-2700 m altitude zone (MOA, 2016).

Ethiopia is not self-sufficient in wheat and a substantial gap primarily due to inefficient transfer of technology and the lack of necessary inputs and blanket type fertilizer application which based on soil color characteristics rather than on soil test results and crop requirements. According to the report of Food and Agriculture Organization of the United Nations (FAOSTAT, 2021) world total wheat production in 2019 was estimated at 765 million tons from a total of 215 million hectares area harvested; with average yield of 3547 kg ha^{-1}. However, in Ethiopia wheat production in 2019 was estimated at 5.3 million tons from 1.7 million ha area harvested with average yield of 2970 kg ha^{-1}. According to this report despite the large area under wheat in Ethiopia, the average yield of wheat is 19.4 % far below the world's average yield.

Each type of plant is unique and has an optimum nutrient range as well as a minimum requirement level. Below this minimum level, plants start to show nutrient deficiency symptoms. Excessive nutrient uptake can also cause poor growth because of toxicity. Therefore, the proper amount of application and the placement of nutrients is important (Silva and Uchida, 2000). Moreover, Sonon and Zhang (2014) reported that soil test calibration is specific for each crop type and they may also differ by soil type, climate, and the crop variety and relates soil test measurement in terms of crop response (Rouse, 1965) and essential that the results of soil tests be calibrated against crop responses from applications of the plant nutrients in question as it is the ultimate measure of a fertilization program. So, to tackle these problems site specific and crop specific new fertilizers recommendation such as NPS (19% N, 38% P_2O_5 and 7% S) have been evaluating by the researchers in Ethiopia as a means of supplementing nutrient depletion from soil and then for successful crop production. Therefore, this study was undertaken with the following objectives:

- To determine economically optimum N fertilizer for bread wheat in Liban Chukala district.
- To determine Phosphorus critical and phosphorus requirement factor for bread wheat.

Materials and Methods

Description of the Experimental Site

The experiment was conducted on a Farmers' field in Liban Chukala district, east Shewa Zone of Oromia regional state in central Ethiopia for three consecutive years (2018 -2022). Liben is one of the woredas in the Oromia Region of Ethiopia. It is part of the East Shewa Zone located in the Great Rift Valley. Mount Zuqualla (2989 m) is also a prominent peak as well as a notable landmark, as the monastery of Saint Gebre Manfas Qeddus is located on it.

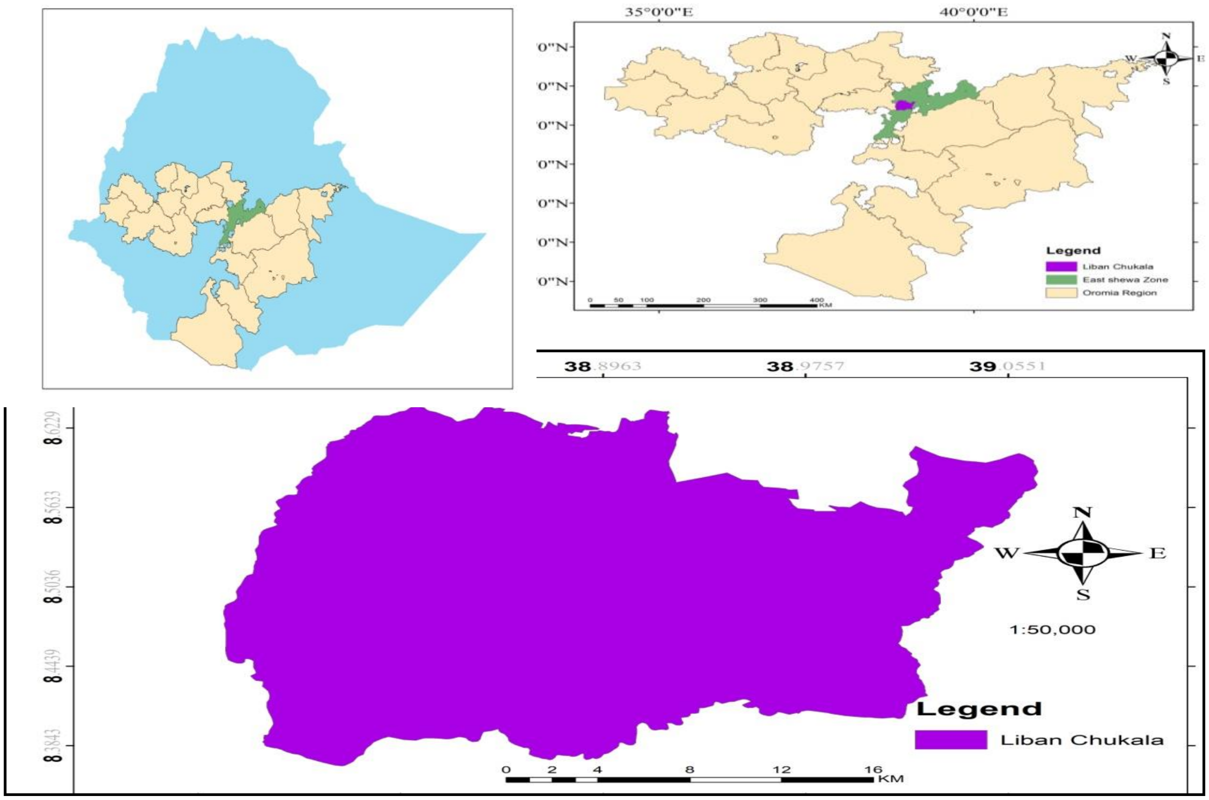


Figure 1. Location Map of Liban Chukala District

Experimental Materials

- ✓ Bread wheat variety (Qaqaba) was used for the study area.
- ✓ TSP (46% P_2O_5),
- ✓ NPS (19%N: 38%P_2O_5:7%S) and Urea (46% N) were used

Treatments and Experimental Design

In the first year the experiment was conducted to determine optimum nitrogen rate and the treatments were consisted of factorial combinations of three levels of NPS (0, 100 and 200) kg ha^{-1} with six levels of nitrogen (0, 23, 46, 69 92 and 115) kg ha^{-1} that gave a total of eighteen treatments. However, by using the determined optimum Nitrogen (69 kg ha^{-1}) at first year; phosphorus critical (Pc) and phosphorus requirement factor (Pf) were determined in the second two consecutive years. So the treatments were consisted of six levels of phosphorus (0, 10, 20, 30, 40, and 50) kg ha^{-1} combined with single level of nitrogen (69 kg ha^{-1}) that gave a total of seven treatments. The experiments were laid out in randomized complete block design (RCBD) with two replications and the gross plot size was 4 m x 5 m (20 m^2) were used nd also harvested from 4m^2 plot areas.

Management of the Experiment

The experimental fields were prepared following the conventional tillage practice which includes three times plowing before sowing of the crop. As per the specification of the design, a field layout was prepared; the land was leveled and made suitable for crop establishment. Sowing was done in mid-July of 2018, 2019 and 2020 using seed rate of 150 kg ha^{-1}. Full dose of NPS and TSP as per the treatment and one-third of N alone was applied at sowing time. The remaining two-third of N alone was top dressed at the mid-tillering crop stage. While conducting the experiment, others necessary agronomic management practices such as fungicide (Natura) sprayed for yellow rust and herbicide (Palas) sprayed to control both grass leaf and broad leaf were carried out uniformly for all treatments.

Data Collection and Measurement

Yield components and Yield Parameters

Plant height (cm) Plant height was measured from the soil surface to the tip of a spike (awns excluded) from 10 randomly tagged plants from the net plot area at physiological maturity

Number of seed per spike: The mean number of seeds per spike was recorded as an average of 10 randomly taken spikes from the net plot area.

Thousand kernel weight: Thousand kernels weight was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot by counting using electronic seed counter and weighed with electronic sensitive balance. Then the weight was adjusted to 12.5% moisture content.

Spike length (cm):- was measured from 10 randomly selected wheat heads per plot at harvesting time

Aboveground dry biomass yield: The aboveground dry biomass yield was determined from plants harvested from the net plot area after sun drying to a constant weight and expressed in kg ha^{-1}.

Grain yield: The grain yield was taken by harvesting and threshing the grain yield from net plot area. The yield was adjusted to 12.5% moisture content and expressed as yield in kg ha^{-1}.

Harvest index (HI): The harvest index was calculated as ratio of grain yield per plot to total above ground dry biomass yield per plot expressed as percent.

Soil Sample collection and analysis:- After 21 days composite soil samples were collected from each plots by using soil auger from a depth of 0-20cm and analyzed for phosphorus

Determination of Critical P Concentrations

Critical phosphorus concentration is below which there were a response while above phosphorus was not respond. Intensive composite soil samples were collected after 21 days of planting. At this time the applied phosphorus was ready to be utilized by crop. Critical P value (mg/kg)has been determined following the Cate-Nelson graphical method where soil P values were put on the X-axis and the relative grainyield values on the Y-axis.

$$\text{Relative grain Yield \%} = \frac{\text{Yield}}{\text{Maximum Yield}} * 100$$

The Cate-Nelson graphical method was dividing the Y axis and X axis scatter diagram into four quadrants and maximizing the number of points in the positive quadrants while minimizing the number of points in the negative quadrants (Nelson and Anderson, 1977).

Determination of Phosphorus Requirement Factor

Phosphorus requirement factor (Pf) is the amount of Phosphorus in kg needed to raise the soil P by 1ppm. Average of Olsen P-ppm after 21 days of each applied P-treatment and Phosphorus increase over the control were calculated. Finally Pf (phosphorus requirement factor) was determined by the following formula.

$$\mathbf{Pf} = \frac{\textbf{Kg P applied}}{\Delta \textbf{ Soil P}}$$

Statistical Analysis

The data subjected to analysis of variance (ANOVA) as per the experimental design using GenStat (15th edition) software (GenStat, 2012). The Least Significance Difference (LSD) at 5% level of probability was used to determine differences between treatment means.

Partial Budget Analysis

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using this technique were referred to as dominated and un dominated treatments, respectively. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula MRR (%) = $\frac{\text{Change in NB (NBb}-\text{NBa)}}{\text{Change in TCV (TCVb}-\text{TCVa)}} \times 100$

Where NB_a = NB with the immediate lower TCV, NB_b = NB with the next higher TCV, TCV_a = the immediate lower TCV and TCV_b = the next highest TCV.

Results and Discussion

Plant Height, Thousand Kernels Weight and Harvest Index

The analysis of variance indicated that Plant height, thousand kernels weight and harvest index of bread wheat were not significantly ($p < 0.05$) affected by the main effect of blended NPS and N fertilization at study area (Table 4).

Table 3. Interaction effect of NPS and N fertilizer rates on Biomass Yield of bread wheat

NPS (kg ha^{-1})	N from Urea (kg ha^{-1})					
	0	23	46	69	92	115
0	5292^{i}	6792^{h}	8875de	7625^{fgh}	8542^{defg}	9708^{abcd}
100	7417^{gh}	8500^{efg}	8750^{def}	10584^{a}	9542^{abcde}	10083^{abc}
200	7042^{h}	7542^{gh}	9333^{bcde}	10166^{ab}	8958^{cde}	9542^{abcde}
LSd (0.05)	1170.3					
CV (%)	6.5					

Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher protected LSD test.

Biomass yield

The analysis of variance showed that biomass yield of bread wheat was significantly ($p < 0.05$) affected by the interaction effect of blended NPS and N fertilizer rates (Table 3). Biomass yield increased as the rate of both NPS and N increased from zero to the highest rate of application. Maximum (10584 kg ha^{-1}) biomass yield was obtained at application of (100 kg NPS ha^{-1}) and (69 kg N ha^{-1}) While the lowest (5292 kg ha^{-1}) biomass yield was recorded by control plot (Table 3). This result is in agreement with (Tagesse *et al*., 2018) who recorded the highest (17129 kg ha^{-1}) and (16855 kg ha^{-1}) biomass yield by application rate of 200 kg NPS ha^{-1} and 92 kg N ha^{-1} respectively. Also, the result is in parallel with (Bizuwork and Yibekal, 2020) who recorded the highest (17383 kg ha^{-1}) biomass yield were recorded at combined application of 150 kg blended NPSB with 115 kg N ha^{-1} for durum wheat.

Table 4. Spike length, seed per spike, grain yield, Plant height, thousand kernels weight and harvest index of bread wheat variety as influenced by main effect of Blended NPS and N fertilizers rates.

Treatment (NPS kg ha^{-1})	SPL (cm)	NSPS	GYd (kg ha^{-1})	PH (cm)	TKW(gm)	HI (%)
200	7.342^{a}	39.94^{a}	3547^{a}	91.1	36.40	40.54
100	7.325^{a}	39.46^{a}	3614^{a}	84.3	36.08	40.12
0	7.027^{b}	36.77^{b}	3139^{b}	79.3	36.51	40.45
LSD (0.05)	0.1898	1.836	350.4	NS	NS	NS
N (kg ha^{-1})						
115	7.350^{a}	42.38^{a}	3703^{a}	84.5	35.80	37.86
92	7.367^{a}	38.97^{b}	3803^{a}	84.7	36.12	42.24
69	7.300^{a}	39.05^{b}	3752^{a}	83.8	36.33	40.10
46	7.255^{a}	37.47^{b}	3404^{ab}	82.7	36.30	37.99
23	7.150^{ab}	36.73^{b}	3127^{bc}	93.8	36.47	41.16
0	6.967^{b}	37.75^{b}	2812^{c}	79.8	36.96	42.89
LSD (0.05)	0.2684	2.597	495.5	NS	NS	NS
CV (%)	3.0	5.5	11.8	15.5	2.0	14.1

Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher protected LSD test; SPL= Spike length, NSPS= Number of seed per spike, PH= plant height, TKW = Thousand kernels weight; GY = Grain yield; HI% = Harvest index.

Spike Length

The analysis of variance revealed that spike length did not significantly ($p < 0.05$) affected by the interaction effects of blended NPS and N fertilization at the study area. However, it was significantly ($p<0.05$) influenced by the main effects of both blended NPS and N fertilizers applied (Table 4).

The result showed that spike length increased as the rate of both NPS and N enhanced from zero to the highest rates of application. The highest (7.325 cm) and (7.36 cm) spike length were recorded in response to (100 kg NPS ha^{-1}) and (92 kg N ha^{-1}) respectively while the lowest spike length (7.027 cm) and (6.967 cm) were recorded by control plot respectively (Table 4). This result is consistent with (Lemi and Negash, 2020) who recorded the highest (8.73cm) spike length for Ogolcho variety at 100/100 kg ha^{-1} NPSZnB/Urea application.

Number of Seed per Spike

The analysis of variance revealed that number of seed per spike was not significantly ($p < 0.05$) affected by the interaction effects of blended NPS and N fertilization at the study area. However, it was significantly ($p<0.05$) influenced by the main effects of both blended NPS and N fertilizers applied (Table 4). The result showed that number of seed per spike relatively increased as the rate of both NPS and N enhanced from zero to the highest rates of application. Even though, except the maximum levels of fertilizers application there were no statistically significant differences between the treatment applied on this parameter at the study area. The highest (39.46 gm) and (42.38 gm) number of seed per spike were recorded at maximum application of (200 kg NPS ha^{-1}) and (115 kg N ha^{-1}) respectively while the lowest number of seed per spike (36.77 gm) and (37.75 gm) were recorded by control plot accordingly (Table 4). This result is in line with (Dinkinesh *et al*., 2020) who recorded the highest (42.7 gm) number os seed per spike for bread wheat varieties by application of 183 kg NPS ha^{-1}.

Grain Yield

The analysis of variance revealed that grain yield of bread wheat was not significantly ($p < 0.05$) affected by the interaction effects of blended NPS and N fertilization at the study area. However, it was significantly ($p<0.05$) affected by the main effects of both blended NPS and N fertilizers applied (Table 4). Increasing the rates of blended NPS fertilizer from 0 to 100 kg ha^{-1} and N from 0 to 92 kg ha^{-1} showed consistent increase of grain yield while the yield was become declined at maximum application rates of both fertilizers. This indicated that the plants achieved its optimum application of blended NPS and N fertilization at 100 kg ha^{-1} and 92 kg ha^{-1} and which beyond that application the plant might be logged and not responded to fertilizer application. The highest grain yield (3614 kg ha^{-1}) and (3803 kg ha^{-1}) were obtained in response to application of 100 kg ha^{-1} blended NPS and 92 kg N ha^{-1} fertilizations respectively. While the lowest grain yield (3139 kg ha^{-1}) and (2812 kg ha^{-1}) were recorded by control plots accordingly.This result is parallel with the report of (Tilahun and Tamado, 2019) who reported the highest (5274 kg ha^{-1}) and (5738 kg ha^{-1}) grain yield by maximum application of (200 kg NPS ha^{-1}) and (92 kg N ha^{-1}) for durum wheat respectively.

Partial Budget Analysis

To identify treatments with the optimum return to the farmer’s investment, marginal analysis was performed on non-dominated treatments.

Table 5. partial budget analysis

NPS	N	AGY	GNB	TVC	NR	MRR %
0	0	1,881	18,810	-	18,810	-
0	23	2,373	23,733	830	22,903	493
0	46	2,681	26,811	1,360	25,451	481
0	69	3,373	33,732	1,890	31,842	2,699
0	92	2,699	26,991	2,420	24,571	D
0	115	3,011	30,105	2,950	27,155	D
100	0	2,993	29,925	1,754	28,171	690
100	23	3,022	30,222	2,284	27,938	D
100	46	3,278	32,778	2,814	29,964	1,369
100	69	3,736	37,359	3,344	34,015	774
100	92	2,849	28,485	3,874	24,611	D
100	115	3,290	32,895	4,404	28,491	2,004
200	0	3,617	36,171	3,208	32,963	2,251
200	23	3,885	38,853	3,738	35,115	279
200	46	3,003	30,033	4,268	25,765	293
200	69	4,179	41,787	4,798	36,989	2,157
200	92	3,632	36,324	5,328	30,996	D
200	115	3,868	38,682	5,858	32,824	345

NPS cost = 14.54 Birr kg-1, UREA cost = 10.60 Birr kg-1 of N, NPS, durum wheat grain per ha = 10 Birr kg-1, NPS and Urea application cost = 300 Birr ha-1, AGY = Adjusted grain yield down wards by 10% (kg ha-1), GNB = Gross Net Benefit, TVC = Total variable cost (Birr ha-1), NR = Net return (Birr ha-1), MRR (%) = Marginal rate of return, D = Dominated treatment, Control = unfertilized.

Partial budget and marginal analysis for NPS and N rates of bread wheat was done based on treatment to be considered as worthwhile to farmers, between 50 and 100% marginal rate of return (MRR) was the minimum acceptable rate of return (CIMMYT, 1988). As indicated in table 5, the partial budget and dominance analysis showed that the highest net benefit 36,989 Birr ha^{-1} was obtained in the treatment that was treated with 200 kg ha^{-1} blended NPS and 69 kg ha^{-1} N supplemented while the lowest net benefit 18,810 Birr ha^{-1} was obtained in the control treatment. In general, the economic analysis revealed that, a farmer's investment of one Birr in 200 kg ha^{-1} NPS and 69kg ha^{-1} of supplementation N on bread wheat variety (Kakaba) recoups the one Birr and gives an additional 21.57 Birr.

Determination of Phosphorus critical concentration and P-requirement factor

The Cate_Nelson graphical method was employed to determine phosphorus critical point for *for bread wheat in Dugda district.* Accordingly, the phosphorus critical concentration above which the responses of the crop become minimal was 23 ppm for bread wheat production (Fig 1). Phosphorus requirement factor is the amount of p in kg needed to raise the soil p by 1ppm. Moreover, the determination of Pc defined by the Cate Nelson method for the study area was 23ppm. The soil available phosphorus vs. phosphorus fertilizer of the district was ranges 13.96 and 25.48 ppm for 0 and 50 kg P ha^{-1} respectively. The P requirement factor (Pf), computed from the difference between available soil test P values from plots that received 0-50 kg P ha^{-1}. Where the available p vs. p fertilizer applied were ranges 13.96 to 25.48 ppm for 0 and 50 kg P ha^{-1} respectively. Where, the Pf of the district were ranges 2.29 to 14.13 and the overall average Pf of all treatments was 9.86 for the study area.

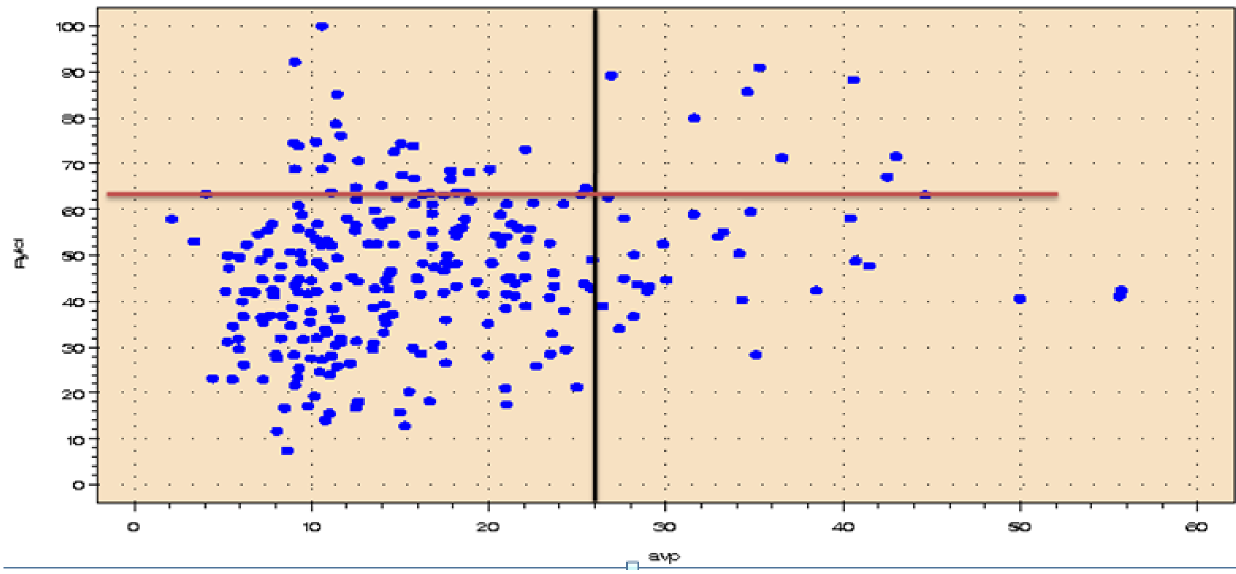


Figure 1. Graph of phosphorus critical for bread wheat production at Liban Chukala district

Table 3. Phosphorus requirement factor of Bread wheat in Liban District

kg P ha^{-1}	Olsen - P (ppm)		P increase Over control	*P*f* kg P^{-1} (ppm)/ Δ P
	Range	Average		
0	5.36-21.32	13.96	0	0
12.59	5.25-27.64	18.85	4.37	0
16.96	5.6-40.42	20.13	11.41	2.29
24	4.08-24.28	16.61	1.59	1.75
14.18	5.32-25.52	17.9	2.83	18.87
15.42	3.4-26.32	25.48	2.26	14.13
Mean		**14.85**		**9.86**

Thousand kernels weight and Harvest index as influenced by phosphorus fertilizer

The analysis of variance indicated that Thousand kernels weight and Harvest index were not significantly ($p<0.05$) affected by the main effect of phosphorus fertilizer application rates during the years of calibration study (Table 1).

Table 1. Effect of NP fertilizer on TKW and harvest index of bread wheat

Treatment		TKW (g)	HI (%)
P (kg ha^{-1})	N (kg ha^{-1})		
0	0	67.31	41.96
0	69	68.66	44.14
10	69	67.77	44.27
20	69	66.88	43.03
30	69	67.21	43.33
40	69	67.69	42.16
50	69	67.39	42.20
LSD (0.05)		NS	NS
CV (%)		0.9	1.8
P – values		0.245	0.103

Spike Length

The analysis of variance indicated that spike length was highly significantly ($p<0.01$) affected by the main effect of phosphorus fertilizer application rates during the years of calibration study (Table 2). The highest (7.385 cm) and lowest (6.81 cm) spike length were recorded at maximum application of (50 kg P ha^{-1}) and control plot respectively.

Plant Height

The analysis of variance indicated that plant height was highly significantly ($p<0.01$) affected by the main effect of phosphorus fertilizer application rates during the years of calibration study (Table 2).

Number of seed per spike

The analysis of variance indicated that number of seed per spike was significantly ($p<0.05$) affected by the main effect of phosphorus fertilizer application rates during the years of calibration study (Table 2). The highest (44.12 gm) and the lowest (38.72 gm) number of seed per spike were recorded by application of (40 kg P ha^{-1}) and control plots respectively.

Biomass Yield

The analysis of variance indicated that biomass yield was highly significantly ($p<0.01$) affected by the main effect of phosphorus fertilizer application rates during the years of calibration study (Table 2). The highest (10.705 ton ha^{-1}) and the lowest (7.365 tone ha^{-1}) biomass yield were recorded by application of (40 kg P ha^{-1}) and control plots respectively

Grain yield

The analysis of variance indicated that plant height was highly significantly ($p<0.01$) affected by the main effect of phosphorus fertilizer application rates during the years of calibration study (Table 2). The highest

(4517 kgha^{-1}) and the lowest (3092 kg ha^{-1}) grain yield were recorded by application of (40 kg P ha^{-1}) and control plots respectively.

Table 2. Effect of NP fertilizer on yield and yield components of bread wheat

Treatment		Yld (kg ha^{-1})	SPL (cm)	PH (cm)	Bm(ton ha^{-1})	NSPS
P (kg ha^{-1})	N (kg ha^{-1})					
0	0	3092^{c}	6.810^{d}	73.22^{e}	7.365^{d}	38.72 ^{c}
0	69	4095^{b}	7.210^{c}	79.83^{d}	9.275^{c}	41.20 ^{b}
10	69	4378^{ab}	7.245 ^{bc}	83.23^{c}	9.875^{bc}	43.09 ^{ab}
20	69	4343^{ab}	7.270 ^{abc}	85.20^{bc}	10.090^{ab}	43.01 ^{ab}
30	69	4473^{a}	7.375 ^{ab}	86.37^{ab}	10.315^{ab}	43.29^{ab}
40	69	4517^{a}	7.380 ^{a}	87.82^{a}	10.705^{a}	44.12^{a}
50	69	4277^{ab}	7.385^{a}	87.02^{ab}	10.130^{ab}	44.05 ^{a}
LSD (0.05)		288.0	0.1321	2.125	0.6413	2.528
CV (%)		2.8	0.7	1.0	2.7	2.2
P - values		< .001	< .001	< .001	< .001	0.010

Conclusion and Recommendation

The treatments consisted of factorial combination of three levels of NPS (0, 100 and 200 kg ha^{-1}) and five levels of supplemental nitrogen (0, 23, 46, 69, 92 and 115 kg ha^{-1}) fertilizer. The experiment was laid out as a randomized complete block design (RCBD) and replicated three times per treatment. The analysis of variance showed that biomass yield was significantly ($P < 0.05$) influenced by the interaction effect of blended NPS and N fertilization. On the other hand the main effect of both blended NPS and N fertilizer were not significantly affect plant height, thousand kernels weight and Harvest index. However, the main effect of both NPS and N fertilization significantly ($P < 0.05$) influenced spike length, seed per spike, and grain yield. The highest spike length (7.342 cm) and (7.367 cm) was obtained by application of 200 kgha^{-1} NPS and 92 kg ha^{-1} of N respectively. Also the highest number of seed per spike (39.94) and (39.05) was recorded by application of 200 kgha^{-1} NPS and 69 kgha^{-1} of N respectively. The highest grain yield (3614 kg ha^{-1}) and (3803 kg ha^{-1}) was obtained in response to application of 100 kg ha^{-1} blended NPS and 92 kg ha^{-1} N applied respectively. While the lowest grain yield (3139 kg ha^{-1}) and (2812 kg ha^{-1}) were obtained by control plots respectively. The highest biomass (10584 kg ha^{-1}) was obtained at interaction effect of 69 kg N ha^{-1} and 100 kg NPS ha^{-1}. The economic analysis revealed that for a treatment to be considered worthwhile to farmers (100% marginal rate of return), application of 200 kg NPS ha^{-1} with 69 kg N ha^{-1} fertilization are profitable and recommended. Moreover, 23ppm phosphorus critical (Pc) and 9.86ppm phosphorus requirement factor (Pf) were identified for bread wheat production for the farmers of Liban Chukala District.

Acknowledgements

We kindly thank the Oromia Agricultural Research Institute (IQQO) for financial sponsorship, and Batu Soil Research Center (BSRC) for financially supporting the study. Also would like to thank all staff members, especially to soil laboratory analysis team for their support and unreserved effort to provide reliable samples analysis data on time. At last but not at least, our special thank also forwarded to experts of Liban Chukala Agricultural office, DA's and participant farmers for their effective collaboration work voluntarily in this study.

References

Assefa M, Johnson MRS, Nyambilila A, Tekalign M, (2015). Wheat Response to Applied Nitrogen, Sulfur, and Phosphorous in three Representative Areas of the Central Highlands of Ethiopia. In J Plant Soil Science 8(5):1-11.

Dinkinesh Abera, Tamado Tana and Tadesse Dessalegn. 2020. Effects of Blended NPSB Fertilizer Rates on Yield and Grain Quality of Durum Wheat (*Triticum turgidum* L.) Varieties in Minijar Shenkora District, Central Ethiopia: Ethiop. J. Agric. Sci. 30(3) 57-76 (2020

Lemi Aga Duressa and Negash Geleta Ayana: Effects of Variety and Fertilizer Rate on Yield of Bread Wheat (Triticum aestivum, L) Varieties in East Wollega Zone, Western Ethiopia. Journal of Agricultural and Biological Sciences Vol. 6, No. 2, 2020, pp. 60-71

Tagesse Abera, Ketema Belete, Prof.Tamado Tana. 2018. Effect of Blended NPS Fertilizer Supplemented with Nitrogen on Yield Components and Yield of Bread Wheat (Triticum aestivum L.): Journal of Natural Sciences Research. Vol. 8(11). ISSN 2224-3186.

Tilahun Abera and Tamado Tana. 2018. Growth, yield component and yield response of durum wheat (Triticum turgidum L. var. Durum) to blended NPS fertilizer supplemented with N rates at Arsi Negelle, Central Ethiopia. *African Journal of Plant Science*, *13*(1), pp.9-20.

Bizuwork Tafes Desta & Yibekal Almayehu | (2020) Optimizing blended (NPSB) and N fertilizer rates for the productivity of Durum wheat (Triticumturgidum L.var. durum) in Central Highlands of Ethiopia, Cogent Food & Agriculture, 6:1, 1766733

CIMMYT. 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, D.F. ISBN 968-6127-18-6.

CSA (Central Statistical Agency). (2016). Agricultural sample survey: area and production of major crops, meher season. Vol. I. Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). 2015. Report on Area and Crop Production forecast for Major Crops (for private Peasant Holdings 'Meher' season), Addis Ababa, Ethiopia.

CSA (Central Statistics Agency) (1994) Agricultural sample survey (1994/95) report: Private peasant holding (Statistical Bulletin) Vol. III Central Statistics Agency, Addis Ababa, Ethiopia.

CSA (Central Statistics Agency) (2018) Agricultural Sample Survey 2017/2018. Volume I. Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Statistical Bulletin 586, Addis Ababa.

Dinkinesh Abera, Tamado Tana and Tadesse Dessalegn, 2020. Effects of Blended NPSB Fertilizer Rates on Yield and Grain Quality of Durum Wheat (*Triticum turgidum* L.) Varieties in Minijar Shenkora District, Central Ethiopia, *Ethiop. J. Agric. Sci*. 30(3) 57-76.

EthioSIS (Ethiopian Soil Information System). 2013. Soil analysis report. Agricultural Transformation Agency (Unpublished)

Fageria NK, Baligar VC and Jones CA. 2011. *Growth and Mineral Nutrition of Field Crops*. 3rd ed, CRC Press.

Gebreselassie Y (2002) Selected chemical and physical characteristics of soils of the Adet research center and its testing sites in North-Western Ethiopia. Eth J Nat Resour 3:199-215.

GenStat. (2012). GenStat Executable Release 15.2. Lawes Agricultural 425 Trust, Rothamstead Experimental Station, Harpenden, Clarendon 426 Press, London.

Hailu H, Tekalign M, Riikka K, Erik K, Heluf G, Taye B (2015). Soil fertility status and wheat nutrient content in Vertisol cropping systems of central highlands of Ethiopia. *Agriculture and Food Security*, 4(19):1-10.

Melesse Harfe, (2017). Response of bread wheat (*Triticum aestivum* L.) varieties to N and P fertilizer rates in Ofla district, Southern Tigray, Ethiopia, *African Journal of Agricultural Research*, Vol.12(19), pp.1646-1660.
Ministry of Agriculture (MoA) (2012). Ministry of Agriculture, Animal and Plant Health Regulatory Directorate. Crop variety register, Issue No. 15. Addis Ababa, Ethiopia.
Minot Nicholas, James Warner, Solomon Lemma, Leulsegged Kasa, Abate Gashaw, Shahidur Rashid. 2015. The Wheat Supply Chain in Ethiopia: Patterns, trends, and policy options. International Food Policy Research Institute (IFPRI) Washington, DC.
Salvagiotti F and Miralles D. 2008. Radiation interception, biomass production and grain yield as affected by the interaction of nitrogen and sulfur fertilization in wheat. *Eur. J. Agron.* 28: 282–290.
Shewry, P.R., 2009. Wheat. *Journal of experimental botany*, *60*(6), pp.1537-1553.
Tagesse Abera, Ketema Belete, Tamado Tana, (2018). Effect of Blended NPS Fertilizer Supplemented with Nitrogen on Yield Components and Yield of Bread Wheat (Triticum aestivum L.*), Journal of Natural Sciences Research*, Vol.8, No.11.
Tariq, J.M.T., Arif, M., Akbar H. and Ali. S. 2007. Response of wheat to source, type and time of nitrogen application. *Sarhad Journal of Agriculture*, 23 (4): 871-879.
Tilahun Abera Ishete and Tamado Tana, (2019). Growth, yield component and yield response of durum wheat (*Triticum turgidum* L. var. Durum) to blended NPS fertilizer supplemented with N rates at Arsi Negelle, Central Ethiopia, *African Journal of Plant Science*, Vol. 13(1), pp. 9-20.
Tilahun Firomsa, Abdurahman Husien*, Kafyalew Assefa, Tilahun Abera, Amante Lemma, Chali Hundessa, (2020). Effect of phosphorus and determination of optimum nitrogen for bread wheat in Kofele District, West Arsi Zone of Oromia, Ethiopia, *Journal of Scientific Agriculture*, 4: 34-37.

Verification of Soil Test Crop Response Based Phosphorus Calibration Study on Bread Wheat (Triticum Aestivum L.) in Bora District of East Shewa Zone, Oromia, Ethiopia.

Amante Lemma[1] and Tilahun Firomsa[2]
Oromia Agricultural Research Institute,Batu Soil Research Center, P.O.Box: 59, Batu, Ethiopia
Corresponding author: amentegashu@gmail.com

Abstract:
*The verification trial of soil test based crop response phosphorous calibration study for bread wheat production was conducted in 2021/22 main cropping season in Bora District of East Shewa Zone. The trial was initiated to verify the phosphorus critical level (10 ppm), requirement factor (6.45 ppm) and optimum amount of nitrogen (69 kg/ha) determined during soil test based crop response phosphorus calibration study for bread wheat production in Dugda District. The treatments were control (without fertilizer as T1), farmers practice (blanket recommendation as T2) and soil test based recommended phosphorus fertilizer rate as T3. The trial was conducted on six farmers' field across the District and the trial was laid out in randomized complete block design that was replicated over farmers as replications. The plot size was 10m * 10m and 150 kgha^{-1} seed rate was used. Analysis of variance for grain yield and above ground biomass indicated that there was significant difference (P<0.05) between the treatments. The highest mean grain yield (4580 kg/ha) and above ground biomass (11.95 ton/ha) were recorded with the soil test crop response-based fertilizer recommendation treatment which was significantly higher than the farmer practice (3647 kg/ha and 9.67 ton/ha respectively); whereas the lowest grain yield (1938 kg/ha) and above ground biomass (5.84 ton/ha) were recorded for the treatment without fertilizer. The economic analysis also showed that the highest net income (104,667 ETB) was obtained from soil test crop response based fertilizer application treatments with marginal rate of return (939.19%) which was greater than the minimum marginal rate of return 100% (CIMMT, 1998). Therefore, it is concluded that, the optimum rates for wheat Production were found to be 150 kg/ha Urea (69 kg N/ha) and the soil test based phosphorus fertilizer recommendation (pc=10 ppm and pf=6.45 ppm) could be followed for bread wheat Production in Bora Districts.*

Keywords: P-critical value, P-requirement factor, Calibration, Verification, *Net benefit, Marginal rate of return*

Introduction

Cereals are the most widely grown crops and comprise about 87.97% of total grain production in Ethiopia (CSA, 2019). Wheat is one of the most important crop plants in the world. It grows under a broad range of latitudes and altitudes; it is not only the most widely cultivated crop but also the most consumed food crop all over the world (CSA, 2016). Wheat is one of the most important cereals cultivated in Ethiopia. It ranks fourth after maize (*Zea mays*), tef (*Eragrostis tef*), and sorghum (*Sorghum bicolor*) both in area coverage and production (CSA, 2018). Ethiopia is the largest producer of wheat in sub-Saharan Africa (SSA), and the area coverage and production of the crop in Ethiopia is estimated to be 1.7 million hectares and 4.8 million tons of grain yields, respectively. This accounts about 15.39% of total grain output in the country (CSA, 2019). The national average productivity of wheat (2.7 tone ha) (CSA, 2019) was still lower than world's average (3.4 tone ha) (Beza *et. al*., 2020). Of the many reason for low productivity of wheat; decline of soil fertility, prevalence of disease, dependency on rain-fed traditional agriculture and low input including fertilizer application are the most important ones.

Unfortunately, many soils of Ethiopian highlands are inherently poor in available plant nutrients and organic matter content (Shewangizaw *et al*., 2020). But; crop production can be profitable if and only if balanced and adequate levels of phosphorus (P) and other nutrients are used. So, at this volatile grain and fertilizer prices condition, sound soil test calibration is essential for successful fertilizer program and crop production. It is essential that the results of soil tests could be calibrated or correlated against crop responses from applications of plant nutrients in question as it is the ultimate measure of a fertilization program. Phosphorus is of primary concern in the assessment of the soil resources of Ethiopia since most of the soils in the highland areas of the country are reported to be deficient in phosphorus (Agegnehu *et al*., 2015). With rapid population growth, continuous and intensive cropping without restoration of the soil fertility has depleted the nutrient base of most soils resulting in poor crop yields. The blanket recommendations that are presently in use all over the country were issued several years ago, which may not be suitable for the current production systems (Taye *et al*., 2002; Gete *et al*., 2010). Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P rate to their fields regardless of soil fertility differences.

To alleviate this problem, sound soil test based calibration study is essential for successful fertilizer program and crop production. It is essential that the results of soil tests could be calibrated or correlated against crop responses from applications of plant nutrients in question as it is the ultimate measure of a fertilization program. Phosphorus calibration is a means of establishing a relationship between a given soil test value and the yield response from adding nutrient to the soil as fertilizer. It provides information how much nutrient should be applied at a particular soil test value to optimize crop growth without excessive waste and confirm the validity of current P recommendations (Getachew and Lakew 2013). Soil tests are designed to help farmers predict the available nutrient status of their soils. Once the existing nutrient levels are established, producers can use the data to best manage what nutrients are applied, decide the application rate and make decisions concerning the profitability of their operations. However, local assessments for the soil P critical levels and soil P -requirement factors even for the major crops of the country are negligible (Girma, 2016).

Hence, calibration is a vital tool to attain the objective while calibrations are specific for each crop type and they may also differ by soil type, climate, and the crop variety. Therefore, Batu soil research center undertaken site specific soil test based crop response fertilizer calibration trail in Dugda District on bread wheat since 2017 to 2019 and optimum nitrogen, p-critical and p-requirement factors were determined for this specific area. Since they have similar soil type, and climate, the finding of this soil test based crop response phosphorus calibration study was verified in Bora district along with farmer practice and the control on farmers' holding. Therefore, this study was initiated with the objectives:

- To verify the feasibility of p-critical and p-requirement factor determined during site specific soil test based crop response phosphorus fertilizer calibration;
- To provide site specific soil test based p-fertilizer recommendation for bread wheat production.

Materials and Methods

Description of the Study Area

This experiment was conducted in Bora District during the cropping season of 2021 on 6 farmers' field. The district was situated in East Shewa zone, Oromia and far from Finfine 109 kilometers to south. The geographical location of Bora District was 8°18′2.08” N and 38°57′4.15” E with an elevation of 1,611 meters above sea level. The average annual rain fall and temperature were 1025 mm and 24°C respectively and the soils are characterized by vertisol.

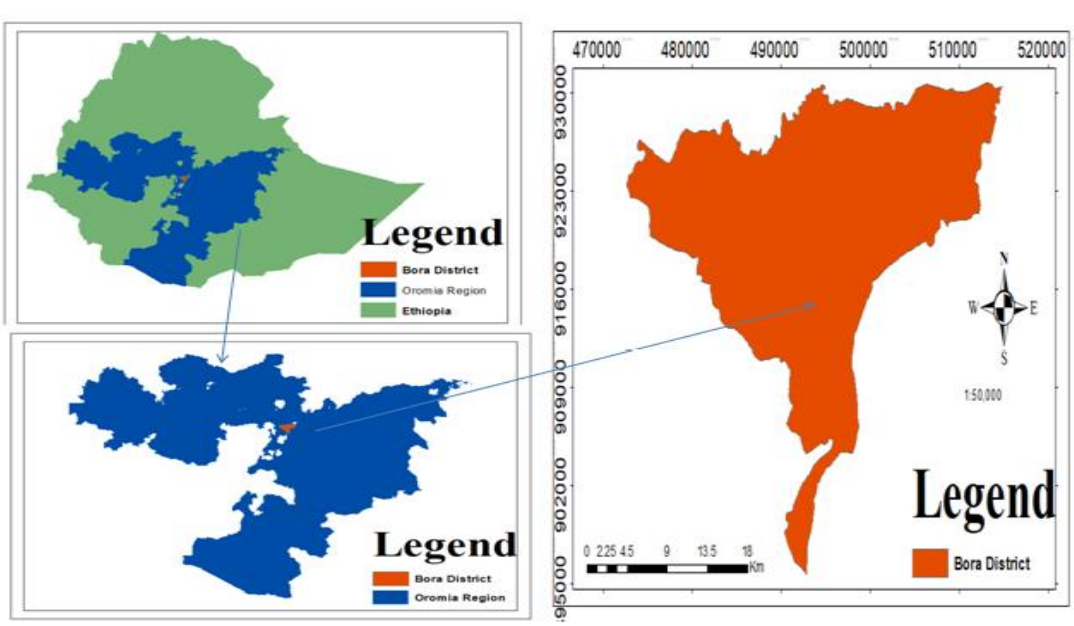


Figure 1: Location map of study area.

Experimental Materials

Kakaba bread wheat variety, TSP fertilizer (46%) and urea (46% N) were used for the experiment.

Treatments and Experimental Design

Before planting time, composite soil samples were collected from ten farmers' field separately at 0-20 cm in zigzag method. The collected soil samples were properly managed, packed, labeled and transported to the laboratory. Then the soil samples were allowed to air dry, grounded, sieved using 2mm sieve and analyzed for its available phosphorus. Using the pc (10 ppm) and pf (6.45 ppm) determined during the calibration study and initial available phosphorus (Pi) in the soil; the amount of phosphorus fertilizer requirement was calculated using the formula:

Phosphorus fertilizer rate = (pc-pi)*pf.

Where, pc- critical phosphorus concentration which was determined from the calibration study, pi-initial P which was determined from soil analysis of each site and pf- phosphorus requirement factor which was derived from the calibration experiment. The verification trail was done using three treatments: soil test based farmers practice (blanket recommendation) and control (without fertilizer). The verification experiment was laid out in randomized complete block design that was replicated over farmers as replications. Urea and TSP fertilizers were used as source of N and P respectively. P fertilizer was applied at planting time and urea was applied in two splits (1/2 at planting and 1/2 at mid-stage). The experimental plot size was 10m × 10m (100 m^2) for each treatments and 150 $kgha^{-1}$ seed rate was used.

Data Collection and Analysis

The agronomic data like plant height, spike length, grain yield, aboveground biomass, seed per spike, and thousand seed weight were collected. Agronomic data which were collected across locations were properly managed using EXCEL computer software. All the collected data was subjected to the analysis of variance (ANOVA) as per the experimental design using GenStat, 2012 (15th edition) software. The least significance difference (LSD) at 5% level of probability was used to determine differences between treatment means.

Economic Analysis

To identify the economic significance of the treatments, partial budget analysis was employed according to CIMMYT (1988). The actual grain yield was adjusted by 10% to reduce the exaggeration of small plot management. The concepts used in the partial budget analysis were the mean grain yield of each treatment, the gross benefit (GB) ha^{-1} (the mean yield for each treatment) and the field price of fertilizers (the costs of NPS and Urea and the application costs). Marginal rate of return, which refers to net income obtained by incurring a unit cost of fertilizer, was calculated by dividing the net increase in yield of durum wheat due to the application of each fertilizers rate. The net benefit (NB) was calculated as the difference between the gross benefit and the total cost that vary (TCV) using the formula NB = (GY * P) – TCV. Where, GY x P = Gross Field Benefit (GFB), GY = Adjusted Grain yield kg per hectare and P = field price kg of the crop. Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using this technique were referred to as dominated and none dominated treatments, respectively. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula:

$$\text{MRR}(\%) = \frac{\text{Net Income From Fertilized Field} - \text{Net Income From Unfertilized Field}}{\text{Total Variable Cost From Fertilizer Application}} * 100$$

The % MRR between any pair of un-dominated treatments was the return per unit of investment in fertilizer. To obtain an estimate of these returns, the % MRR was calculated as changes in NB (raised benefit) divided by changes in cost (raised cost). Thus, a MRR of 100% implied a return of one Birr on every Birr spent on the given variable input.

Results and Discussion

Soil pH and Soil Available Phosphorous

The soil pH of the experimental sites before planting was ranged from 6.56 to 7.84. The available P content of the soil was ranged from low to high (Olsen 1954) with the value ranged from 2.75 to 9.84 ppm. Therefore, the soil of the study areas needs application of phosphorus containing fertilizers for crop production.

Plant Height and Spike Length

The results of analysis of variance (table 1) showed that there were not significant differences ($P \leq 0.05$) among the soil test based and farmer practice treatments for plant height and spike length of bread wheat. However both parameters were significantly affected between control and fertilized treatments. Numerically, the maximum plant height (89.54 cm) and spike length (8.14 cm) were recorded for soil test based; whereas the minimum plant height (72.24 cm) and spike length **(**6.46 cm) was recorded for control.

Seed per Spike

The mean analysis of variance (table 1) showed that seed per spike was significantly influenced ($P \leq 0.05$) between the treatments (table 1). The highest seed per spike (45.98) were recorded for soil test based and followed by farmer practice (40.72); whereas the lowest number of seed per spike (27.59) was recorded for control.

Grain Yield and Biomass

The ultimate goal in crop production is to maximize economic yield, which is a complex function of individual yield components in response to the inputs used. In a broad sense, growth in cereals is directly related to grain yield. Grain yield is the product of the number of grains per unit area and the weight of individual grains (Desalegn *et al*., 2020). The analysis of variance for grain yield and above ground biomass, showed significant ($P < 0.05$) difference among the treatments (table 1). The highest mean grain yield (4580 kg/ha) and above ground biomass (11.95 ton/ha) were recorded with the soil test crop response-based fertilizer recommendation treatment which was significantly higher than the farmer practice (3647 kg/ha and 9.67 ton/ha respectively); whereas the lowest grain yield (1938 kg/ha) and above ground biomass (5.84 ton/ha) were recorded for the treatment without fertilizer. The results of this study were consistent with the previous findings of (Desalegn *et al*., 2020, Dejene *et al*., 2020, Kefyalew *et al*., 2016, Temesgen and Chalsissa, 2020) that reported the highest grain yield and above ground biomass were recorded under application soil test crop response based fertilizer recommendation.

Table 1: Effect of phosphorus fertilizer supplemented with nitrogen application on the mean yield and yield components of bread wheat in Bora District.

Treatments	Plant Height (cm)	Spike Length (cm)	Seed/spike	Grain Y (kg/ha)	Biomass (ton/ha)	TKW (gm)	HI (%)
Control	72.24[b]	6.46[b]	27.59[c]	1938[c]	5.84[c]	34.48[b]	34.0[b]
Farmer practice	87.49[a]	7.657[a]	40.72[b]	3647[b]	9.67[b]	45.93[a]	37.8[a]
Soil test based	89.54[a]	8.14[a]	45.98[a]	4580[a]	11.95[a]	49.39[a]	38.4[a]
LSD	7.73	0.60	4.0	745.09	1.54	4.84	2.74
CV (%)	**6.5**	**5.6**	**7.3**	**15.3**	**11.7**	**7.8**	**11.5**

Thousand Kernel Weight and Harvest Index

The results of analysis of variance for thousand kernel weight and harvest index of bread wheat (table 1) showed that there were not significant differences ($P \leq 0.05$) among the soil test based and farmer practice treatments. However thousand kernel weight and harvest index of bread wheat were significantly ($P \leq 0.05$) affected between control and fertilized treatments. The maximum mean of thousand kernel weights and harvest index (49.39 gm and 38.4 % respectively) was recorded for soil test crop response based fertilizer recommendation; which were significantly higher than the thousand kernel weights and harvest index recorded for control (34.4 gm and 34.0 % respectively). The results of this study were consistent with the previous findings of (Desalegn *et al*., 2020).

Economical Analysis

To verify the feasibility of soil test crop response based fertilizer application for wheat production in the study area, the partial budget analyses was carried out across the treatments and summarized in table 2. According to (CIMMYT, 1998); the MRR of major cereals was range from the minimum recommended rate 50% to 100% in most agricultural production and it is better when the MRR was >100%. Based on the partial budget analyses, the marginal rate of return (MRR) was found to be 939.19 % for soil test crop response based fertilizer application and 1544.89% for the farmer practice as indicated in table 2. Similarly, the economic analysis showed that the highest net income (104,667 ETB) was obtained from soil test crop response based fertilizer application treatments with marginal rate of return (939.19 %) which was greater than the minimum marginal rate of return 100% (CIMMT, 1998).

Table 2: Partial budget analysis for verification of bread wheat in Bora District

Treatments	NPS/TSP (kg ha^{-1})	Urea (kg ha^{-1})	AGY (kg ha^{-1})	GNB (Birr ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	MRR (%)
Control	0	0	1742.32	48,785	0	48,785	-
Farmer practice	100	100	3307.82	92,619	5,308	87,311	1544.89
Soil test based	**208**	**150**	**4097.80**	**114,739**	**10,072**	**104,667**	**939.19**

Where, TSP cost=36.38 Birr kg^{-1}, UREA cost = 16.7 *Birr kg^{-1}o , bread wheat =28 Birr per ha, GY = Grain yield; AGY = Adjusted Grain Yield; GNB = Gross net benefit, TVC =Total variable cost; NB = Net benefit; MRR = Marginal rate of return; Control = without fertilizers*

Conclusion and Recommendation

In Ethiopia, chemical fertilizers are used as one of the most important inputs for maintaining soil fertility and maximizing agricultural production and productivity of the country. Crop production can be profitable if and only if adequate and balanced levels of phosphorus (p) and other nutrient are used. But, the blanket recommendations that are presently in use all over the country were issued several years ago, which may not be suitable for the current production. Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P fertilizer rate to their fields regardless of soil fertility differences. Based on the results of this study, it is generally concluded that, soil test crop response based P fertilizer application gave consistently high grain yield of bread wheat in the study area which showing that the soil of the study area is deficient in P content.

In this study, Analysis of variance for grain yield and above ground biomass indicated that there was significant difference ($P<0.05$) between the treatments. The highest mean grain yield (4580 kg/ha) and above ground biomass (11.95 ton/ha) were recorded with the soil test crop response-based fertilizer recommendation treatment which was significantly higher than the farmer practice (3647 kg/ha and 9.67 ton/ha respectively); whereas the lowest grain yield (1938 kg/ha) and above ground biomass (5.84 ton/ha) were recorded for the treatment without fertilizer. This means, by applying recommended rate of P and optimum urea fertilizer application rate, yield of bread wheat could be increased by 20% over the blanket fertilizer recommendation.

Similarly, the economic analysis also showed that the highest net income (104,667 ETB) was obtained from soil test crop response based fertilizer application treatments with marginal rate of return (939.19 %) which was greater than the minimum marginal rate of return 100% (CIMMT, 1998). Therefore, it is concluded that, the optimum rates for wheat Production were found to be 150 kg/ha Urea (69 kg N/ha) and the soil test based phosphorus fertilizer recommendation (pc=10 ppm and pf=6.45 ppm) could be followed for bread wheat Production in Bora Districts. Further, in order to adopt and popularize this site specific soil test crop response based p fertilizer recommendation, it should be demonstrated in the study area for bread wheat production and productivity.

Acknowledgements

First of all, we would like to thank Almighty God for blessing us with invaluable gifts of health, strength, patience and protection to start and complete this study. Secondly, the authors would like to thank Oromia Agricultural Research Institute for financial support; Batu Soil Research Center for providing research facilities like supply of inputs and logistic. Also we like to express our sincere thanks to Soil Fertility Improvement Team members of the Center for participation in conducting this assessment. Last not least, we thankful for Agriculture and Natural Resource Bureau, and the farmers of Bora District who allowing me us use their farm land for this study.

References

Agegnehu, G., Nelson, P. N., Bird, M. I., & van-Beek, C., 2015. Phosphorus Response and fertilizer recommendations for wheat grown on Nitisols in the central Ethiopian highlands. *Communications in Soil Science and Plant Analysis*, *46*(19), 2411–2424.

Beza Shewangizaw*, Kenzemed Kassie, Shawl Assefa and Tesfaye Feyisa, 2020. On farm verification of soil test-based phosphorus fertilizer recommendations for bread wheat (*Triticum aestivum* L.) on the vertisols of central highlands of Ethiopia. *Cogent Food & Agriculture,* 6: 6: 1807811.

Central Statistical Agency (CSA), 2018. Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season): Agricultural Sample Survey. 1st (Vol.), Statistical bulletin 586, Addis Ababa, Ethiopia.

Central Statistical Agency (CSA), 2019. Agricultural sample survey. Report on area and production of major crops (private peasant holdings, meher season). Addis Ababa, Ethiopia.

CSA (Central Statistical Agency), 2016. Agricultural sample survey report on area and production of major crops: Private peasant holdings in meher season of 2015/2016 (Vol. I, No. 584), Addis Abeba, Ethiopia.

CIMMYT (International Maize and Wheat Improvement Center), 1998. From agronomic data to farmer recommendations*:* An Economics Training Manual, Completely revised edition. Mexico, D.F. ISBN 968- 6127-18-6.

Dejene Getahun*, Dereje Girma, Abreham Feyisa, Ajema Lemma, Lello Dejene, 2020. Verification of Soil Test Crop Response Based Phosphorus Recommendation on Bread Wheat (Triticum Aestivum L.) in Yaya Gulele District of North Shewa Zone, Oromia, *International Journal of Applied Agricultural Sciences*, 6(3): 52-56.

Desalegn Negasa Soresa*, Pichiah Gomathinayagam, 2020. Response of Bread Wheat (Triticum aestivum L.) Genotypes to Different Rates of Blended Fertilizer in Horro District, Western Ethiopia, *Agricultural and Biological Sciences Journal,* Vol. 6, No. 3, pp. 137-142

Beza Shewangizaw , Kenzemed Kassie , Shawl Assefa & Tesfaye Feyisa, 2020. On farm verification of soil test-based phosphorus fertilizer recommendations for bread wheat on the vertisols of central highlands of Ethiopia, *Cogent Food and Agriculture*, 6:1, 1807811, DOI: 10.1080/23311932.2020.1807811

Getachew Agegnehu and Lakew B., 2013. Soil test phosphorus calibration for malting barley (Hordeumvulgare L.) on Nitisols of central Ethiopian highlands. Tropical Agriculture 90, 177-187.

Girma Chala. 2016. Soil test phosphorous calibration for potato production on Nitisols of central highlands Ethiopia. Ethiop J. Sci. Sus. Dev. 120-137.

Haileslassie A, Priess JA, Veldkamp E, Lesschen JP, 2006. Smallholders' soil fertility management in the central highlands of Ethiopia: Implications for nutrient stocks, balances and sustainability of agroecosystems. Nutr. Cycl. Agroecosyst. 75: 135-146.

Kefyalew Assefa Gejea, Tilahun Firomsa Erenso, and Tadesse Hunduma Banja, 2016. Verification and Demonstration Pc and Pf Determined Through Soil Test Based Crop Response Study for P on Bread Wheat at Lume Area of Oromia Region, Ethiopia, *International Journal of Research and Innovations in Earth Science*, Volume 3, Issue 6, ISSN (Online) : 2394-1375.

Korkmaz, K., Ibrikci, H., Karnez, E. B. R. U., Buyuk, G., Ryan, J., Ulger, A. C., & Oguz, H., 2009. Phosphorus use efficiency of wheat genotypes grown in calcareous soils. *Journal of Plant Nutrition*, *32*(12), 2094–2106.

Olsen, S. R. Cole, Watanable, F. S. and Dean L. A., 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate, Circ. U.S. Dep. Agric. 939.

Taye, B., Hassan, Y., Setsu, S., Gorfu, A., Hassana, M., Tanner, D. G., Tesemma, T., & Gebre, T. 2000. *Optimizing fertilizer use in Ethiopia-Corelation of soil analysis with fertilizer response in Hetosa Woreda, Arsi Zone*. Sasakawa-Global.

Temesgen Chimdessa*, Chalsissa Takele, 2020. Verification of Soil Test Based Phosphorous Calibration Study for Bread Wheat (Triticum Aestivum L.) Production in Horo District, Oromia Regional State, Ethiopia, *Advances in Biochemistry*, 8(3): 52-56.

Scoones, I. and Toulmin, C., 1999. Policies for soil fertility management in Africa. *Policies for soil fertility management in Africa.*

Zeleke, G., G. Agegnehu, D. Abera and S. Rashid, 2010. Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system. Washington, DC: IFPRI.

Determination of NPS Fertilizer Rates on Yield and Yield Components of Bread Wheat (Triticum Aestivum L.,) in Kofole District, West Arsi Zone of Oromia, Ethiopia

Abdurahman Husien, Tilahun Abera and Tilahun Firomsa
Batu Soil Research Center, P.O. Box 59, Batu Oromia, Ethiopia
Corresponding Author, e-mail: abdurahmanh2010@gmail.com

Abstract

Fertilizer is the most important input, which contributes significantly towards final grain yield of wheat and to exploit the inherited potential of cultivar, but productivity of wheat for long time was low due to the absence of essential/unbalanced crop nutrition. Therefore, the study was conducted for two years on farmers' fields in Kofole District in 2020/21 to 2021/22 with the following objectives to evaluate the effect of rates of NPS fertilizer on growth, yield and yield components of bread wheat and to determine economically appropriate rate of NPS fertilizer for bread wheat production. Moreover, the experiment was laid out in randomized complete block design (RCBD) with two replications with a plot size was 5m x 4 m (20 m2) accommodating 20 rows each spaced 20 cm. Spacing of 1.0 m and 0.5 m were maintained in between adjacent blocks and plots, respectively. The treatments was applied based on already determined Phosphorous critical and requirement factor on the bases of initial soil phosphorus and consisting of 100% Pc from TSP fertilizer and 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application) on a Bread Wheat Variety Ogolcho with Seed Rate 150 kg ha^{-1}, Weeds and yellow rust were managed by pallas and Rexcido respectively. The main effects of NPS fertilizer rate on yield and yield components were highly significant with respect to phosphorus critical and requirement factors ($P < 0.01$) on plant height, spike length, seed per spike, aboveground dry biomass and grain yield. The thousand kernels weights were not significant. The partial budget analysis showed that the maximum net benefit with an acceptable MRR was obtained from 100 % pc NPS fertilizer and supplemented with 69 kg N ha^{-1} application on Eutric Vertisols. The main effects of NPS fertilizer rate were highly significant with respect to phosphorus critical and requirement factors ($P < 0.01$) on plant height, aboveground dry biomass, and spike length, seed per spike and grain yield. The thousand kernels weights were not significant. The highest grain yield was obtained due to the application of 100 % pc NPS with recommended 69 kg N ha^{-1} and flowed by rate of 100% pc TSP with recommended 69 kg N ha^{-1}. The lowest grains yield (2468 kg ha^{-1}) was obtained in response to control. The partial budget analysis showed that the maximum net benefit with an acceptable MRR was obtained from 100 % pc NPS fertilizer and supplemented with 69 kg N ha-1 application on Eutric Vertisols and recommended for the study area.

Keywords: Rate, Fertilizers, NPS, Yield, Eutric Vertisols and Benefit

Introduction

Bread wheat (*Triticum aestivum L.*) is one of the most important cereal crops globally and is a main food for about one third of the world's population (Hussain *et al.,* 2002). This is particularly true to the major food crops grown total grain crop area, 81.39% (10,358,890.13 hectares) was under cereals. Wheat took up 13.73% (1,747,939.31 hectares) of the grain crop area. Likewise, cereals contributed 87.97% (about 277,638,380.98 quintals) of the grain production and the wheat 15.33% (48,380,740.91 quintals) of the grain production (CSA, 2019). Wheat provides more protein than any other cereal crops (Iqtidar *et al*., 2006). In Ethiopia, wheat grain is used in the preparation of a range of products such as: the traditional staple pancake ("injera"), bread ("dabo"), local beer ("tella"), and several others local food items (i.e., "dabokolo","ganfo", "kinche"). Besides, wheat straw is commonly used as a roof thatching material, and as a feed for animals. It accounts for about 11% of the national calorie intake (Demeke, 2013).

Low soil fertility, especially nitrogen (N) deficiency, is one of the major constraints limiting wheat production in Ethiopian Highlands (Teklu and Hailemariam, 2009). In Ethiopia, erratic seasonal rainfall, inadequate availability of other nutrients, nitrate leaching during the short but heavy rainy seasons, ammonia volatilization and continuous removal in the cereal mono cropping systems of the highlands are the major factors that result in inefficient use of N fertilizer (Tanner *et al.*, 1993). lack of soil fertility database and absence of area and crop specific fertilizer recommendation will be taken as a key obstacle in realizing the first GTP of doubling agricultural production by the end of the five-year plan period (IFDC, 2015). According to the soil fertility map made over 150 districts, most of the Ethiopian soils lack about seven nutrients (N, P, K, S, Cu, Zn and B) (Ethio-SIS, 2013). Moreover, Hailu *et al*. (2015) reported that, Soil analysis data of wheat fields in central highland Vertisols of Ethiopia showed deficiency in the levels of N, P, S, Zn, Mo and B. Moreover, the plant analysis data from the same sites indicated that wheat plants will be deficient in N, P, Zn and K.

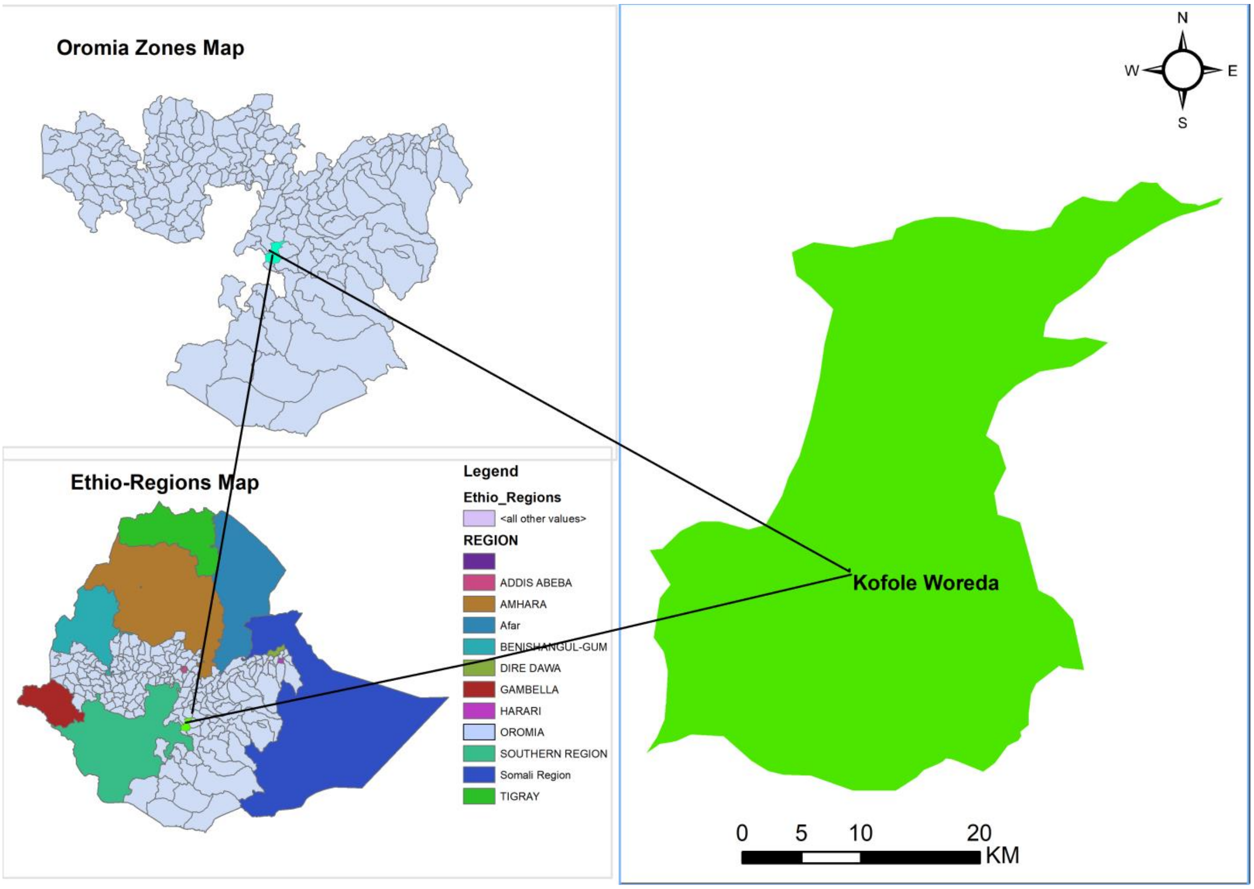
Phosphorus fertilizer application significantly and positively influenced grain yield and number of tillers of wheat (Damene, 2003). Similarly according to Assefa *et al*. (2015) reported that, Grain yield, plant height, effective tiller number/m^2 and biomass yield of bread wheat variety increase linearly with planting density and N/P_20_5 fertilizer rate. Moreover, it also reported that grain yield and yield components of wheat 100% fully responded to applied nitrogen, 72.3% showed response to sulfur and 78% showed response to applied phosphorus on eighteen fields studied in central high lands of Ethiopia and strongly indicated sulfur deficiency and its importance to include in balanced fertilizer formula. According to Kiros *et al.* (2013) the optimum grain yield for two bread wheat varieties was found at 100 kg N ha−1; couple with 20 kg S ha$^{-1,}$ beyond which the yield increase was non-significant, suggesting that higher N rates are to be avoided. Depending upon available sulfur levels, the wheat yield can increase from 0 to 42% (De Ruiter and Martin, 2001) usually obtaining the best response with sulfur application between 10 and 20 kg ha-1 (McGrath et al., 1996). Due to these, new blended fertilizers such as NPS (19% N, 38% P_2O_5 and 7% S) are currently being used by the farmers in Ethiopia including the study area. In addition to this, the amount of N in the NPS is small as compared to the requirement of bread wheat. Therefore, this study was undertaken with the following objectives to assess the effect of rates of NPS fertilizer and to determine economically appropriate rate of NPS fertilizer on yield components and yield of Bread wheat.

Materials and Methods

Description of the experimental site

Kofole district which is located in West Arsi zone of Oromia Regional Sate in the central highlands of Ethiopia. Maize is grown mainly by subsistence farmers which is located at 06^0 50' to 07^0 09' N and 38^{0}38' to 39^{0}04' E at a distance of about 280 km Southeast of Addis Ababa and at an altitude of 2620 m above sea level. Bread wheat is grown mainly by subsistence farmers. The area is characterized by high altitude in the humid temperate climatic zones. According to National Ethiopia Meteorology agency Station records the experimental field was under continuous cereal production for long time. The long-term (1998-2019) mean total annual rainfall was 1036 mm with mean maximum and minimum temperatures of 19.64 and 7.53oC, respectively. The environment is seasonally humid and major soil type of the trial sites was Eutric Vertisols. The environment is seasonally humid and major soil types of area are Eutric Vertisols, Haplic Luvisols, Chromic Luvisols and Humic Nitosols.

Figure 1. Maps of the study area



Treatments and experimental design

The experiment was laid out in randomized complete block design (RCBD) with two replications. The details of the treatments are shown in table 1. The gross plot was 4m x 5 m (20 m^2) accommodating 20 rows each spaced 20 cm. Spacing of 1.0 m and 0.5 m were maintained in between adjacent blocks and plots, respectively. The treatments were based on already determined phosphorous critical and requirement factor and consisting of 100% Pc from TSP fertilizer and 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application).

Applied P = (Critical P - Po)* Pf. Whereas Pc= 19 ppm and Pf = 3.30 on Eutric Vertisols of bread wheat in the district (Kefyalew *et al*., 2016).

Nitrogen fertilizers in the form of urea were used according to the recommended optimum rate of 46 and 69 kg N ha^{-1} on Eutric Vertisols. Moreover the available phosphorus was determined by extraction with 0.5 M $NaHCO_3$ according to the methods of Olsen et al. (1954).

Table 1. Rates of fertilizers treatment used with their nutrient contents in kg for the experiment on Eutric Vertisols

No	Treatments	Fertilizer source	Kg P ha^{-1} = *(Pc - Po)* Pf.* ***Pc= 19 ppm and Pf = 3.30 ppm***	kg N ha^{-1}	kg S ha^{-1}
1	Control	-	0	0	0
2	100% Pc	TSP	(19- Po) x 3.30	69	0
3	100% Pc	NPS	(19- Po) x 3.30	69	
4	75% Pc	NPS	(14.25- Po) x 3.30	69	
5	50% Pc	NPS	(9.5- Po) x 3.30	69	
6	25% Pc	NPS	(4.75- Po) x 3.30	69	

Whereas Pc = phosphorus critical, Pf = phosphorous requirement factor, Po = initial soil phosphorus.

Experiment managements

The experimental field was prepared following the conventional tillage practice which includes four times plowing before sowing of the crop. As per the specification of the design, a field layout was prepared; the land was leveled and made suitable for crop establishment. Sowing was done in July 2020 and 2021 using seed rate of 150 kg ha^{-1}. Full dose of NPS and TSP as per the treatment and one-third of N alone was applied at sowing time. The remaining two-third of N alone was top dressed at the mid-tillering crop stage. While conducting the experiment others necessary management practices such as fungicide (Tilt) sprayed for yellow rust were carried out uniformly for all treatments.

Data collection:

Agronomic data collected were plant height, biomass yield, grains per spike, spike length, 1000 kernel weight (TKW) and grain yield. All agronomic parameters were average of 5 plants. A total biomass and grain yields recorded on plot basis were collected and converted to kg ha^{-1} for statistical analysis.

Partial budget analysis:

Partial budget analysis was employed and calculates the marginal rate of return (MRR) (CIMMYT, 1988) manual. Total variable cost was cost incurred due to application of NPS fertilizers rate with pc and Pf of soil which was Eutric Vertisols from 25%Pc, 50% Pc, 75% Pc and 100% Pc of NPS and 100%Pc TSP for bread wheat and the grain yield was adjusted by 10% to reduce the exaggeration of small plot management.

Data management and analysis:

All agronomic which were collected across locations was properly managed using the EXCEL computer software. It was subjected to ANOVA using GLM procedures of statistical Analysis System of computer software (SAS, version 9.1.3, 2004) and LSD was used for mean comparison.

Results and Discussion

Soil test based crop response phosphorus calibration study was executed on major soil types (Eutric Vertisols) in Kofole District for the determination of optimum nitrogen, P-critical (Pc) and phosphorus requirement factor (pf). Economically Optimum Nitrogen rate for Eutric Vertisols was 69 N kg ha^{-1}. .While determined P critical (Pc) concentrations and a P (Pf) requirement factor on Eutric Vertisols for bread wheat in Kofole was 19 ppm and 3.30 respectively.

Yield and Yield Components of Bread Wheat on Eutric Vertisols

The main effects of NPS fertilizer rate on EutricVertisols highly significant with phosphorus critical and requirement factors ($P < 0.01$) effect on plant height, spike length, seed per spike, aboveground dry biomass and grain yield. However, the thousand kernels weights were not significant. The highest grain yield was obtained due to 100 % pc NPS with recommended 69 kg N ha^{-1}, and flowed by the rate of 100 % pc TSP ha^{-1} fertilizer with recommended 69 kg N ha^{-1}. The highest grain yield (6486 kg ha^{-1}) and (5933 kg ha^{-1}) was obtained in response to application of 100%pc NPS and 100% pc of TSP fertilizers, respectively. While the lowest grains yield (3352 kg ha^{-1}) was obtained in response to control.

Table1. Effect of NPS fertilizers rate on yield and yield components at Kofole District on Eutric Vertisols

Treatments	**Plant Height (cm)**	**Spike Length (cm)**	**Seed Per Spike**	**Biomass kg ha^{-1}**	**Grain Yield (kg ha^{-1})**	**TKW (gm)**
No appl	90.79 ^{a}	7.50 ^{a}	35.20 ^{a}	9940 ^{a}	3352 ^{a}	44.81
25 % pc	96.03 ^{ab}	8.11^{b}	44.57 ^{b}	14230 ^{b}	5036 ^{b}	46.66
50 % pc	98.80 ^{b}	8.17 ^{b}	46.86 ^{b}	14830 ^{b}	5363 ^{b}	45.96
75 % pc	99.96 ^{b}	8.361^{b}	44.20 ^{b}	15630 ^{b}	5671 ^{bc}	46.56
100 % pc NPS	101.81 ^{b}	8.28 ^{b}	45.12 ^{b}	16950 ^{b}	6486 ^{c}	46.94
100 % pc TSP	100.43 ^{b}	8.16 ^{b}	45.44 ^{b}	15310 ^{b}	5933 ^{bc}	47.92
Lsd (0.05)	6.88	0.43	4.70	2.47	9.66	NS
CV (%)	10.60	8.10	16.30	25.80	27.50	8.60

Means followed by the same letter with in the same column of the respective treatment are not significantly different ($P \leq 0.05$) according to fishier Test, PC= Phosphorus Critical, CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant.

Partial Budget Analysis for Eutric Vertisols

The showed that the maximum net benefit with an acceptable MRR was obtained from 100%pc NPS and 100%pc TSP fertilizer and supplemented with 69 kg N ha^{-1} application. The net benefit obtained by the use of improved bread wheat with rates of 100 % pc NPS ha^{-1} fertilizer were found to be greater than the benefit of applying 100 % pc TSP and 75 %pc NPS rates. Therefore, the net positive benefit obtained with application of 100 % pc NPS ha^{-1} + 69 kg N ha^{-1} to bread wheat are economically profitable application rates and can be recommended for farmers on Eutric Vertisols of the study area and other areas with similar agro-ecological conditions.

Table 2: Partial Budget analysis for the verification trial of bread wheat at Kofole District on EutricVertisols.

Treatments	Gy (kg ha^{-1})	AGY (kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
No appl	3352	3017	84112.20	0.00	84112.20	0.00
25 % pc	5036	4532	128064.60	1099.50	126965.10	3897.49
50 % pc	5363	4827	136599.30	1205.65	135393.65	7939.88
75 % pc	5671	5104	144638.10	2088.95	142549.15	810.09
100 % pc NPS	6486	5837	165909.60	3312.68	162596.92	1638.25
100 % pc TSP	5933	5340	151476.30	3396.05	148080.25	D

ETB= Ethiopian birr; GFB = gross field benefit; TVC = total variable cost; NB = net benefit; MRR = marginal rate of return, PC = Phosphorus critical, GY = grain yield, AGY= adjusted grain yield

Conclusion and Recommendations

Soil test based fertilizer use and its suitability with economic benefit of NPS fertilizer recommendation. Therefore, fertilizer recommendations based on soil test had evolved for Eutric Vertisols for bread wheat in Kofole District. Accordingly, the highest grain yield was obtained due to the application of 100 % pc NPS supplemented with 69 kg N ha^{-1} and flowed by rate of 100% pc TSP ha^{-1} with supplemented 69 kg N ha^{-1}. The highest grain yield (6486 kg ha^{-1}) and (5933 kg ha^{-1}) was obtained in response to application of 100%pc NPS and 100%pc TSP fertilizers, respectively. While the lowest grains yield (3352 kg ha^{-1}) was obtained in response to control on Eutric Vertisols. Generally, the net positive benefit obtained with application of 100% pc NPS ha^{-1} + 69 kg N ha^{-1} on Eutric Vertisols were recommended for farmers of the study area. Research institute and BoARD should work and harmonize on the transfer of the technology to farmers or end users.

Acknowledgements

The authors would like to thank Oromia Agricultural Research Institute for funding the research and Batu Soil Research Center for providing all the necessary facilities required for the research. Lastly but not least, our special thank also forwarded to all staff members.

Reference

Assefa Menna, Johnson M R Semoka, Nyambilila Amuri, and Tekalign Mamo.(2015). Wheat Response to Applied Nitrogen, Sulfur and Phosphorous in three Representative Areas of the Central Highlands of Ethiopia. *International Journal of Plant and Soil science*, 8 (5): 1–11.

CSA (Central Statistical Agency).(2019). Agricultural sample survey: area and production of major crops, meher season. Vol. I. Addis Ababa, Ethiopia.

De Ruiter, J.M. and Martin, R.J. (2001). Management of nitro nitrogen and sulphur fertilizers for improved bread wheat (*Triticum aestivum*) quality. *New Zealand Journalof Crop and Horticulture Science*, 29:287-299.

Demeke M., Di Marcantonio F., (2013). Analysis of incentives and disincentives for wheat in Ethiopia. Technical notes series, MAFAP, FAO, Rome.

EthioSIS (Ethiopian Soil Information System). (2013). Soil analysis report. Agricultural Transformation Agency (Unpublished)

Hailu Hillette, Tekalign Mamo, Riikka Keskinen, Erik Karltun, Heluf Gebrekidan, and Taye Bekele. (2015). Soil fertility status and wheat nutrient content in Vertisol cropping systems of central highlands of Ethiopia. *Agriculture and Food Security*, 4 (19): 1-10.

Hussain, M.I., Shah, S.H. (2002). Growth, yield and quality response of three wheat (*Triticum aestivum* L.) varieties to different levels of N, P and K. Int. *Journal of Agriculture and Biology.* 4 (3): 362-364.

IFDC (International Fertilizer Development Center).(2015). Assessment of Fertilizer consumption and use by Crop in Ethiopia. Accessed from http://www.africafertilizer.org/wp-content/uploads/2017/05/FUBC-Ethiopia-Final-Report-2016.pdf.

Iqtidar, H., Muhammad, A. K., Ejaz, A. K. (2006). Bread wheat varieties as influenced by different nitrogen levels. J Zhejiang Univ Sci. 7(1), 70-78.

Kiros Habtegebrial, Mersha, S. and Habtu, S., (2013). Nitrogen and sulphur fertilizers effects on yield, nitrogen uptake and nitrogen use efficiency of upland rice variety on irrigated Fulvisols of the Afar region, Ethiopia. *Journal of Soil Science and Environmental Management*, 4(3):62-70.

McGrath, S.P., Zhao F.J. and Withers P.J.A. (1996). Development of sulfur deficiency in crops and its treatment. Proc. Fertilizer Society No. 379. The Fertilizer Society, Peterborough.

Olsen S. R., Cole, C.W., Watanabe F.S. and Dean, L.A.(1954). Estimation of available phosphorous in soils by extraction with sodium bicarbonate. *Soil Science,* 96: 308-12.

Tanner, D., Amanuel Gorfu and Asefa Tilahun. (1993). Fertilizer effect on sustainability in the Wheat based smallholder farming systems of southeastern Ethiopia. *Field Crops Research* 33: 235- 248.

Teklu, E., Hailemariam, T. (2009). Agronomic and economic efficiency of manure and urea fertilizers use on vertisols in ethiopian highlands. J.Agri. Sci. 8(3), 352-360.

Tilahun Abera and Tamado Tana. (2019).Growth, yield component and yield response of durum wheat (Triticum turgidum L. var. Durum) to blended NPS fertilizer supplemented with N rates at Arsi Negelle, Central Ethiopia. African Journal of Plant Science, DOI: 10.5897/AJPS2018.1697, Vol. 13(1), pp. 9-20.

Tagesse Abera, Ketema Belete and Tamado Tana .(2018). Effect of Blended NPS Fertilizer Supplemented with Nitrogen on Yield Components and Yield of Bread Wheat (Triticum aestivum L.). Journal of Natural Sciences Research, ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online) Vol.8, No.11.

Adamu Molla. (2018). Response of Wheat to NP Fertilizer Rates, Precursor Crops and Types of Vertisols in Central Highlands of Ethiopia Journal of Agricultural Science; Vol. 10, No. 4;ISSN 1916-9752 E-ISSN 1916-9760.

CIMMYT(1988). From Agronomic Data to Farmer Recommendations: An Economics Training Manual. revised edition. Mexico, D.F. ISBN 968.

Verification of Phosphorus Critical Level for Bread Wheat (Triticum aestivum L.) in Dugda District of East Shewa Zone of Oromia, Ethiopia

Abdurahman Husien, Tilahun Firomsa and Tilahun Abera
Batu Soil Research Center, P.O. Box 59, Batu Oromia, Ethiopia
Corresponding Author, e-mail: abdurahmanh2010@gmail.com

Abstract

*Verification of phosphorus critical level for bread wheat was conducted in Dugda District in 2021 cropping season with the objectives to verify phosphorus critical (Pc) level and determined during soil test crop response based phosphorus fertilizer calibration and to create awareness on soil test crop response based fertilizer recommendation. A Composite soil samples at the depth of 0-20 cm in zigzag method were collected from farmers' fields. Likewise, soil samples analyses were made to identify available P in the level of the required phosphorus in the select crop fields for actual experiment. The treatments included (1) soil test based phosphorus calibration result; (2) farmers' practice in the area which was assessed from the surrounding farmers' and (3) no fertilizer application (control) and each treatment was planted on 10*10m experimental plot & the design was randomized complete block design replicated over farmers. Bread wheat, Kakaba variety, was used with seed rate of 150 kg $ha^{-1}$and other cultural practices such as weed and rust management were used from which had been recommended for the area. The partial budget analysis showed that the highest net income (130,433.81 ETB ha^{-1}) was from soil test based recommended and the lowest net benefit (59,560.20 ETB ha^{-1}) was obtained from control treatment with marginal rate of return (3106.54%) which is greater than the minimum rate of return (MRR) 100%. The result showed that the average grain yield of 5157 kg ha^{-1} was obtained from the application of soil test based phosphorus calibration (Pc and Pf) followed by blanket recommendation (4243 kg ha^{-1}) and (2282 kg ha^{-1}) for the control treatment. The recommended N rate, 69 kg N ha^{-1} with soil test based phosphorus critical level gave 44.25 % grain yield advantage over the control. In general, soil test and crop response based fertilizer recommendation for crops increases crop yields through application of adequate nutrient rates for the identified soil nutrient deficiencies in specific locations.*

Key-words: Verification, Farmer, Concentration, Application and Calibration

Introduction

Bread wheat (*Triticum aestivum L.*) is one of the most important cereal crops globally and is a main food for about one third of the world's population (Hussain et al., 2002). Wheat took up 13.73% (1,747,939.31 hectares) of the grain crop area. Likewise, cereals contributed 87.97% (about 277,638,380.98 quintals) of the grain production and the wheat 15.33% (48,380,740.91 quintals) of the grain production (CSA, 2019). Moreover, wheat production in the country is adversely affected by low soil fertility and suboptimal use of mineral fertilizers in addition to diseases, weeds, erratic rainfall distribution in lower altitude zones, and water-logging in the Vertisols areas (Amanuel et al., 2002).

Phosphorous is the most yield limiting of soil-supplied elements, and soil P tends to decline when soils are used for agriculture (David and David, 2012). Additionally, the nutrient deficiencies identified in this study could be due to either inherently low availability of these nutrients in the soils or as a consequence of continuous intensive cropping without applying fertilizer or manure containing these nutrients (Hailu et al., 2015). Similarly, the blanket recommendations that are presently in use all over the country were issued several years ago, which may not be suitable for the current production systems. Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P rate to their fields regardless of soil fertility differences (Gete et al., 2010).

Phosphorus calibration is a means of establishing a relationship between a given soil test value and the yield response from adding nutrient to the soil as fertilizer. So that it provides information how much nutrient should be applied at a particular soil test value to optimize crop growth without excessive waste and confirm the validity of current P recommendations (Getachew et al., 2013). Likewise, they enable to revise fertilizer recommendations for an area based on soil and crop type, pH and soil moisture content at time of planting. Soil tests are designed to help farmers predict the available nutrient status of their soils. Once the existing nutrient levels are established, producers can use the data to best manage what nutrients are applied, decide the application rate and make decisions concerning the profitability of their operations (Girma et al., 2016). Hence, calibrations are specific for each crop type and they may also differ by soil type, climate, and the crop variety. Generally, soil test based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops. Therefore, optimum return from the investment on input and minimum environmental pollution are the two major issues to be addressed while prescribing soil test based nutrient recommendations (Singh et al., 2010).

Therefore, to alleviate this problem Batu Soil Research Center undertaken soil test crop response based fertilizer calibration Kofole District on bread wheat and determined optimum nitrogen to be applied, P critical and P-requirement factors. But to ensure confidence in recommendations, these determined values should be verified for grain yield and economic benefit as compared to blanket recommendation and control. Therefore, the objectives of this verification were to verify phosphorus critical (Pc) level determined during soil test crop response based P fertilizer calibration, and to create awareness on soil test crop response based fertilizer recommendation.

Materials and Methods

Description of the Study Area

Wheat is grown mainly by subsistence farmers in East Shewa Zone of the highlands of the country. The experiment will be undertaken at Dugda District which is located at 060 50' to 070 09' N and 38038' to 39004' E in the humid temperate climatic zones.

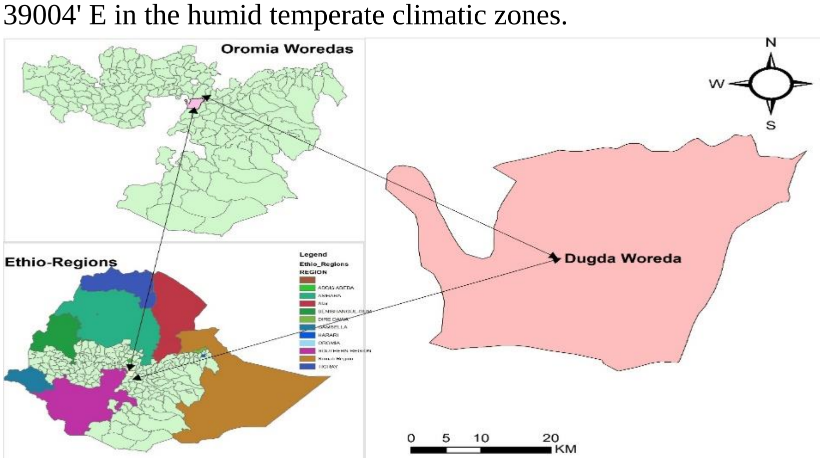


Fig.1. Map of the study area

Experimental Design and Treatments

For verification, first selection of the sites was done and 10 composite soil samples were collected at the depth of 0-20 cm in zigzag method from ten farmers' fields for Eutric Vertisols. Moreover, available phosphorus was determined by extraction with 0.5 M $NaHCO_3$ according to the methods of Olsen et al. (1954). Among ten (10) farmers, six (6) were selected for actual experiment based on initial phosphorus concentration categories below critical P-concentration for Kofole District. Therefore phosphorus fertilizer requirement was calculated from the formula:

Phosphorus fertilizer rate = (pc-pi)*pf;

Where, **Pc-** critical phosphorus concentration which was determined from the calibration study (**10 ppm**), **Pi-**Initial available P obtained from laboratory analysis from each farmers' fields and
Pf- phosphorus requirement factor derived from the calibration experiment **(6.45).**

Verification of phosphorus critical level was done with three treatments (1) soil test crop response based P criticl level; (2) farmers' practice in the area (blanket recommendation) and (3) control (no fertilizer application). It was conducted on 10*10m plot for each treatment with 20 cm row spacing. The experiment was laid out in randomized complete block design and replicated over farmers' fields. The fields were prepared by the local ox plow and after bund application of fertilizer; it was incorporated by the local plow during sowing. Urea split application was used, and top dressing of urea and incorporating it with soil was done 25-30 days after sowing and all cultural practices with recommended production practices were used. Weeds were controlled by Pallas. Yellow rust was controlled by spraying fungicide (Reoxido) at the rate of 0.5 Liter ha^{-1} immediately at the appearance of the symptom of the disease.

Data Collection and Analysis

Agronomic data collected were plant height, biomass yield, grains per spike, spike length, 1000 kernel weight (TKW) and grain yield. Generally all data were properly managed and subjected to the analysis of variance using the SAS computer package version 9.0 (SAS Institute, 2002) statistical software.

Cost–Benefit Analysis

The partial budget, dominance and marginal analyses were done for both farmer practice and soil test based values using CIMMYT (1988). Total variable cost was cost incurred due to application of P fertilizer (separately for soil test based P critical level result and farmers' fertilizer rate) with the assumption that the rest of the costs incurred were the same for all treatments. The discarded and selected treatments using this technique were referred to as dominated and un-dominated treatments, respectively.

Results and Discussion

Soil available phosphorus

The available P content of the soil was ranged from very low to medium according to Cottenie (1980) with the value ranged from 2.36 to 8.26 ppm (Table 1). Therefore, the soil of the study area needs application of phosphorus containing fertilizers and phosphorus fertilizer requirement was calculated from the formula: **Phosphorus fertilizer rate = (pc-pi)*pf** for crop production.

Table 1. Available soil phosphorous status before planting in Dugda District, East shewa Zone

Sites	Site code	Available soil phosphorus (mg kg^{-1} soil)
1	F1	**4.06**
2	F2	**8.26**
3	F3	**4.52**
4	F4	**5.48**
5	F5	**3.36**
6	F6	**7.16**
7	F7	**6.20**
8	F8	**3.88**
9	F9	**5.28**
10	F10	**2.36**
	Average Initial P	**5.06**

Grain Yield

Analysis of variance revealed that the trials conducted in Dugda District shows that grain yield of bread wheat was highly increased with application of site specific fertilizer recommendation. This gave 2875 kg ha^{-1} yield advantages over the control treatment and 914 kg ha^{-1} over farmer practices with grain yield increment (Table 2). The optimum N was 69 kg N ha^{-1} which influence highly yields of bread wheat in the district. Accordingly the site specific fertilizer recommendation rates were influence grain; biomass yield and the mean maximum of grain yield were 5157 kg ha^{-1} of 44.25 % grain yield and 52.21 % straw yield advantage over the control treatment. Therefore the yield increment due to the soil test based phosphorus fertilizer recommendation rate (STBR) was perceived positively. Moreover, different stakeholders should work and harmonize on the transfer of the technology and additionally further effort should be made to disseminate the Soil test based phosphorus fertilizer recommendation rate (STBR) to farmers or end users. Generally this study in line with Kefyalew et al.(2017) mean comparison of grain yield was also computed at ($\alpha < 0.05$) for verification experiment and the study revealed that mean grain yield of the calibrated phosphorus (critical concentration) treatment showed 320 & 877 kg for bread wheat yield increment over blanket recommendation and control plot, respectively.

Table 2.Effect of verification of phosphorus critical level on yield and yield components of bread wheat in Dugda District

Treatments	Plant height (cm)	Spike length (cm)	Seed per spike	Biomass yield (kg/ha)	Grain yield (kg/ha)	TKW (gm.)
Control	77.88 a	6.96	42.48	7100 a	2282 [a]	45.80 a
FP	90.36 b	7.10	46.68	12000 b	4243 [b]	51.60 b
ST	95.28 b	7.58	46.64	13600 c	5157 [c]	52.40 b
LSD(0.05)	6.30	NS	NS	1.35	7.49	3.981
CV (%)	4.90	7.70	7.50	8.50	12.70	5.50

Means followed by the same letter with in the same column of the respective treatments are not significantly different ($P \leq 0.05$) according to fishier Test, ST = Soil Test, FP = Farmer practices, CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant.

Economic analysis

The partial budget analysis (CIMMYT, 1988) was employed to calculate the Marginal rate of return (MRR) to investigate the economic feasibility of treatments. Based on actual unit prices during the year 2022 harvesting season (personal observation) farm gate price of 29.00 ETB (Ethiopian Birr) per kg of wheat. Bread wheat seed price 39.30 Birr per kg, 17.05 & 16.70 Birr per kg of Phosphorus from NPS & Nitrogen from Urea respectively were used to calculate variable cost. The Marginal Rate of Return (MRR) was found to be 3106.54% for soil test based fertilizer rate and farmer practice was dominated soil test based fertilizer rate. The partial budget analysis showed that the highest net income (130,433.81 ETB) was obtained from soil test based recommended treatment. Marginal rate of return (3106.54%) which is greater than the minimum rate of return (MRR) 100 % (Table 3). Generally, this study in line with Dejene et al. (2020) the economic analysis showed that the highest net income (51284 ETB) was obtained from soil test based recommended treatments with marginal rate of return (857.27%).

Table 3: Partial Budget analysis for the verification trial of bread wheat at Dugda District

Treatments	GY (kg ha^{-1})	AGY (kg ha^{-1})	GFB (ETBha^{-1})	TVC(ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
Control	2282	2054	59560.20	0	59,560.20	0
FP	4243	3819	110742.30	3419.93	107,322.37	1396.58
ST	5157	4641	134597.70	4163.89	130,433.81	3106.54

ETB, Ethiopian birr; GFB, gross field benefit; TVC, total variable cost; NB, net benefit; MRR, marginal rate of return, ST, Soil Test, Fp, Farmer Practice, grain yield, AGY, adjusted grain yield.

Conclusion and Recommendations

Verification of phosphorus critical level with farmer practices and control on the selected farmers' fields was encouraging indicator of use of soil test crop response based fertilizer recommendation for bread wheat. Accordingly, verifying phosphorus critical level influences biomass yield and the mean maximum of grain yield were 5157 kg ha^{-1} of 44.25 % grain yield and 52.21 % straw yield advantage over the control treatment. The economic analysis showed that the highest net income (130,433.81 ETB) was obtained from soil test based recommended fertilizer application with marginal rate of return (3106.54%). Therefore farmers had positive responses on soil test based phosphorus fertilizer recommendation. Further effort should be made to disseminate the soil test based phosphorus fertilizer recommendation. Generally different stakeholders should work and harmonize on the transfer of the technology to farmers or end users.

Acknowledgements

The authors would like to thank Oromia Agricultural Research Institute for funding the research and Batu Soil Research Center for providing all the necessary facilities required for the research. Lastly but not least, our special thank also forwarded to all staff members.

References

CIMMYT (1988). From Agronomic Data to Farmer Recommendations: An Economics Training Manual. revised edition. Mexico, D.F. ISBN 968.

Cottenie(1980). Soil and plant testing as a basis of fertilizer recommendations. FAO Soil Bulletin 38/2. Food and Agriculture Organization of the United Nations, Rome, Italy.

CSA (Central Statistical Agency) (2019). Report on Area and Crop Production forecast for Major Crops (for private Peasant Holdings 'Meher' season). Addis Ababa, Ethiopia.

David and David (2012). Modeling an Improvement in phosphorous utilization in Tropical Agriculture. *Journal of Sustainable Agriculture*, 36:18-35.

Dejene Getahun, Abraham Feyisa, Lello Dejene, Dereje Girma(2020). Soil Test Based Crop Response Phosphorus Calibration Study on Bread Wheat in Degem District of North Shewa Zone, Oromia. International Journal of Economy, Energy and Environment. Vol. 5, No. 1, 2020, pp. 1-5. doi: 10.11648/j.ijeee.20200501.11.

Gete Zeleke, Getachew Agegnehu, Dejene Abera, and Sofia Rashid (2010). Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system. *Washington, DC*: IFPRI.

Hailu Gebre Mariam, Tanner, D.G and Mengestu Hulluka (ed) (2015).Wheat Research in Ethiopia historical perspective. IAR/CIMMYT, Addis Ababa

Hussain, M.I., Shah, S.H. (2002). Growth, yield and quality response of three wheat (*Triticum aestivum* L.) varieties to different levels of N, P and K. Int. *Journal of Agriculture and Biology.* 4 (3): 362-364.

K.N. Singh, Abhishek Rathore, A.K. Tripathi, A.Shubba Rao and salman Khan (2010). Soil fertility mapping and its validation using spatial prediction technique.

Kefyalew Assefa, Tilahun Firomsa and Tadesse Hunduma (2017).Verification and Demonstration Pc and Pf Determined Through Soil Test Based Crop Response Study for P on Bread Wheat at Lume Area of Oromia Region, Ethiopia. International Journal of Research and Innovations in Earth Science Volume 3, Issue 6, ISSN (Online) : 2394-1375.

Olsen, Cole, Watanabe and Dean (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *USDA, Circ. 939.*

SAS. (2002). User's Guide: Statistics Version 9.00. SAS Institute, Inc., Cary, North Carolina. USA.

GetachewAgegnehu and Lakew, B. (2013). Soil test phosphorus calibration for malting barley (Hordeumvulgare L.) on Nitisols of central Ethiopian highlands, Tropical Agriculture 90, 177-187.

Girma Chala. (2016). Soil test phosphorous calibration for potato production on Nitisols of central highlands Ethiopia. Ethiop. J. Sci. Sus. Dev. 120-137.

Tanner, Tesfaye Tesemma and Takele Gebre. (2002). Optimizing fertilizer use in Ethiopia.

Amanuel Gorfu., Kuhne, R.F., Tanner, D.G. and V lek, P.L.G. (2002). Recovery of 15- N labeled urea applied to wheat in the Ethiopian Highlands as affected by P fertilization. Journal of Agronomy and Crop Science, 189: 30-38.

Agroforestry

Assessment of agroforestry practices in Buno Bedele and Ilu Abba Bora zone of Oromia region, Ethiopia

Mosisa Mezgebu
Bedele Agricultural Research Center, P.O.Box-167, Bedele, Ethiopia
Corresponding Author: mosisamez17@gmail.com

Abstract

Agroforestry practices are considered as one of the major source of food and income to meet the needs and the wellbeing of the rural community. This study was conducted in Buno Bedele and Ilu Abba Bora zone, with the aim to identify and assess agroforestry practice, constraints and Importance and farmers' perception on the existing agroforestry practice in study area. Accordingly 3 districts from each zone and 12 Kebele in 6 districts were selected by purposely sampling methods and similarly 299 household were selected. Semi-structured questionnaire data was generated by conducting household survey interview, key informant, and direct field observation were applied. Based on the respondent's idea across the both zones, the results of this study have shown that ,Homegardens (96 %), Coffee based agroforestry practice (91.3) ,Fruit trees based agroforestry practice (86.6%), woodlot (65.6%), windbreak/shelterbelts (62.5%), Trees on rangeland (57.2%), Life fencing (53.8%), Parkland agroforestry (43.1%), Taungya (26.4%) and Alley cropping (16.7%) are the exist agroforestry practices in the study area. The major Importance of agroforestry practices were for income, regulated climates, soil improvement, used for shade, food and livestock feed, properly using the land, construction, fuel wood and timber. On the other hand, impacts of wild animals, Insect pest and disease, Competition trees with crop (i.e. shading effect), shortage of land for tree planting, lack of capital, lack of knowledge, taking long time for profit, lack of seed accessibility and Shortage of labor the major constraints recorded in the study areas. Majority of respondents were strongly agreed with the agroforestry practices; increase farm income, improve soil fertility and conserved soil and water, saved time on collecting fodder and fuel wood from the forest and improve the natural condition. Those show that the respondents in study area have positive attitude with existing agroforestry practices. Albizia gummifera (78.2 %), Cordia africana (67.9%) and Croton macrostachyus (63.2%) were the most common trees that dominated in the study area. Albizia gummifera (67.2%) and Cordia africana (61.9%) also were most preferred trees by farmers in field. Avocado (91.3%), Banana (79.6%) and Mango (61.9%) were the most dominant fruit trees/shrubs, while Maize (95%), Coffee (91.3%), Teff (76.6%), Chat (65.9%) and Sorghum (52.8%) were the most dominant crops and Cow, Oxen, Calve, Chicken were the most dominant livestock. The study recommends further studies have to be done on positive interaction trees/shrubs selection in component, management and introducing new agroforestry practices and manage the exist agroforestry practice at study area.

Keywords: Agroforestry practice, Taungya, alley cropping

Introduction

Agroforestry is a form of sustainable land use systems that integrates trees with crops or animal husbandry to initiate an agro ecological succession (*FAO, 2013*).Worldwide believes that agroforestry gives various ecosystem services through providing diversification of household needs in addition to cultural services such as agro-tourism, aesthetic values, demonstration and education. Principally, agroforestry affords amendable services such as soil conservation, watershed management, pest control and sinks for carbon. In so doing that, it gives contributing to the mitigation of global climate change (*Jose and Bardhan, 2012).*

In developing countries especially Africa, rapid population growth, decline in per capita food production and environmental degradation are the main problems. Consequently, the need for intensification of agricultural production coupled with population growth forces poor farmers to expand their cultivation to hilly and marginal areas. This aggravates the degradation of natural resource and unsustainability. In relation to this, agroforestry practice can be the only option to condense pressure on leftover natural forests as of deforestation and sustain biodiversity (*Kang, Akinnifesib, 2000; Gustavo, et al., 2004*).

In Ethiopia, the integration of trees and shrubs into agriculture emerged many years ago (*Edmond et al., 2000*). The historical development of farming in the country followed the human settlement times past and thus is much older in northern Ethiopia than the other parts. The Current agricultural land coverage in Ethiopia is estimated about 46% by supporting 83% livelihoods of the population, 80% of export earnings and 73% of the raw materials in agro-based industries (*Brown et al., 2012; Bishaw et al., 2013*). Various agroforestry systems are practiced in different parts of the country. One of the oldest indigenous agroforestry systems is the retention of scattered trees (Faidherbia albida) on farmlands of rift valley and highlands of eastern Ethiopia (*Abebe, 2005; Asfaw and Ågren, 2007*). The deliberate retaining of naturally occurring trees on farmlands is a common land use practice carried out by these smallholders for monetary, material, environmental, and cultural uses (*Jamala et al., 2013; Iiyama et al., 2017*). However, the practice of farmland agroforestry is declining in many agricultural landscapes in Ethiopia due to increase in fuel wood demand and degradation of nearby forests (*Onyekwelu et al., 2015*), agricultural intensification, the increasing popularity of exotic tree species which generate larger economic benefits for farmers (*Teshome, 2009*), and the fact that land proclamations do not specify clear instructions for farmers on how to manage and conserve indigenous trees. Generally, integration of trees in to the farms have to be adapted as biological soil and water conservation for livelihood diversification to meet multiple demands of farmer through agro-forestry practice thereby to mitigate global climate change (*Pandey, 2002*).

In Ilu abba bora and Buno bedele zones, many agroforestry practices in farmlands for value of indigenous conservation measures. However the existing farmers' agroforestry practices and systems are not assessed , identifying by research to documented and characterize the existing farm land agroforestry practice and also to share best practice agroforestry existing at study area. So the study was initiated with the aim to identify and assess Agroforestry practice, constraints and opportunities and farmers' perception on the existing agro-forestry practice in study area.

Research Methodology

Description of Study Areas

The study was conducted in Bacho, Alle and Darimu districts of Ilu Abba Bora zone and Gechi, Chora and Bedele districts of Buno Bedele zone of the Oromia Regional state, South Western Ethiopia. Buno Bedele and Ilu Abba bora Zones are located between the distances 474-600km, south western of Addis Ababa, the capital city of the country. Both zones located at latitude and longitude lies between 8° 27` - 8°45`N and 36° 21' - 36°35` E, respectively. The zones contain highland (10%), midland (67%) and lowland (23%) agro-ecologies; and located at altitude ranges 500- 2575m a.s.l. The annual precipitation ranges from 1500-2200mm with 6 to 9 months of rain fall (*MOA, 2010*). The farming system of the zones are characterized by mixed farming system comprising both cropping and livestock production (Figure 1).

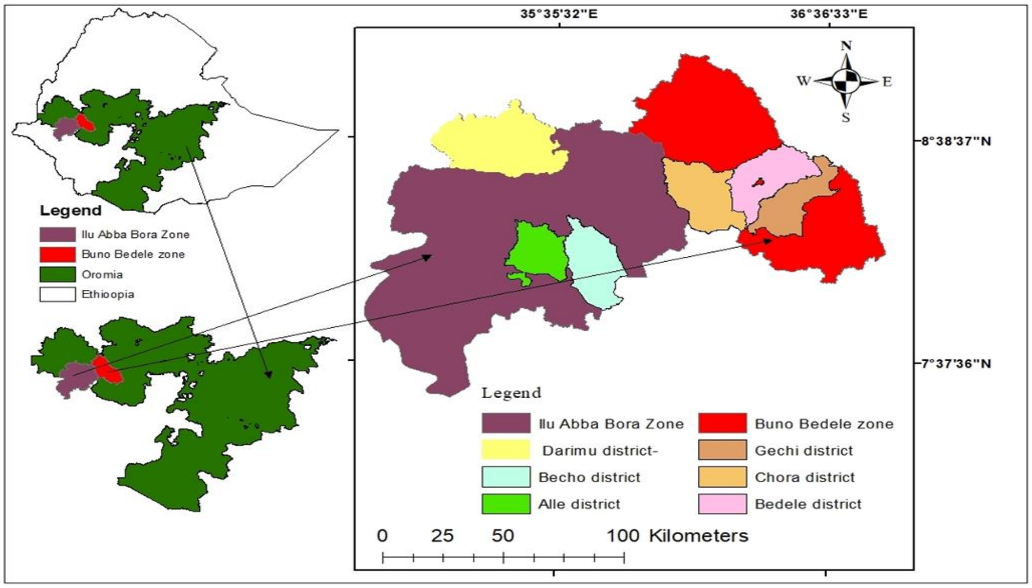


Figure1.Map of study area

Sample Size and Sampling Technique

Firstly the discussion was made with two zones (Buno Bedele and Ilu Abba Bora) in order to isolates the most potential districts by agroforestry practice for studies. Then three districts were selected from each zone and by same procedure. The discussion was made with all selected districts and identified the potential kebele by agroforestry practice. Totally six districts, three from Buno Bedele zone (Bedele, Gechi and Chora districts) and three from Ilu Abba Bora zone (Bacho, Alle and Darimu districts) were selected purposively based on representative of agroforestry practice. Two kebeles also were selected purposively from each district. Accordingly 150 household from Buno Bedele zone, 149 from Ilu Abba Bora zone and totally 299 household were participated.

Methods of Data Collection and Analysis

The data was collected in each zone at kebele level through interview using questionnaires, key informant and direct field observation. The types of agroforestry practices exist were identified based on linked with farmer's indigenous knowledge on component, arrangement of agroforestry practice and direct field observation. The data collected from samples household responses were analyzed by using statistic, package for social science (SPSS version 20). Descriptive analysis employed the tools such, percentage, and frequency distribution.

Results and Discussion

Characteristics of Respondents

The general characteristics related with agroforestry practice of household respondents distributed by Sex, Age, Marital status, Family size education status and experience of farming system were stated (Table 1).

A total of 299 households including, the majority respondents about 91.6% were male whereas 8.4% were Female. This implies that majority of household head in agroforestry practice in zones were male and low number of females observed at studies. The majority of the household heads were between 31-40 years age group (31.4%), followed by age group 20-30 years age group (23.7%) and 42-52, 53-63 and above 63 years which in percent 21.1%, 15.4% and 8.4% respectively. From the result conclude that, the household interviewed about agroforestry practice were dominated by working group and the farmers in study area were comparatively medium age group. The smallest portion of age group was above 63 years old.

The marital status of the household head shows that the married respondents share the majority percentage (96%), followed by a single and divorced constitute 2% and 2% respectively. About 55.9% household respondents had range between 5-8 members of families while, 30.1 % respondents had range between 1-4 members of families and remain respondents (14%) had above 8 family members.

Concerning to education status, the higher (76.9%) respondents are educated while, 23.1% of respondents were uneducated. From educated respondents 56.6% of respondents educated levels were above grade four (4). The majority of the respondents (57.9%) had above 24 years' experience farming system (Table 1).

Table1. Characteristics of the sample household at study area

Category	Variables	Buno Bedele Zone N (%)	Ilu Abba Bora Zone N (%)	Overall N (%)
Sex	Male	141(94)	133(89.3)	274(91.6)
	Female	9(6)	16(10.7)	25(8.4)
Age class	20-30	35(23.3)	36(24.2)	71(23.7)
	31-40	46(30.7)	48(32.2)	94(31.4)
	42-52	36(24)	27(18.1)	63(21.1)
	53-63	25(16.7)	21(14.1)	46(15.4)
	>63	8(5.3)	17(11.4)	25(8.4)
Marital status	Single	4(2.7)	2(1.3)	6(2)
	Married	144(96)	143(96)	287(96)
	Divorced	2(1.3)	4(2.7)	6(2)
Family size	1-4	48(32)	42(28.2)	90(30.1)
	5-8	83(55.3)	84(56.4)	167(55.9)
	>8	19(12.7)	23(15.4)	42(14)
Education	Illiterate	36(24)	33(22.1)	69(23.1)
	Grade 1-4	34(22.7)	27(18.1)	61(20.4)
	Grade 5-8	51(34)	61(40.9)	112(37.5)
	Grade 9-12	28(18.7)	26(17.4)	54(18.1)
	Diploma	1(0.7)	2(1.3)	3(1)
Experience of farming	1-5 years	3(2)	7(4.7)	10(3.3)
	6-14 years	22(14.7)	29(19.5)	51(17.1)
	15-24 years	39(26)	26(17.4)	65(21.7)
	> 24 years	86(57.3)	87(58.4)	173(57.9)

Source: Households survey; April, 2021

Agroforestry practice in study area

Based on the results of study ten (10) agroforestry practices were identified, and documented for study area. Like ways, in Ethiopia, smallholder farmers practice various agroforestry practices depending on the socioeconomic and biophysical conditions were explained (Jamala et al., 2013; Abrham et al., 2016; Iiyama et al., 2017). The result showed that, among the identified agroforestry practice homegardens, is the most dominated (96%) agroforestry practice followed, by Coffee based agroforestry practice (91.3%), fruit trees based agroforestry practice (86.6%), Woodlot (65.6%), windbreak/Shelterbelts (62.5%), trees on rangelands (57.2%), life fencing(53.8%), parkland agroforestry(43.1%), taungya(26.4%), and alley (16.7%) cropping respectively (Table 2). The identified agroforestry practice in both zones (Buno Bedele and Ilu Abba Bora) almost in similar status.

As the respondent's reason out why the homegardens agroforestry practice widely practiced in study area is because of this practice simplicity for management, especially for keeping from wild animals and it consists of multipurpose trees, fruit trees and livestock in around home of households and get diversity outputs from it. The second major respondents (91.3%) were participated in Coffee based agroforestry practice because the area is suitable for coffee production and households get most income from it.

From exist agroforestry practice at study area Alley cropping is the least percentage (16.7%) at both zone. In contrast in East Hararghe parkland agroforestry (58%), followed by alley cropping as hedge row intercropping (33%), homegardens (22%), multipurpose trees on farmland (19%), live fence/boundary tree planting (18%), and wind breaks (4%) were identified (Musa et al., 2022). In this report alley cropping the second dominant agroforestry practice. In similarly based on the findings of the study in Arba Minch Zuriya district of Gamo Gofa Zone, homegardens, intercropping and livestock production were identified to be the major agroforestry practices of the area, the dominant being the homegardens practice (Alemu, 2016). In these finding similar with study area home garden agroforestry practice the dominated one.

Table 2 .Types of existing agroforestry practice in study area

	Respondents %		
Agroforestry practice	Buno Bedele	Ilu Abba Bora	Overall
Homegardens	98	94	96
Coffee based agroforestry practice	87.3	95.3	91.3
Fruit trees based agroforestry Practice	76.7	96.6	86.6
Woodlot	66	65.1	65.6
Windbreak/Shelterbelts	76.7	48.3	62.5
Trees on Rang land	60.7	53.7	57.2
Life Fencing	38	69.8	53.8
Parkland agroforestry practice	40	46.3	43.1
Taungya	28	24.8	26.4
Alley cropping	13.3	20.1	16.7

Source: Households survey; April, 2021

Homegardens: is one of dominant identified agroforestry practice in the study area. Homegardens are categorized by being practiced around home and composed of a high diversity of plants and an important source of diversified products used for household. Fruit (Avocado, Banana, Mango, Orange, Guava custard Apply and enset), Maize, Chat, Coffee Cardamom, livestock were cultivated in study area of homegardens practice. *Albizia gummifera, Cordia africana, Varnonia amygdalina and Ricinus communis* were the most exist trees species in homegardens at study areas.

Coffee based agroforestry practice: It was second major agroforestry practice identified at study areas. The farmers of study areas were cultivated coffee under diverse shade trees. *Albizia gummifera, Acacia spp, Cordia africana, Croton macrostachyus* and *Sesbania sesban* were the most trees used for coffee shade in study area.

Fruit trees based agroforestry Practice: This practice widely existing at farmers of at study areas and it has a role in household family by given multiple benefits. As respondents reply fruit trees had contribution for theirs live by provide income generation, reduce food security and also used for shade service. Avocado, Banana, Mango, Orange, Guava and Custard apple were the most dominate fruit trees dispersed through crop land, pasture and near home at study area.

Woodlot: It was practiced by farmers at study area by planting tree on a small-scale as land use practices, for their income and construction service. *Eucalyptus spp, Grevillea robusta* and *Pinus patula* trees species were the most preferred for woodlot agroforestry practice at study area.

Windbreak/Shelterbelts: its lines of trees or shrubs whose main aim is the reduction of wind speed and also this practice existing at study area. *Eucalyptus spp, Grevillea robusta*, *Juniperus procera* and *fruits* like Avocado and Mango species were planted in line and used as wind break at study area.

Trees on rang land: is scattered trees in rangeland and beneficial in providing shade for livestock. At study area the trees/shrubs dispersed on grazing land mostly found in nature. *Grevillea robusta and Pinus patula* trees species were planted dispersed on range land at study area.

Life fencing: is widespread agroforestry in practice trees/shrubs area established to determine of plot of land such as homegardens and farmland. It was served at study area for protection wild animals and cattle from crops and used for soil conservation. *Erythrina brucei* and *Capparis tomentosa* tree species were most used as a live fence at study area. Azena (2007) stated that, Erythrina brucei used for firewood, medicine, fodder, beforage, mulch, nitrogen fixation, soil conservation and life fence, also Capparis tomentosa used for firewood, medicine, life fence and fencing material.

Parkland agroforestry practice: This practice involves the growing of individual trees and shrubs in scattered in the farmland, while field crops are grown under the trees/shrubs. Some of the naturally grown tree species includes *Cordia africana*, *Acacia spp*, *Ficus vasta* and *Croton macrostachyus Syzygium guineense Albezia gumufera and Prunus africana* were dispersed on farm land at study area.

Taungya practice: is trees planting; growing agricultural crops for 1-3 years, until the shade of trees become too dense. At study area the farmers exercised this practice by using Cardamom crop under *Grevillea robusta* and *pinus patula* plantation and it's used for purposely used land and rise income.

Alley cropping: is one of an important agroforestry practice in which legumes trees species planted in row and crops again planted between of hedgerow trees species and high organic biomass produced from the pruning's of hedgerow species and build soil organic matter constituted with beneficial soil nutrients. From identified agroforestry practice at study area this practice was the least percentage at both zones.

Banana Mango and avocado are use around home as alley cropping trees/shrubs with maize crop at study are.

Major Common Trees at Study Area

In identified agroforestry practice or on farm land most trees are naturally exist and some of them are planted by farmers. *Albizia gummifera, Cordia africana, Croton macrostachyus, Eucalyptus spp*, *Grevillea robusta*, *Acacia* spp, *Sapium ellipticum* and *Varnonia amygdalina, Juniperus procera, Ficus vasta*, *Syzygium guineense*, *Podocarpus facaltus* and *Prunus africana* were most common trees at study area (Table 3).These common trees are multipurpose trees so its provide two or more benefits for farmers. All common trees exist at study area were used for improve soil fertility and for shade except *Eucalyptus* spp and *Juniperus procera* (Table 3). As response of respondents *Cordia africana* is the best trees for timber at the area. According to Ebisa and Abdela (2017), stated that *Albizia gummifera, Cordia africana, Croton macrostachyus and Vernonia amygdalina* are popular in smallholder coffee farms in Ethiopia for coffee shade.

Table 3. Major common trees on the study area

			Respondents %		
Tree species	Local name	Uses of trees for:	Buno Bedele	Ilu Abba Bora	Total
Cordia africana	Waddeessa	Soil fertility/shade/construction/timber	64.7	71.1	67.9
Croton macrostachyus	Bakkannisa	Soil fertility/shade/construction/medicinal	54.7	71.8	63.2
Eucalyptus spp	Bargamoo	construction/income	44.7	62.4	53.5
Ficus vasta	Qiltuu	Soil fertility/shade	6	22.1	14
Grevillea robusta	Giravilaa	Soil fertility/shade/construction/timber	44.7	39.6	42.1
Juniperus procera	Gaattiraa	timber	16.7	12.1	14.4
Podocarpus facaltus	Birbirsa	Soil fertility/shade/construction/timber	14	0.7	7.4
Prunus africana	Hoomii	Soil fertility/shade/medicinal/timber	8.7	6	7.4
Sapium ellipticum	Bosoqa	Soil fertility/shade/construction/timber	3.3	26.2	14.7
Syzygium guineense	Baddeessa	Soil fertility/shade/construction/timber	12.7	4.7	8.7
Varnonia amygdalina	Eebicha	Soil fertility/shade/medicinal	12.7	16.8	14.7
Acacia spp	Laaftoo/Sondi	Soil fertility/shade/construction	41.3	24.2	32.8
Albizia gummifera	Ambabbeessa	Soilfertility/shade/construction/medicinal	70.7	85.9	78.2

Source: Households survey; April, 2021

Tree Species most Preferred in Field by Farmers

The farmers were not equal desired trees in the field, they preferred one rather than other based on the contribution of trees through their experience. This contribution defined by finding of this survey (Table 3). Based on these, *Albizia gummifera*, *Cordia africana*, *Grevillea robusta*, *Acacia* spp, *Eucalyptus* spp, *Croton macrostachyus*, and *Varnonia amygdalina* were most preferred trees by farmers in field at study area respectively (Figure 2). *Eucalyptus* tree species was planted on uncultivated land as woodland used commercialized to extra cash income for the household economy. This same line with (*Endale, 2017*) *Eucalyptus camaldulensis* and *Cupressus lusitanica* tree species are the most trained tree, which more preferred for woodlot agroforestry practice around Jimma town.

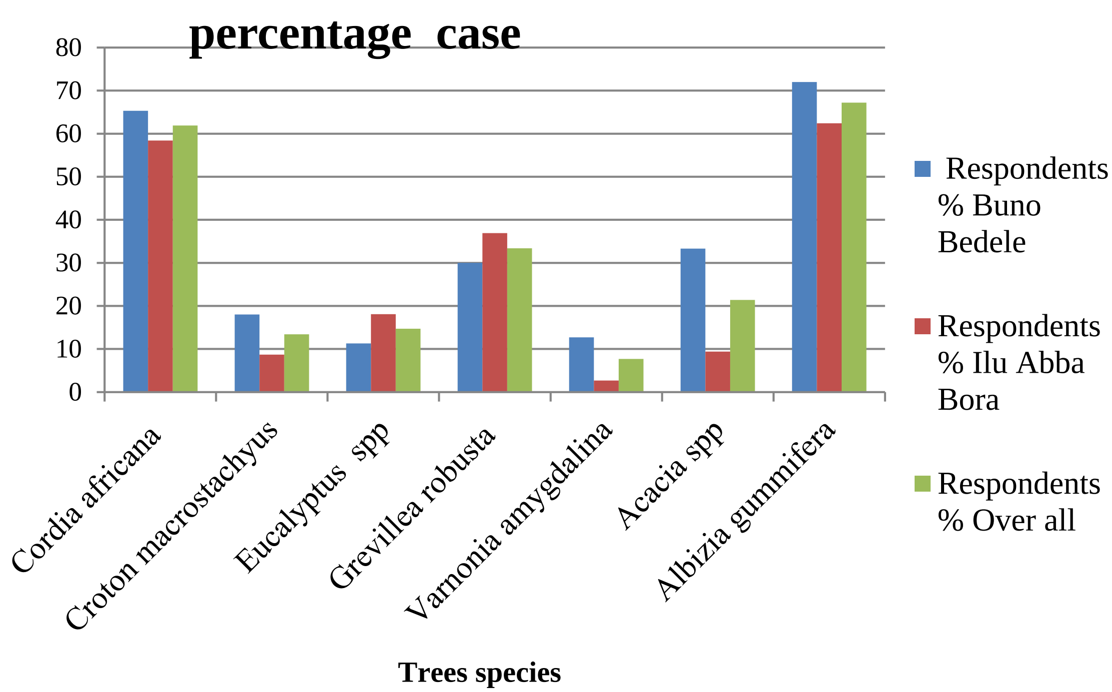


Figure 2.Tree species most preferred in field by Farmers

Source: Households survey; April, 2021

Trees Planted by Farmers at Study Area

As survey results the most common trees at study area were regenerated by nature and widely adopted by farmers as dominant on agricultural land and the farmers managed these trees within agroforestry practice. However some multipurpose trees were planted by farmers on their land and managed in different indigenous management within agroforestry practices. The result showed that, among the identified planted trees by farmers at study area are *Eucalyptus spp* and *Grevillea robusta*, are the most dominated one followed, by *Cordia africana*, *Juniperus procera*, *Albizia gummifera*, *Varnonia amygdalina*, *Sesbania sesban*, *Croton macrostachyus*, *Acacia spp*, *Ricinus communis* and *Pinus patula* respectively (Table 4).

Table 4. List of some trees Planted by farmers on the area

Tree species	Local Name	Respondents %		
		Buno Bedele	Ilu Abba Bora	Over all
Cordia africana	Waddeessa	30.7	20.1	25.4
Croton macrostachyus	Bakkannisa	3.3	4	3.7
Eucalyptus spp	Baargamoo	56.7	75.2	65.9
Grevillea robusta	Giravila	64	59.1	61.5
Juniperus procera	Gaattiraa	24	26.2	25.1
Pinus patula	Pachula	1.3	0.7	1
Ricinus communis	Qobboo	2,7	nil	1.3
Sesbania sesban	Sasbaaniyaa	8	3.4	5.7
Varnonia amygdalina	Eebicha	7.3	7.4	7.4
Acacia spp	Soondii/Laaftoo	4.7	0.7	2.7
Albizia gummifera	Ambabbeessa	11.3	8.1	9.7

Source: Households survey; April, 2021

Major fruit trees/shrubs, crops and livestock at study area

In the survey results the farmers at study area were participated in different agroforestry practice and fruit trees/shrubs, crops and livestock were the component of these practice. The results indicated that among the fruit trees/shrubs Avocado (91.3%), Banana (79.6%) and Mango (61.9%) were the most dominant fruit trees/shrubs, while Maize (95%), Coffee (91.3%), Teff (76.6%), Chat (65.9%) and Sorghum (52.8%) were the most dominant crops and Cow ,Oxen, Calve, Chicken, sheep ,Goat, Donkey and Horse were the most dominant livestock at study area respectively (Table 5). Coffee and Chat were the major cash crops respectively for study area. Although, FAO (2013) mention that agroforestry is a form of sustainable land use systems that integrates trees with crops or animal husbandry to initiate an agro ecological succession.

Table 5. Major fruit trees/shrubs, crops and livestock at study area

Category	Respondents %		
	Buno Bedele	Ilu Abba Bora	Overall
Fruit trees/shrubs			
Mango	57.3	66	61.9
Banana	67.3	92	79.6
Orange	18	34	26.1
Lemon	8	15.3	11.7
Avocado	90.7	92	91.3
Papaya	20	16.7	18.4
Apple	13.3	9.3	11
pineapple	5.3	10	7.4
Guava	21.3	17.3	19.1
Custard Apple	20.7	16	18.1
Citron	3.3	4.7	4
Cashmere	10	6	8

Crops			
Maize	90.7	99.3	95
Haricot bean	4.7	30.1	17.4
Teff	82	71.1	76.6
Fingermilet	19.3	22.8	21.1
Sorghum	31.3	74.8	52.8
Coffee	87.3	95.3	91.3
Chat	77.3	54.4	65.9
Hot pepper	2	14.1	8
Barely	24	6.7	15.4
Wheat	20.7	15.4	18.1
Fabien	9.3	10.7	10
Field pea	4.7	4	4.3
Livestock			
Oxen	83.3	79.9	81.6
Cow	86.7	83.2	84.9
Chicken	64.7	89.9	70.2
Sheep	38	51	44.5
Goat	34.7	12.8	23.7
Calve	75.3	65.8	70.6
Donkey	17.3	12.8	15.1
Horse	6.7	20.8	13.7

Source: Households survey; April, 2021

Farmer's Perceptions about Agroforestry

The result showed that farmers in study area widely participated in agroforestry on their farmland and around home. Majority of respondents were strongly agreed with the agroforestry practices on; increase farm income, improve soil fertility and conserved soil and water, saved time on collecting fodder and fuel wood from the forest and improve the natural condition (Table 6). This response revealed that agroforestry helps the farmers in increasing farm income and reduce the risk regarding to food and fodder, fuel wood and climate change. Based on respondent's reply most household had good perceptions and approach for agroforestry practice at study area. The results of this study similar with the finding of Alemayehu et al. (2021), the farmers had positive perception on agroforestry practices and they know very well on its utilities for income diversification, improvement of soil quality, fuel, construction materials, food, and feed, provision of shade, accessibility and ecological value could be understood from the given inquiry parameters.

Table 6.Farmer’s perception about agroforestry practice at study area

	Statements	Respondents %				
		1	2	3	4	5
Agroforestry practices	Increased farm income	59.9	37.1	2.3	0.7	0
	Increased soil fertility & conserved soil & water	69.2	30.8	0	0	0
	Reduced chances of complete crop failure	43.1	48.2	7.4	1.3	0
	Saved time on collecting fodder and fuel wood from the forest	64.2	33.1	2.3	0.3	0
	Took a long time to get income	45.5	45.8	7.1	1.7	0
	Sustain/improve the natural condition	65.6	33.1	0.7	0.7	0
Preferred trees in farmland increase crop productivity		49.8	45.2	5	0	0
Trees in farmland used as windbreak, &increase soil fertility& crop production.		64.4	34.6	1	0	0

Source: Households survey; April, 2021, 1=strongly agree, 2=Agree, Neutral, 4=Disagree, 5= strongly Disagree

Major Constraints and Importance to Agroforestry Practices at Study Area

Survey results showed that the study area was potential of agroforestry practices. The finding revealed that, among the identified importance of agroforestry at study area increasing income of household, regulate climate of the area, shading importance, add soil fertility, purpose for food and fodder, properly using the land, for construction, fuel wood and timber were the major opportunities of agroforestry respectively (Table 7). In similarly agroforestry practices are considered as one of the major source of food and income to meet the needs and the wellbeing of the rural community (Galhena et al., 2013). On other side, impacts of wild animals, Insect pest and disease, competition trees with crop (i.e. shading effect), shortage of land for tree planting, lack of capital, lack of knowledge, taking long time for profit and lack of seed accessibility and shortage of labor are the main constraints in agroforestry practices respectively at study area (Table 8).

Table 7 .Major importance to agroforestry practice at study area

Importance	Respondents %	
	Buno Bedele	Ilu Abba Bora
Properly using the land	29.5	24.5
Add income	51.4	55.2
Shading importance	37.7	28.7
Regulated climates	48.6	52.4
Timber	9.6	14.7
Construction	28.1	16.8
Fuel wood	15.8	18.2
Add soil fertility	52.1	23.8
Food and livestock feed	24.7	37.1
Save time	3.4	nil

Source: Households survey; April, 2022

Table 8.Major constraints to agroforestry practice at study area

Constraints	Respondents %	
	Buno Bedele	Ilu Abba Bora
Shortage of land for tree planting	4.4	9.9
Take long time for profit	9.7	nil
Lack of capital	6.2	4.4
Insect pest and disease	25.7	19.8
Impacts of arboreal animals	45.1	54.9
Lack of seed accessibility	9.7	nil
Lack of knowledge	8.8	1.1
Shortage of labor	1.8	7.7
Competition trees with crop (i.e. shading effect)	19.5	11.0

Source: Households survey; April, 2021

Trends of each value over last ten years

The result showed that fruit trees and agroforestry practice were increase at study area over last ten years. As the respondent's reason out why it's increased the farmers get awareness about tree planting and maintains of natural resource. Whereas Honey production, Animal husbandry and crop production were decreased respectively (Figure 3). The crop production was decrease because shortage of agricultural land, lack of oxen for plough farm land and increasing agricultural input costs. Therefore the farmers practically participated in planting Coffee, fruit trees and Eucalyptus instead of crops production.

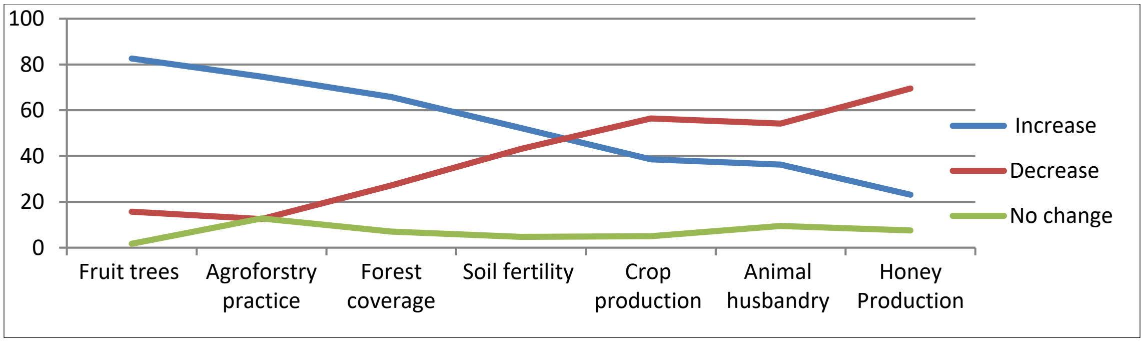


Figure 3. Response of respondents in percentage on trends of each value over ten years
Source: Households survey; April, 2021

Conclusion and Recommendation

As a result of Assessment existing agroforestry practices on study areas indicates; home garden, Coffee-based AF practice ,fruit trees based agroforestry, Woodlot, Windbreak/Shelterbelts, Trees on rangelands, life fencing, parkland agroforestry, taungya, and alley cropping were the most common types of agroforestry practices identified in the study area. These practices had components of common trees *Albizia gummifera*, *Cordia africana*, *Croton macrostachyus*, *Eucalyptus spp*, *Grevillea robusta*, *Acacia* spp, *Sapium ellipticum* and *Varnonia amygdalina*, *Juniperus procera*, *Ficus vasta*, *Syzygium guineense*, *Podocarpus facaltus* and *Prunus africana*. The major fruit trees species are; Avocado, Banana and Mango with Major crops Maize, coffee, Teff, Chat and sorghum. The agroforestry practice at study area were played for household importance in; increasing income of household, regulate climate of the area, shading importance, add soil fertility, purpose for food and fodder, properly using the land, for construction, fuel wood and timber. The respondents in study area had positive attitude with existing agroforestry practices. Major constraints to the consideration of agroforestry practice mentioned by the respondents included: impacts of wild animals, Insect pest and disease, competition trees with crop (i.e. shading effect), shortage of land for tree planting, lack of capital, lack of knowledge, taking long time for profit, lack of seed accessibility and shortage of labor. Generally the study results indicated that, home garden the dominant and alley cropping the least agroforestry practice and impacts of wild animal is the main constraint in agroforestry practice at study area.

So, further studies for the improvement of agroforestry practice should be done on positive interaction trees/shrubs selection in component, and with best management, to improve the livelihoods of farmer by reducing the exist constraints. In the present studies, Alley cropping agroforestry practice showed the least exercised by respondents at study area. Therefore, the research should be done on this practice to be introduces widely on famers land.

References

Abebe T, 2005.Diversity in home garden agroforestry systems in Southern Ethiopia PhD thesis Wageningen University, Wageningen.

Abrham, A., Demel, T., Georg, G., Maru, S., 2016. Tree planting by smallholder farmers in the upper catchment of lake Tana Watershed, Northwest Ethiopia. Small-scale Forest. 15, 199–212.

Alemayehu. D., Shimalis.D, and wasihun, G., (2021). Assessment of Existing Agroforestry Practices in West Hararghe Zone of Oromia Region, Ethiopia. *International Journal of Research GRANTHAALAYAH*, *9*(12), 286-302. doi:10.29121/granthaalayah.v9.i12.2021.4436

Alemu, M. (2016) Indigenous Agroforestry Practices in Southern Ethiopia: The Case of Lante, Arba Minch. *Open Access Library Journal*, **3**, 1-12. doi: 10.4236/oalib.1103278

Agbogidi, O.M., Adolor, E.B., 2013. Home gardens in the maintenance of biological diversity. Department of Botany, Faculty of Science, Delta State University, Abraka, Delta State, Nigeria

Asfaw, Z. and Ågren, G.I. 2007.Farmers' local knowledge and topsoil properties of agroforestry

Bekele-Tesemma, A. 2007. Uaseful trees of Ethiopia: identification, propagation and management in 17 agro ecological zones. Nairobi: RELMA in ICRAF Project, 552p.

Bishaw, B, Neufeldt,H, Mowo, J, Abdelkadir, A, Muriuki, J, Dalle, G, Assefa, T, Guillozet, K, Kassa, H, Dawson, I.K, Luedeling, E. and Mbow, C, 2013.Farmers'strategies for adapting to and mitigating climate variability and change through agroforestry in Ethiopia and Kenya. In: Davis, C.M., Bernart, B. & Dmitriev, A. (Eds.) Forestry Communications Group, Oregon State University, Corvallis, Oregon.

Brown, S, Grais, A, Ambagis, S. and Pearson, T,2012. Baseline GHG emissions from the agricultural sector and mitigation potential in countries of East and West Africa. CCAFS Working paper no. 13.CGIAR research program on climate change, agriculture and food security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org

Duguma LA, Hager H (2009). Forest products scarcity perception and response by tree planting in the rural landscapes: farmers' views in central highlands of Ethiopia. Ekológia, 28 (2): 158.

Ebisa, L., Abdela, G., 2017. Diversity of shade tree species in smallholder coffee farms of western Oromia, Ethiopia. Int. J. Agroforest. Silvicult. 5, 294–304.

Edmond, N, Yakam-Simen, F, Tadesse, K.K. & Romeij, P, 2000. Gedeo Zone Mapping Project. Phase 2. Final Report. Treemail, Heelsum, the Netherlands, Privateers N.V. and the Agricultural Bureau for Gedeo Zone. http://www.treemail.nl/download. Accessed 24 March, 2009.

Endale B (2017). Environmental Contribution of Agroforestry Systems to Smallholder Farmers around Jimma town, southwestern Ethiopia, unpublished MSc. Thesis.

FAO, 2013. Advancing agroforestry on the policy agenda: a guide for decision- makers.FAO, Rome. Agroforestry Working Paper No. 1. http://www.fao.org/docrep/017/i31 82e/i3182e00.pdf. (Accessed 25 March 2021).

Galhena, D. H., Freed, R., and Maredia, K. M. (2013). Home gardens: a promising approach to enhance household food security and wellbeing. Agriculture and Food security 2, 1-13.

Gustavo SG, Fonseca AB da, Harvey CA, Gascon C, Vasconcelos HL, 2004. Agroforestry and Biodiversity Conservation in Tropical Landscapes. Island Press, USA, pp. 537.

Iiyama M, Derero A, Kelemu K, Muthuri C, Kinuthia R, Ayenkulu E et al (2017) Understanding patterns of tree adoption on farms in semi-arid and sub-humid Ethiopia. Agrofor Syst 91(2):271–293. https ://doi.org/10.1007/s1045 7-016-9926-y

Jamala GY, Shehu HE, Yidau JJ, Joel L (2013) Factors influencing adoption of agro-forestry factors influencing adoption of agro-forestry among smallholder farmers in Toungo, South-eastern, Adamawa State, Nigeria. IOSR J Environ Sci Toxicol Food Technol (IOSR-JESTFT) 6(6):66–72

Jose, S. & Bardhan, S, 2012. Agroforestry for biomass production and carbon sequestration: an overview. Agroforestry Systems 86:105–1

Kang BT, Akinnifesib, FK, 2000. Agroforestry as alternative land-use production systems for the tropics. Natural Resources Forum 24, pp. 137-151.

Kebebew Z, Ayele G (2010). Profitability and household income contribution of growing Eucalyptus globulus (Labill.) to smallholder farmers: The case of central highland of Oromia, Ethiopia. European Journal of applied science, 2 (1): 25-29.

Ministry of Agriculture (MOA), 2010. Livestock Services Project. Volume 1 (Credit application to the IDA). Livestock and Meat Board, Addis Ababa, Ethiopia, pp: 31

Musa .A, ,Bira . Ch, . Robe. E. Assessment of Existing Agroforestry Practices in East Hararghe Zone Oromia, Ethiopia. *International Journal of Natural Resource Ecology and Management.* Vol. 7, No. 1, 2022, pp. 29-41. doi: 10.11648/j.ijnrem.20220701.15

Onyekwelu JC, Olusola JA, Stimm B, Mosandl R, Agbelade AD (2015) Farm-level tree growth characteristics, fruit phenotypic variation and market potential assessment of three socio-economically important forest fruit tree species. For Trees Livelihoods 24(1):27–42. https ://doi.org/10.1080/14728 028.2014.94238 6

Pandey, D.N, 2002. Carbon sequestration in agroforestry systems. Climate policy 2: 367−377.

Teshome T (2009) Is eucalyptus ecologically hazardous tree species? Ethiopian e-JResInnForesight 1 (1), 128–134. Available online at www.nesgl obal.org/eejri f4/index .php?journ al=admin&page=artic le&o

Yemenzwork Endale, Abayneh Derero, Mekuria Argaw and Catherine Muthuri (2017). Farmland tree species diversity and spatial distribution pattern in semi-arid East Shewa, Ethiopia. Forests, Trees and Livelihoods 26: 199-214

Growth and Yield Performance Evaluation of Mango (MangiferaindicaL.) Varieties in AdolaRede District, Guji zone, Southern Ethiopia

AschalewEmire*, SintayoDemise,TemesgenGiri and WakeyoTadele
Bore Agricultural Research Center, Bore, Oromia, Ethiopia
Corresponding author: aschu1511@gmail.com

Abstract

*Mango is among the most important fruit crop in the tropical and subtropical regions of the world and Ethiopia also has large tract of suitable land and agroecology for mango production. The study was conducted to evaluate Mango (Mangiferaindica*L.*) varieties for their vegetative growth and yield performance in Adola Rede District, Guji Zone, Southern Ethiopia. The treatments consisted of four mango varieties and the trial was laid out in randomized complete block design (RCBD) with three replications. A plot size of 10mx6m was used for each mango varieties. A plot consisted of two rows of grafted mango seedlings. On each row three grafted mango seedlings were planted and each plots had six mango trees. The findings of this study showed that, in terms of Vegetative growth parameters significant differences (at P<0.05) were observed between mango varieties. Regarding survival rate, Keitt variety was significantly higher than the others and statistically similar survival rate was recorded from Kent and Tommy Atkins varieties. The recorded stem thickness data showed that Kent and Tommy Atkins varieties were significantly higher (at P<0.05)than the others. The present study revealed that maximum tree height(4.693m*) *was recorded from Kent variety and the minimum tree height (2.65m) was obtained from Keitt variety. In terms of canopy spread, the maximum were recorded from Tommy Atkins (4.14m) and Kent (3.95m) Varieties. However, the minimum canopy spreads were observed in Keitt and Apple mango varieties. The highest fruit length was recorded from Keitt variety (13.87cm) and from others varieties similar fruit length was recorded. The highest fruit width of 10.567cm and 9.767cm were obtained from Keitt and Apple mango varieties respectively. However, the lowest values of fruit width were found in Tommy Atkins* (6.533cm) *and Kent variety (7.21cm). The largest fruit weight was recorded from Keitt (614.1gm) followed by Kent (493.8gm) variety and the lowest fruit weight were obtained from Tommy Atkins (388.3gm) and Apple mango (396.4gm). As the findings of this study showed that, significant differences were observed among the mango varieties in terms of yield per tree. Yield per tree of Kent variety was 7.943kg followed by Apple variety (6.173kg/tree). Regarding number of fruits per tree, Kent and Apple mango varieties produced a significant maximum number of fruits per tree (96.67) and (70) respectively. Whereas, Keitt and Tommy Atkins varieties were produced minimum number of fruits per tree. In terms of yield per plot, the maximum was recorded from Kent (47.9kg/plot) and Apple mango (47.41kg/plot). From Tommy Atkins and Keitt varieties lower number of yield per plot (27.92kg) and (12.72 kg) was recorded respectively. In general, the maximum fruit yield per hectare was obtained from Kent (7,983 kg/ha) and Apple variety (7,901kg/ha). However, the minimum yield/ha was recorded from Tommy Atkins (4,320 kg/ha) and Keitt variety (2,120kg/ha). Therefore, depending on their yield performances Kent and Apple mango varieties were recommended for mango producers of the study area and for similar agroecologies.*

Keywords*: Mango, Performance, Variety, Vegetative growth, Yield*

Introduction

Mango (*Mangiferaindica* L.) is one of the 73 genera of the family Anacardiaceae and order Sapindales which is one of the most versatile and widely grown fruit crops of tropical and subtropical regions (Ahmed and Mohamad.2015;Vasugi et al.,2012). It is believed to have originated from South East Asia and more than 1000 varieties have been identified all over the world and it is grown in more than 85 countries of the world with annual production of 35 million tons (Rymbai et al., 2014; Takele,2014).

Mango (*Mangiferaindica* L.) is among the most important fruit crop in the tropical and subtropical regions of the world. It is cultivated approximately on 3.7 million hectares worldwide, occupied the 2nd position among the tropical fruit crops and 5th from fruit crops of the world after citrus, banana, grape, and apple(Jahurul et al.,2015; Shi et al., 2015). The fruit is considered important because it provides; income, nutrition security and health to smallholder farmers and consumers at large(Ssemwanga,2003).

In Sub-Saharan Africa, growing both domesticated and wild fruit species on farms diversifies the crop production options of small-scale farmers and can bring significant health, ecological and economic revenues (Weinberger and Lumpkin, 2005). Mango (*Mangiferaindica* L.) is known as the king of the fruits due to its excellent flavor, delicious taste and high nutritive values that makes the crop valued for both food and nutritional security especially for developing countries like Ethiopia where the realization of food and nutritional security is still a challenge (Ullah et al.,2010).

Mango (*Mangiferaindica* L.) is one of the most widely grown among the fruit crops cultivated in Ethiopia preceded only by banana in terms of economic importance. A total of 69,743.39 tons of mango is produced from 12,799 ha of land (Fita,2014; CSA,2015). Moreover, within the past 10 years both area coverage and production of mango increased by 208.4 and 247%, respectively (Dessalegn,2014). It is grown in several parts of the country where the western and eastern Ethiopia are among the major producing belt that accounts >50% of the total mango production in Ethiopia (CSA,2015).

Ethiopia has large tract of suitable land and agroecology for mango production. It is mainly produced in Oromia, SNNPR, BenishangulGumuz, Amhara, Harari and Gambela regions (Desta,2013). Mango production in Ethiopia is in fluctuated conditions, because of occurrence of diseases, lack of proper management and also weather conditions(CSA,2009). More than 47 thousand hectares of land is under fruit crops in Ethiopia. Mangoes contributed about 12.61% of the area allocated for fruit production and took up 12.78% of fruit production in comparison to other fruits growing in the country. The annual consumption of mango by the processing plant at full production capacity is 8.6 tones which is only 1.8% of the current production of mango(Elias,2007).

In Midland Agro-ecology of Guji Zone, production of Mango (*Mangiferaindica*L.) is mainly constrained by lack of adaptable, high yielding and better quality of improved mango varieties. Likewise, available information on growth and yield performance evaluation of Mango (*Mangiferaindica*L.) varieties for Midland Districts of Guji zone has not been generated so far. Thus, introduction of adaptable and disease resistance improved Mango (*Mangiferaindica* L.) varieties can be one of the strategies to increase production of mango in the study area. Therefore, this study was initiated to identify well adaptable and high yielding Mango (*Mangiferaindica* L.) varieties for AdolaRede District and similar agroecologies.

Materials and Methods

Description of the Study Area

The trial was conducted at AdolaRede District, Guji zone,in Southern part of Ethiopia at a distance of 475 km from Addis Abeba, the capital city of Ethiopia. Astronomically, the absolute location of the study district isbetween 5°44'10” - 6°12'38” North latitude and 38°45'10” -39°12'37” East longitude (Figure 1). AdolaRede district is characterized by three agro-climatic zones namely humid, sub humid and dry arid zones. The mean annual maximum and minimum temperature of the study district is 23 and 16°C, respectively.

The type of rainfall of the study area is bimodal with longest rain season that has the maximum rainfalls which falls between 1200-1800mm annually and the shortest rainfalls records between 800-1200mm with an erratic distribution patterns. The major soil of the study district is Nitisols and orthcacrosols and it is dominantly brown soil. Moreover, the study area has an elevation ranging from 1500 m above sea level in the southern part of the District. However, in the north-western part of the District, it has an elevation greater than 2000 m above sea level.

The farmers of the study district produce both in autumn and spring seasons.The traditional farming system of the study area is characterized by cultivation of major crops such as teff, bread wheat, food barley, maize, haricot bean, lentils, chick pea and sweet potato. Farmers of the study district also engaged in the production of coffee as means of livelihood.

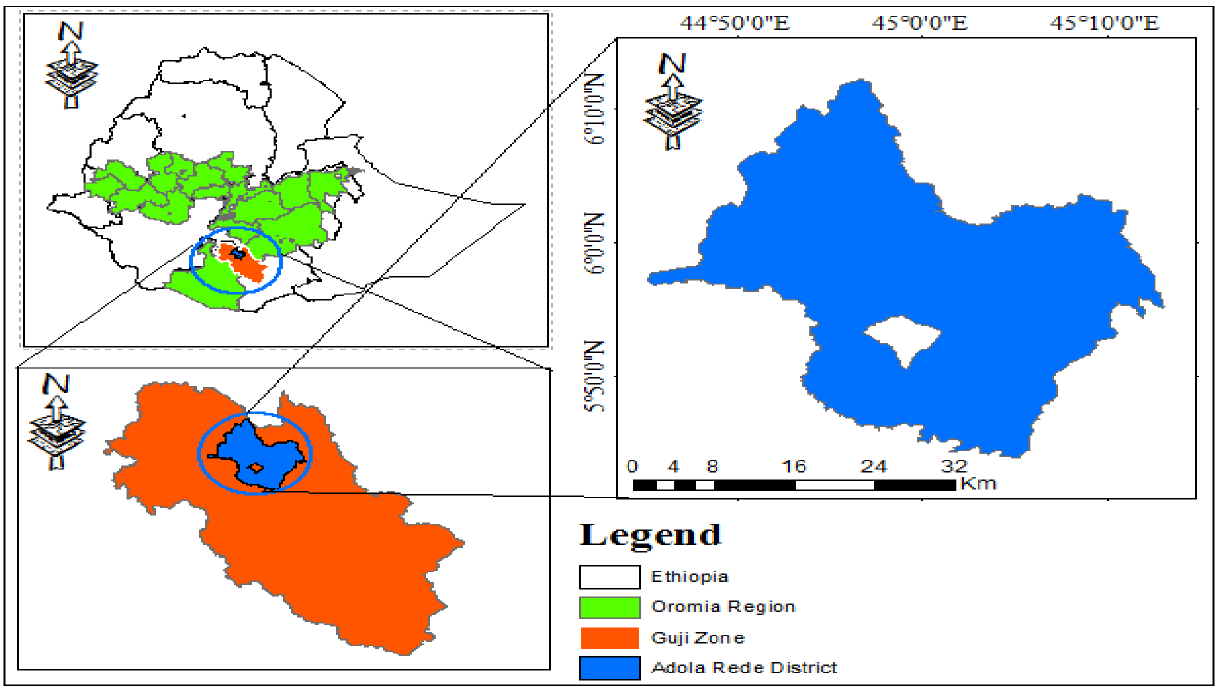


Figure 1. A map of the study area

Experimental Design and Layout

Four Mango (*Mangiferaindica*L.) varieties namely Apple, Keitt, Kent and Tommy Atkins were selected for this study. Grafted seedlings withthe same age of these four mango varieties were planted in Adola Sub site using a randomized complete blockdesign with three replications. The appropriate types of grafted seedlings of mango varieties were planted in a well-prepared hole with a depth, diameter and width of 50, 50 and 50 cm, respectively. A plot size of 10mx6m was used for each mango varieties. A plot consisted of two rows of grafted mango seedlings. On each row three grafted mango seedlings were planted and each plots had six grafted mango trees. Distance between the mango trees in the same row was 4m and distance between rows in the same plot was also 4m. The space between each plots andblocks was 1.5m and 2m respectively.

Field Management

All field management practices such as manuring, mulching, watering, weeding, and pest and disease control were performed as necessary during the study time.

Data Collection

Growth Parameters

Vegetative growth parameters data like survival rate, tree height, stem thickness and canopy spread were collected during the study time.

Yield parameters

From yield and yield components, necessary data such as fruit length, fruit width, fruit weight, fruit number /per tree, fruit yield/ per tree, fruit yield /per plots and total yields/ per hectare were collected.

Data Analysis

The analysis was performed by using Genstat 18^{th} Edition. Vegetative and yield data recorded from each Mango (*Mangiferaindica*L.*)* varieties were subjected to analysis of variance and Least significance differences (LSD) tests to enable comparison of the mango varieties.

Results and Discussion

Vegetative Growth Parameters

Survival Rate (%)

The finding of this study revealed that in terms of their survival rate significance differences were observed among the Mango (*Mangiferaindica*L.) varieties. The survival rate of Keitt mango variety was significantly higher (*P<0.05*) thanthe others. The survival data recorded of the four Mango (*Mangiferaindica*L.) varieties under the present investigation showed that Keitt variety was higher (88.87%) followed by Kent and Tommy Atkins varieties (72.23%). While, survival rate of Apple mango was only 38.1% (Figure 2). The mango varieties studied revealed different growth performance in terms of survival rate was due to the varietal nature and environmental influence. Similar to these study findings Reddy et al.,2003 held similar views that both the environment and genotype interactions are responsible for the control of vegetative growth parameters.

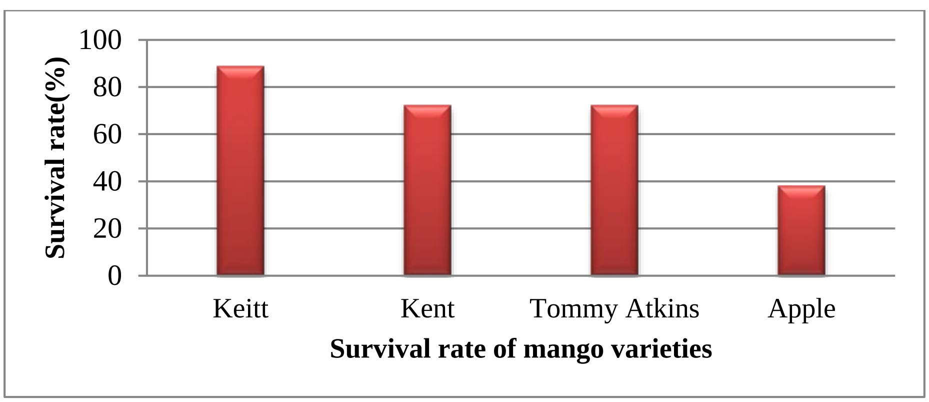


Figure 2. Survival (%) for Keitt, Kent, Tommy Atkins and Apple mango varieties

Stem Thickness (cm)
As the finding of this study showed that, the recorded stem thickness of mango varieties ranged from 14.23 cm (Kent) to 10.14 cm (Keitt variety) with average of 12.07 cm stem thickness. As compared to the others mango varieties used on this study, Kent andTommy Atkins varieties were significantly higher (at P<0.05)than Keitt and Apple mango varieties (Table 1). However, statistically significance differences (at *P<0.05*) were not observed between keitt and Apple mango varieties.

Table 1. Survival rate,Tree height, Stem thickness and canopy spread of Kent, Keitt, Tommy Atkins and Apple mango varietiesat Adola sub site

Treatment	Vegetative growth parameters			
	Survival rate (%)	Tree Height (m)	Stem Thickness(cm)	Canopy Spread(m)
Kent	72.23[b]	4.69[a]	14.23[a]	3.95[a]
Keitt	88.87[a]	2.65[c]	10.14[b]	2.27[b]
Tommy Atkins	72.23[b]	3.55[b]	13.18[a]	4.14[a]
Apple mango	38.09[c]	2.82[bc]	10.72[b]	2.61[b]
Mean	67.8	3.45	12.07	3.24
CV (%)	21.9	8.6	5.5	6.9
LSD (5%)	28.64	0.557	1.238	0.424

Means in columns with the same letters are not significantly different at (P<0.05)
**Means in columns with the different letters are significantly different at (P<0.05)*

Tree Height (m)
In terms of tree height increments significant differences (at P<0.05) were observed among the mango varieties (Table 1). As compared to the others, tree height of Kent variety was significantly higher than the others mango varieties used on this study. The highest tree height (4.693m) was recorded from kent mango variety and the minimum tree height (2.65m) was observed from keitt variety. These results are in contrast with the findings of (Parshant, 2012). On their study results reported that maximum plant height (5.82m) and minimum plant height of 2.93m was recorded from mango varieties under rain fed areas of Jammu . The findings of this study also in agreements with study results ofSawant et al.,2018 which were reported maximum plant height of 7.55m from Pairi mango variety and lowest plant height (2.53 m) from Karel mango variety.

The mango varieties their growth and yield performances studied showed different in tree height increments was due to varietal nature and environmental influence of the study area. On their study findingsReddy,2003, reported similar views that both the environment and genotype interactions are responsible for the control of tree height.Moreover, Kanpure et al., 2009indicated that the differences in the tree height of mango cultivars could be due to pruning, varietal nature and environmental influence.

Canopy Spread (m)
The results of this study revealed that a significant difference (*P<0.05*) in canopy spread among the mango varieties was observed. During the study time, kent variety had larger canopy spread of 3.95 m. While the least canopy spread was recorded on variety of keitt (2.27m). The finding of current study was in contrary with the study results of Parshant et al., 2012. In the past study results reported that highest and minimum

canopy spread of 8.09m and 2.57m was recorded respectively from mango varieties. Previous study results conducted on Evaluation of Mango hybrids and Varieties under Telangana region of Andra Pradesh and In Madhya Pradesh also reported the variation in tree canopy spread of mango cultivars (Srivastava et al.,1987; Sarkar et al.,2001).

Yield Parameters

Fruit Length (cm)

There was highly a significance difference in fruit length was observed between the mango fruit tree varieties (Table 2).The greatest fruit length (13.87cm) was recorded from keitt mango variety and the shortest fruit length (9.60cm) was found in Tommy Atkins variety. Based on the findings of this study, fruit length of Kiett mango variety was significantly ($P<0.05$) higher than the others mango varieties. However, statistically a significance differences were not observed between Apple mango, Kent and Tommy Atkins varieties.

Fruit Width (cm)

In terms of Fruit width a significance variations was recorded between mango varieties used on this study. The greatest (10.567cm) fruit width was found in keitt variety (10.567cm) followed by Apple Mango (9.767cm) and minimum (6.533cm) fruit width was recorded from Tommy Atikins variety. The main reason for differences in fruit width among mango varieties could be due to fruit size is mainly determined by the number of cells per fruit and their subsequent enlargement and both factors are affected by the competition for carbon between developing fruits as crop load increases (Harada et al., 2005).

Fruit Weight

A marked variation was found in fruit weight among the four mango varieties their growth and yield performances was conducted at the study area. The highest individual mean fruit weight was obtained from variety 'keitt' (614.1 gm) followed by Kent (493.8 gm) and the lightest mean fruit weight was recorded from 'Tommy Atkins' (388.3 gm) (Table 2). This variation of fruit weight between mango varieties might be due to genetic differences, management practice and environmental conditions of the study area. The finding of this study agrees with the findings of Anila and Radha, (2006) and Gopu et al., (2014). On their study resultsindicated that the fruit weight depends on varietal nature, cultural practices and climatic conditions of the growing region of mango varieties.

In terms of fruit weight recorded, the result of current study was contradicted with the findings of Kobra et al.,(2012). On their former study findings conducted on Performance of Mango Cultivars Grown in Different Agro-Ecological Zones of Bangladesh reported that maximum and minimum fruit weight of 648 g and 130 g was recorded respectively from mango cultivars. The result of this study also contradicted with the findings of Snehapriya et al., 2021. On their former findings reported that the maximum fruit weight (408.87 gm) and the minimum fruit weight of (175.38 gm). Therefore, from the finding of current and previous study results conducted in different countries observed that fruit weight of mango influenced by cultivars and varietal characteristics, management practice and agrorcology of the growing area.

Table 2.Fruit length, Fruit width, Fruit weight, Fruit number/tree, Yield/tree, Yield/plot and Yield/hectare of Mango varietiesat Adola Sub site

Treatment	Yield and Yield Components Parameters						
	Fruit Length (cm)	Fruit Width (cm)	Fruit Weight (kg)	Fruit No/ Tree	Yield/ Tree(kg)	Yield/ Plot (kg)	Yield/Hectare (kg)
Kent	10.60[b]	7.21[b]	0.49[ab]	96.67[a]	7.94[a]	47.90[a]	7983[a]
Keitt	13.87[a]	10.56[a]	0.61[a]	35.67[c]	2.09[d]	12.72[d]	2120[d]
Tommy Atkins	9.60[b]	6.53[b]	0.38[b]	46.67[bc]	4.32[c]	27.92[c]	4320[c]
Apple Mango	10.37[b]	9.76[a]	0.39[b]	70.00[b]	6.17[b]	47.41[a]	7901[a]
Mean	11.11	8.52	0.47	62.2	5.13	33.49	5581
LCD (5%)	1.15	0.76	0.11	16.92	4.1	5.73	954.3
CV (%)	5.5	4.8	0.31	14.4	0.87	9.1	9.2

**Means in columns with the same letters are not significantly different at (P<0.05)*
**Means in columns with the different letters are significantly different at (P<0.05*

Number of Fruits per Tree

There was marked differences in fruit number per tree was observed among the mango fruit tree varieties. The number of fruits per tree ranged from 46.67 to 96.67 and the maximum fruit number per tree was recorded from kent variety followed by Apple mango. While, the minimum fruit number per tree was recorded from Tommy Atkins variety. Similar to this study results, previous findings also indicated that fruit number per tree was negatively related to the fruit size in weight basis. Fruit size and total fruit yield were all affected by crop load, although there were differences between cultivars, and affect negatively the mean fruit weight (Embree et al.,2007; Marini,2003). Moreover, the finding of this study result is in line with Ddamuliraet al.,(2019) which was reported that in terms of fruit number per tree significance differences were observed between mango genotypes.

Fruit Yield per Tree

Data of fruit yield per tree recorded from mango varieties used on this study revealed significant differences among the varieties. The maximum fruit yield/tree was obtained from kent (7.943 kg/tree) followed by that of Apple mango variety (6.173kg/tree). However, the minimum fruit yield per tree 4.320kg/tree and 2.093 kg/tree were recorded from Tommy Atkins and Keitt mango varieties respectively. On their earlier study findings Majumder and Sharma,1985 reported that the yield is a highly variable factor depending upon the cultivars and age of the plants, climatic conditions, incidence of the pests and diseases. Furthermore, these findings were supported by study results of Yeshitela et al., 2004.On their study results reported that the variation in yield per tree may be attributed to fruit size and weight of different genotypes studied. Moreover, direct relationships between fruit set and yield per tree which contributes to increase in mango yield under ideal environmental conditions.

A. Apple

B. Kent

C.Keitt

D. Tommy Atkins

Figure 3. Yield performance of mango varieties after harvesting time

Fruit Yield Potential of Different Mango Varieties

The results of present investigation in terms yield per plot showed that, significance differences were observed among the mango varieties (Table 2). The mean maximum yield of 47.90 kg /plot was recorded from Kent variety followed by Apple mango (47.41kg/plot). Whereas, variety Keitt showed mean lower yield of 12.72kg per plot. The variability of yield per plot between the mango varieties might be due to genetic variation of the varieties as well as strong influence of environment. The findings of these study was supported by study results of Singh,(2003) who reported the variation between yield of different mango genotypes may be attributed to the difference in agroecology and the cultivars under study as fruit set is a varietal character, based on the time of flowering, sex ratio, efficient cross pollination, and intensity of fruit drop leads to varying fruit set in different varieties.

In terms of yield per hectare significant variations were observed between mango fruit tree varieties their growth and yield performance was studied. In comparison with others varieties, the recorded mean yield per hectare of kent and Apple mango varieties were significantly higher. Kent and Apple mango varieties had the highest yield per hectare of 7,983 kg and 7,901 kg respectively. However,keitt mango variety had the minimum fruit yield of 2,120 kg / hectare. Similar to this study the finding of Linda,(2006) and Smith,(2006) reported that the yield varies depending on age of tree, cultivars, weather, location and other condition. Moreover, the level of yield per hectare of fruit tree varieties varies based on effective pollination, crop husbandry practices and cultivars.

Conclusion and recommendation

Mango is one of the most widely grown among the fruit crops cultivated in Ethiopia preceded only by banana in terms of economic importance. However, its potential has not yet been fully utilized due to occurrence of diseases, lack of proper management and shortage of improved mango (*Mangiferaindica* L.)

varieties. The findings of this study showed that, in terms of vegetative growth parameters significance differences were observed among the mango (*Mangiferaindica* L.) varieties. Higher survival rate was recorded from Keitt variety followed by Kent and Tommy Atkins varieties. In general, Kent mango variety exhibited maximum tree height (4.693m) and the minimum tree height (2.65m) was recorded from Keitt mango variety. Based on their canopy spread, Tommy Atkins and Kent mango varieties were observed to have larger canopy spread. However, from Keittand Tommy Atkins mango varieties minimum canopy spread of was recorded.

Regarding yield and yield components, significance differences were observed between mango varieties. The highest fruit length 13.87 cm was recorded from Keitt mango variety. Whereas, in terms of their fruit length among the others mango varieties (Kent, Tommy Atkins and Apple) significance differences were not observed. The highest fruit width of 10.567 cm and 9.767 cm were recorded from keitt and Apple mango varieties respectively. Moreover, the findings of this study showed that the maximum 614.1gm fruit weight was found in Keitt mango variety. The average number of fruits per tree of the four mango varieties was varied statistically. Kent mango *(Mangiferaindica* L.) variety was found outstanding produced a significant higher number of fruits per tree followed by Apple mango variety. On the other hand, keitt and Tommy Atkins mango Varieties produced the least number of fruits per tree. With regard to fruit yield per tree the maximum was obtained from Kent variety (7.943 kg/tree) followed by Apple mango variety (6.173 kg/tree). While, the lowest yield per tree 2.093 kg and 4.320 kg were recorded from Keitt and Tommy Atkins mango varieties respectively.

In terms of fruit yields per plot, the maximum yield performances were recorded from Kent (47.9kg/plot) and Keitt mango variety (47.41 Kg/plot). While, the minimum 27.92 Kg/plot yield was obtained from Tommy Atkins variety followed by Keitt variety (12.72kg/plot). Regarding with the total fruit yields per hectare, the maximum yields were obtained from Kent (7983kg/ha) and Apple mango (7901kg/plot). While, the minimum yield per hectare were recorded from Tommy Atkins (4320kg/plot) and Keitt mango variety (2120 kg/plot). Therefore, based on their yield performance Kent and Apple mango varieties were recommended for AdolaRede District and similar agro-ecologies. Furthermore, for mango disease control additional studies could be recommended and given emphasis for future works.

Acknowledgments

The authors acknowledge Oromia Agricultural Research Institute (OARI) for the financial support to conduct the experiment properly and Bore Agricultural Research Center (BOARC) for provision of the necessary facilities for research work. The authors are also thankful for researchers and technical staffs who have contributed for the success of the study.

References

Ahmed THM, Mohamed ZMA. 2015. Diversity of Mango (*Mangiferaindica*L.) cultivars in Shendi area: morphological fruitcharacterization. International Journal of Research in AgriculturalSciences 2(4):2348-3997.

Anila R, Radha T. 2006. Physico-chemical analysis of mango varieties under Kerala conditions. Journal of Tropical Agriculture 41:20-2.

Central Statistical Agency (CSA) .2009. Agricultural sample survey: report on area and production for major crops, stastical bulletin 427. Addis Ababa, Ethiopia

Central Statistical Agency (CSA) .2015. Agricultural sample survey time series data for national and regional level, Addis Ababa, Ethiopia

Ddamulira G , Ramathani I , Sebikejje T, Naluyimba R, Otim A, Pariyo A, Maphosa M. 2019. Mango Yield Performance in Lake Victoria Cresent Region of Uganda. American Journal of Plant Sciences, 2019, 10, 1142-1153

Dessalegn Y, Assefa H, Derso T, Tefera M .2014. Mango production knowledge and technological gaps of smallholder farmers in Amhara region, Ethiopia. American Scientific Research Journal for Engineering, Technology, and Sciences 10(1):28-39.

Desta H .2005. Export potential of Ethiopia processed fruit and vegetables, export promotion department of English, P., S. Jaffee and J.J. Okello.2006. "Exporting out of Africa: The Kenya

Elias. A. 2007. Technical Assessment on Viability of Integrated Fruits Processing in Ethiopia; Master of sciences Thesis, Addis Ababa, Ethiopia

Embree CG, MTD Myra, DS Nichols, and AH Wright. 2007. Effect of blossom density and crop load on growth, fruit quality, and return bloom in Honeycrisp' apple. Hort. Science 42: 1622-1625.

Fita T .2014. White mango scale, *Aulacaspistubercularis,* distribution and severity status in east and west wollega zones, western Ethiopia. Science, Technology and Arts Research Journal 3(3):1-10.

Gopu B, Balamohan TN, Soman P, Jeyakumar P. 2014. Canopy Management in Mango (Mangiferaindica L.) cv. Alphonso with reference to Growth and Physiological Characters under Ultra High Density Planting. Madras Agricultural Journal 2014, 101.

Harada T, W Kurahashi, M Yanai, Y Wakasa, and T Satoh. 2005. Involvement of cell proliferation and cell enlargement in increasing the fruit size of Malus species. ScientiaHorticulturae 105: 447-456.

Jahurul MHA, Zaidul ISM, Ghafoor K, Al-Juhaimi FY, Nyam KL, Norulaini NAN, Mohd Omar AK .2015. Mango (*Mangiferaindica*L.) by-products and their valuable components: A review. Food Chemistry 183:173-180.

Kanpure RN, Singh HP, Reja RK.2009. Evaluation of mango hybrids for Kymore Plateau of Madhya Pradesh. Journal of Community Mobilization and Sustainable Development 4(2):1-3.

Kobra K, Hossain M.A, Talukder M.A.H and. Bhuyan M.A.J.2012. Performance of Twelve Mango Cultivars Grown in different Agro-Ecological Zones of Bangladesh.*Bangladesh J. Agril. Res. 37(4): 691-710*

Linda, S. 2006. All about avocados. Internet Document, America net/Q-A/News Paper Ltd

Majumder, P.K. and D.K. Sharma. 1985. Mango. In: Fruits: Tropical and Subtropical. 3rd edn. Vol. 1 (Eds. T.K. Bose and S.K. Mitra), NayaProkash, 206 BidhanSarani, Kolkata, India. Pp.27.

Marini RP. 2003. Peach fruit weight, yield and crop value are affected by number of fruiting shoots per tree. Hort. Science 38(4):512-514.

ParshantBakshi, Rakesh Kumar, Amit Jasrotia and V.K. Wali .2012. Growth and Yield performance of mango varieties under rainfed areas of Jammu. *Indian J.ric. Res., 46(3): 281-285, 2012*

Reddy, Y.T.N., Kumar, R.M., Singh, G. and Raghupati, H.B. 2003. Long term effects of nitrogen on growth, leaf nutrient status and fruit yield of Totapuri mango (*Mangiferaindica* L.). Indian Journal of Agricultural Sciences, 73(4): 206-208.

Rymbai H, Laxman RH, Dinesh MR, Sunoj VSJ, Ravishankar KV, Jha AK .2014. Diversity in leaf morphology and physiological characteristics among mango (*Mangiferaindica L.*) cultivars popular in different agro-climatic regions of India. ScientiaHorticulturae 176:189-193.

Sarkar, S.K., Gautham, B., Neeraja, G. and Vijaya, N. 2001. Evaluation of mango hybrids under Telangana region of Andhra Pradesh. The Horticulture Journal, 14(1): 13-21.

Sawant SV, Dahatonde KN and Gajbhiye PN .2018.Performance of different varieties of mango under sub-montane zone of Maharashtra.Journal of Pharmacognosy and Phytochemistry 2018; 7(6): 1992-1994

Shi S, Ma X, Xu W, Zhou Y, Wu H, Wang S .2015. Evaluation of 28 mango genotypes for physicochemical characters, antioxidant capacity, and mineral content. Journal of Applied Botany and Food Quality 88:264-273

Singh, S. 2003. Evaluation of mango genotypes for their flowering, fruiting and fruit quality attributes. Annals of Agricultural Research, 24(2): 234-238.

Smith, B. 2006.The farming Hand book. Technical Center for Africa (CTA), Wageningen,The Netherlands, PP:310-312

Snehapriya MS, Raj Kumar M, Kiran Kumar A and Sathish G .2021. Performance of different table varieties of mango (*Mangiferaindica* L.) for growth and yield under ultrahigh density planting in Telangana state. The Pharma Innovation Journal 10(11): 389-392

Srivastava, S.S., Asati, K.P., Patel, M.P., Tiwary, B.L. and Bhaduria, U.P.S. 1987. Evaluation of mango varieties in Madhya Pradesh. Indian Journal of Agricultural Sciences, 44(3-4): 197-201

Ssemwanga, J .2003. Assessment of Market Potential for Selected Tree Fruits in Uganda. FORRI-ICRAF Report, ICRAF-Kampala, Kampala

Takele. H .2014. "Review of mango value chain in Ethiopia." Journal of biology, agriculture and health care, Vol. 4, pp. 230-239, 2014.

Ullah H, Saeed A, Thompson AK, Ahmad W, Azher Nawaz M .2010. Storage of ripe mango (*Mangiferaindica*L.) cv. alphonso in controlled atmosphere with elevated CO2. Pakistan Journal of Botany 42(3):2077-2084.

Vasugi C, Dinesh MR, Sekar K, Shivashankara KS, Padmakar B, Ravishankar KV .2012. Genetic diversity in unique indigenous mango accessions of the Western Ghats for certain fruit characteristics. Current Science103 (2):199-207.

Weinberger, k., Lumpkin, T. A .2005. Horticulture for poverty alleviation – the un-funded revolution, Working Paper No. 15, AVRDC (The World Vegetable Center), Shanhua, NTaiwan

Yeshitela, T., Robbertse, P.J. and Stassen, P.J.C. 2004. Paclobutrazol Suppressed Vegetative Growth and Improved Yield as Well as Fruit Quality of Tommy Atkins Mango (*Mangiferaindica*L .) in Ethiopia. New Zealand Journal of Crop and HorticulturalScience , 32, 281-293. https://doi.org/10.1080/01140671.2004.9514307

Growth and Yield Performance of Avocado (PerseaamericanaMill.) Fruit Tree Varieties at Midland Agroecology of Guji Zone, Oromia Region, Southern Ethiopia

AschalewEmire*, Sintayew Demise and TemesgenGiri
Bore Agricultural Research Center
Corresponding author: aschu1511@gmail.com

Abstract

Ethiopia is one of the top five Avocado producers in sub-Saharan Africa and it was first introduced to Ethiopia around 1938 by private orchardists in Hirna (Eastern Highlands of Ethiopia) and Wondo-genet (Southern Highlands of Ethiopia). The study was conducted at Adola Rede District, Guji Zone, and Oromia Region, Southern Ethiopia. The objective of this study was toidentify the best adaptable and high yielding Avocado (Perseaamericana) fruit tree varieties for midland agroecology of Guji Zone. Seedlings of grafted Avocado fruit tree varieties were laid out in randomized complete block design (RCBD) with three replications. A plot size of 10mx6m was used for each Avocado fruit tree varieties. A plot consisted of two rows of grafted Avocado seedlings. On each row three grafted Avocado seedlings were planted and each plots had six grafted Avocado trees. Based on the objective of this study, vegetative growth parameters, yield and yield components data were collected during the study time. The results of this study revealed that, in terms of Vegetative growth parameters significance differences (at $P<0.05$) was observed among avocado varieties. In terms of survival rate, the highest survival rate was recorded from Bacon and the least one was Ettinger. The recorded stem thickness data showed that Fuerte variety was significantly higher (at $P<0.05$)than the others. The tree height data recorded revealed that the maximum and minimum tree heights were observed in Fuerte and Nabal varieties respectively. Moreover, there was a significantly ($P<0.05$) difference in canopy spread among the avocado varieties was observed. Pinkerton had larger canopy spread (4.627m) and least canopy spread was recorded on variety Nabal (1.287m). Avocado fruit length, fruit width, and fruit weight was significantly ($P<0.05$) difference among the varieties. The highest fruit length was recorded from Pinkerton (7.212cm) and the lowest value was found in Bacon (5.833cm). *In terms fruit width, the highest was obtained from Bacon (8.333cm) and the least one was recorded from Hass variety (6.033cm). The largest Fruit weight was obtained from Fuerte (0.285kg) and lowest fruit weight was recorded from Hass (0.111kg) avocado. The finding of this study revealed that the average number of fruits per tree of the six improved avocado varieties was varied statistically. Hass avocado produced a significant maximum number of fruits per tree (382) and Pinkerton variety produced the minimum number of fruits per tree (131).In terms of yield per plot, the maximum fruit yield per plot was obtained from Fuerte (140 kg) and the lower number of yield per plot (110.367kg) was recorded from Ettinger. The recorded total fruit yield per hectare of Fuerte variety was significantly higher than the other varieties. The maximum fruit yield per hectare was obtained from Fuerte (14,372 kg/ha) and the minimum was obtained from Pinkerton (12,262kg/ha). Therefore, Fuerte, Bacon and Hass avocado varieties are recommended for avocado producers at midland agroecology of Guji Zone and for similar agroecologies.*

Keywords*: Avocado, Fruit tree, Improved, Performance, Variety, Yield*

Introduction

Avocado (*Perseaamericana.)* is an evergreen, subtropical fruit species is a native tree of Central American countries, the northern coast of South America and the West Indies. It has been grown on five continents and widely distributed to more than 50 countries around the world, which mainly includes sub-tropical and tropical areas such as sub-Saharan Africa. (Zentmyer, 1987; Knight, 2002). Avocado (*Perseaamericana*)is a polymorphic tree species that originated in a broad geographical region stretching from the Pacific coast of Central America through Guatemala to the eastern and central highlands of Mexico. Three distinct and separate sub-species now termed the Guatemalan, Mexican and West Indian or Antillean races have been selected over millennia (Popenoe, 1920; Knight, 2002).

Ethiopia is one of the top five Avocado (*Perseaamericana*)producers in sub-Saharan Africa. Avocado was first introduced to Ethiopia around 1938 by private orchardists in Hirna (Eastern Highlands of Ethiopia) and Wondo-genet (Southern Highlands of Ethiopia). Gradually, it has been distributed to different agroecologic conditions where the crop could be adapted (Edossa1997;Megersa and Alemu2013;Woyessa and Berhanu2010). Despite its long history since introduction and the diverse agro-ecologic conditions of Ethiopia, its distribution is still limited to few areas of the country (CSA 2014).The avocado industry in Ethiopia is in its infancy and has not yet utilized the immense potential of this crop. Annual avocado production in Ethiopia is 25633.16 tons. Avocado is now produced by 1,149,074.00 farmerscountry wide who collectively farm more than 8938.24 ha of land (CSA, 2013; Yilma, 2009).

In Ethiopia, major Avocado (*Perseaamericana*) producing areas include Sidama and Wolayita areas in the South, Jimma and Mizan areas in southwestern and Hararge area in eastern region of the country (CSA 2014; Megersa and Alemu2013). In midland agroclimatic Districts of Guji Zone, Southern Ethiopia, communities of the area mainly grown Avocado trees around their homesteads, as an integral component of coffee which is used as a shade tree and in combination with other crops.

Study results conducted by WoyesaGaredew (2010) in Mana Districts, Jimma Zone indicated that even though Avocado has economically and socially play a significant role its production is confronted by a number of constraints such as Degeneration of fruits, Disease problem and production practice is poorly supported by scientific agronomic practice. As well, in midland agroecology of Guji Zone, production of Avocado is mainly hindered by insufficient number of avocado fruit trees per Ha, lack of adaptable, high yielding and better quality Avocado varieties. So far, available information on the Growth performance of improved Avocado (*Perseaamericana*) fruit tree varieties at Midland Districts of Guji zone is not conducted. Thus, introduction of adaptable improved Avocado fruit tree varieties can be one of the strategies to increase production of avocado at the study District. Therefore, this study was conducted to identify the best productive and adaptable Avocado fruit tree Varieties for Mid land Districts of Guji Zone.

Materials and Methods

Description of the study Area

The trial was conducted at AdolaRede District, Guji zone, Oromia Region**,** in Southern part of Ethiopia, at a distance of 475 km from Addis Abeba, the capital City of Ethiopia. Astronomically, the absolute location of the District isbetween 5°44'10” - 6°12'38” North latitude and 38°45'10” -39°12'37” East longitude (Figure 1). AdolaRede District is characterized by three agro-climatic zones namely humid, sub humid and dry arid zones. The mean annual maximum and minimum temperature of the study District is 23 and 16°C, respectively. The rainfall pattern of the District is bimodal for lowlands and midland areas and mono-modal for high land parts. The major soil of AdolaRede District is Nitisols and orthcacrosols and it is dominantly brown soil. Moreover, the study area has an elevation ranging from 1500 m above sea level in the southern part of the District. Whereas, in the north-western part of the District, it has an elevation greater than 2000 m above sea level. The farmers of the study District produce both in autumn and spring seasons.The traditional farming system of the study District is characterized by cultivation of major crops such as Teff, Bread wheat, Food Barley and Maize, Haricot bean and Sweet potato. Farmers of the study District also engaged in the production of coffee as means of livelihood ((CSA, 2013).

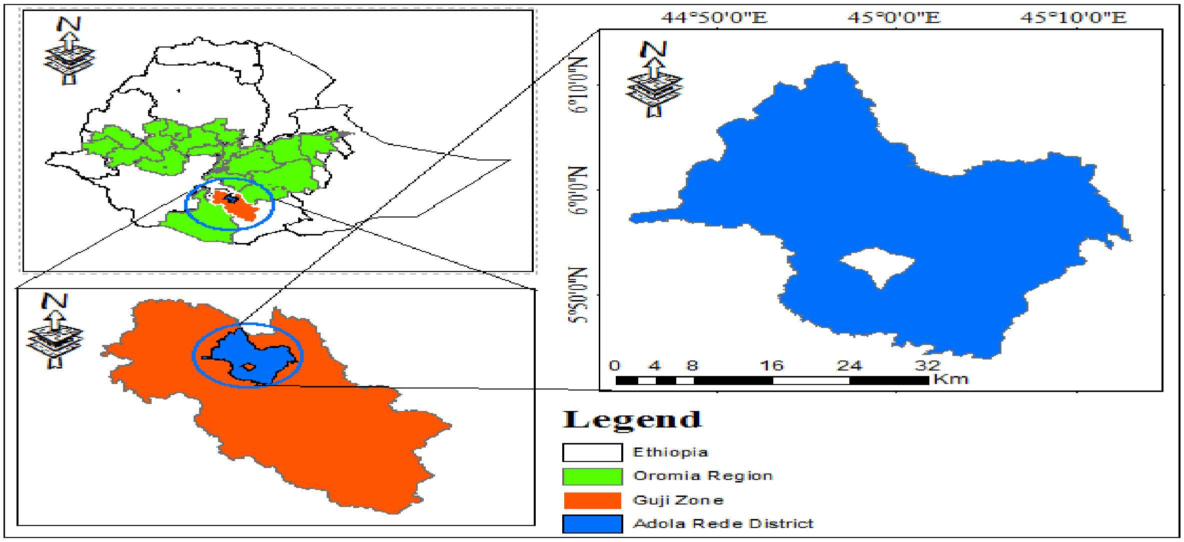


Figure 1. A map of the study area

Source of Avocado Fruit Tree Varieties and Experimental Design

Seedlings of six grafted improved Avocado (*Perseaamericana*) fruit tree varieties, namely Ettinger, Bacon, Nabal, Fuerte, Hass and Pinkerton were used as experimental material and they were obtained from Melkasa Agricultural Research Center. The appropriate types of grafted seedlings were planted in a well-prepared hole with a depth, diameter and width of 50, 50 and 50 cm, respectively. The trial was arranged in randomized complete block design (RCBD) with three replications. A plot size of 10mx6m was used for each Avocado fruit tree varieties. A plot consisted of two rows of grafted Avocado seedlings. On each row three grafted Avocado seedlings were planted and each plots had six grafted Avocado trees. Distance between the Avocado trees in the same row was 4m and distance between rows in the same plot and distance between blocks was 4m and 1.5m respectively.

Field Management

All field management practices such as manuring, mulching, watering, Weeding, and pest and disease control were performed as necessary.

Data Collection

Growth Parameters

Tree height (m): was considered by measuring the height of the largest scaffold branch from the ground level

Canopy spread: was calculated by mean measurements of the spreading of branches from North to South and From East to West.

Yield and Yield Components

Total Yields: were calculated in hectare base from the yield obtained from the plot measured by using the standard sensitive balance.

Fruit number per Tree: Was taken by counting all the fruits per tree and then make the average by dividing the number of trees per plot.

Average fruit weight (g): Was done by taking about 20 fruits randomly from each tree and make the average of them.

Data Analysis

The analysis was performed by using Statistical Analysis System (SAS version 9). Vegetative and yield recorded from each selected Avocado(*Perceaamericana*) fruit tree varieties were subjected to analysis of variance and Least Significance Differences (LSD) tests to enable comparison of the Avocado varieties.

Result and Discussion

Growth Parameters

Survival Rate and Stem Thickness of Avocado Fruit Tree varieties

The results of analysis (ANOVA) revealed that in terms of survival rate and stem thickness growth parameters, significant differences ($P<0.05$) were observed among six avocado fruit tree varieties. Survival rate of Avocado varieties (*Perseaamericana*) under the present investigation showed that Bacon Avocado variety was the highest(93.97%) followed by Fuerte(93.00%), Nabal(86.03%), Pinkerton(84.23%),Hass (83.13%),while survival rate of Ettinger(76.20%) was the lowest(Table 1). As the finding of this study revealed that, the recorded stem thickness of avocado varieties ranged from 6.576 cm (Fuerte) to 5.120cm (Hass) with average of 5.912cm stem thickness (Figure 2). From all Avocado varieties used on this study by stem thickness Fuerte avocado variety was significantly higher (at $P<0.05$) than Bacon, Ettinger, Nabal and Hass avocado varieties. While statistically significance differences (at $P<0.05$) was not observed between Fuerte and Pinkerton, and among Bacon and Ettinger improved avocado varieties (Table 1).

Tree Height and Canopy Spread of Avocado Fruit Tree Varieties

The analysis of variance indicated that there was significant difference ($P < 0.05$) in tree height was observed among the avocado varieties. The tree height of avocado varieties showed that, Fuerte and Pinkerton varieties were significantly higher (at $P<0.05$) than the others avocado varieties (Table 2). However, Hass avocado variety had statistically similar plant height performance with Nabal Variety. As the finding of this study showed that, the variety Fuerte had higher growth in height (3.30m) and Nabal avocado variety showed less growth in height which is 2.257m (Table 1). Therefore, as compared to others recorded mean height of Fuerte avocado variety was higher than the others variety. The finding of this study supported with previous finding which was indicated that taller plants are more productive than shorter trees due to light interception favored by taller plant (Day *et al*, 1999)

The result of this study revealed that there was a significant difference ($P<0.05$) in canopy spread among the avocado varieties over the growing years was observed. However, statistical difference was not observed between Nabal and Bacon avocado varieties (Table 1). In general, Pinkerton avocado variety had larger canopy spread (4.63m) as compared to others. While the least canopy spread was recorded on variety Nabal (1.29m). The analysis also showed that between Nabal and Bacon avocado varieties statistically a significance difference was not observed in canopy spread during growing years. In support of this study, previous Study results showed that, tree vigor, is expressed by different parameters like plant height and canopy spread per volume, affected the photosynthetic rate and productivity and hence ultimately affected the economic yield (Almeida *et al.,* 2016).

Table 1.Analyzed growth parameters results on Performance of Avocado Fruit Tree Varieties at AdolaRede District, Guji Zone, southern Oromia

Treatment	Vegetative Growth Parameters			
	Survival rate (%)	Tree Height(m)	Stem Thickness(cm)	Canopy Spread(m)
Bacon	93.97[a]	2.52[b]	6.11[bc]	1.39[e]
Ettinger	76.20[f]	2.40[c]	5.89[c]	4.34[b]
Fuerte	93.00[b]	3.30 [a]	6.57[a]	4.12[c]
Hass	83.13[e]	2.33[de]	5.12[e]	1.52[d]
Nabal	86.03[c]	2.25[e]	5.45[d]	1.28[e]
Pinkerton	84.23[d]	3.25[a]	6.31[ab]	4.62[a]
Mean	86.01	2.67	5.91	2.88
CV (%)	0.411	2.24	2.5	2.81
LSD	0.263	0.12	0.26	0.14

Means in columns with the same letters are not significantly different at (P<0.05)

**Means in columns with the different letters are significantly different at (P<0.05)*

Yield and Yield Components

Fruit length, Fruit Width and Fruit Weight of Avocado Fruit Tree Varieties

The combined Analysis of variance (ANOVA) showed that fruit length was highly variable among the avocado varieties studied; the highest fruit length was recorded from varieties Pinkerton (7.21 cm) and the lowest value was found in Bacon which is 5.83cm (Table 2). From all avocado varieties, in terms of fruit length Pinkerton was significantly higher ($P<0.05$) than Bacon, Nabal and Hass improved avocado varieties. Whereas, among the others avocado varieties statistically significance differences were not observed. As the finding of present investigation revealed that in terms fruit width, the highest was obtained from Bacon variety (8.33cm) and the least one was recorded from Hass avocado variety (6.03 cm) (Table 2). The analysis of variance also indicated that, by fruit width Bacon avocado variety was significantly higher ($P<0.05$) than the others variety. In contrary with this study finding, in Turkey maximum fruit length 13.9 cm from Pinkerton avocado variety and the minimum fruit length 9.1 cm recorded found Hass avocado variety and greatest fruit width 8.1 cm was recorded from Reed avocado variety (SuleymanBayram*et al.*, 2012).

Table 2.Analyzed yield and yield components results on Performance of Avocado (*Perseaamericana)* Fruit Tree Varieties at AdolaRede District,Guji Zone, Southern Ethiopia

Treatment	Yield and Yield Components of collected Parameters					
	Fruit Length (cm)	Fruit Width(cm)	Fruit Weight(kg)	Fruit number/Tree	Yield/Plot (kg)	Yield/Hectare (kg)
Bacon	5.83^{b}	8.33^{a}	0.24^{b}	210^{c}	117.93^{c}	$13{,}16^{b}$
Ettinger	6.31^{ab}	6.43^{ab}	0.22^{b}	169^{e}	110.36^{d}	$12{,}53^{d}$
Fuerte	6.93^{ab}	6.40^{ab}	0.28^{a}	285^{b}	140.76^{a}	$14{,}37^{a}$
Hass	5.52^{b}	6.03^{c}	0.11^{c}	382^{a}	116.43^{c}	$12{,}86^{c}$
Nabal	5.53^{b}	6.23^{ab}	0.23^{b}	186^{d}	120.03^{c}	$13{,}33^{d}$
Pinkerton	7.21^{a}	7.82^{ab}	0.23^{b}	131^{f}	130.46^{b}	$12{,}26^{d}$
Mean	6.22	6.77	0.22	227	122.66	13,08
LCD (5%)	2.63	2.54	0.12	9.46	4.24	5587
CV (%)	15.32	13.23	12.4	2.33	1.72	9.377

**Means in columns with the same letters are not significantly different at (P<0.05)*
**Means in columns with the different letters are significantly different at (P<0.05*

From the results of this study, the highest individual mean fruit weight was recorded from the Varieties 'Fuerte' (0.285kg) and 'Bacon' (0.245kg) respectively and the lowest mean fruit weight was obtained from 'Hass' (0.1110 kg) (Table 2). Whereas, among others avocado varieties such as Bacon, Ettinger, Nabal and Pinkerton their fruit weights were not significantly different. In contrary to this study finding, in Ghana and Turkey obtained mean avocado fruit weight ranged from 0.66kg to 0.78kg and 0.3kg to 0.663 kg respectively (SuleymanBayram*et al,,*2012 ; G.O.Nkansah*et al.,* 2011). However, the finding of this study is relatively similar with research findings carried out in California on Selection and evaluation of improved varieties and root stocks of avocado and the maximum obtained average fruit weight was 271.6 gm (MaryluArpaia, 2006).

Number of Fruits per Tree, Yield per Plot and Yield per Hectare of Avocado Varieties

The result revealed that the average number of fruits per tree of the six improved avocado (*Perseaamericana*) varieties was varied statistically during the study time. As it is indicated in Table 2, from all avocado varieties used on this study, Hass avocado produced a significant higher number of fruits per tree (382) and Pinkerton produced the least number of fruits per tree (131). The finding of this study is relatively similar with research findings conducted in Ghana on Avocado Germplasm conservation and improvement. On their study results indicated that the obtained maximum and minimum number of fruits per plant was ranged from 5 to 240(G.O.Nkansah*et al.,* 2011).

In terms of yield per plot, the mean maximum fruit yield per plot was obtained from Fuerte avocado variety (140.77kg).While from Ettinger avocado variety lower number of yield per plot (110.37kg) was recorded. However, the recorded mean yield per plot of three avocado varieties such as Nabal, Hass and Bacon did not showed significant difference. The analysis revealed that total fruit yield per hectare of the evaluated avocado varieties showed statistically significant difference (at *P<0.05*). Therefore, recorded total fruit yield per hectare of Fuerte avocado variety was significantly higher than the other varieties. The maximum fruit yield per hectare was obtained from Fuerte (14,372 kg/ha) and the minimum fruit yield was obtained from Pinkerton avocado variety (12,262 kg/ha). The result agrees with the finding of Smith (2006) which was indicated that the yield varies greatly with cultivar, age of tree, location, weather and other condition. The level of yield per hectare obtained also depends on cultivars, effective pollination and crop husbandry practices (Edosa, 1997; Linda, 2006).

Conclusion and Recommendation

Ethiopia has suitable growth conditions that support optimal cultivation of many fruit trees in general and avocado in particular. However, a small proportion of this potential is used. Avocado cultivation in Ethiopia is characterized by insufficient number of trees per Ha, disease problem, lack of adaptable high yielding and better quality avocado varieties and production practice is poorly supported by scientific agronomic practice. Based on the findings of this study in terms of growth parameters like (survival rate, stem thickness, tree height and canopy spread) statistically significance differences was observed among the avocado varieties. The highest survival rate was recorded from Bacon (93.97%) and the least one was Ettinger (76.2%). In terms of tree height and canopy spread between avocado varieties significance variation was observed. The maximum and minimum tree heights were recorded from Fuerte (3.30m) and Nabal (2.25m) varieties respectively. While in terms of canopy spread, variety Pinkerton was observed to have larger canopy spread and theleast canopy spread was recorded on variety Nabal. According to this study, in terms of yield and yield components parameters significance differences was observed among the avocado varieties. The highest fruit length 7.21 cm was recorded from Pinkerton avocado variety and the lowest fruit width (8.33cm) was found in Bacon avocado variety. The average number of fruits per tree of the six improved avocado varieties was varied statistically. Hass and Fuerte avocado varieties were found outstanding produced a significant higher number of fruits per tree respectively. On the other hand, Pinkerton avocado variety produced the least number of fruits per tree. Moreover, the maximum fruit yield per plot was obtained from Fuerte variety (140.77kg/plot) and the lower number of yield per plot (110.37kg/plot) was recorded from Ettinger variety. As compared to others avocado varieties, the recorded total fruit yield per hectare of Fuerte variety was significantly higher. The maximum fruit yield per hectare was obtained from Fuerte (14,372kg/ha), Nabal (13,338kg/ha) and Hass (12,862 kg/ha) respectively and the minimum yield per hectare was obtained from Pinkerton (12,262 kg/ha). Therefore, Fuerte, Nabal and Hass Avocado Fruit Tree varieties were recommended for production at midland agroecology of Guji Zone and similar agro-ecologies.

Acknowledgements

The authors acknowledge Oromia Agricultural Research Institute (IQQOI) for the financial support and Bore Agricultural Research Center for provision of the necessary facilities for research work. We also express our sincere appreciation to the Melkasa Agricultural Research Center for provision of seedlings of improved grafted avocado varieties for the study.

References

Almeida GK, GAB Marodin, HT Queiroz, and MP Gonzatto. 2016. Productive and vegetative performance of peach trees grafted on six rootstocks in a replanting area. Universidade Federal do Rio Grande do Sul (UFRGS) Brazil 51(4): 364-371.

Ayelech. T, 2011, *Market chain analysis of fruits for Goma woreda*Jimma zone, Oromia regional state'A Thesis Submitted to School of Graduate Studies of Haramaya University.

CSA, 2013, Agricultural Sample Survey 2012 / 2013; Volume I, Report on Area and Production of Major Crops, Statistical Bulletin 532; Addis Ababa, Ethiopia.

Corelli C and S Sansavini. 1989. Light interception and photosynthesis related to planting density and canopy management in apple. Acta Hort. 243: 159-67.

Day KR, RS Johnson, S Searcy, and BA Allen. 1999. Tree height and volume Studies for fresh shipping stone fruits. CTFA Research Report, Kearney Agricultural and Extension Center, CA, USA.

Edossa E (1997) Selection of avocado (Perseaamericana.) for collection of desirable fruit characteristics and yield at Jimma. In: Proceedings of the 8th annual conference of the crop science society of Ethiopia, Addis Ababa, pp 26–35, 26–27 Feb 1997

G.O.Nkansah,K.G. Ofosu-Budu and A.W. Ayarna. 2011.Avocado Germplasm conservation and improvement in Ghana. *Proceedings VII World Avocado Congress 2011. Caims, Australia 5-9 September 2011.*

Knight, J. R. J. 2002. History, distribution and uses. In Whiley, A. W., Schaffer, B. and Wolstenholme, B.N. (eds). The Avocado: Botany, Production and Uses. CABI Publishing, 1:14.

Megersa B, Alemu D (2013) The role of avocado production in coffee-based farming systems of South Western Ethiopia: the case of jimma zone. J AgricSciAppl 2(2):86–95

Mary Lu Arpaia. 2006. Enhancement of Avocado Productivity. Plant Improvement: Selection and Evaluation of Improved Varieties and Rootstocks.*Proceedings of the California Avocado Research Symposium, November 4, 2006. University of California*

Popenoe, W., 1920. Manual of Tropical and Subtropical Fruits, Macmillan, London, pp 524.

SuleymanBayran,M.AlperArslan, ErtugrulTurgutoglu and Mustafa Erkan. 2012. The Performance of Some avocado cultivars underMediterranean Costal Conditions in Turkey. *Journal of Food, Agriculture &Enviroment Vol.10(2): 588-592.2012*

Woyessa G, Berhanu T (2010) Trends of avocado (Perseaamericana M.) production and its constraints in ManaWoreda, Jimma zone: a potential crop for coffee diversification. Trends Hort Res, ISSN 1996-0735, doi: 10.3923/thr., 2010

Zentmyer, G. A. 1987. Avocados around the World. California Avocado Society Yearbook **71**:63-77.

Assessment of Factors Affecting Seedling Survival in Adami Tullu and Dugda District of Central Rift Valley of Oromia, Ethiopia

Desta Negayo[1],, Bonsa Fentale[2], Gemeda Terfassa[2]
Adami Tullu Agriculture Research Center, Adami Tulu, Oromia, Ethiopia
Coresponding Author:

Abstract
Tree planting initiatives and activities have been conducting at different periods of time in Ethiopia specifically in Oromia aiming to curb the effect of climate change and deforestation. Following production of large number of seedling each year; plantation campaign has conducted in large scale. The study was designed to assess the seedling production and its survival in East Shewa zone of Oromia region. From East Shewa Adami Tulu Jido Kombolcha and Dugda Districts were selected as both are one of the districts conducting high plantation campaign every year. Household survey interview (n=132, 66 for each districts) and planting sites survival count on communal plantation sites were the methods used to obtain the primary data. Direct observation and the record of government nurseries seedling production data were obtained from the districts nursery during survey operation. As a result, even though there is a mass production of seedling and large scale plantation, there is insignificant number of survival of planted seedlings on the field according to the data from survey result and actual count from selected plantation sites. The average survival rate at Dugda district of protected communal sites (46.79 %) and un protected communal sites (19.42 %) while that un protected Communal site at Adami Tulu District is 8.6 %. Among the factors responsible for less seedling survival un accessible water sources and lack of overall management are the common factors that has gotten significance value at p(α=0.05) at both districts. Therefore, it is important to take the revert action to save the undermined huge investment cost to the success of plantation. Post plantation management and budget allocation for transplanted plants also crucial for plantation success

***Keywords**:communal sites, seedling production, survival rate, private holdings*

Introduction
Tree plantation on degraded lands can play a key role in harmonizing long-term forest ecosystem rehabilitation or restoration goals. Forest plantations, using appropriate tree species can play an important role in the tropical ecosystem rehabilitation (Founoune et al., 2002). In such cases, planting of nurseryraised seedlings may accelerate regeneration (Yirdaw and Luukkanen, 2003).Successful seedling establishment and growth depends on the soil condition and the stored soil moisture to ensure survival into the next growing season (Warren et al., 2005). Because, seedlings of some trees are sensitive to drought, and may be killed by even short dry spells (Engelbrecht et al., 2007).

Climate change affects a number of variables in plant growth and development. Several of the primary effects were seen in seedling mortality rates. Fluctuations in soil moisture content, light, or temperature influence seedling growth and development as forested ecosystems contribute to global hydrologic cycles. Seedling mortality and survival, especially when planted on public lands, was typically influenced by a number of factors including drought, poor planting practices or herbicide drift from nearby (Stanturf et al. 1998, 2004). A lack of precipitation and belowground water resources leads to increased seedling mortality and extensive dieback in many species (Valladares and Niinemets 2008; Hoffman et al. 2011), while others are minimally affected (Klopcic and Bocina 2012).

The Ethiopian government has a big dream: restoring 22 million hectares of degraded lands and forests by 2030. By doing so, the country aims not only to increase tree cover and restore degraded forests, but also to significantly enhance the forestry sector's contribution to agricultural production systems, water and energy; to improve food and nutritional security; and to create more opportunities for employment and household income (Ethiopia's new forestry law 2018). In the dry and more degraded lands of central rift-valley of Ethiopia particularly Adami Tullu and Dugda District, have been planting many seedlings of different tree species year after year but the survival of those seedlings were very poor as we informed from district offices.Again, the area had not been given much research attention and are still lacking clear information on factor affecting plantation successes. Therefore, the study was designed to assess the seedling production and responsible factors for the success of plantation to understand forest establishment and development

General Objective

The overall objective of this study was to assess the seedling production and responsible factors for the success of plantation to understand forest establishment and development

Specific Objectives

To assess the capacity of seedling production of the selected study areas
To evaluate the success of plantation after five years of planting in the study area and assess the more survived species in the study area
To determine factors affecting seedling survival after planting in the study area

Research Methodology

Description of the Study Site

This study was conducted in Adami Tuluand Dugdadistricts in central rift-valley of Ethiopia. Adami Tulu district lies between 7° 9'N lat, 38° 7'E long; elevation 1650 m above sea level. The mean annual rainfall and temperature of the area is 760.9 mm and 19.8°C respectively. The pH of the soil is 7.88. The soil is fine sandy loam in texture with sand, clay and silt in proportion of 34, 48 and 18% respectively (ATARC, 1998). The altitude ranges from 1500-2300 m.a.s.l. Adami Tulu Jido Kombolcha Woreda has semi-arid and arid agro-climate zones. The Woreda receives an average annual rainfall of 760 mm. The mean monthly temperature varies from 18.5°C to 21.6°C with mean annual temperature of 20°C. Rainfall extends from February to September with a dry period in May to June, which separates the preceding short rains from the following long rains (Diaz et al, 2015).Three land use systems: croplands, controlled grazing lands with closed areas and communal open access grazing land exist in the study area (Mesku et al., 2008).The soil is fine sandy loam in texture with sand, clay and silt in proportion of 34, 48 and 18% respectively (ATARC, 1998).

Dugda Woreda is located in East Shewa Zone of Oromia Regional State. Geographically the Woreda is located between 8^0 01'N to 8^0 10'North latitude and 38^0 31'E to 38^0 57'E longitude. The total area of the Woreda is 959.45 km2. Altitude ranges from 1600 to 2020 meters above sea level (Spielman*et al.*, 2011). The mean annual temperature was about 22.8^0C, while mean annual rainfall was 750 mm (Dugda Woreda Agricultural Office, 2015). The land use of the Woreda consists of cultivated land (65.25%), forest (8.32%), pasture (3.55%), water bodies (12.54%), swampy and rocky mountain areas (0.31%) and 10.03% others and, the dominant types of crops are maize, wheat and teff (DWAO, 2015).These soil types have light texture making them vulnerable to both wind and soil erosions. In addition, these soil types are saline and alkaline contents, though the degree of salinity is very low.

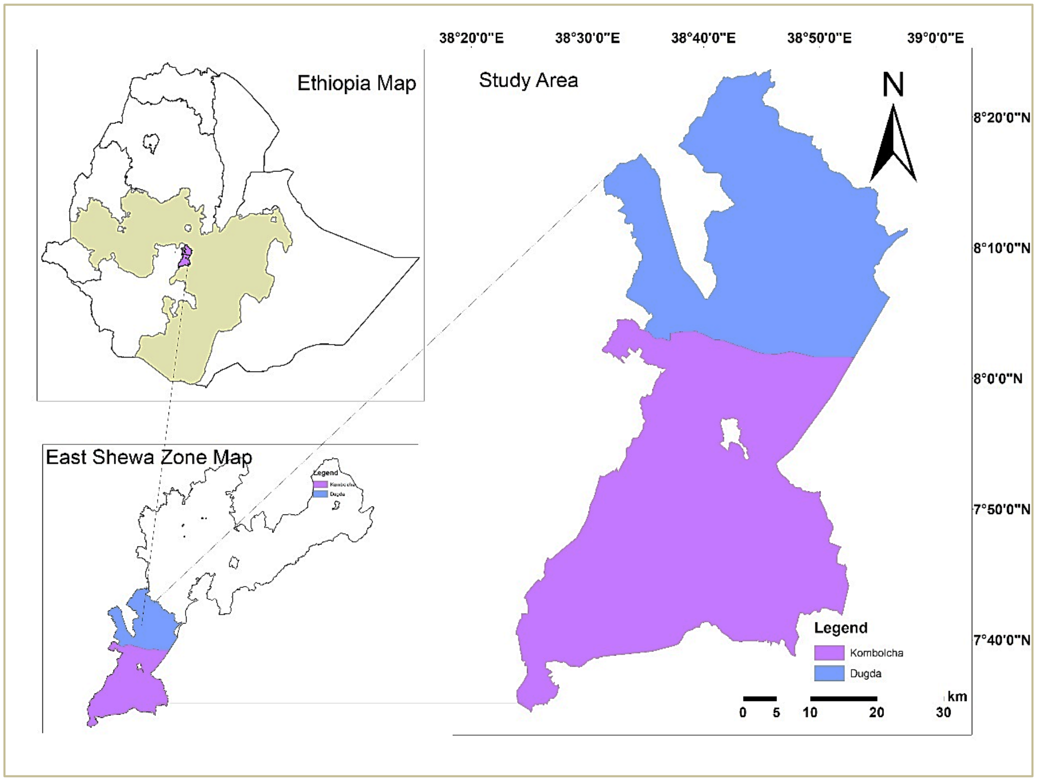


Figure 1: Map of the study area

Sampling Procedure and Data Collection

Based on the population data, sample of the people to be interviewed were selected from farmers in the study area. From this list, semi-structured questionnaires were prepared to farmers randomly selected from the study area to ask their perception on factors hindering seedling survival including which one they consider mostly affecting factor in the area. Discussion with concerned development workers and local leaders was conducted mainly focused on strengths, weakness, opportunities and threats to forest development and facts about the failure of forest development in the study area. Five years back Data of seedling production and its plantation success was assessed from District office and field observation at planted areas. From 2012 E.C. assessment was done for green legacy plantation status for the two consecutive years. Number of seedling raised on nursery by their species and number of seedling planted and survived was assessed. Field observation was also carried out at different times of the investigation year to have an idea where and how are seedlings performing on the field.

Sample Size and Sampling Techniques

The sample size was determined using the method proposed by Yamane (1967).

$$n = \frac{\mathrm{N}}{1 + \mathrm{N}\ (\mathrm{e}2)}$$

Where n is the sample size, N is the population size, and e is the desired level of precision.

Statistical analyses

Data from the questionnaire responses and field observation was coded and entered in Statistical Package for Social Scientists (SPSS version 20) and converted to status for analysis. Descriptive statistics was used to show the major factors that farmers considered as mostly dominant problem for survival of the plants on field.

Results and Discussion

Demography of Household Respondents'

Table 1: Demographic characteristics of household respondents' at Adami Tulu District (n=66)

Description	Frequency (N)	Percentage (%)
	Sex	
Male	60	90.9
Female	6	9.1
Total	66	100
	Marital status	
Married	63	95.5
Widow	3	4.5
Total	66	100
	Education	
Illiterate	2	3
Primary Education	51	77.3
Secondary Education	11	16.7
College/University	2	3
Total	66	100
	Average	**Range**
Age	37	22-80
Family size	7	1-12

Table 2: Demographic characteristics of household respondents' at Dugda District (n=66)

Description	Frequency (N)	Percentage (%)
	Sex	
Male	58	87.9
Female	8	12.1
Total	66	100
	Marital status	
Married	61	92.4
Single	3	4.6
Widow	2	3
Total	66	100
	Education	
Illiterate	5	7.6
Primary Education	41	62.1
Secondary Education	19	28.8
College/University	1	1.5
Total	66	100
	Average	**Range**
Age	37	20-82
Family size	7	1-12

Government Nursery Seedling Production and Distribution

In the study area the sizes of the polythene tubes 8 cm, 10 cm and 12 cm were used to raise seedlings on the nursery. The size of the polythene 12 cm is used to raise the seedlings of fruit trees while the left two sizes were used to raise the seedlings of other trees. From the nursery observation at Adami Tullu Jido kombolcha district the soil which filled in the polythene is not compacted and disintegrated during transportation to the site. This may be due to the soil type used and mixing ratio. In addition to soil compactness problem there is more than two seedlings per single polyethene tube and long nursery life time for some species. Due to the reason stated above seedling survival potential for long dry season may be affected in addition to other factor identified from the interview and field observation. Despite its poor management and un availability of nursery calendar, there is massive number of seedling production and high cost investment specially post green legacy mobilization at both districts (Figur 2).

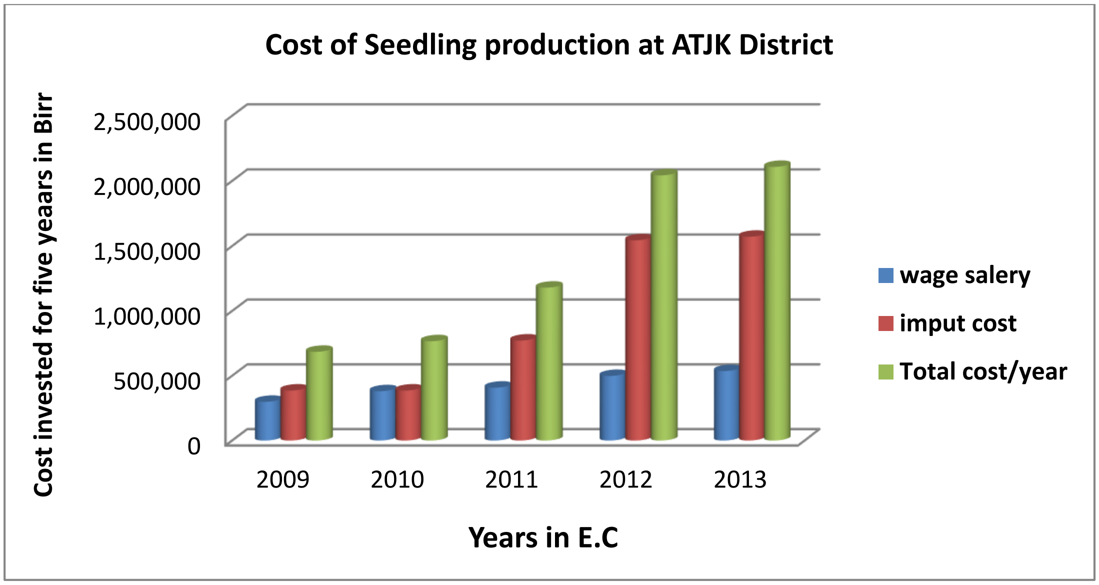


Figure 2 . Costof seedling production at Adami Tullu Jido Kombolcha District (2009 – 2013 E.C)

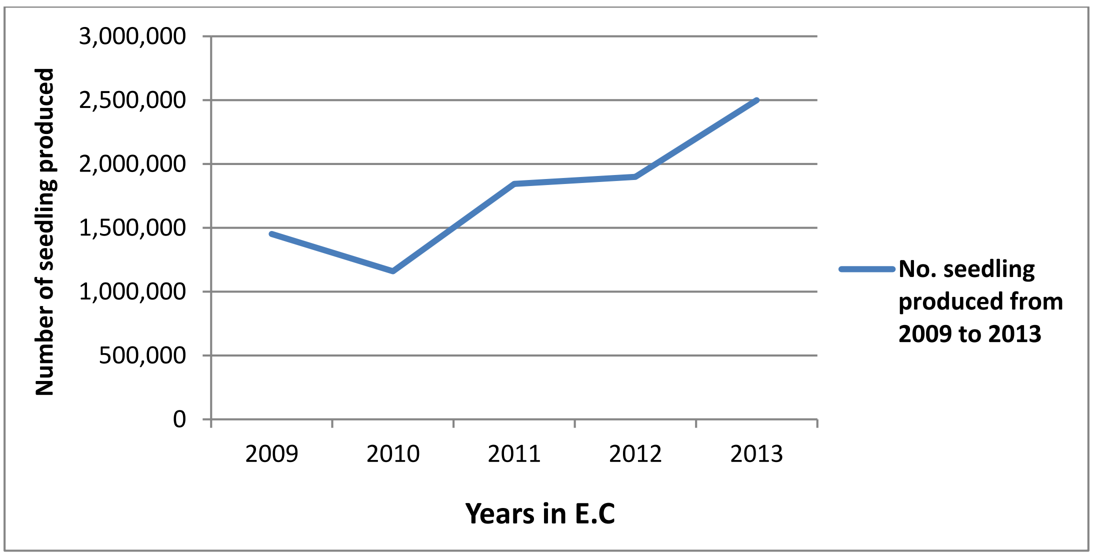


Figure 3. Seedling produced at Adami Tullu Jido Kombolcha District (2009-2013 E.C)

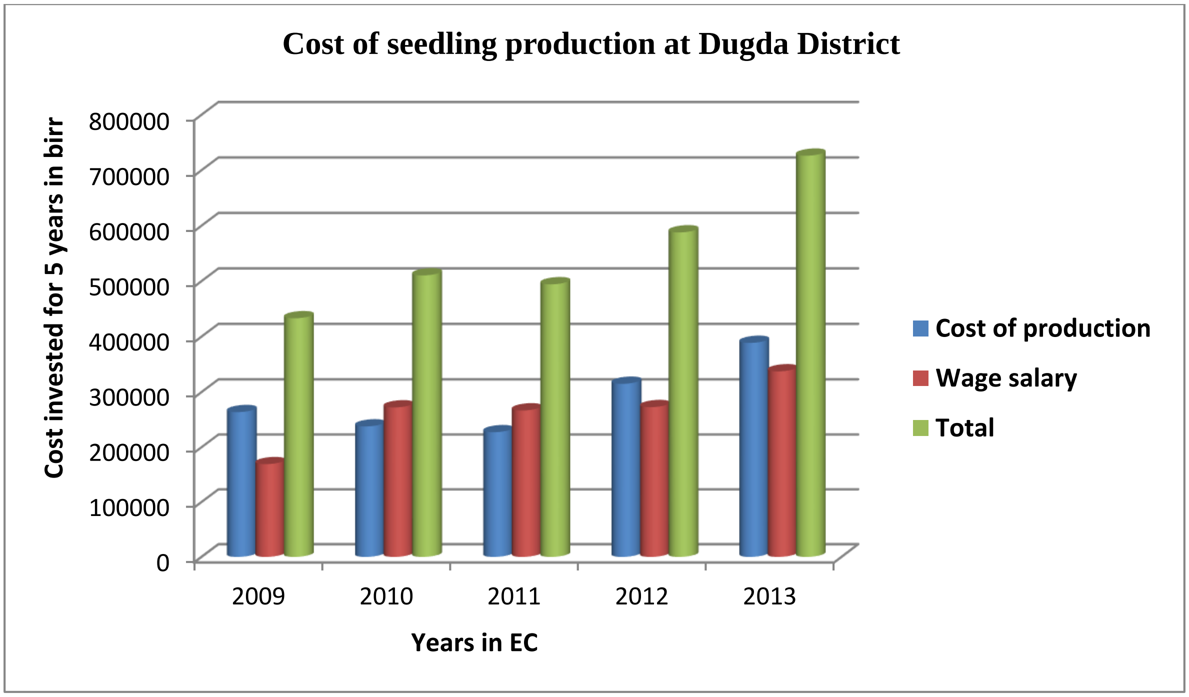


Figure 4. Cost of seedling production at Dugda District (2009 – 2013 E.C)

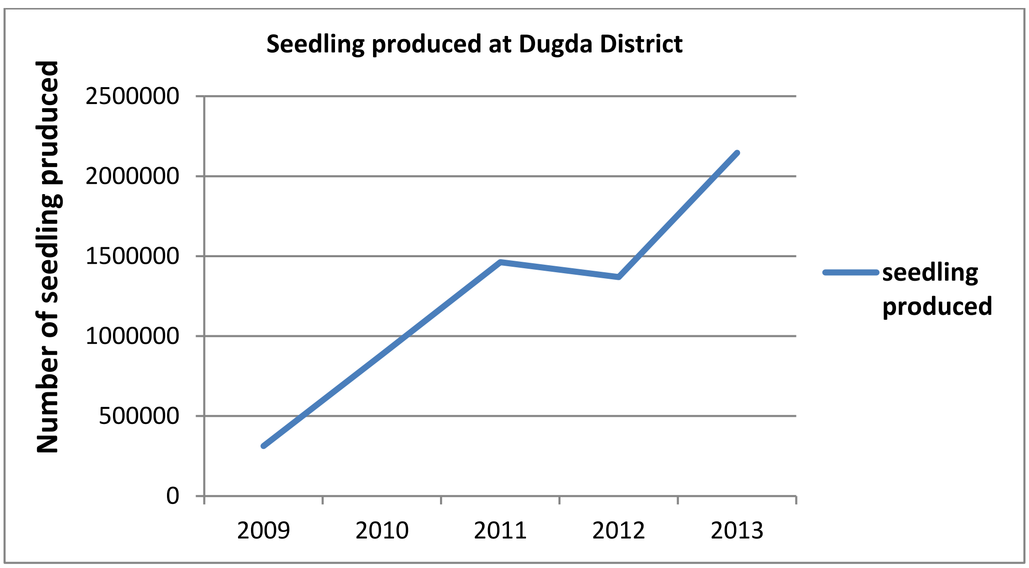


Figure 5. Seedling produced at Dugda District(2009-2013 E.C)

According to the data from the nursery management there is an increase of seedling production starting from green legacy initiative at both district (Fig. 1 and 2). Every year there is distribution of more than half millions of seedlings for different kebeles and large scale plantation campaign.

Tree seedlings Plantation and Survival

The Size of Planting Pit and the Quality of Planting Technique

Planting technique is among factors for low survival of seedlings in the field. Among the observed problem during the campaign plantation, seedling was transported to the site before 1-2 days of campaign which may cause the shock of seedling especially in moisture stress areas like the study area. Again it is also observed that most of the pit preparation was carried out during the day of planting which is not recommended. In addition the pit sizes were below the standard, i.e. the standard pit for seedling planting is 30*30 cm, for dry land areas even 40*40 cm is recommend. Reversely, the observed major average pit size was 15*10 cm as the sample picture was taken randomly during the field survey(Picture1).The majority of the pits were prepared without soil and water conservation structures which may support the survival of the seedlings. The importance of the structures is on improving moisture supply to the seedlings and reducing overall moisture loss by controlling competing vegetation (Harrington et.al. 2004).So, such planting pit structure is incapable of holding sufficient water and fertile soil for seedlings in the study area as it was observed during field inventory. Due to this the seedling performance after planting was weak and unable to resist long dry season. Mubarek et al. (2020) also reported that the majority of planting was done without water harvesting structure in north eastern Amhara regional state.

Picture: 1. Field observation for green legacy plantation site

Seedling Plantation and Survival at the Communal Sites

The result of actual ground count from each kebeles of the Dugda district also confirmed that more than twenty thousands of seedlings were distributed for each kebeles every year. However large number of seedling was planted every year the survival rate was very low according to the data from the field and social survey result indicates (Figure 3). A number of factors could be stated for low survival rate of seedling on the field, but the major factor that affecting the plantation success on the field was watering (32.6 %) and animal interference (25.8 % table 2 below) at Dugda district (Table 2). The same factors like poor seedling watering and animal damage were affecting seedling survival at Adami Tullu Jido Kombolcha District.Similar results have been reported by Holl et al. (2000) that tree seedling death during drought can occur both as a direct result of water stress, or because drought can exacerbate the effects of non-drought factors such as pathogens, herbivores. In addition to the mentioned factor a seedling planting technique, planting seedling without soil and water conservation structure were another factor observed on the field. At both districtsmall rat also one of the factors (20 %) for low seedling survival especially at Adami Tullu Jido Kombolcha District and soil compactness at both district were also factor that negatively affecting seedling growth. In line to this finding (Geberkiden et. al, 2020) also reported that plantation approach has, been challenged because of the poor survival rates of seedling on the field particularly in dry-land areas and improving survival rate through supporting watering is required for their survival performance.

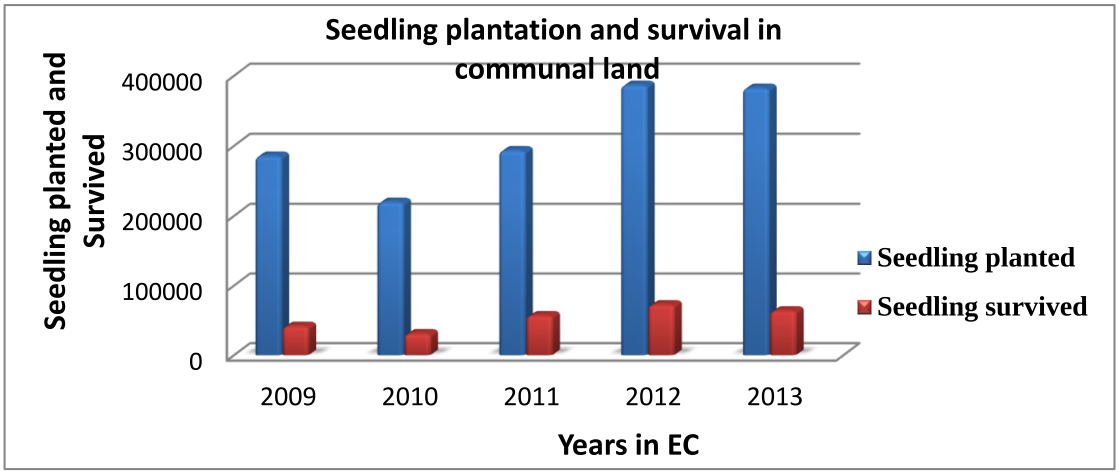


Figure 6. Seedling plantation and survival in communal land at Dugda 2009-2013 EC

Seedling survival at protected area like schools and religious site was better than that of communal land. This is due to the factor that affecting seedling survival at the field may limited. Almost more than 48% of the seedling survived in average and increased survival rate at protected site was recorded during the inventory. This enhanced survival rate could be attributed to different factors such as good management (absence of animal trampling and browsing) and access to water.

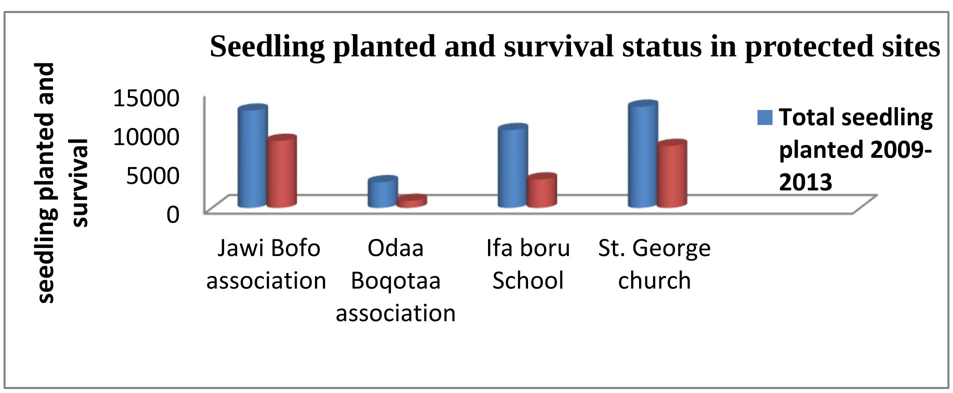


Figure 7. Seedling planted and survival status at protected site Dugda

Seedling survival was better at protected site like church, school and different association area. At communal land seedling survival was lower compared to the protected area at both districts. The lower survival rate at communal land may be due to lack of management factors such as protection from animals and watering. The study of Sorecha (2017) also identified the problem of low survival rate of seedling due to high interference by local peoples.

Tree Seedling Plantation and Survival under Private Holdings

The government initiative of degraded areas rehabilitation has led to establishment of more species for plantation purposes. Seedlings raised in the nurseries of Adami Tulu and Jido Kombolchaand Dugda District mainly consisted of *Melia azandrich Casuarina equestifolia, Eucalyptus spp, Cordia Africana, Moringa stenopetal, Schinusmolle, Acacia senegal, Acacia seligna, Sesbania sesban, Jacaranda mimosifolia Leucaena leucociphala, Grevilea robusta Pericia americana, Mangifera indica and Carica papaya* are the most importantly produced tree seedlings. Among seedling under the nursery *Melia azandrich Casuarina equestifolia, Eucalyptus spp, Cordia Africana, Moringa stenopetal, Schinusmolle, Pericia americana, Mangifera indica and Carica papaya* are species that are planted under the private land. The average survival rate of those planted species under private land was 33% and 28 % at Adami Tulu and Jido Kombolchaand Dugda District respectively. The survival rate under the private land is relatively better than that of communal land plantation (Table 5 and Fig 5). This may be due to better management of seedling under private land compared to communal land plantation.

Table 3: The status of tree seedlings planted under private Holdings at Adami Tulu District (n=66, multiple responses possible)

List of trees	Frequency planted	% planted	Frequency survived	% survived	Total seedlings Planted	Total seedlings Survived	Survival rate %
Schinusmolle	28	42%	27	41%	434	99	22.8
M. azandrica	38	58%	32	49%	725	106	14.6
C. equestifolia	15	23%	14	21%	429	53	12.4
Eucalyptus spp.	24	36%	24	36%	1045	394	37.7
A.saligna	6	9%	6	9%	445	250	56.2
D. engustifolia/ittacha	1	2%	1	2%	2	2	100
C. Africana	10	15%	10	15%	51	14	27.5
O. Africana	1	2%	1	2%	2	1	50
F. sychomorous	3	5%	3	5%	5	2	40
J. procera	1	2%	1	2%	5	0	0
C. lusitanica	2	3%	2	3%	302	20	6.6
H. nilotica	1	2%	1	2%	2	2	100
Moringa spp.	24	36%	23	35%	175	50	28.6
A.tortilis	1	2%	1	2%	10	0	0
Z. spinachristi	1	2%	1	2%	1	1	100
A.Senegal	1	2%	1	2%	10	0	0
D. abyysinica/Koshim	5	8%	5	8%	70	58	83
G. robusta	5	8%	2	3%	140	4	2.9
S. sesban	1	2%	1	2%	5	0	0
L. leucociphala	1	2%	1	2%	2	1	50
J. equistifolia	5	8%	4	6%	26	2	7.7
D. regia	1	2%	0	0%	300	0	0
Psidium guajava	1	2%	1	2%	3	1	33.3

Periciaamericana	19	29%	18	27%	470	185	39.4
Carica papaya	15	23%	16	24%	467	287	61.5
Mangifera indica	6	9%	6	9%	129	4	3.1
Casimiroa edulis	2	3%	2	3%	20	3	15
Average survival rate (%)							**33 %**

Table 4: The status of tree seedlings planted under private Holdings at Dugda District (n=66, multiple response possible)

List of trees	**Frequency of planted**	**% planted**	**Frequency of Survived**	**% survived**	**Total seedlings Planted**	**Total seedlings Survived**	**Survival rate %**
S. mole	43	65%	39	59%	657	174	26.5
M. azandrica	46	70%	39	59%	822	258	31.4
C. equestifolia	23	35%	18	27%	305	104	34.1
Eucalyptus spp.	19	29%	16	24%	921	294	31.9
A.saligna	8	12%	6	9%	237	11	4.6
D. engustifolia/ittacha	4	6%	4	6%	110	28	25.5
C. Africana	9	14%	8	12%	54	13	24.1
C. macrostachyus	2	3%	2	3%	17	2	11.8
O. Africana	4	6%	2	3%	39	6	15.4
J. procera	2	3%	2	3%	15	6	40.0
C. lusitanica	7	11%	7	11%	134	7	5.2
Moringa spp.	7	11%	6	9%	89	7	7.9
A.tortilis	2	3%	2	3%	7	7	100.0
Axxee	2	3%	1	2%	12	1	8.3
B. egyptica	1	2%	1	2%	12	10	83.3
A.Nilotica/laaftoo	1	2%	1	2%	7	3	42.9
Z. spinachristi	1	2%	1	2%	20	3	15.0
D. viscosa/Harooressa	1	2%	0	0%	15	5	33.3
A.Senegal	4	6%	4	6%	22	5	22.7
D. abyysinica/Koshim	6	9%	5	8%	292	245	83.9
G. robusta	12	18%	11	17%	213	45	21.1
S. sesban	2	3%	1	2%	12	0	0.0
L. leucociphala	2	3%	1	2%	25	10	40.0
J. equistifolia	3	5%	3	5%	21	4	19.0
D. regia	1	2%	1	2%	5	3	60.0
Zaytun	3	5%	3	5%	35	2	5.7
Avucado	14	21%	11	17%	115	16	13.9
Papaya	14	21%	12	18%	129	21	16.3
Mango	17	26%	16	24%	70	11	15.7
Average survival rate (%)							**28 %**

Factors Affecting Seedling Survival

Biotic Factor

Most of the respondent noted that the major biotic factors for seedling survival wereanimal intervention (62.12%) followed by mallrat (22.73%)andInsects and pests/ including termites (11.67%) were the major biotic factor affecting seedling survival on the field at ATJK district. However, its impact was lesser compared to ATJK district the same biotic factors were affecting seedling growth at Dugda district (table 2). According to the respondent, lack of management like fencing and guard after planting and absence of regular monitoring at site were result for animal trampling and browsing. Similarly, Mubarek *et. al.*

(2020) stated that Cattle can negatively affect seedling growth rate and survival by trampling and browsing on seedling and pests including termites seem to be a negative factor for plants in that they cause trees to wither and suppress plants' growth.

Abiotic Factor

Another factor which was negatively affecting seedling growth and plantation success on the field was abiotic factor in addition to biotic factor. According to the survey results major abiotic factors were water stress (54.5%) followed by soil factor like compactness and salinity (18.18%) at Adami Tulu and Jido Kombolcha District. Abraham Mahari (2014) that most notably seedlings in dry lands are highly limited by water availability and may have less survival in dry and moisture stressed areas where desiccation is high probable during the dry season. Berli (2004) also stated that compaction of soil or low soil fertility results in high dry density which definitely reduced the rate of root penetration and development. In moisture stress environment like the study area planting seedling on time to harvest the shortest rain season is crucial for energetic and vigorous seedling growth and watering during the dry season up to seedlings developed deep roots to consume water from the soil. In Reverse to this in the study areaSome respondents, 7.57%, were indicated that late Planting time was problem at Adami Tulu and Jido Kombolcha District and Problem with planting technique were another biotic factors for seedling survivalat Adami Tulu Jido Kombolcha and Dugda District

Table 5: Binomial test (Yes/No) of factors affecting Seedling Survival at Adami Tulu District

List of Factors	N	%	Observed Prop.	Test Prop.	P-value (α=0.05)
SoilFactors (Hard soil core, saline soil, etc)	12	18.18	1.00	.50	***
Water (Shortage, salty, un accessibility)	36	54.55	1.00	.50	***
Delayed plantingtime	5	7.57	1.00	.50	Ns
Problem in planting technique	2	3	1.00	.50	Ns
Lackof management (Protection/Fencing, Browsing/	41	62.12	1.00	.50	***
Mallrat	15	22.73	1.00	.50	***
Diseases and Insect/ pests	11	11.67	1.00	.50	**

Table 6: Binomial test (Yes/No) of factors affecting Seedling Survival at Dugda District

List of Factors	N	%	Observed Prop.	Test Prop.	P-value (α=0.05)
Water (Shortage, salty, un accessibility)	45	68.18	1.00	.50	***
Problem in planting technique	5	7.58	1.00	.50	Ns
Lack of management (Protection/Fencing, Browsing, Fertilizing, Watering/	29	43.94	1.00	.50	***
Mallrat	5	7.58	1.00	.50	Ns
Diseases and Insect pests	2	3	1.00	.50	Ns

As the average result from the two districts indicates the two factors namely moisture deficit (61.37 %) and lack of seedling protection from animal browse (53.03 %) were ranked as the first and seconded bottle neck for seedling survival on the field at both districts. At Dugda district among the factors affecting seedling survival moisture deficit was ranked as first (68.18 %) while seedling protection from animal browse (43.94 %) was the second rank. In addition to the two factors mallrat (22.73 %) and soil compactness (18.18 %) were affecting seedling growth and survival at Adami Tulu and Jido Kombolcha. Similar to this finding McKay (2006) also stated internal water status at planting, the condition of the nursery root system, the ability to control water loss through the stomata, the area of contact between the soil and functioning roots after planting, the soil moisture availability and the ability of the plant to produce new roots are all important factors.

Conclusion and Recommendations

Tree planting has the vital role in ecosystem productivity and enhance biological and chemical restoration of degraded land. Over all from what have been seen managements of the trees especially at the seedling stages is very crucial. Keeping the quality of the planting procedure followed by post seedling management after planted was the major problems in both areas. Different factors that are greatly affect the survival of tree seedlings on the field were identified. This factors were compounded by the environmental factors and human induced factors. However, the contribution of livestock grazing, and water stress impacts were pointed out by the farmers as main barriers for plantation success in the study area, the other factors that hindering tree seedling survival were, technique of planting, inappropriate site preparation, small rat, soil factors, pest/insect and delayed time of planting were also pointed out by the farmers as the obstacles for tree and shrub plantation development. Therefore, as dry land areas commonly known by its moisture stress, integrating seedling plantation with soil and water conservation stricture to encourage water retention and soil fertility, and supplementing water in a hard season of the year (prolonged drought periods) is compulsory to enhance seedling survival rate. This mean that planning management the same as planning for production is a win-win solution the failed survival and over all to our degrading environment. Also to enhance early growth and survival of planted seedlings; critical evaluation and selection of best nursery soil mixing ratio is important, protecting of planting site from animalinterference are ideal to improve seedling survival, and seedling transportation and planting techniques must be adjusted as suitable for dryland areas.

References

Abraham Mahari 2014. Factors Affecting Survival of Tree Seedlings in the Drylands of Northern Ethiopia Department of Natural R;esource Management, Adigrat University, Ethiopia

Berli KO, Kulli B, Attinger W, Keller M, Leuenberger J, Fluhler H, Springman SM and Sculin R (2004). Compaction of agricultural and forest subsoils by tracked heavy construction machinery. Soil Till. Res., 75: 37-52

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J. R., Arico, S., Báldi, A. &Bartuska, A. (2015). The IPBES Conceptual Framework— connecting nature and people. Current Opinion in Environmental Sustainability, 14, pp. 1-16.

Engelbrecht MJ, Comita IS, Condit R, Kursar TA, Tyree MT, Turner BL and Hubbell SP (2007). Drought sensitivity shapes species distribution patterns in tropical forests. Nature, 447: 80-83.

Founoune H, Duponnois R, Ba AM and El Bouami F (2002). Influence of the dual arbuscular endomycorrhizal/ectomycorrhizal symbiosis on the growth of Acacia holosericea (A. Cunn. Ex G. Don) in glasshouse conditions. Annals of Forest Sciences, 59: 93-98.

GebrekidanAbrhaet. al 2020. Screening of tree seedling survival rate under field condition in TanquaAbergelle and Weri-LekeWereda’s, Tigray, Ethiopia Abergelle Agricultural Research Center, Tigray Agricultural Research Institute (TARI), Ethiopia.

Harrington JT, Loveall MW, Kirksey RE. Establishment and early growth of dryland plantings of Arizona cypress in New Mexico, USA. 2004:183-192.

Holl KD, Loik ME, Lin HV and Samuels IA (2000). Tropical montane forest restoration in Costa Rica: overcoming barriers to dispersal and establishment. Restoration Ecol. 8:339-349.

Klopcic M, Boncina A. 2012. Recruitment of tree species in mixed selection and irregular shelterwood forest stands. Ann For Sci, 69(8): 915–925.

Mckay HM. (2006) A review of the effect of stresses between lifting and planting on nursery stock quality and performance.

Mesku, D., Zeleke, A., Yasin, A., &Wole, K. (2008). FRG Project Completed Repass, EIAR, OARI and JAICA Cooperation, Adami Tulu Agricultural Research Center.

Mubarek Eshetie, MelkamuKassaye, Getu Abebe3, YonasBelete ,GrimaNgusie , SleshAsmare 2020. Factors Hindering Seedling Survival in Sekota District, North Eastern Amhara, Ethiopia. SekotaDryland Agricultural Research Center, P.O. Box 62, Sekota, Ethiopia; 2 Department of Forestry, Injibara University; 3Gondar Agricultural Research Center; 4Department of Forestry, Debretabor University

Mubarek Eshetie*et. al. (*2020).Factors Hindering Seedling Survival in Sekota District, North Eastern Amhara, Ethiopia

OESPO (2003) Regional Government of Oromia; Oromia Economic Study Project Office.Adami Tullu-Jido Kombolcha Woreda Based Development Programme.

Sorecha EM (2017). Growth and survival rate of endemic trees of Ethiopia: Olea africana and Hageniaabysinicca in Lake Haramaya Watershed, Eastern Ethiopia. Journal of Horticulture and Forestry 9(5):33-39.

Stanturf JA, Conner WH, Gardiner ES, Schweitzer CJ, Ezell AW. 2004. Recognizing and overcoming difficult site conditions for afforestation of bottomland hardwoods. Ecol Restor, 22(3): 183–193.

Valladares F, Niinemets U. 2008. Shade tolerance, a key plant feature of complex nature and consequences. Ann Rev Ecol Evol Syst, 39: 237–257.

Warren JM, Meinzer FC, Brooks JR and Domec JC (2005). Vertical stratification of soil water storage and release dynamics in Pacific Northwest coniferous forests. Agric. For. Meteorol. 130: 39-58.

Yirdaw E and Luukkanen O (2003). Indigenous woody species diversity in Eucalyptus globules Labill. ssp globules plantations in the Ethiopian Highlands. Biodiversity and Conservation, 12: 567-582.

Lowland bamboo species' adaptation and growth performance in Fedis District East Hararghe Zone, Oromia, Ethiopia

Musa Abdella*, Bira Cheneke and Robe Elema
Fedis Agricultural Research Center, Harar, P.O. Box 904, Ethiopia
*Corresponding author:musaabdellah345@gmail.com

Abstract

The study was carried out to assess the adaption and growth performance of four lowland bamboo species in Fedis District, East Haraghe Zone, Oromia, Ethiopia from June 2019 to June 2022. Three replications of a randomized complete block design were used to assess four lowland bamboo species. At intervals of three months, measurements and records of the growth parameters survival rate, new emerging shoot, internodes length, number of nodes, culm height, culm diameter, and its root culm diameter were made. The results showed that there were relatively significant ($p < 0.05$) differences between lowland bamboo species in the study area. Dendrocalamus hamlitonii and Dendrocalamus memebranceous, two of the species tested, performed the best and had higher survival rates than Oxythenantera abyssinica. D. hamlitonii and D. memebranceous are the bamboo species with the fastest rates of growth and the best rates of survival. O. abyssinica, however, has a medium survival rate compared to those with a lower survival rate. Generally speaking, D. hamlitonii, D. memebranceous, and O. abyssinica were the examined species that showed faster growth performance and better performance under Fedis conditions, respectively, while D. asper demonstrated lower performance. D. hamlitonii, D. memebranceous, and O. abyssinica outperformed D. asper in terms of new emerging shoot, internodes length, the number of nodes, culm height, and culm diameter at breast height, and its root culm diameter. Based on this, three bamboo species, D. hamlitonii, D. memebranceous, and O. abyssinica, are the best-performing introduced bamboo species for promotion in the research region. As a result, the best-performing species should be demonstrated and promoted in and around Fedis, as well as other places with similar soil and climatic conditions. Based on these findings, we recommended D. hamlitonii, D. memebranceous, and O. abyssinica for various production and constriction because they have good internode length, ability to emerge new shoots, culm height, and diameter. It is preferable to use it for soil and water conservation purposes in the restoration of degraded areas. Because bamboo only produces seed once every 40 years, which poses a considerable barrier to resource expansion, more study on bamboo propagation methods is required. These species could be promoted for a variety of end uses, including industrial usage, carbon sequestration, human and animal food (D. hamiltonii edible shoot), and animal feed (because of their high biomass).

Keywords: Bamboo; exotic; indigenous; lowland; Plantation, growth potential, carbon sequestration

Introduction

Bamboo is a perennial plant belonging to the Poaceae (sometimes called Gramineae) family (Wong, 2006). In terms of taxonomy, it is considered a giant grass. Ecologically, bamboo plants have tree-like functions (Nadgauda, 2002). Ethiopia is one of the most endowed countries in area coverage of natural bamboo forests of the country that estimated to have about 1 million ha, which is about 7% of the world total and 67% of the African bamboo forest areas (Embaye ,2000). Even though Ethiopia is one of the most endowed countries in having huge coverage of bamboo resources in Africa, the country has narrow genetic diversity and only has two species. Ethiopia possesses two very important indigenous bamboo species (African alpine bamboo or Yushania alpina and lowland bamboo or *Oxythenantera abyssinica*) that have numerous traditional and industrial applications. The area coverage of bamboo forests comprised of the two species is estimated at 1.47 million ha very recently (INBAR, 2017). With these two species, it is very difficult to secure a constant supply of bamboo raw materials for bamboo industries and local handicrafts.

Currently, there is indiscriminate forest loose and depletion hence the unique bamboo resource will be appearing before its economic and environmental advantage is appreciated, unless important reversing mechanisms could not take place (Yuming et al., 2004). The current economic policy of the nation strongly urges development practitioners to contribute to the economic development of the country. By the year 2020, Ethiopia is envisioning to reach middle-income group countries of the world. In this regard, bamboo can contribute more to generating income since it can be processed into products for domestic use and the export market. It can also create employment opportunities for a considerable portion of society and harness environmental degradation problems.

Despite these facts; research and development activities on the bamboo resource of the country are scanty. Bamboo is not included in tree planting programs in which millions of tree seedlings have been established every year. Up to now only, very limited research works have been undertaken: vegetative propagation of highland bamboo (Tesfaye and Yohannes, 2005), propagation of lowland bamboo by seed (Kassahun et al, 2003), utilization-suitability of *Yushania alpina* for oriented particle board (Seyum, 2005), the use of lowland bamboo as re-enforcement in construction (Zhaohua Z., 2004) and Adaptation and Growth performance of Different lowland bamboo species (Regassa et al,2013). Bamboo protects steep slopes, soils, and waterways, prevents soil erosion, provides carbon sequestration, and brings many other ecosystem benefits. Its extensive root network may help to prevent erosion. Bamboo in the future may be able to increase bio-capacity by simultaneously increasing the area of fertile global hectares. It has immense potential in reducing CO_2 which is blamed for environmental pollution and is the most valuable species for environmental protection. And also bamboo is a fast-growing and high-yielding perennial plant with considerable potential for socioeconomic development and environmental protection (Baghel et al., 1998). Among the various measures that should be taken in averting these problems, widening the genetic base of the resource is indispensable. These will require the introduction and evaluation of potential species from different parts of the world to establish bamboo plantations in areas where indigenous species could not grow. So that the overall aim of this study is to evaluate the adaptability and growth performance of different introduced bamboo species in different agroecologies of the country.

Therefore, it is important to introduce and adapt the high economic value of exotic bamboo species to improve the income of small farm holders, to divers the genetic resources of bamboo species, and for environmental protection in Ethiopia. Bamboo is versatile with a very short growth cycle. Bamboo is a high-yield renewable natural resource for agro-forestry and engineering-based products (Robert Henrikson.2009). Based on these indispensable values of the species, the study of bamboo adaptation was started at Fedis district East Hararghe condition in 2018 with the objectives of evaluating the adaptability potential of different provenance of lowland bamboo species around the study area and to provide the best performing of lowland bamboo species. Therefore, it is important to introduce and adapt the high economic value of exotic bamboos species in the study area, with the objectives of evaluating the adaptability potential of different lowland bamboo species around the study area and providing the best-performing of lowland bamboo species

Materials and Methods:

Description of the Study Area

The study was carried out in the Fedis district of Oromia Regional State's East Hararghe Zone. Fedis district is one of twenty districts in the East Hararghe zone, which is located 550 km east of Addis Abeba as well as about 24 kilometers south of Harar town. The district is located at 80 22' 0" and 90 14' 0" N, and 420 62' 0" and 420 19' 0" E.

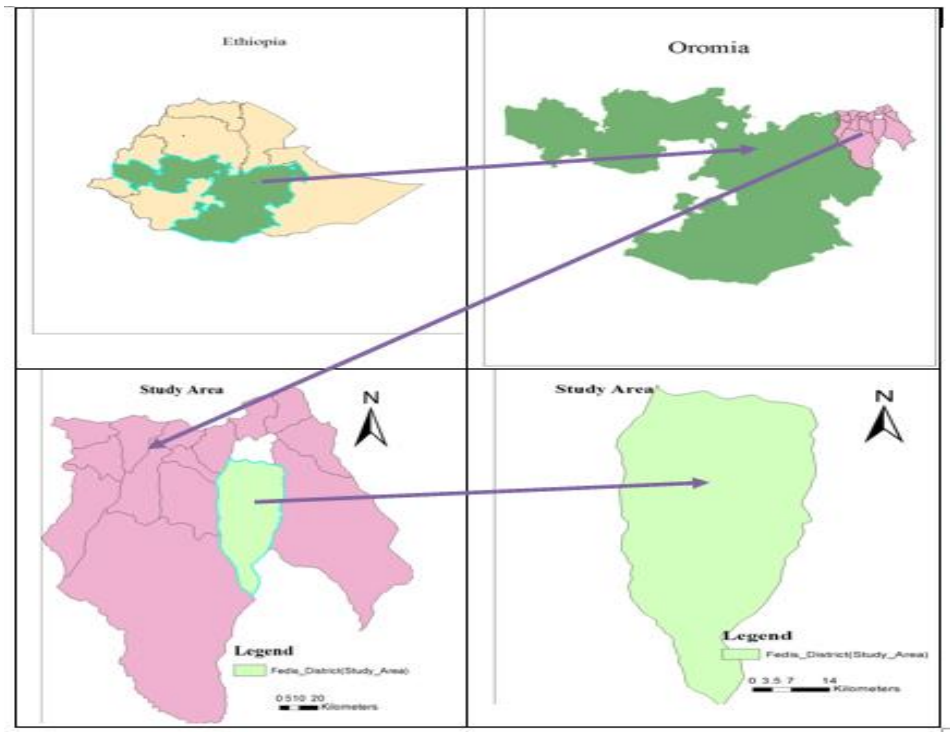


Figure 1: Map of the study area

The altitude of the area ranges between 850 to 2100 m.a.s.l. The district comprises 19 peasant associations (PAs), which are associated with two different agro-ecological zones. According to DOA 2018 report, the district has two basic agro-climatic conditions, namely midland (39%), and lowland (61%). The district experience mean annual rainfall of 650 to 850mm and the average temperature is 25 ^{0}C to 30 ^{0}C. The district has a bimodal rainfall distribution pattern with heavy rains from April to June and long and erratic rains from August to October. The topographic features of the study area are 70% plain area, 28% plateau, and 2% mountain or hill. Cultivable land/cropland (21.02%), pasture (2.80%), forest (11.2%), grassland (38.01%), communal land (10.5%), and remaining (14.04%) is considered as mountainous, valley and otherwise unusable (DOA 2018). The district consists of 19 rural PAs and two rural towns and has a total human population is 149,664 of which 76,182(50.9%) are males and 73,482(49.09%) are females (CSA, 2007). The average family size is estimated to be 6 and 4 per household in rural and urban areas respectively. The average landholding per farm family is 0.73 hectares and has a total area of 110502 hectares (DOA 2018). Agriculture in the district is characterized by a small-scale subsistence mixed farming-system with livestock production as an integral part. The soil of the study area is dominantly red-brown clay soil. The vegetation type of the district is characterized by forests, bushes, and shrubs. The area of the district covered by forest, bushes, and shrubs is 42954ha (DOA 2018).

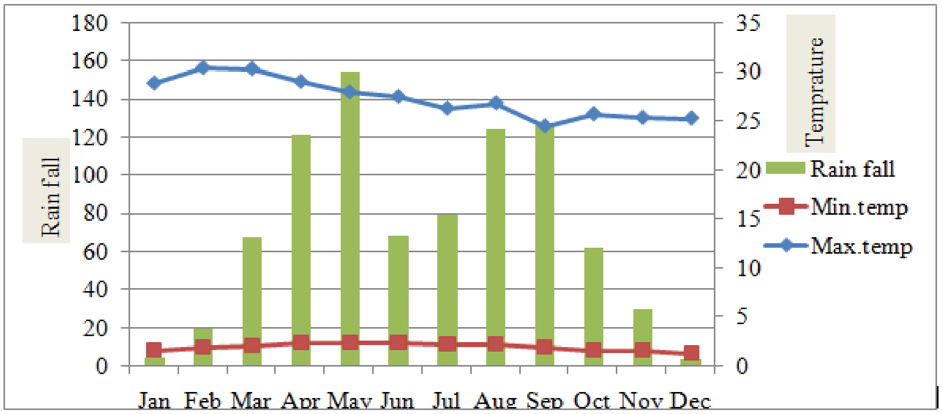


Figure 2. Rainfall and temperature data of fedis district, 2021GC.

Treatments and Experimental Design

The studies were designed in RCBD and included three replications. The blocks were folded to allow for the four treatments to be administered under somewhat homogenous soil conditions. The distances between blocks and plots were three meters and three meters, respectively. In addition, the distance between each plant was 3m. Four lowland bamboo species were employed as treatments: *D. hamlitonii*, *D. memebranceous*, *O. abyssinica*, and *D. asper*. The indigenous bamboo species, O. abyssinica, is one of those mentioned. Mechara Agricultural Research Center provided the cuttings. Exotic bamboo species originated in China, and they thrive in warm temperate subzones to tropical zones. The cuttings/seedlings were then planted at filed planting sites to assess the species' adaptation and performance.

Data Collection

The number of culms, culm height, diameter at breast height (DBH), number of shoot sprouts per clump, shoot sprouts height, root collar diameter, biomass, and species adaptation were all measured. When collecting data on the growth performance of lowland bamboo species, data such as culm height, culm diameter, internode length, number of nodes, new shoot appearing, survival rate, and other growth factors were taken into account. Data were collected at two-month intervals to track changes in the species.

Statistical Analysis

Using SAS statistical software version 9.4, the gathered raw data were analyzed using the analysis of variance (ANOVA) and the General Linear Model (GLM) approach. Mean separation using LSD was performed at a 5% threshold of significance for significant differences. As a result, the following factors were evaluated and quantified for these analyses: number of new emerging shoots, survival rate in percent, root collar diameter, internode length, number of nodes, culm height, and diameter data.

Result and Discussion

The four years of lowland bamboo adaptation trial at Fedis district revealed statistically significant ($p < 0.05$) differences in survival rate, new emerging shoot, internode length, number of nodes, culm height, culm diameter, and root culm diameter across treatments (Table 1 and 2).

Survival Rate of Lowland Bamboo Species

The selected lowland bamboo species acclimated and performed effectively in the Fedis area throughout the four-year trial years. As shown in Table 1, *D. hamaltoni* (94.4%) has the highest survival rate, followed by *D. membracius* (90.6%) and *O. abyssinica* (65.4%). D. asper, on the other hand, was less adaptive and had the lowest survival rate (38.5%). These results show that Fedis' agroecology is suitable for the three species during the trial years. *D. hamaltoni* and *D. membracius* preferred lowland bamboo species that were resistant to pests and diseases. However, due to the species' growth and adaptation qualities, some growth and morphological variance were noticed among the species. As indicated in Table 1 the least adapted was D. asper (38%). *D. asper* was more susceptible to pests and diseases attack. These are also indicators, as the species fare poorly in the Fedis area. The outcome is comparable to Bako's report (Regassa et al., 2016).

Table 1: Treatments (lowland bamboo species) survival rate by year and an overall mean

Treatments (Species)	Survival rate (%)				
	Year 1	Year 2	Year 3	Year 4	Overall mean
D. hamaltoni	94.4 [a]	94.4 [a]	94.4 [a]	94.4[a]	94.4 [a]
D. membracius	90.6 [a]	90.6[a]	90. 6[a]	90.6[a]	90.6[a]
O. abyssinica	68.3[b]	68.3 [b]	65.0 [b]	60.0[b]	65.4[b]
D. asper	40.6 [c]	40.6 [c]	37.6 [c]	35.3[c]	38.5 [c]
CV (%)	19.49	22.70	25.58	28.15	22.74
LSD(0.05)	3.59	4.05	4.10	4.22	6.73

New Emerging Shoot of Bamboo Species

The ability of lateral buds to create new rhizomes and shoots is intimately tied to the age, vigor, and nutrition storage of the rhizome. Based on the four-year data analysis, D. hamlitonii bamboo species (5.33) showed a significant difference in the quantity of new emerging shoots during the trial years. D. memebranceous (3.39) and O. abyssinica (3.67) are the species performing well in emerging new shoots. This is owing to the species' better performance, adaptability, and ability to produce new emergent shoots as compared to the other lowland bamboo species chosen for this experiment under Fedis conditions.The findings are consistent with Yared, 2013 (unpublished) report, which reveals more shoots sprouting for D. hamlitonii. D. asper (2.75) was found to have low performance in terms of the number of sprouting new shoots during the trial periods. According to the treatment comparison, D. asper was considerably different in new emerging shoots when compared to others, while the other two species were not significantly different. The findings are consistent with the report (Regassa et al., 2016). This suggested that the decreased shoot emerging ability was caused by the species' poor growth performance.

Table 2: Treatments (lowland bamboo species) performance; the number of emerging new shoots, internode length, number of nodes, culm height, culm diameter, culm diameter and root collar diameter

Treatment/Species	Emerging new shoots	Internodes length (cm)	Number of nodes	Culm height (m)	Culm diameter (cm)	Root collar diameter (cm)
D.hamlitonii	5.33[a]*	20.37 [a]	25.33[a]	6.34[a]	3.44[a]	3.51[a]
D. memebranceous	3.39[b]	18.07 [a]	23.39[a]	5.95[b]	2.93[b]	3.18[a]
O.abyssinica	3.67[b]	11.84 [b]	16.33[b]	4.84[c]	2.71[b]	2.89[b]
D. asper	2.75[c]	10.07 [b]	15.83[b]	4.81[c]	2.71[b]	2.89[b]
CV (%)	22.26	24.8	28.71	25.5	21.13	9.4
LSD (0.05)	6.91	6.08	6.92	1.35	1.09	0.55

Means comparisons between treatments at 0.05 significant levels (Mean); *Means with the same letter are not significantly different.

Bamboo Species Internode Length

Direct or indirect bamboo internodes length can indicate the quality of the bamboo product used for a different purpose. The bamboo culms structure is cylindrical and is divided into sections by diaphragms or nodes. The section between two nodes is internodes. Internodes are hollow in most bamboo, but solid in some species. As the present study revealed that the results of internode length among the selected species were significantly different. So, as indicated in **Table 2.** *D. hamlitonii* and *D. memebranceous* showed higher internode length as compared to others which were similar to the report of Yared, 2013 (unpublished) which shows higher internode length for *D. hamlitonii*. Whereas, *O. abyssinica* and *D. asper* showed lower internode length. *D. hamlitonii* and *D. memebranceous* had significantly higher culm internode length (20.37 cm) and (18.07cm) respectively than *O. abyssinica* (11.84 cm) and *D. asper* (10.07 cm). These values are similar to others (Salam and Pongen, 2008). Other studies said *D. hamlitonii* has a range of 41.95 to 56.1 cm of culm internode length in different districts (Nirala et al., 2016) and 30-60 cm culm internode length in India (Singh et al., 2010).

Bamboo Species Sprouting Node Count

The current investigation found that the findings of the number of nodes among the selected species differed significantly. *D. hamlitonii* (25.33) and *D. asper* (23.39) have significantly more nodes than *O. abyssinica* (16.33) and *D. asper* (23.39). (16.83). *D. hamlitonii* and *D. memebranceous* had a higher number of nodes than others, which is consistent with Yared (2013) research (unpublished). *O. abyssinica* and *D. asper*, on the other hand, had fewer nodes. According to a similar study, the maximum mean number of nodes was determined to be 19.44. (Yigardu et al., 2016).

Culm Height and Diameter of the Bamboo Species

D. hamlitonii (5.34 m), *D. memebranceous* (4.95 m), *O. abyssinica* (3.84 m), and D. asper (3.81 m) had no statistically significant height results four years after establishment (Table 2). In line with this study, the matured *D. hamlitonii* has a culm height of 20 m and D. asper has a culm height of 20-30 m, which is practically identical among species (Salam and Pongen, 2008; Yigardu et al., 2016). According to Kumar et al. (2017), the highest mean height of *Bambusa balcooa* over five years was about 7.39 m. According to other studies, *Bambusa tulda* has a culm height range of 15.95-18.65 meters in a different districts (Nirala et al., 2016), 17.7-21.3 meters in India (Bhattacharya et al., 2006), and 8-20 meters in India (Singh et al., 2010).

From the result, *D. hamlitonii* (3.44 cm) showed a significantly higher diameter at breast height than that of *D. memebranceous* (2.93 m) *O. abyssinica* (2.71m), and *D. asper* (2.71 m). In line with this research, the mean diameter of *D. hamlitonii* has been 5.42 cm over five years (Kumar et al., 2017). The culm diameter of matured *D. hamlitonii* has ranged between 10-18 cm, *D. memebranceous* 6-10 cm and *Denderocalamus asper* has 20cm (Salam and Pongen, 2008; Yigardu et al., 2016). On the contrary, the highest average diameter (4.03 cm) was recorded for similar species result at the age of two years in India (Dutta & Baruah, 2016). According to other studies, the same species' culm diameter can vary from 4.415 to 8.373 cm in different districts (Nirala et al., 2016), and from 5 to 10 centimeters in India (Singh et al., 2010). Therefore, *D. hamlitonii* and *D. memebranceous* has better for construction, flutes, handicrafts, edible shoots, paper/pulp, bamboo boards, composites, and laminates due to their thicker culm diameter (Salam & Pongen, 2008). The result agreed with the report from Pawe by Yared k, 2013 (unpublished) which shows a higher culm height for *D. hamlitonii*. Though, the culm diameter is indicated by the thickness or size of the culm which is directly or indirectly related to the quality of bamboo production.

According to the current analysis, *D. hamlitonii* is statistically significant as displayed in Table 2 while *Denderocalamus asper* shows the least in culm height with compare to the rest. The result agreed with the report from Pawe by Yared k, 2013 (unpublished) which shows higher culm height for *D. hamlitonii* and lower culm height recorded for *Denderocalamus asper*. This may depend upon the growth performance and adaptability of the species. Besides this, the culm diameter was also analyzed and compared. Though, the culm diameter is indicated by the thickness or size of the culm which is directly or indirectly related to the quality of bamboo production. As the result, the current analysis shows slight variation between the species on culm diameter. Therefore, as shown in Table 1 above, *D. hamlitonii* and *O. abyssinica* bamboo species had statistically larger culm diameters than both *Denderocalamus asper*. *Dendrocalamus hamiltonii* measured a higher average height (6.34 m) than what Rai and Mallik (2013) discovered, which was 8 m.

Root Collar Diameter of the Bamboo Species

The examined species show significant variance (p0.05) in the growth of the root collar diameter (table 2). In terms of root collar diameter, the four-year-old *D. hamlitonii* (3.51 cm), *D. memebranceous* (3.18 cm), O. abyssinica (2.89 cm), and D. asper (2.89 cm) all displayed statistically significant results. Throughout the trial, *D. hamlitonii* had the largest root collar diameter (3.51 cm), followed by D. memebranceous (3.18 cm), which was observed.

Conclusion and Recommendations

In conclusion, the study and observation made showed clearly that *D. hamlitonii*, *D. memebranceous*, and *O. abyssinica* are the fastest-growing species of bamboo and have a better survival percentage than *D. asper*. Generally, among the species *D. hamlitonii*, *D. memebranceous* showed faster growth performance at Fedis and *O. abyssinica* was showed better performance. *D. asper* showed lower performance. Concerning new emerging shoots, internodes length, the number of nodes, culm height, and culm diameter at breast height and its root culm diameter, *D. hamlitonii*, *D. memebranceous* and *O. abyssinica* were significantly higher than Denderocalamus asper. Based on this, three *D. hamlitonii*, *D. memebranceous* and *O. abyssinica* are best performing introduced bamboo species for promotion in the study area. Additionally, it needs training for the local communities and small enterprises on the production and management of those three bamboo species.

Therefore, *D. hamlitonii*, *D. memebranceous,* and *O. abyssinica* should be demonstrated and popularized around Fedis and in areas that have similar soil and climatic conditions. So, based on these results we recommend *D. hamlitonii*, *D. memebranceous,* and *O. abyssinica* for different production since they have good quality internodes length, ability to emerge new shoots, culm height, and diameter. it is better to use for soil and water conservation purpose on degraded area rehabilitation. Since bamboo gives seed once in 40 years which is a big challenge in the expansion of the resource, he needs further study on the bamboo propagation method.

Acknowledgments

The authors would like to acknowledge the Fedis Agriculture Research Center's Agroforestry Research Team for their follow-up and data collecting, as well as the Oromia Agricultural Research Institution for their financial support.

Reference

Baghel, L.M.S.,Angila Gupta, R.K. verma and N.G. Totey. 1998. Socio economic and Bamboo consumption pattern in village around Jebelbul and mandla , mahdhya Pradesh :A case study journal of tropical forestry 1998 ,14:4 , 252-261

CSA. Ethiopian Housing and Population Survey. 2007.

Kassahun Embaye, .2000.The indigenous bamboo forests of Ethiopia: an overview .Ambio 29, 518-521.

Kassahun Embaye, 2003. Ecological aspects and resource management of bamboo forests in Ethiopia. Doctoral dissertation, ISSN 1401-6230, Swedish University of Agricultural Siences, Uppsala, Sweden.

Kumar, Adarsh, Meena Dhawan and B. B. Gupta.1998. Flowering and rooting of *Bambusa tolda* culm cuttings in response to growth regulating substances. *The Indian Forester.* 1998, 116:7, 574-553.

Nirala, P. D., Jain, S. C., & Kumari, P. (2016). Distribution of different bamboo species in different areas of North Chota Nagpur division of Jharkhand. *Biosci. Disc*, *7*, 21-24.

Robert Henrikson.2009.Bamboo plantation and carbon sequestration.Ronore Entreprises Inc

Salam, K. A. M. E. S. H., & Pongen, Z. U. L. U. (2008). Hand book on bamboo. *New Delhi: National bamboo Mission Ministry of Agriculture, Government India dan Cane and Bamboo Technology Centre*.

Seyum Kelemework, 2005. Suitability of *Yushania alpina* for Oriented Particle Board. University of Putra Malaysia. Doctoral dissertation.

Tesfaye Hunde and Yohannes Adane. 2005. Assessment of different vegetative propagation techniques on rooting and shooting of Arundinaria alpina. Ethiopian Journal of Natural Resources.2005. 7 (1): 131-139.

Wang X. 2006. Comparative Analysis and Policy Recommendations on Developing Bamboo Resource Tenure Systems in Asia and Africa. Joint Project in Cooperation with INBAR and WFI.

Yigardu, M., Asabeneh, A., & Zebene, T. (2016). Biology and management of indigenous bamboo species of Ethiopian, based on research and practical field experience.

Yuming, Yang, Wang Kanglin, Pei Shengji, and Hao Jiming. 2004. Bamboo diversity and traditional uses in .Yunna, China, *Mountain Research and Development* 24(2):157-165pp

Zhaohua Z.2004.A general Introduction for Bamboo Development in China, In International Training workshop on small bamboo daily product processing technologies and machines.INBAR,September 6- 20,2004,Zhejiang province, China

Adaptation and Growth Performance Evaluation of Selected Agroforestry Tree Species at Fadis and Metta Districts of East Hararghe Zone, Oromia, Ethiopia

Introduction

The vegetation cover of the eastern Ethiopian highlands is well recognized, and the majority of the surrounding area is covered by forests made of a diverse range of woody species (Yadessa et al., 2000). Despite the importance of the forest ecosystem to the livelihoods of the people in the area, the forest is gradually declining owing to overexploitation of woody and non-woody goods. Rapid deforestation as a result of rising demand for fuel wood and expansion for agricultural has put an increasing strain on local woodland species (Mihretu et al., 2004). If no remedial action is taken, this will cause severe impact on agricultural productivity leading to energy poverty and environmental degradation.

Frequent and severe droughts often present a serious threat for millions of lives (Brockerhoff, 2008), which have occurred once in a decade in the 1970s and 1980s. Shortages of animal feed and biomass energy are also such an unsustainable use of natural resources. Currently, biomass energy constitutes 88.7% of all energy consumed in Ethiopia which is mainly derived from the woody biomass resources (forests, woodlands, shrub lands, planted trees, agro forests). Agro forestry system has much potential for supplying fodder, poles, farm equipment, fuel wood and agricultural improvements (Yadessa et *al.*, 2000). Multipurpose tree and shrubs species (MPTS) play a considerable role in addressing such multifaceted demands in the mixed crop-livestock production system. They have the ability to fit into the farming system to be used as a source of manure, mulch, soil conservation, forage, fuel wood, farm implements and other like shade and shelter (Berhe et al., 2001).

Farmers in East Hararghe practice agroforestry on their farms and home gardens for economic, social, and environmental benefits (Yakob et al., 2014). To meet the demands of the rising population, these traditional agroforestry practices could be expanded by adopting fast growing multipurpose tree species (MPTS). Thus, before introducing any species into a given agro ecosystem, a well-conducted field trial is always required to match the species/provenance to a specific site (Mihretu et al., 2004).

The species screening trial will examine the species' survival and early growth in one to three years. Choosing which species to plant in any agroforestry system to achieve the desired goals necessitates a well-conducted field trial to match a species to a specific site. Many species screening experiments have been carried out in various sections of the country (Mihretu et al., 2004). However, there is insufficient information in the Fedis and Metta areas to identify promising multipurpose tree and shrub species for use in agroforestry operations. As a result, there is an urgent need to explore adaptable and promising tree and shrub species in the area. Therefore, this study was designed to evaluate the adaptation and growth performance of four multipurpose tree species and to identify early best performing exotic and indigenous trees species to Fedis and metta conditions and sites of similar agro ecologies.

Materials & Methods

Description of the Study Area

The experiment was carried out in the Fedis and Metta Districts of the East Hararghe Zone of Oromia. Fedis district is one of twenty districts in the East Hararghe zone, which is approximately 550 km east of Addis

Abeba and about 24 km south of Harar town. The district's coordinates are 90 14' 0" N and 420 19' 62" E.

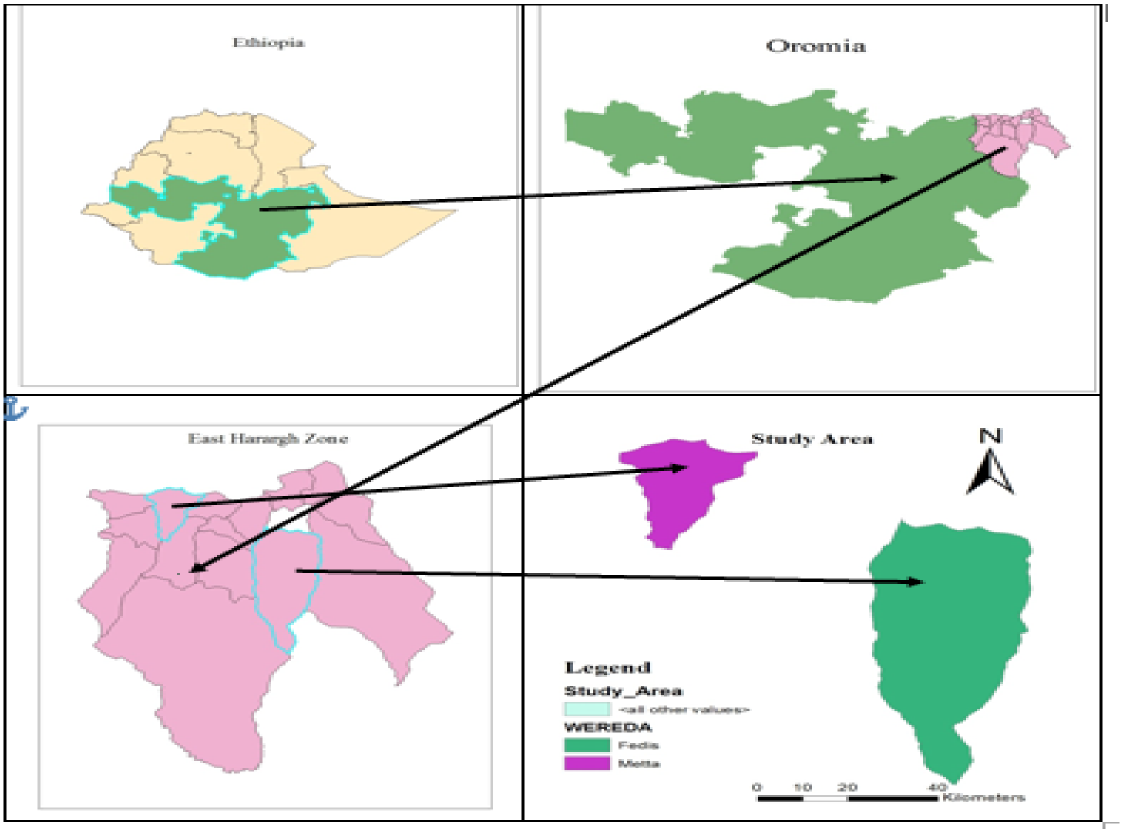


Figure 1: **Map of study area**

The area's elevation ranges from 1200 to 2100 meters above sea level. The average annual rainfall in the district is 650 to 850 mm, and the average temperature is 25 ^{0}C to 30 ^{0}C. The district has two basic agro-climatic conditions, according to the DOA 2017/18 report: midland (39%), and lowland (61%). The district is comprised of 19 rural PAs and two rural towns, and the total human population is 149,664, with 76,182 men and 73,482 females (50.9%). (CSA, 2007). In rural and urban areas, the typical family size is estimated to be 6 and 4, respectively. The average farm family has 0.73 hectares of land, with a total area of 110502 hectares (DOA 2017/18). Agriculture in the district is characterized by a small-scale subsistence mixed farming practice that includes livestock raising.

Meta district is one of twenty districts in the East Hararghe zone, which is located 532 km east of Addis Abeba and 84 km north of Harar town. The district's coordinates are 90 14' 60" N and 410 24' 59" E. The area's elevation ranges from 1400 to 2850 meters above sea level. The average annual rainfall in the district ranges from 350 to 900 mm, while the average temperature ranges from 17 to 27 degrees Celsius. The district has three basic agro-climatic conditions, namely highland (28%), midland (44%), and lowland (28%). The district is constituted of 22 rural PAs, and the total population of Meta is 252,185 (127,311 males and 124,874 females) (CSA, 2007). In rural and urban areas, the typical family size is estimated to be 7 and 3, respectively. The average farm household owns 0.74 hectares of land. Agriculture in the district is characterized by a small-scale subsistence mixed farming practice that includes livestock production.

Description of the Selected Tree Species

Faidherbia Albida

Faidherbia albida belongs to the Fabaceae family and is one of the largest thorn trees, reaching 30 m in height and having spreading branches and a rounded crown. The basal thickening distinguishes this species from other acacias with long thorns. *Faidherbia albida's* agroecological zone is dry and moist kolla and dry weyna dega. *Faidherbia albida* grows at an elevation of 270-2700 meters, with a mean annual temperature of 18-300 degrees Celsius, a mean annual rainfall of 250-1200 millimeters, and soil type of coarse-textured well-drained alluvial soils. It can endure seasonal waterlogging and salinity but not heavy clayey soils. People eat the seeds of *Faidherbia albida* during the dry season. Firewood, lumber, farm tools, household tools, medicine, fodder, and ich from *F. albida*. *F. albida* are scattered on crop land, in homestead, boundary/live fence, and soil conservation. Tree species provide ecological services such as dead fence, shade, erosion control, soil fertility improvement through nitrogen fixation, and wind break. The origin of *Faidherbia albida* is native (Bekele-Tesemma, A. 2007; Orwa *et. al*.2009).

Acacia Saligna

Acacia saligna belongs to the Fabaceae family and is a thick and multi-stemmed, thornless, spreading shrub or a single-stemmed, small tree up to 9 m tall with smooth, grey to red-brown bark that becomes dark grey and fissured with age. *Acacia saligna's* agroecological zones are dry and moist kolla and dry weyna dega. *Acacia saligna* grows on light-to-medium loams and well-drained soils at an altitude of 0-500 m, with a mean annual temperature of 23-360 C and a mean annual rainfall of 250-600 mm. Income, firewood, timber for construction, fodder, and gums/resins are products from *Acacia saligna.* Nich of *Acacia saligna* in scattered on crop land, in homestead, boundary/live fence, Woodlot, Soil conservation, riparian areas. Ecological Services; live fence, shade, erosion control, soil fertility improvement through nitrogen-fixing, wind break. The origin of *Acacia saligna* is exotic species. The trees are susceptible to white-scale insects, which attack the leaves and stems (Bekele-Tesemma, A. 2007; Orwa *et. al*.2009).

Casuarina Equisetifolia

Casuarina equisetifolia is an evergreen, dioecious or monoecious tree 6-35 (60) m tall with a highly branching crown in the Casuarinaceae family. Crown form is originally conical but flattens with maturity. Straight, cylindrical trunk up to 10 m in length and 100 cm in diameter. Its natural climate ranges from semi-arid to sub-humid (dry, moist, and wet kolla and wenya dega). Altitude: 0-1400 m, mean annual temperature 10-35^{0}C, mean annual rainfall 200-3 500 mm, soils are constantly well-drained and coarse-textured, primarily sands and sand loams. The wood of *C. equisetifolia* is hard to very hard and robust. *C. equisetifolia* is used to reduce erosion along coastlines, estuaries, riverbanks, and rivers because it is salt tolerant and grows in sand. Its general resistance to high winds has encouraged its usage in windbreak planting. C. equisetifolia is used to fix nitrogen from the atmosphere. *C. equisetifolia* shows potential as an agroforestry species for arid and semi-arid environments due to its high production and soil fertility-enhancing qualities. Exotic species are the source of *C. equisetifolia*. Unless grown in poor conditions, *C. equisetifolia* is rarely attacked by diseases and pests (Bekele-Tesemma, A. 2007; Orwa *et. al*.2009).

Moringa Stenopetala

Moringa stenopetala is a moringaceae family tree with a diameter of 60 cm (DBH) and smooth bark. *M. stenopetala* grows natively in dry, semi-arid, and semi-humid environments, and is commonly found in well-drained soils at altitudes of 400-2100 m, with a mean annual temperature of 24-30 ^{0}C. The plant is drought tolerant. It has been discovered in places with annual rainfall ranging from 500 to 1400mm. Because the plant does not resist frost, cold temperatures are a limiting factor in its production in Ethiopia. Except for not growing in damp or swampy soils, the plant has no specific soil needs. The soil pH ranges from acidic to alkaline, but most responses are neutral. The leaves and fruits are used as vegetables (food), and they are high in proteins, calcium, iron, phosphorus, and vitamins A and C. Products include fruits, other edibles, firewood, construction timber, and medicinal value. In comparison to their usage for human food, the use of leaves and pods for animal fodder is now small. However, because of their high protein content, this is an intriguing potential use. These trees, which grow quickly, have softwood that is not very suited for fuel. The species is grown in multi-story stands alongside food crops. *M. stenopetala* is more resistant to insect infestations than other Moringaceae species. Most farmers in the tree's natural region report seeing no illnesses or pests on it (Bekele-Tesemma, A. 2007; Orwa *et. al*.2009).

Table 3. Summary of characteristics of selected species

Description	Tree Species			
	Faidherbia albida	*Acacia saligna*	*Casuarina equisetifolia*	*Moringa steopetala*
Family	Fabaceae	Fabaceae	Casuarinaceae	Moringaceae
Agroecological Zone	Dry and Moist Kolla and Dry Weyna Dega	Dry and Moist Kolla and Dry Weyna Dega	Dry, moist, and wet Kolla and Wenya Dega	*Arid, semi-arid and semi-humid areas*
Rainfall	250-1200 mm	250-600 mm	200-3 500 mm	500-1400mm
Temperature	18-30^{0}C	23-36^{0}C	10-35^{0}C	24-30^{0}C
Altitude	270-2700 m	0-500 m	0-1400 m	400-2100m
Height	30 m in height	up to 9 m in height	6- 35 (60) m tall	6-12 m tall
Products	Firewood, Timber, Farm tools, Household tools, Medicine, Fodder	Income, Firewood, Timber for construction, Fodder, Gums/Resins	Fodder	Fruits, Other Foods, Firewood, Timber for construction, Medicine
Niche	Scattered on crop land, in homestead, boundary/live fence, Soil conservation	Scattered on crop land, in homestead, boundary/live fence, Woodlot, Soil conservation, Riparian areas	Scattered in homestead	Scattered in homestead, Contours/Soil conservation
Ecological Services	Dead fence, Shade, Erosion control, Soil fertility improvement through	live fence, Shade, Erosion control, Soil fertility improvement through	Live fence, Shade, its use in protective planting	Ornamental, Shade. It is a valued ornamental in its natural range.

	Nitrogen-fixing, Wind break	Nitrogen-fixing, Wind break		
Growth rate	Fast growing	Fast growing	Fast growing	Fast growing
Soil	Coarse-textured well-drained alluvial soils	light-to-medium loams and well-drained soils	sands and sand loams soils	The species does not have any specific soil requirements, except it does not grow on waterlogged or swampy soils.
Origin	Native	Exotic	Exotic	Native

Sources: Bekele-Tesemma, A. 2007

Treatments and Experimental Design

The activity was conducted at Fedis and Metta Districts; Boko research station and Metta TVET College. Seeds of the species utilized in the experiment (*Casuarina equisetifolia*, *Moringa istinipetala, F. lbida*, and *Albizia gummifera*) were purchased from the Central Ethiopian Environment and Forestry Research Center (EEFRC) and the Ethiopian Biodiversity Institute (EBI). Seedlings were raised directly in polythene tubes on the nursery site at Fadis, which is near to the study region and has recommended nursery activities. Tree seedlings were planted in the field at experimental sites in June 2019 using a randomized complete block design (RBCD) with three replications. Each replication comprised four experimental plots, each with nine seedlings from a different tree species. The distance between blocks and plots was 2 m, and the distance between trees on a plot was 2 m.

Data Collection

To satisfy the objectives, data on the following parameters were gathered at three-month intervals for four years: on growth and adaptability metrics such as survival rate, Plant height, root collar diameter, and diameter at breast height. Tree height and survival rate were measured every three months until the conclusion of the activity period, while root collar diameters were measured only until the tree reached 1.3m in height, and diameter at breast height was measured when the tree reached 1.3m. Height growth was measured with a measuring tape, and root collar diameter and diameter at breast height were measured with a digital caliper.

Data Analysis

To assess for significant differences between tree species, an analysis of variance was performed using the Genstat software (18th version). Using the software package, the least significant difference (LSD) test was used to differentiate statistically different means at the 0.05 level of probability.

Result and Discussion

Survival Rate at Fadis and Metta Districts Across a year

The analysis of variance revealed that highly significant variations among tree species in survival rate ($P<0.05$) was recorded. The survival that recorded in this experiment for *F. albida, A. saligna,* and *C.*

equistifolia were relatively show better survival rate than *M. stenophatala,* at Metta site. *F. albida, A. saligna C. equistifolia* and *M. stenophatala, show* good performance among tested trees species at Bokko station. Generally four tree species performed well at Fedis condition, survival about 84.01%, 88.33%,80.33% and 86.8%, recorded for *F. albida, A. saligna, C. equistifolia and M. stenophatala,* respectively show good performance. At Metta condition, survival about 83.35%, 92.09%, and 84.01% recorded for *F. albida, A. saligna,* and *C. equistifolia* respectively showed good performance than *M. stenophatala* (35.93%) showed least performance. Therefore, planting of these better performing tree species and increase their promotion to in the study area. Hence, it can be show that the condition of Fedis and Metta matched well with the environment requirement of these species adapted. Moges and Tsegaye (2004) also reported that Moringa olifera ,*A. saligna* and *F. albida,* species are quite drought resistant species which is similar to the observation of the present study. *M. stenophatala* showed least performance *35.93%* due environmental factors of metta not suitable for moringa stenopetala. The survival trend for all tree species showed declining trend their survival rate for all the assessment period.

Table 1. The mean of survival rate (%) of the species over the years of experimental period

Tree species		***F. albida***	***A. saligna***	***C. equistifolia***	***M. stenophatala***	**CV (%)**	**LSD (0.05)**
Year I	Fadi	89.30^{b}	94.38^{a}	85.51^{b}	92.38^{a}	1.2	2.11
	Met	89.50^{b}	100.0^{a}	86.13^{b}	42.33^{c}	2.3	3.54
Year II	Fadi	83.55^{b}	89.33^{b}	81.07^{b}	85.99^{b}	1.7	2.8
	Met	83.30^{b}	90.16^{a}	85.87^{b}	38.33^{c}	3	4.4
Year III	Fadi	82.53^{b}	85.60^{b}	80.37^{b}	85.60^{b}	2.4	3.75
	Met	82.54^{b}	89.60^{b}	84.32^{b}	34.33^{c}	2.4	3.4
Year IV	Fadi	80.67^{b}	84.00^{b}	78.37^{b}	83.33^{b}	8.18	20.93
	Met	78.07^{b}	88.60^{b}	80.12^{b}	27.77^{c}	15.9	11.2
Total mean	Fadi	84.01^{b}	88.33^{a}	80.33^{b}	86.83^{a}	7.16	19.73
	Met	83.35^{b}	92.09^{a}	84.11^{b}	35.93^{c}	9.18	22.73

N/B: Means in columns with the same letters are not significantly different, LSD= Least significant difference

Results obtained from the study show that, except the site significant difference ($p<0.05$) were observed for the survival rate of the species of *M. stenophatala* (table 1). During the years of study period, *F. albida, A. saligna, and C. equistifolia* attain the highest mean values ranging from 80.33% to 92.01%. This indicted the condition of the study area matched well with the environmental requirement of these species. Against to this *M. stenophatala* had the lowest survival rates over the entire experimental period at Metta condition.

Tree Height, Root Collar Diameter, and Diameter at Breast Height Increments

During the adaptation and growth performance of the same (provenance) tree species, other growth parameters such as tree height, root collar diameter, and diameter at breast height were measured. However, in this particular study, the growth performance is simply dependent on the survival rate (%) to examine variations among tree species in the study area. Tree species' height, root collar diameter, and diameter at breast height were measured independently in both locations. According to measurements made in the Fedis district, F. albida (1.42m), *A. saligna* (3.24m), *C. equistifolia* (3.22m), and *M. stenophatala* (2.69m) had height growth measurements made. *F. albida* (2.78cm), *A. saligna* (4.01), *C. equistifolia* (3.89cm), and *M. stenophatala* (3.65cm) all had increases in their root collar diameter. The diameter at breast height growth of F. albida (1.21cm), *A. saligna* (3.22cm), *C. equistifolia* (3.42cm), and *M. stenophatala* (2.22cm) trees, respectively.

At Metta district height growth of *F. albida* (1.11), *A. saligna* (3.76m). *C. equistifolia* (3.26m) and *M. stenophatala* (1.01m) were measured, and root collar diameter growth of F. albida (2.53cm), A. saligna (4.10cm), *C. equistifolia* (4.05cm) and *M. stenophatala* (1.66cm) were measured and diameter at breast height growth of *F. albida* (1.12cm), *A. saligna* (3.31cm), *C. equistifolia* (3.07cm) and *M. stenophatala* (0.32cm) respectively. Accordingly, *F. albida (*1.42m) the shortest trees at Fedis district. The tree species having greatest root collar diameter were those, which grew tallest. Similarly, species with lower height growth had lower root collar diameter growth (Raebild *et. al.*2003). Raebild *et al.* (2003) stated that the growth and productivity of trees , height may also be seen as a measure of the adaptability of trees to the environment as tall trees usually being better adapted to the site than short trees (Table 2).

Table 2. Average mean growth performance of tree species in plant height (m), root collar diameter (cm) and diameter at breast height (cm) across experimental period

Types of Trees	Others growth parameters					
	Fedis district			**Meta district**		
	Height(m)	RCD(cm)	DBH(cm)	Height(m)	RCD(cm)	DBH(cm)
A. albida	1.42[c]	2.78[c]	1.21[c]	1.12[b]	2.53[b]	1.11[b]
A .saligna	3.24[a]	4.01[a]	3.22[a]	3.76[a]	4.10[a]	3.31[a]
C. equistifolia	3.22[a]	3.89 [b]	3.42[a]	3.26[a]	4.05[a]	3.07[a]
M. stenophatala	2.69[b]	3.65[b]	2.22[b]	1.01[b]	1.66[c]	0.32[c]
CV (%)	**5.53**	**8.42**	**24.35**	**6.37**	**7.37**	**22.40**
LSD(0.05)	**2.40**	**2.83**	**3.75**	**1.36**	**4.40**	**3.40**

Note: RCD- Root Collar Diameter, DBH- Diameter at Breast height

Conclusion and Recommendations

The results indicated that there were significant different among tree species for survival rate. The survival rate of *A. saligna, M. stenophatala, F. albida,* and *C. equistifolia* were showed good performance at Fedis condition. The survival rate of *A. saligna*, *C. equistifolia* and *F. albida* were good performance than *M. stenophatala* at Meta condition. While *M. stenophatala* showed poor survival rate at the Meta condition. Poor survival rate and growth performance of *M. stenophatala* might be attributed to the condition environmental factors like climatic condition and soil types of the study area. Concerning of plant height, root collar diameter and diameter at breast height of individual trees of A. *saligna* and *C. equistifolia* were showed better tree height increment, followed by *M. stenophatala* but *F. albida* were measured the shortest tree heights at Fedis site. *A. saligna* and *C. equistifolia* were showed the tallest tree height, followed by *F. albida* and *M. stenophatala* were show the shortest tree height at Meta site. The maximum diameter were measured for A. *saligna* followed by *C. equistifolia* than *M. stenophatala* and *F. albida* at Fedis site and for A. *saligna* and *C. equistifolia* followed by *F. albida* then and *M. stenophatala,* at Meta site entire experimental period were measured.

Generally, based on these results, we further recommend those four tree species A. *saligna, F.albida,C.equistifolia and M. stenophatala* had better performance and high mean value of survival rate in the study area of Fedis and those three tree species A. *saligna, F. albida, and C.equistifolia* showed better performance and higher mean value of survival rate. However, *M. stenophatala* performed least and failed to adapt at Meta district. Therefore; planting of these better performing tree species and increase their promotion as agroforestry practices for soil conservation, shading, forage, fuel wood and in general multifunction purposes in the area. It is also better to use for plantation purpose on degraded area rehabilitation.

Acknowledgements
The authors would like to acknowledge the Fedis Agriculture Research Center's Agroforestry Research Team for their follow-up and data collection, as well as the Oromia Agricultural Research Institution for their financial support.

Reference

Bekele-Tesemma, A. 2007. Useful trees of Ethiopia: identification, propagation and management in 17 agroecological zones. Nairobi: RELMA in ICRAF Project, 552p.

Berhe, T., Gebretsadik, Z., Edwards, S., & Araya, H. (2011, November). Boosting tef productivity using improved agronomic practices and appropriate fertilizer. In *Achievements and prospects of Tef improvement. Proceedings of the second International Workshop* (pp. 133-140).

Brockerhoff EG, Jactel H, Parrotta JA, Quine CP, Sayer J (2008). Plantation forests and biodiversity: oxymoron or opportunity? Biodiversity Conservation. 17: 925-951.

CSA. Ethiopian Housing and Population Survey. 2007.

Institute of Biodiversity Conservation. Convention on biological diversity Ethiopia's 4th Country Report. Addis Ababa, Ethiopia. 2009; 161.

Mihretu, M., Gezahegn, A., & Gizachew, B. (2004). Early survival and height performance of some Australian species in field trials at Didessa, Western Ethiopia. *Ethiopian Journal of Natural Resources.*

Moges, Y., & Tsegaye, T. (2004). Status, biodiversity and threats of Northwestern lowland vegetations of Ethiopia. In *A National Conference on Forest Resources of Ethiopia,, Addis Abeba (Ethiopia), 27-29 Nov 2002*. Institute of Biodiversity Conservation/GTZ.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., & Simons, A. (2009). Agroforestree Database: a tree reference and selection guide. Version 4. *Agroforestree Database: a tree reference and selection guide. Version 4.*

Ræbild, A., Diallo, B. O., Graudal, L., Dao, M., & Sanou, J. (2003). *Evaluation of a species and provenance trial of Prosopis cineraria, P. pallida and Acacia senegal at Djibo, Burkina Faso*. Danida Forest Seed Centre.

Wong, L. L. (2006). *US Bamboo house of the future: standardizing ecological living* (Doctoral dissertation, Massachusetts Institute of Technology).

Yadessa, A., Bekere, D., & Bekele, T. (2000). Growth performance of different multipurpose tree and shrub species at Bako, Western Oromia. *Nutrient Management for Improving Soil/Crop Productivity in Ethiopian Agriculture*, 30-31.

Yakob, G., Asfaw, Z., & Zewdie, S. (2014). Wood production and management of woody species in homegardens agroforestry: the case of smallholder farmers in Gimbo district, south west Ethiopia. *International Journal of Natural Sciences Research*, *2*(10), 165-175.

Assessment of Wild Edible Plant Species in East Hararghe Zone, Oromia, Ethiopia

Musa Abdella*, Bira Cheneke and Megarsa Ketama
Fedis Agricultural Research Center, Harar, P.O. Box 904, Ethiopia
*Corresponding author email:musaabdellah345@gmail.com

Abstract

Wild edible plant species are very important to improve food security and diversify household income sources. However, its identification and document of wild edible plant species limited. The study was conducted in four districts of East Hararghe Zone, to assess, identify and document of wild edible plant species in the study area. Wild edible plant species surveys, and data such as wilderness, edibility or parts used, growth form, threatening factors, conservation measures assessed at the field. People perceptions were captured from a total of 170 informants using an informal interview, focus group discussions, and questionnaires and observation in the field. Most species taxonomically known and for those unknown, were collected and identified with elder peoples. Descriptive methods of data analysis were employed to analyze data on wild edible plant species. The result showed that a total of 26 wild edible plant species were recorded in the study area. Four life forms: 65% species were found growing as trees, 15% as shrubs, 8% as herbs, and 8% as climbers. Parts of wild edible plant species used were fruits 83%, bark 5%, seed 4%, leaf 4%, stem 2.94 and root 2% were recorded. Most of wild edible plant species were consumed as raw fruit 80% and the majority consume wild edible plant species as supplementary food supply. Women and children are responsible in wild edible plants collection. Potential of existed wild edible plants in the study area were low and the current abundance of wild edible plant species was decreasing. The most threatening factors to hinder the development of wild edible plant species were agricultural expansion and deforestation. These findings confirm the assumption that wild edible plant species are important for the generation of household income. This study identified the most importance of wild edible plant species to local communities, particularly in the selected districts. Wild edible plant play an important role in rural livelihoods by ensuring food, medicine, and sustained income. Therefore, there is an urgent need for research on the more domestication of wild edible plants in home gardens, mixing with domesticated crop plants in the study area to enhancing the wild edible plan species production for food security and dietary diversity in East Hararghe Zone. Further research also need to collect and conserve, propagation and management activities of the wild edible plants species identified in the study area. Further study also carried out on nutritional contents of the wild edible plants species. Finally, further study must be on strengthening botanical information, germplasm collection and genetic improvement, increasing the supply of high-quality planting materials, and promoting on-farm cultivation in the form of agroforestry systems to recognize the identifying and selecting preferred species.

Keywords: Identification, wild edible plants, domestication, food supply, traditional knowledge

Introduction

Wild edible plant species refer to species that are neither cultivated nor domesticated, which are available from their wild natural habitat and used as sources of food (Beluhan and Ranogajec, 2010). These trees are generally grown in different habitats such as forests, cultivable fields, and even anthropogenic ally disturbed areas such as roadsides and wastelands (Ranogajec 2010). Wild edible plant species have played a significant role in the livelihoods of rural communities in developing countries (Mabaya et al. 2014; Khruomo & Deb 2018) due to their nutritional and medicinal value (Biswas et al. 2018). Wild edible plant species are important sources of traditional food recipes, medicines, fodder, firewood, and building materials for rural communities (Navia et al. 2020; Suwardi et al. 2020a). Even though the primary dependence of most agricultural societies on staple crop plants such as wheat, maize and rice, while the conventional eating of wild edible plant species products are used as food are more than 7,000 species in human history continues until the present day (Grivetti and Ogle, 2000). Wild edible plant species are closing food gaps and play an important role in maintaining livelihood food security for many people in developing countries during seasonal food shortages, as emergency food aid (Afolayan and Jimoh, 2009). Moreover, the indigenous edible plant species are adapted to the local culture and environment welfare through natural growing manner with a minimum requirement of external inputs and maintenance such as management, fertilizer and pesticides (Ruffoet al., 2002).

Despite the fact that can easily be integrated into sustainable farming systems by the majority of the rural population, they are still not treasured as of cultivated fruit trees, such as mango, avocado, Papaya and orange due to lack of scientific support. Therefore, traditional knowledge of wild plants, generally in Africa and particularly in Ethiopia are in danger of being lost, as habits, value systems and the natural environment change (Ruffoet al., 2002). There is a widespread failure with knowledge especially among young people and urban dwellers to preserve wild edible plant species in order to be valuable for future generations. So it needs to be recorded systematically (Demel et al., 2010).

In general, the regardless of their importance, wild edible plant species are faced with serious threats of anthropogenic and environmental factors in the country due to agricultural expansion, overgrazing/overstocking, deforestation and urbanization (Teklehaymanot and Giday, 2010). In Ethiopia, where more than 80% of the population is rural, the people have depended on their traditional knowledge for utility of edible plant species without exhaustive documentation of their contribution, management and utilization in their surroundings. This is particularly true in rural population of East Hararghe Zone, where rural communities of the area depend on wild edible plant species for various purposes.

Wild edible plants species also faced with serious threats of anthropogenic and environmental factors (Teklehaymanot, 2010). However, there are no any researches so far done, on assessment of wild edible plant species in the study area to being as impetus for policy makers, NGOs, and end users in order to sustain utilization and management of wild edible plant species without jeopardizing for future generation. Hence, as natural resources of the area along with their identification, conservation and domestication for future food security. However, there are no any researches so far done, on assessment of wild edible plants species in the study area Therefore, it needs to identify and recorded systematically in scientific ways (Demel *et al.*, 2010). The study was filled the gap of indigenous knowledge related to utility and management as well as constraints and potentials of wild edible plant species. Therefore, the specific objectives of the study were initiated to,

- ✓ To identify wild edible plant species in different agro ecology,
- ✓ To identify traditional knowledge and skill of rural communities on management and utilization of commonly used wild edible plant species and
- ✓ To assess constraint and potential role of wild edible plant species in combating food insecurity in the study area.

Materials and Methods

Descriptions of the Study Area

Eastern Hararghe is one of the 20 administrative zones of the Oromia regional state. It is located in the Eastern part of the country about 600 km of the capital, Addis Ababa (Figure 1).

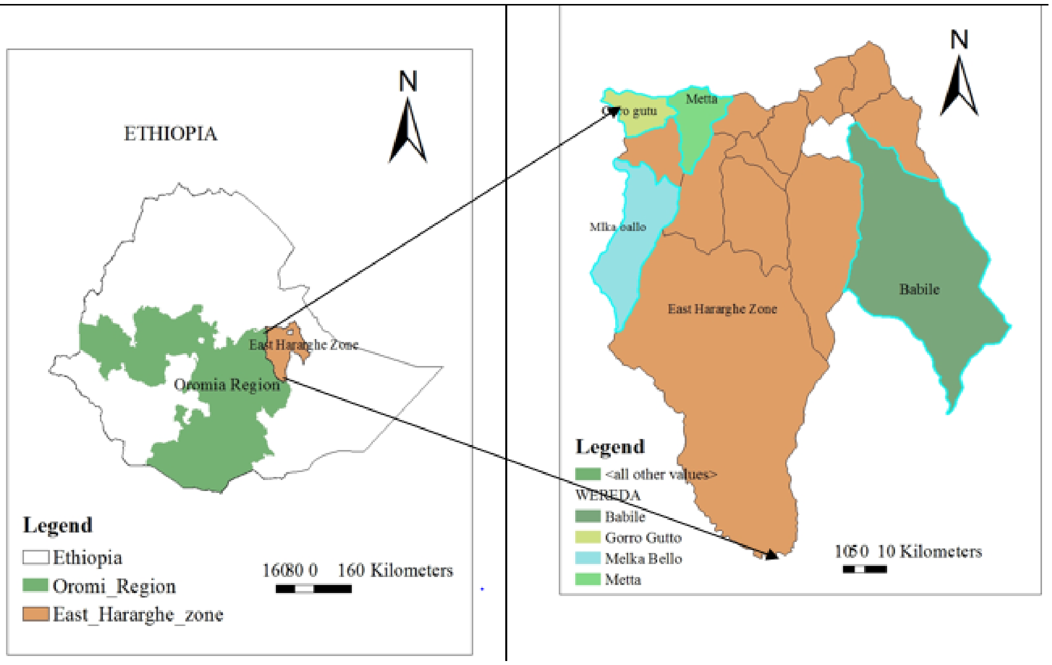


Figure 1:Study area/districts

East Harerghe Zone is geographically located 9° 42' 41" North latitude and 42° 0' 9" East longitudes. The zone is bordered on the southwest by Bale, on the west by West Hararghe Zone, on the north by Dire Dawa and on the north and east by the Somali Region. The Administrative center of this zone is Harar. The capital town of the Zone is Harar, which is located at a distance of 526 km East of Addis Ababa. The area coverage of the Zone is 2,260,000 ha (22,600 km2), comprising of 20 districts with a total population of 2,723,850, an increase of 48.79%. Hararge has a population density of 151.87. While 216,943 or 8.27% are urban inhabitants, a further 30,215 or 1.11% are pastoralists, 17% agro-pastoralists, and the rest are agriculturalists (74%).

Melka balo: The study area is found at 487kms of east of Addis Ababa, the capital city of the country. The average temperature in the area is 24^0c with the average rain fall is 1800 mm and the altitude ranges from 1300-3140m above sea level and the various topographic features of district include Dega (high land)(20%), Woyna Dega (Mid-high land) (39%) and kola (Lowland) (41%) (NAMSA, 2015). Mixed farming system is the mode of agriculture in the districts play an important role for the livelihood of the local population (CSA, 2009).

Babile: The study is located 31km away from the Harar town and about 557 km east from Addis Ababa. The altitude is 1000 -2000 a. s. l. and the various topographic features of district more kola (Lowland) (NAMSA, 2015).Rainfall pattern in the area is bi-modal rain fall .Average annual rainfall amount is 1145 mm. Mean annual temperature is 24°C (FARC, meteorological data). Mixed farming system is the mode of agriculture in the districts play an important role for the livelihood of the local population (CSA, 2013). The population of the woreda according to the 2007 census was 93,674. Rural residents account for 81.1 percent of the population. The agro-climatic condition of the area is semi-arid, arid. The annual maximum and minimum temperatures are 26 and 20^0C, respectively.

Goro-Gutu, is located 420 km east of Addis Ababa, on the main road to Harar. The woreda is located 140 km north-east of the zonal capital, Harar. According to the 2007 Population and Housing Census, the population of the woreda was 143,896, of which 93 percent live in rural areas. The total population of the woreda is 143,896 (73,512 male persons and 70,384 female persons and the total number of households (HHs) in the woreda is 24,284 (22,666 male headed HHs and 1,618 female headed (HHs). The majority of inhabitants work in agriculture. The agro-ecology is divided in to highland (dega) that covers 23 percent of the area, midland (weynadega) 29 percent and the remaining 48 percent is classified as lowland (kolla). Meta contains three agro-ecologies like the zone even though the proportion varies. The agro ecology of the woredas falls in highlands (Dega), midland (Woina Dega) and low land (Kolla). The proportion of highland (Dega), midlands (Woina Dega) and low lands (Kolla) vary. The Meta total population is 252,185 (127, 3 11 male persons and 124,874 female persons and the total number of households (HHs) and in is 51,398 (25,974 male headed HHs and 25,424 female headed HHs.

Methodology and Research design

Selection of the Study Area

The location for the studies were identified in collaboration with a multidisciplinary research team and local administration. Reconnaissance surveys were undertaken. The study districts, Melka ballo, Goro gutu, Metta and Babile were selected purposively based on it’s their altitude range that from low land, mid land and highland of agro ecology zones.

Procedures and Sample Size determination

Sampling Procedures

The location for the studies were identified in collaboration with a multidisciplinary research team and local administration. Reconnaissance surveys were undertaken. Multistage sampling technique was used for this particular study. In the first stage, Melka ballo, Goro gutu, Metta and Babile districts were selected purposively for thisstudy. In the second stage, the study kebeles were stratified into three different strata to cover varying agro-climate due to time shortage and to have a representative sample. In the third stage, the six Kebeles were randomly selected from each agro-climate. In the fourthstage, sample households were selected from each Kebeles. To select sample households, a systematic sampling method was applied by taking the n^{th} element of the sample frame. There are 6387 households in six selected Kebeles. The list of households were obtained from Woreda agricultural office in the study area. The total households were divided by sample size (170) and it gave 40. So that the 40^{th} value is 39. So that every 40^{th} number was selected to getsampled household. It also assures that the community will be evenly sampled (Johnson et al., 2007)

Table 1: Study area characteristics

Distruct	Kebeles	Agro ecology	Altitude (m a.s.l)	Latitude (N)	Longitude (E)	Total HHs	Sample HHs
Babile	B. babile	Lowland	1664	9^0 35’ 43”	42^0 18’ 50”	1030	27
	Abdi buch	Lowland	1778	9°17’59’’	42° 17’26’	1010	30
Goro gutu	Madisa	Midland	1889	9^0 22’ 45”	41^0 25’ 10”	1168	26
Melka Ballo	Dire kufa	Midland	2000	9^0 4’ 44”	41^0 21’ 51”	918	30
Meta	Ch. lola	Highland	2185	9^0 41’ 54”	41^0 37’ 18”	1085	29
	B. oromia	Highland	2200	9^0 14’ 60”	41^0 24’ 59”	1176	28
Total						**6,387**	**170**

Sample Size Determination

The household head were considered for household interview; other members of the family were included in focus group discussions and key informant interviews. Population size of the study area was determined. Sample size was calculated with the simple random sampling method based on proportional to population size using (Yemane, 1967) formula, presented below

$$n = \frac{N}{1 + N(e)}2$$

n= No. of samples, N= No. of population in selected kebeles, σ^2 = Variance of Population, D= $(d/t)^2$, D= A certain rate of deviation (5%) from the average and t= t table value (1.96) corresponding to the limit of the confidence interval 95%. Where n is the sample size, N is a total number of households in the selected kebeles [the sample size (n) in each Kebele was picked based on its proportion to N because the number of households in each Kebele is different], the maximum variability or margin of error5 % (0.05), 5 = probability of the event occurring. Based on the above technique, 170 sample households were selected. Therefore, the total sample size was 170.

Data Collection

Data collected tools are observations, interview questions and questionnaires. Data on types: local names, growth form, parts used, pattern of consumption, management and major threatening factors of wild edible plants species were gathered. In order to asses and identify the existing wild edible plants species, checklist were set to list the species by the guide and support informants for the study areas. The wild edible plant species in different agro ecology, traditional knowledge and skill on management and utilization commonly used wild edible plant and the constraint and potential role of edible plant species for combating food insecurity in the area were collected.

Data analysis

The data collected were analyzed by means of descriptive statistics, with Microsoft Excel and SPSS (Statistical Package for Social Sciences, Version 26). In addition data was analyzed using both qualitative and quantitative methods. Close ended questions were analyzed through tables and percentage to compare the results while open ended questions like interview and observations were analyzed using descriptive methods.

Result & Discussion

Identified Wild Edible Plants Species in the Study Area

Wild edible plant species in the study area were assessed and identified. A total of 26 wild edible plant species were identified and most frequently the habitat of wild edible plants were at the wild and forests in the study areas. A total of 170 respondents were interviewed through both household survey and key informant interviews. The study were considered by respondents to be commonly consumed by the community, and they were considered to be the most useful species among those listed for the studied areas. The number of wild edible plants reported in this study was relatively low compared with the number of species documented in previous studies carried out by (Assefa *et al.,* 2010) in other parties of Ethiopia. The lower number of wild edible plants found in the present study may be associated with differences in local traditions and customs relating to the use of wild plants in different parts of the country.

Table 2. Listed of identified, their part used, growth form, and habitat of wild edible plants species in the study areas

No	Local names	Scientific names	Edible part	Growth form	Habitat
1	Gora	Rosa abyssinica	Fruit	climber	W
2	Tinii	Balanites aegyptiaca	Fruit	Shrubs	W/F
3	Xaxessaa	Grewia ferruginea	Fruit	Shrubs	W/F
4	Agamsa	Cassia siamese	Fruit	climbers	W
5	Shimirkolii	Dovyalis abyssinica	Fruit	Shrubs	W/F
6	Zeyituna	Psidium guajava	Fruit	Trees	Wild/FL
7	Buruurii	Vanqueiria ariseppala	Fruit	Trees	W/F
8	Bissii/sukee	Ocimum urticifolium	Leaf	Herbs	wild
9	Walensuu	Erythiria brucei	bark	Trees	W/F
10	Ulaagaa	Ehretia cymosa.	Leaf	Trees	W/F
11	Jilboo	Oncobaspinosaforss	Fruit	Shrubs	W/F
12	Dabobessa	Rhus natalensis	Leaf	Trees	W
13	Biqaa/Gambelo	Gardenia ternifolia	fruit	Shrubs	W
14	Rummana	Runicagranetum	Fruit	Trees	W/FL
15	Qancaraa	NA	leaf	Shrubs	W/F
16	Birreessa	Terminalia brownii	Leaf	climber	W/F
17	Qurquraa	Ziziphus mucronata	Fruit	Trees	W/F/FL
18	Waddeessa	Cordia africana	Fruit	Trees	W/F/FL
19	Harbuu	Ficus sur	Fruit	Trees	Forest
20	Baddeesaa	Syzygium guineesa	Fruit	Trees	Forest
21	Roqaa	Tamarindus indica	Fruit	Trees	W/F
22	Hudhaa	Ximenia americana	Fruit	Trees	Forests
23	Xossinnoo	Ruta chalepensis	leaf	Herbs	W/F
24	Darguu	Achayrentesaspera	Leaf	Shrubs	W/F
25	Buruurii	Discorea sp	Fruit	Shrubs	W/F
26	Dhangaggoo	Rumex nervosus	Leaves	Herbs	W/F

Note: W-wild, F-forest, FL-farm land, W/F –wild & forest

Thus, this may reflect social variations in attitudes and preferences towards wild food sources. Hence, it also explains differences in agro ecology in different parts of the country. The number of interviewed households were visited mainly for of the species on their local name, edibility, growth form, and habitats forms of wild edible plants. 26 wild edible plants species represents 4 life forms: Trees, Shrubs, Herbs, and Climbers. The study carried out in the sampled study area founded 26 wild edible plant species comprising life forms in percent across in different agro ecology

The majority of the wild edible plants were recorded in the wild, but the integration of some plants in farm lands and home gardens indicate their potential to be used in different land use systems. Based on the identified wild edible plants by respondents were categorized into different parts (wild and domestic). Wild edible plants were mainly used for directly edible purpose and unripe fruits trees were used in pickle making. The farmers opined that, wild edible plants were also used in many herbal medicines. Preferred wild edible plants for domestication based on farmer's perception. Farmers in the study area were interviewed and their perception on domestication of some species was documented. The farmers preferred *Psidium guajava, Oncobaspinosaforss*, *Annona senegalenis*, *Tamarindus indica*, and *Cordia africana* species for domestication.

Identify Traditional Knowledge, Management and Utilization of Commonly used Wild Edible Plants Species in the Study Area

Parts Used of Wild Edible Plant Species

The wild edible plants species had different plant parts are consumed. Six edible parts of wild edible plants recorded in the districts. These are fruits, barks, seeds, leaves, stem, and root (Table. 5). Fruits comprise 82% of edible parts whereas bark 5%, seed 4%, leaf 4%, stem 3% and root were 2% provided. This means fruits are the major parts consumed followed by barks, seeds and leaf. Stem and root are the least. Most fruits consumed in raw. Regarding wild edible parts consumed, five edible parts were documented namely fruits, bark, stem, leaves, seeds, and root. This indicates the edible parts of reported wild edible plants in study area is also highly diverse. The most widely consumed parts are fruits (82%) that eaten raw. The preference of fruits to other parts might be low energy investment. Fruits are harvested and consumed in the field or outdoor when they ripe by children while collecting fuel wood or herding cattle. The result ofthis research is in agreement with current study results (Tebkew *et al.*, 2014; Regassa *et al.*, 2015; Betti *et al*., 2020; Mutie *et al.*, 2020). In other studies, leaves are the main consumable part of wild edible plants in a different part of the world (Ali-Shtayeh *et al*., 2008). This implies the types of wild edible parts and culture of the communities vary from location to location. This indicates that the different cultural groups in Ethiopia make use of diverse wild edible fruit trees and shrubs species parts as food sources.

Table 3: Wild edible plants parts used for consumption in the study area

Parts used	Parts used of wild edible plants along different agro-ecologies							
	Babile district		M. ballo & G. gutu districts		Metta district		Total	
	Freq.	Per (%)	Freq.	Per (%)	Freq	Per (%)	Freq.	Per (%)
Fruit	51	80.95%	50	81.97%	40	86.96%	141	82.94%
Bark	3	4.76%	4	6.56%	1	2.17%	8	4.71%
Seed	1	1.59%	4	6.56%	2	4.35%	7	4.12%
Leaf	4	6.49%	0	0.00%	2	4.35%	6	3.53%
Stem	2	3.17%	2	3.28%	1	2.17%	5	2.94%
Root	2	3.17%	1	1.64%	0	0.00%	3	1.76%
Total	**63**	**100%**	**61**	**100%**	**46**	**100%**	**170**	**100%**

The wild edible plants species parts that commonly used were the fruit, bark, seed, leaf, stem and root.

Habits of Wild Edible Plants in the Area:

In the study area, generally the identified species were mostly different life forms/growth forms and existed, occurred, distributed of these species their production and utilization. The wild edible plant species belong to four life forms namely trees, shrubs, herbs and climbers. Trees contributed 69%, shrubs 15%, and herbs 8%, whileclimbers contributed only 8% of all identified wild edible plant species (Table. 4). The life forms of wild edible plants in this study were diverse and accordingly the largest number of wild edible plant species foundto be trees followed by shrubs, herbs and climbers. The least diverse wild edible plants in terms of life forms were climbers. This result is also seen in a study conducted nearby area by Tebkew *et al.* (2018) in the Northern part of Ethiopia where trees are dominant life forms of wild edible plants followed by shrubs. However, this result is different from a result reported by Alemayehu *et al.* (2015) and by Amente (2017) in the western part of Ethiopia. This shows the variation of the life forms of edible wild plants from place to place that might be due to variations in type edible wild plant species and culture of the communities. In the study area, products from edible plants species are generally identified for subsistence used mainly because the production of edible parts, such as fruit, as seasonal and, therefore, can only be gathered for a short period of time.

Table 4: Growth forms of wild edible plants species identified in the study area

Variables	Life form of wild edible plants along different agro-ecologies							
	Babile district		M. ballo & G. gutu districts		Metta district		Total	
Life form	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)
Trees	37	58.73%	50	81.97%	30	65.22%	117	68.82%
Shrubs	11	17.46%	7	11.48%	8	17.39%	26	15.29%
Herbs	8	12.69%	2	3.33%	4	8.69%	14	8.24%
Climbers	7	11.11%	2	3.33%	4	8.69%	13	7.65%
Total	63	100%	61	100%	46	100%	170	100%

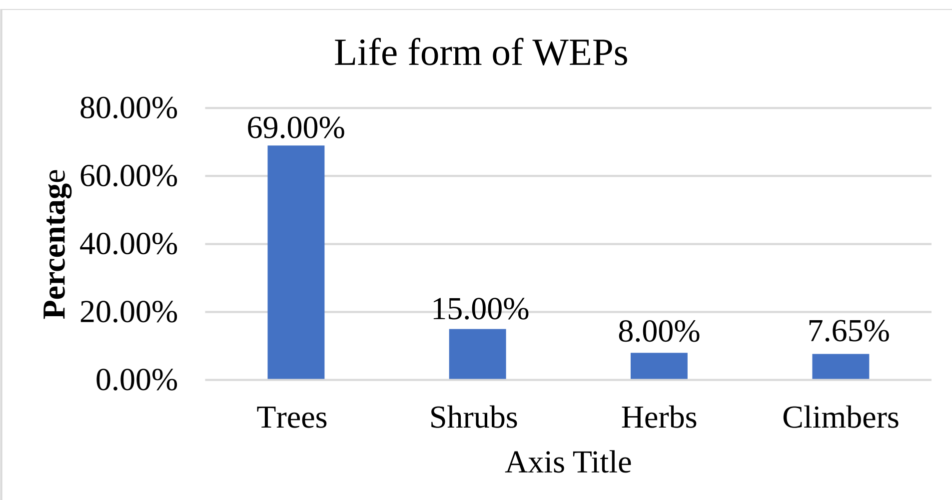


Fig. 1. Growth form of wild edible plants of the study area

Consumption Method of Wild Edible Fruit Trees and Shrub Species

Most wild edible plants parts were eaten directly in fresh forms as consumption method. The mode of consumption of wild edible plants in study area, showed that were consumed raw fruit and followed by raw/cooked were consumed cooked/roasted were consumed and Preserved and consumed with any ingredients were consumed in three agro ecologies. In the study area, the local people reported that about 80% of wild edible plants consumed raw fruit outdoor. However, about 15% can be consumed raw or cooked, about 3% can be consumed roasted and the rest 2% of wild edible plants in the area are found to be eaten preserved or cooked (Figure 2).

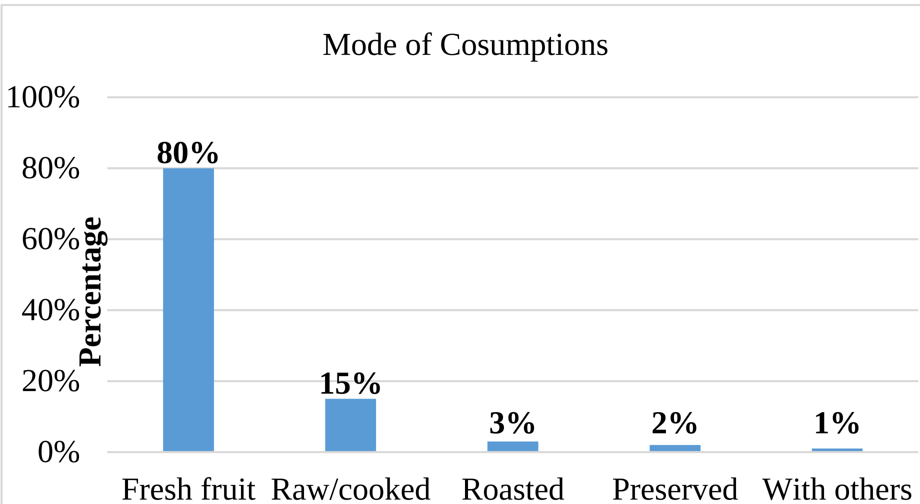


Fig. 2. Consumption method of wild edible plants of the study area

According to the report of this finding, majority of the wild edible plants in the area consumed raw except *Ocimum urticifolium, Erythiria brucei, Ehretia cymosa, Rhus natalensis, Terminalia brownie, Ruta chalepensis, Achayrentesaspera, Rumex nervosus*. In the study area, the respondents reported that majority of the wild edible plants in the area were consumed as raw fruit. The study of Beche *et al.,* (2016) also indicated that the majority of the recorded edible species were consumed fresh without ripening or processing. The study conducted by Tebkew *et al.,* (2018) indicated that wild edible plants were consumed fresh, dried and cooked, or prepared in different forms. Majority of the edible plants were consumed fresh, while only nine of them were consumed after drying. There was no need for cooking, boiling, or roasting the edible parts for consumption in the majority of wild edible plants in the area (Anbessa, 2016). Seyoum (2017) indicated that nearly half of the identified plant species are consumed raw, and many of them are fruits. Others are used after various food preparation techniques. For instance, leafy vegetables are used after frying and/or boiling or steaming over a fire, and some fruits can be used following non-fire-processing methods.

The Purpose and Contribution of Wild Edible Plant Species in the Study Area

Wild edible plants are used for various purposes: Among different uses, used as food. It was found that most of the wild edible plants were used for direct consumption. Different parts of wild edible plants such as fruits, were used for edible purposes. Majority of respondents were used for food sources followed by income sources with additional diet along with domestic foods as refreshment. Response of more farmers (in table 7) shown that the reason of consumption were/used as food 55.88%, income 15.88%, as medicinal

15.29% and refreshment 12.94% different agro ecologies. Majority of respondents were used for food followed by income purpose with additional diet along with domestic foods as refreshment.

Table 5: Farmers preference for of wild edible fruit trees and shrubs in the study area.

Variables	Objective used of wild edible plants along different agro-ecologies							
	Babile district		**M. ballo & G. gutu districts**		**Metta district**		**Total**	
Purposes	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)
Income	33	52.38%	38	62.29%	24	52.22%	95	55.88%
Food	14	22.22%	11	18.03%	2	4.35%	27	15.88%
Refreshme	8	12.69%	8	13.11%	10	21.74%	26	15.29%
Medicinal	8	12.69%	4	6.56%	10	21.74%	22	12.94%
Total	63	100%	61	100%	46	100%	170	100%

Contribution of Wild Edible Plant Species for the Household

The survey results showed that the contribution of wild edible plants for the livelihood of the community in the study area, consumed as supplementary food. The contribution of wild edible plants for food consumption role followed by supplementary role with additional diet according to the major respondents responded. The results showed that the contribution of wild edible plant for the livelihood of the community in study area selected districts, consumed as supplementary food. Seasonal food supply 70.59%, yearly food supply 27.65% and regular food supply 1.76% were contributed. Wild edible plants have little economic importance compared to other economic activities, for some people selling fruits at local markets do provide some income for the poorest so as to supplement food as well as cash in order to meet their basic needs. Some of the wild edible plants were contributed as additional income sources. Thus, conservation and development of wild edible plants should be considered as an integral element of the farming system to avert food insecurity problems and improve the livelihoods of the rural community in East Hararghe Zone. The role of wild edible plants in bridging the gap in food supply, particularly to resource-poor members of the community, is significant (Teketay *et al.* 2010). The fruit harvesting season and uses vary from place to place, even from species to species. This is due to climatic and intraspecific variations (Teketay *et al.* 2010). Our survey revealed that edible plant were commonly used during periods of food shortage, seasonally during periods of food scarcity. In surveyed respondents reported that the food shortage period occurred in May, June, July and August.

Table 6: Contribution of wild edible fruit tree and shrub species for the household

Contribution	Contribution of wild edible plants along different agro-ecologies							
	Babile district		**M. ballo & G. gutu districts**		**Metta district**		**Total**	
	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)
Seasonal food supply	39	61.90%	45	73.77%	36	78.26%	120	70.58
Yearly food supply	23	36.51%	15	24.59%	9	19.56%	47	27.65
Regular food supply	1	1.59%	1	1.64%	1	2.17%	3	1.76
Total	**63**	**100%**	**61**	**100%**	**46**	**100%**	**170**	**100%**

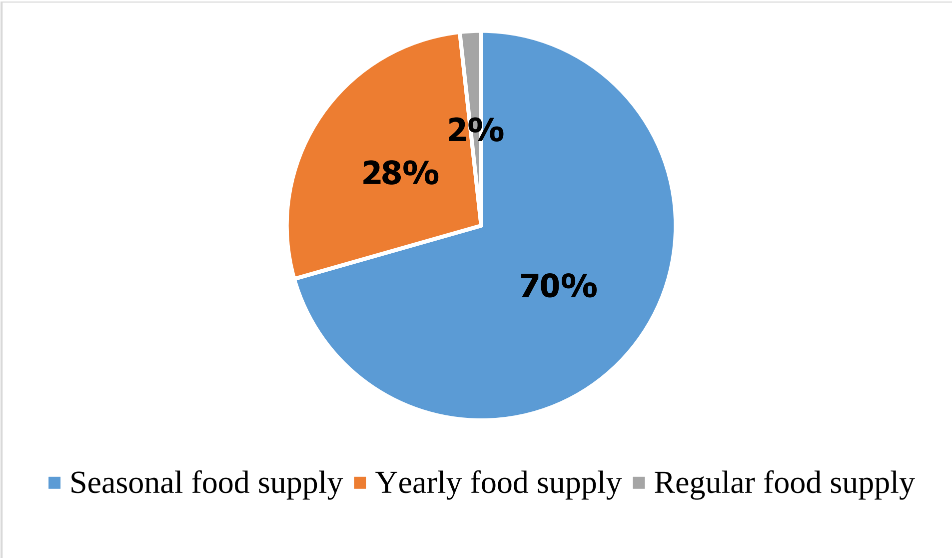


Fig. 2. Consumption method of wild edible plants of the study area

Common wild edible plant species commonly consumed during time of food shortage

The results revealed that some wild edible plant species are only consumed during periods of food shortage, such as *Balanites aegyptiaca* 43%, *Cordia africana* 15%, *Annona senegalenis* 12%, *Rosa abyssinica* 8%, *Cassia Siamese* 8%, *Ziziphus mucronata* 7%, & *Psidium guajava* 6% in the study area. The respondents indicated that most of the wild edible plants have multiple edible uses in the study area. Wild edible Fruit trees have been used as a source of food and medicine since time immemorial and they have become an integral part of the culture of the society throughout the country (Kassaye, *et al.*, 2006). This might be because these species are only used to supplement the normal diets of many rural people (Hidden, 2019).

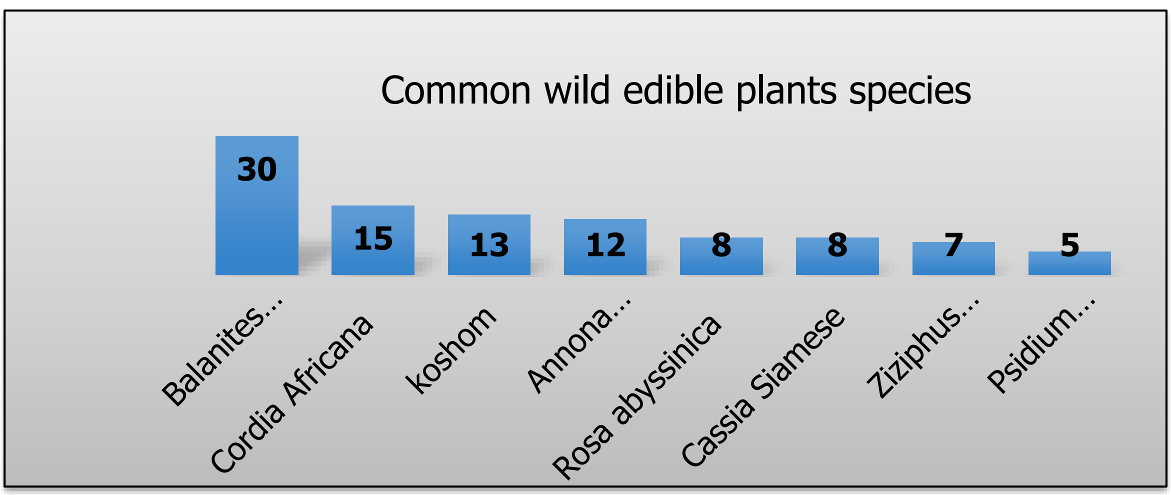


Fig 3: Common wild edible plants commonly consumed during time of food shortage

The Main Sources of Income for the Household in the Study Area

The main sources of income of the sampled households were farming (100%). Some income source revealed by the respondents included crop sale 40%, livestock products 24%, coffee and chat sales 17%, edible plants 13%, charcoal selling 3.53% as well as fuel wood selling 2.35%. The income generated from sales of wild edible fruit trees is marginal because of several social, economic, and cultural factors. This finding suggests that future promotion efforts towards enhancing the commercialization of wild edible fruit trees should be designed with packages that comprise cultural and social suits targeted to address specific local conditions. Domestication and integrating promising wild edible fruits trees into the existing land use systems in such a manner will eventually contribute to improved rural livelihoods (Asfaw & Tadesse, 2001, Teketay *et al*., 2010).

Table 7: Farmers preference for income adjacent to farming

Income sources	Income of respondents along different agro-ecologies								
	Babile district		M. ballo & G. gutu districts		Metta district		Total		
	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Rank
Crop sale	26	41.26%	22	36.07%	20	43.47%	68	40.00	1st
Livestock products	17	26.98%	13	21.31%	11	23.91%	41	24.12	2nd
Coffee and chat	7	11.11%	10	16.39%	5	10.87%	29	17.06	3rd
Edible fruit trees	9	14.29	11	18.03	9	19.56	22	12.94	4th
Charcoal selling	3	4.76	2	3.28	1	2.17	6	3.53	5th
Fuel wood selling	1	1.59	3	4.92	0	0	4	2.35	6th
Total	63	100%	61	100%	46	100%	170	100%	

Some of the common products are vegetables, grains, agricultural produce, fruits, animals, and their by-products sold in the village, local and road sides markets. The frequency of the market days and the demand for goods depends on the socio-economic conditions of the people in the area. In the study area, wild edible plants in limited quantities sold in door to door or on the roadside around villages. The respondents were sold wild edible plant at Villages market, local markets, road sides market and district markets. The respondents state that the value addition of wild edible plants may increase the price of the product by three to four times. For example, mango in raw fruit form is sold in villages markets, at 30 birr/kg whereas, it may increase to 60 birr/ kg if processed into mango juice.

Diversification of products is expected to increase profits, which are a good source of income for the community. In the. Similar result have been reported (Badimo *et al*., 2015). Hence, improving access to market and increasing the quality and quantity of wild edible fruits trees production are issues to be carefully addressed to enhance the market value of wild edible fruits trees and facilitate their domestication.

Wild Edible Plant Collector in the Study Area

In the study area, women and children usually collected wild edible plants in limited quantities in the wild, forests, woodland, home garden and from farmland. Though the total size of the population involved in wild edible plants collection is less significant, the result provides an indication that women and children are responsible in wild edible plants collection in numbers were 39% and 36% and totally were frequent 75.88% of the households that collect wild edible plants. Differences between genders in the collected of wild edible plants are influenced by different objectives, perceptions, interests, and access to resources between communities. This result substantiates the considerable opportunity gained by these family members to contribute to the overall household economy. It was noted that people from areas closer to the wild and forests tend to collect and sell edible wild plants more than those from distant areas. Wild edible plants have been associated with the traditions and culture of local peoples (Medley & Kalibo 2007; Addis *et al.* 2013).

Table 8: Household members collected wild edible fruit tree

Wild edible plant collected	Collector of wild edible plants along different agro-ecologies							
	Babile district		**M. ballo & G. gutu districts**		**Metta district**		**Total**	
	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)
Women	26	41.26%	23	37.70%	18	39.13%	67	39.41%
Young children	23	36.51%	23	37.70%	16	34.78%	62	36.42%
Youth	14	22.22%	14	22.95%	10	21.74%	38	22.35%
Elder peoples	0	0.0	1	1.639	3	6.52	4	2.35%
Total	**63**	**100%**	**61**	**100%**	**46**	**100%**	**170**	**100%**

Abundance of Wild Edible Plant Species in the Study Area

The potential of wild edible plants varied from site to site with altitudinal differences. The distribution of wild edible plant varied between agro ecology. A total of potential are low 55.29%, medium 40.59% and high 4.18%. The lowland area had the medium potential, midland area had the lowest and highland area had the lowest potential of wild edible fruit trees. Overall, potential production from trees and shrubs were highest than herbs and climber.

Table 9: Potential of wild edible plants in the land use system in the study area

Potential of wild edible plants	Potential of wild edible plants along different agro-ecologies							
	Babile district		**M. ballo & G. gutu districts**		**Metta district**		**Total**	
	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)
Low	15	23.81%	39	63.93%	40	86.96%	94	55.29%
Medium	45	71.43%	18	29.51%	6	13.04%	69	40.59%
High	3	4.76%	4	6.56%	0	0.0%	7	4.18%
Total	**63**	**100%**	**61**	**100%**	**46**	**100%**	**170**	**100%**

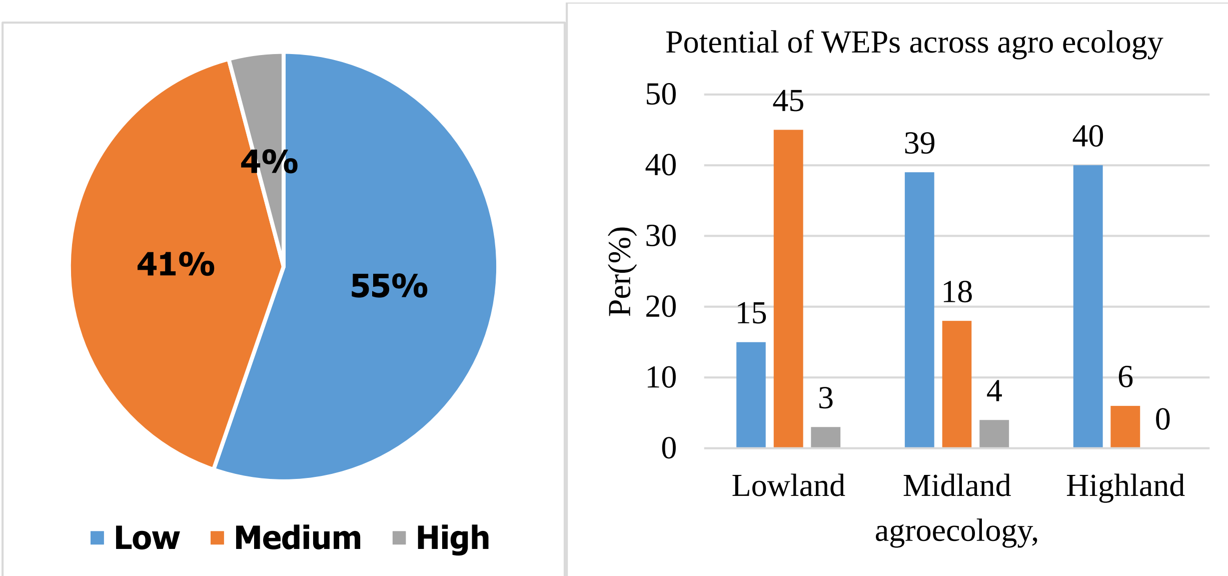


Fig.3. Distributions of edible wild plants in different agro-ecologies in the study area

The number of wild edible plants species were higher in highland next to mid-land agro-ecology than in lowland agro-ecologies of the study area. Lowland was the least agro-ecology in the distribution of wild edible plants in study districts (see fig. 3). The distribution of different wild edible plants in different agro-ecologies indicates the adaptation of these species in different environmental conditions. This indicates that plants adapted to variable climate are generally drought intolerant. The response of majority respondents to abundance of wild edible plants species in the study area now day comparing to the past is decreasing 94.71% and increasing 5.29%. Most of the respondents believed that, the abundance is decreasing followed by those who said it is as previous and no increasing happened to them. These plants grow abundantly in the wild and have economic potential as a source of household income. However, efforts should be made to domesticate or cultivate them in the communities' farmlands.

Table 10: Current abundances wild edible fruit trees

Current abundances	Current abundances of wild edible plants along different agro-ecologies							
	Babile district		M. ballo & G. gutu districts		Metta district		Total	
	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)
Decreasing	59	93.65%	60	98.36%	42	91.30%	161	94.71%
Increasing	4	6.35%	1	1.64%	4	8.69%	9	5.29%
No change	0.0%	4.76%	0.0%	6.56%	0.0%	0.0%	0.0%	0.0%
Total	63	100%	61	100%	46	100%	170	100%

Demographic and Socio-Economic Characteristics of Household Respondents

The farmers in the study area live under different socioeconomic conditions in terms of gender, age, family size, education, marital status, household relationships, occupation, farming experience, and wealth status. A total of 170 respondents were interviewed through both household survey and key informant interviews.

The study were observed that the respondents relationships and consumed by the community, and they were the most useful species among those listed for the studied areas.

Table 2: Demographic and socio-economic characteristics of households respondents (n = 170)

Variables	Respondents information along different agro-ecologies							
	Babile district		**M. ballo & G. gutu districts**		**Metta district**		**Total**	
Gender	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)
Male	52	82..54%	46	75.41%	34	73.91%	132	77.65%
Female	11	17.46%	15	24.59%	12	26.08%	38	22.35%
Total	**63**	**100%**	**61**	**100%**	**46**	**100%**	**170**	**100%**
Age	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)
20-30	32	50.79%	17	27.89%	27	58.69%	76	44.71%
31-40	19	30.16%	34	55.74%	15	32.61%	68	40.0%
41-60	8	12.69%	7	11.46%	2	4.35%	17	10.0%
>61	4	6.35%	3	4.92%	2	4.35%	9	5.29%
Total	**63**	**100%**	**61**	**100%**	**46**	**100%**	**170**	**100%**
HH size	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)
1-3	35	55.56%	22	36.06%	24	52.17%	81	47.65%
4-7	17	26.98%	31	49.21%	16	34.78%	64	37.65%
8-11	6	9.52%	5	8.19%	4	8.69%	15	8.82%
>12	5	7.94%	3	4.92%	2	4.34%	10	5.82%
Total	**63**	**100%**	**61**	**100%**	**46**	**100%**	**170**	**100%**
Education	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)
Illiterate	34	53.96%	28	45.90%	19	41.30%	81	47.65%
Pri. school	26	41.26%	28	45.90%	20	43.47%	74	43.53%
Sec. school	3	4.76%	5	8.19%	6	13.04%	14	8.14%
Diploma	0	0%	0	0%	1	2.17%	1	0.59%
Total	**63**	**100%**	**61**	**100%**	**46**	**100%**	**170**	**100%**
Mar. status	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)	Freq.	Per (%)
Married	62	98.41%	58	95.08%	44	95.65%	164	94.47%
Divorce	1	1.59%	0	0%	0	0%	1	1.76%
single	0	0%	1	1.64%	2	4.35%	3	1.18%
widowed	0	0%	2	3.28%	0	0%	2	0.59%
Total	63	100%	61	100%	46	100%	170	100%

The majority of the respondents were male and next to female. The analyses depicted that male-headed families were common, making up to about 77.65% and 22.35 % were female-headed families. When concerned age groups, from each study site, 20 to 30 households participated with an age range of 20 years and above. The age majority of the respondents were between 20-30 and 31-40 years old, with a share of more than 45% and 40%), followed by 41-60 and greater than 60 years old occupying 110% and 5.29%, respectively. The average family size of the households was 6.5. Household size ranged from 1 to 3 household size were 47.65% followed by 4 to 7 household size, 37.65% and 8 to 11 household size 8.82% and lastly, household size greater than 12 were 5.82%.

The majority of respondents had not received formal education 48%. Education level ranged from no formal education 47.65% followed by primary school 43.53% and secondary schools 8.14% and lastly, tertiary schools (post-secondary) (0.59%). Marital status, the majority of the respondents were married, with a share of more than 96.47%, followed by single and widowed 1.76% and 1.18% respectively, as well as those divorced were less 0.59% (**Table 2**).

Household occupation also assessed, the majority of the respondents were farming occupation 90% and followed by government employment were 8.23% and local trader were 1.76%. All of the respondents had inhabited the area in average years for 35 at the category of 21 to 40 years lived were 52.94%, next 15 to 20 were 31.18% and the last were 15.88% lived more than 41 years in the area ,in the three agro ecologies. The Farming experience of the respondents were analyzed, the respondents were accounted in average 15 years' has farming experience ranged from 10 to 20 were 57.06% followed by 21 to 40 years were 31.18% and lastly, the respondents greater > 41 year were 11.76% in thee agro ecologies.

Table 3: Demographic and socio-economic characteristics of households respondents (n = 170)

Variables	Respondents information along different agro-ecologies							
	Lowland (Babile woreda)		**Midland (M. ballo & G. gutu woreda)**		**Highland (Metta woreda)**		**Total**	
Occupation	Number	Frequency	Number	Frequency	Number	Frequency	Number	Frequency
Farming	59	93.65%	51	83.61%	43	93.47%	153	90.0%
Employer	4	6.49%	7	11.48%	3	6.52%	14	8.23%
Trading	0	0%	3	4.91%	0	0%	3	1.76%
Total	63	100%	61	100%	46	100%	170	100%
Year lived	Number	Frequency	Number	Frequency	Number	Frequency	Number	Frequency
15-20	18	50.79%	17	27.89%	18	58.69%	53	31.18%
21-40	33	30.16%	34	55.74%	23	32.61%	90	52.94%
>41	12	12.69%	10	11.46%	5	4.35%	27	15.88%
Total	63	100%	61	100%	46	100%	170	100%
Experience	Number	Frequency	Number	Frequency	Number	Frequency	Number	Frequency
10-20	36	55.56%	32	36.06%	29	52.17%	97	57.06%
21-40	16	26.98%	24	49.21%	13	34.78%	53	31.18%
>41	11	9.52%	5	8.19%	4	8.69%	20	11.76%
Total	63	100%	61	100%	46	100%	170	100%
W. status	Number	Frequency	Number	Frequency	Number	Frequency	Number	Frequency
Rich	2	31.75%	6	9.84%	7	15.22%	15	8.83%
M. income	32	50.79%	39	63.93%	23	50.0%	94	55.29%
The poor	29	46.03%	16	26.22%	16	34.78%	61	35.88%
Total	63	100%	**61**	100%	**46**	100%	**170**	**100%**

Analysis among households with different wealth status were assessed. Wealth status of the households from middle income were 55.29% and followed by from poor households were 35.88%, and last of respondents from rich households in wealth status were 8.83% (**Table 3**).

Correlation of Age, Gender, Family Size, Education, Occupation and Wealth status with Traditional Knowledge of People on Edible Wild Plants in the Study Area

Traditional knowledge of respondents on wild edible plants positively correlated with age, gender, family size, and wealth status and negatively correlated with education, occupation and marital status of household of respondents. Traditional knowledge of respondents in the study area significantly correlated with age, gender, family size, and wealth status ($p<0.05$). There was some knowledge difference between genders. The gender, age, family size and wealth status have a direct proportion with traditional knowledge of respondents on edible wild plants. There was some knowledge difference between genders (Table 7).

Table 7: Pearson's correlations of gender, age, family size, education, occupation and wealth status with indigenous knowledge of respondents on wild edible plants

Demographic and socio-economic characteristics	Indigenous knowledge with P value
Gender	0.013*
Age	0.027**
Family Size	0.04**
Education	0.221
Occupation	0.661
Marital status	0.402
Wealth status	0.020*

The analysis showed that female households relatively collector of wild edible plants more than male-headed household do significant mean differences ($P<0.05$) were observed. The gender distinction in collected of wild edible plants from wild were ascribed to many different reasons, including that it was a job familiar to females, it was a work during feul wood collection, and female income is low. Differences between genders in the collected of wild edible plants are influenced by different objectives, perceptions, interests, and access to resources between communities. It was noted that female from areas closer to the wild and forests tend to collect and sell edible wild plants more than those from distant areas.

The relation of age and wild edible plants results of differences in knowledge among average age groups of farmer households. The results of the study showed that middle age (40 age) informants identified wild edible plants relatively more knowledge than younger people, with a significant difference ($P<0.05$).This agrees with the general fact regarding age-wise distribution of indigenous botanical and ecological knowledge among rural farming communities. On the other hand, the number of edible wild plants listed by youths is smaller than mentioned by older persons that might be by fast westernization and lack of interest for their culture as noted by (Wiryono *et al*., 2017) in Central Bengkulu District, Bengkulu Province, Indonesia.

The family size have a direct proportion with traditional knowledge of respondents on edible wild plants. This might be people having large family member are more dependent on edible wild plants. An increase in the household size by one member, increases the likelihood of collecting wild edible plants (Kebede *et* *al*., 2017). Larger households with sufficient labor source tend to collect wild edible plants compared with those of small households. Analysis among households with different wealth status were assessed. Wealth status of the households from poor households were used edible wild plants than rich households. A majority of poor respondents agreed that edible wild plants are important part of their traditional diet. Traditional knowledge related to eating and harvesting wild edible plants are still passed on, while at some extent declining.

Major Threats Factors / Disappearances of Wild Edible Fruit Tree and Shrub Species

In the study area, most of the people were using variety of wild edible plants from forests. They were using roots, leaves, fruit or berries and other parts as a source of food and medicinal values for many years. But now day those plants are threatened comparing to the past by many factors. Despite their importance, wild edible plants face serious anthropogenic and environmental threats. Most of the respondents stated the factors for disappearing of wild edible plants were expansion of agriculture, deforestation, overgrazing, charcoal production/ fuel wood collection, tree pest and diseases, urbanization, drought and age of trees. So, agricultural expansion contribute 45.88%, deforestation 23.53%, overgrazing 13.53%, charcoal production 5.88%, and charcoal production/fuel wood collection were 5.29% found to be the most threatening factors. Due to these reason, many wild edible plants were became scarce in the study area. This finding was in agreement with the report by Tigist *et al.* (2006). It is also similar with results obtained in different investigation by Endashew (2007) which showed agriculture and population pressure severely threatened plant species in general. This is also similar to the a report which states the most common threats reported to wild edible plants were agricultural expansion, overgrazing/overstocking, deforestation and urbanization (Addis, 2009; Asfaw, 2009; Tilahun T and Mirutse G., 2010).

Table: Responses to the factors / disappearances of wild edible fruit trees and shrubs species

Major threats factors wild edible plants	Respondents information along different agro-ecologies					
	Lowland	**Midland**	**Highland**	**Total**	**Percent (%)**	**Rank**
Exp. of agriculture	30	28	20	78	45.88	1st
Deforestation	12	16	12	40	23.53	2nd
Overgrazing	7	8	8	23	13.53	3rd
Charcoal production	8	2	0	10	5.88	4th
Tree pest and diseases	3	4	2	9	5.29	5th
Urbanization	1	1	2	4	2.35	6th
Drought	1	2	1	4	2.35	7th
Age of trees	1	0	1	2	1.18	8th
Total	**63**	**61**	**46**	**170**	**100**	

Conservation/ Strategies Commonly Practiced by in Rural Communities for Wild Edible Plants Species

According to the respondents, the conservation measures taken to minimize challenges to wild edible plants were retain wild edible wild edible plants on farm, keeping existed plants from danger , prevent the miss use of plants , no cutting of wild edible trees , replanting the deforested areas ,and restoring with community and youth in the study area. Majority of respondents said that the conservation measures were retain wild edible plants on farm 34.12%, keeping existed plants from danger 28.82%, prevent the miss use of wild edible plants 18.24%, no cutting of wild edible plant 15.88%, replanting the deforested areas by traditional way 1.76%, and restoring in collaboration with community and youth 1.18%. This finding was in agreement with the reviewed research outputs on wild edible plants of the country indicate the need for conservation as well as documentation (Tekle and Giday, 2010; Fantahun and Hager, 2010). Conserving Ethiopian wild edible plants (Tekle and Giday, 2010). Conservation measures that combine domestication of potential wild edible plants into the existing production systems contributes towards diversification of food sources, ensuring food security and dietary diversity as well as maintaining biodiversity and environmental integrity (Asfaw & Tadesse 2001, Teketay et al. 2010).

Table: the conservation measures of wild edible fruit trees and shrubs species in the study area

Conservation measures of wild edible plants	Reposes of respondents along different agro-ecologies					
	Lowland	**Midland**	**Highland**	**Total**	**Per. (%)**	**Rank**
Retain wild edible fruit trees	26	17	15	58	34.12	1st
Keeping existed plants from danger	16	17	16	49	28.82	2nd
Prevent the miss use of plants	13	13	5	31	18.24	3rd
No cutting of wild edible l trees	4	14	9	27	15.88	4th
Replanting the deforested areas	2	0	1	3	1.76	5th
Restoring with community and youth	2	0	0	2	1.18	6th
Total	**63**	**61**	**46**	**170**	**100**	

Domestication of Wild Edible Plants Species in the Study Area

According to the respondents responded that they were not to domesticated because lack of convenience domestic wild edible plant species were 29.41%), slow growth rate were 28.82%, long productivity cycle 14.18%, wild edible plant yield less 14.18%, and no available all times 13.53% in all agro ecology of study area.

Reasons of not domesticating	Reposes of respondents along different agro-ecologies					
	Lowland	**Midland**	**Highland**	**Tota l**	**Per.(%)**	**Rank**
Lack of domestic wild edible trees	22	21	7	50	29.41	1st
Slow growth rate of wild edible trees	17	12	20	49	28.82	2nd
Long productivity cycle	5	7	12	24	14.18	3rd
Wilde edible fruit trees yield less	11	9	4	24	14.18	4th
No available all times	8	12	3	23	13.53	5th
Total	**63**	**61**	**46**	**170**	**100**	

Conclusions and Recommendations

Our survey study were identified 26 wild edible plants species represents 4 life forms: Trees, Shrubs, Herbs, and Climbers. The majority of the wild edible plants were recorded in the wild, but the integration of some plants in farm lands and home gardens indicate their potential to be used in different land use systems (wild and domestic). The wild edible plant species belong to four life forms namely trees, shrubs, herbs and climbers. Trees contributed 69%, shrubs 15%, and herbs 8%, while climbers contributed only 8% of all identified wild edible plant species. The life forms of wild edible plants in this study were diverse and accordingly the largest number of wild edible plant species found. Six edible parts of wild edible plants recorded in the districts. These are fruits, barks, seeds, leaves, stem, and root. Fruits comprise 82% of edible parts whereas bark 5%, seed 4%, leaf 4%, stem 3% and root were 2% provided. Most wild edible plants parts were eaten directly in fresh forms as raw fruit for consumption method.

The local people reported that about 80% of wild edible plants consumed raw fruits. Majority of respondents were used for income and food sources with additional diet along with domestic foods. It contribute as seasonal food supply and yearly food supply. Wild edible plant species are only consumed during periods of food shortage, such as *Balanites aegyptiaca*, *Cordia africana*, *Annona senegalenis*, *Rosa abyssinica*, *Cassia Siamese*, *Ziziphus mucronata*, and *Psidium guajava* in the study area. The main sources of income of the sampled households were farming (100%) and wild edible plants contribute income sources about 13%. Though the total size of the population involved in wild edible plants collection is less significant, the result provides an indication that women and children are responsible in wild edible plants collection. The distribution of wild edible plant varied among agro ecologies and the total potential of wild edible plants in the study area are low.

Distributions of edible wild plants in different agro-ecologies higher in highland than lowland area of wild edible plants. The current abundance of wild edible plants species in the study area comparing to the past is decreasing. The relationships of farmer's respondent of traditional knowledge on wild edible plants positively correlated with age, gender, family size, and wealth status and negatively correlated with education, occupation and marital status of household of respondents. Despite their importance, wild edible plants face serious anthropogenic and environmental threats. The threats factors for disappearing of wild edible plants were expansion of agriculture, deforestation, overgrazing, and charcoal production/ fuel wood collection. Some conservation measures taken to minimize challenges to wild edible plants were taken retain wild edible plants on farm, keeping existed plants from danger, prevent the miss use of plants, no cutting of wild edible trees. Not to domesticated because lack of convenience domestic wild edible plant species, slow growth rate.

Recommendations:

- ✓ There is an urgent need for research on the more domestication of wild edible plants in home gardens, mixing with domesticated crop plants in the study area to enhancing the wild edible plan species production for food security and dietary diversity in East Hararghe Zone therefor.
- ✓ Further research also targeted to collect and conserve, propagation and management activities of the wild edible plants identified species in the study area are.
- ✓ Further study must be carried out on nutritional contents of the wild edible plants species.
- ✓ Further study must be on strengthening botanical information, germplasm collection and genetic improvement, production, increasing the supply of high-quality planting materials, and promoting on-farm cultivation in the form of agroforestry systems to recognize the identifying and selecting preferred species,

Acknowledgements
The authors express their gratitude to the staff of Agroforestry Research Team of Bako Agriculture Research Center for their follow- up and data collection and Oromia Agricultural Research Institution for its financial support.

References

Addis, G. (2009). Wild and Semi-wild edible plants of Hamar and Xonso (South Ethiopia) with emphasis on their ethnobotany and nutritional composition of selected species.PhD thesis, Addis Ababa University.

Afolayan, A. and Jimoh, F. (2009).Nutritional quality of some wild leafy vegetables in South Africa. International Journal of Food Science and Nutrition 60 (5): 424-431.

Asfaw, Z. (2009). The future of wild food plants in southern Ethiopia: Ecosystem conservation coupled with enhancement of the roles of key social groups. ActaHorticulturae 806: 701-707.

Beluhan, S. and Ranogajec, A. (2010).Chemical composition and non-volatile components of Croatian wild edible mushrooms. Food Chemistry 124: 1076-1082.

DemelTeketay., FeyeraSenbeta., Maclachlan, M., Bekele, M. and Barklund, P. (2010).Edible Wild Plants in Ethiopia.Addis Ababa University Press, 575pp.

Grivetti, L. and Ogle, B. (2000). Value of traditional foods in meeting macro and micronutrient needs: the wild plant connection. Nutr.Res. Rev. 13: 31-46.

managementunit, SIDA, Nairobi, Kenya. Pp 766.

Ruffo, C.K., Birnie A. &Tengnäs B. 2002.Edible wild plants of Tanzania. Regional land

Teklehaymanot, T. and Giday, M. (2010).Ethnobotanical study of wild edible plants of Kara and Kewegosemipastoralist people in Lower Omo River valley, DebubOmo Zone, SNNPR, Ethiopia.Journal of Ethnobiology and Ethnomedicine 2010, 6: 23

Effect of Tapping on Gum and Incense Yield of Selected Trees Species in Elwaye and Dhas Districts, Borana Zone, Southern Oromia

Siraj Kelil, Sisay Taye, Tadesse Negash
Yabello Pastoral and Dryland Agriculture Research Center, Yaballo, Ethiopia.
Corresponding author's e-mail:kelilsiraj2012@mial.com

Abstract
Gum and resin-bearing tree species were one of the very important resources in Ethiopia. Particularly, Borana pastoralists used these resources as a source of income generation for their livelihoods. Gum arabic, a natural product used in numerous industries, is obtained from species of Acacia Senegal and Ethiopia is one of the producing countries with a large potential. Until now gum arabic production from Ethiopia comes mainly from the collection of naturally oozing tears of Acacia species. Improved tapping mechanism that enhance production quality and quantity is not common practice in Ethiopia. A study was conducted to determine the effect of different tapping machines on gum and incense producing tree species and to investigate the effect of tapping at different tree diameter classes on gum and incense yield improvement in the study area. Commiphora corrugate, Boswellia microphylla and Boswellia neglecta tree species were selected for their potential existence and economic importance. A factorial experiment was arranged in a randomized complete block design (RCBD) in which three types of tapping materials including natural oozing and three levels of tree size (diameter classes) were used. Accordingly, materials (Banga, axe, Sonki, and control) were applied at diameters of (5-8cm, 8.1-11cm and >11cm) for a tree height below DBH (at < 130cm) and above DBH (at >130cm) on selected tree species while natural oozing was remained untapped and used as controls. Accordingly, the highest mean yield was recorded for trees tapped by axe (5.99g/tree) followed by Sonki (5.01g/tree) and bigger diameter class >11cm (7.10g/tree) for Commiphora corrugate. The highest mean yield was also obtained for trees tapped by axe (10.76g/tree) in the first year and (43.71g/tree) in the second year and bigger diameter class >11cm (15.16 g/tree) in the first year and (47.81g/tree) in the second year for Boswellia microphylla. Moreover, the highest mean yield was recorded for naturally oozing trees (6.16g/tree) and bigger diameter class >11cm (6.33g/tree) for Boswelia neglecta. Tapped trees generally provided significantly higher yields than untapped or control trees and frankincense yield increased with increasing tree size (diameter). Thus gum yield can be increased significantly by tapping at a bigger stem diameter which can be used to boost the income of the producing rural community.

Keywords: Gum-resin, frankincense, tapping materials, yield, tapping diameter, tapping position

Introduction

Ethiopia owns one of the extensive forest vegetation resources in the Horn of Africa (WBISPP, 2005). Gum and resin-producing species cover substantial areas of Ethiopia and the country also has vast areas that can be considered potentially suitable for cultivating these tree crops all the country's arid and semi-arid lands, which cover an area of 560,000 – 615,000 km^2 (Mulugeta and Habtemariam, 2011). Ethiopia is one of the countries well-endowed with various species of Acacia, Boswellia and Commiphora that are known to produce gum arabic, frankincense and myrrh, respectively (Tadesse *et al*., 2007).Several Ethiopian indigenous trees and shrubs in these vast arid and semiarid lowlands of the country have been known to yield economically valuable products for several millennia (Eshetu, 2002 and Tadesse *et al*., 2004). Accordingly, Combretum-Terminalia woodlands, Acacia-Commiphora woodlands and lowland semi-desert and desert vegetation are known to harbor diverse high-value woody species, such as those that produce commercial gums and resins (i.e., gum arabic, frankincense and myrrh) (Abeje *et al*., 2005; Mulugeta and Habtemariam, 2011). Thus, over 60 gum and resin bearing species are found in the country and the total areas of oleo-gum resin bearing woodlands cover about 2.9 million ha of land in the country (Girmay, 2000, Tadesse *et al*., 2007).

In terms of regional distribution, gum-resin-bearing woody species are found in almost all regions occupies a significant portion of the landmass (Mulugeta *et al*., 2003; Jiregna *et al*., 2007; Adefires and Mohamed, 2008). In its economic importance, oleo-gum and resin collection and sale is reported to provide an income that ranked second after livestock in the livelihood of the pastoral community (Mulugeta *et al*., 2003). Moreover, the gum-resins producing species provide essential socio-economic and ecological services; the potential role they can play in the livelihood of local society and the nation at large is very significant (Mulugeta *et al*., 2003 and Adefires *et al*., 2011). The gum and resins-producing species were collected to serve as a source of food mainly during slag periods, means of income generation, and employment among local poor communities (Adefires *et al*., 2011; Yasin and Salah, 2014). Thus, a study from Tadesse *et al*., (2007) and his colloquies, at the household level, studies carried out in one region of Ethiopia have shown that the gum resins business provides income about 3 times greater than the contribution of crop farming. A similar report from (Abdulla, 2013) in the Yabello district, Borana zone indicated that the collection of NTFPs is the major cash income source of this rural. The use of these products adds a crucial dimension to a diversified livelihood base, and thus acts as a safety net particularly when there is a shortfall in agricultural production to minimize risk and fill the gap of food shortage.

However, despite the enormous importance of gum and resin-bearing species' ecological and socio-economic importance worldwide, these resources are under increasing anthropogenic and natural pressures (Adefires *et al*., 2012). This has been due to degradation resulting from agricultural expansion, overgrazing, fire, poor incense harvesting practices, etc. They are declining both in terms of size (deforestation) and quality of stands (degradation) at an alarming rate associated with the expansion of crop and livestock production as well as human settlement, overgrazing, fuelwood, and charcoal production, anthropogenic fire, and poor tapping practices (Jiregna *et al*., 2007; Mulugeta and Habtemariam, 2011).

Most of the current gum arabic production in Ethiopia is through collection from natural exudates (Mulugeta, 2005). The collection is mostly carried out by cattle herders, women, and children from tree trunks and branches. Tapping for the production of gum arabic involves removing sections of the bark with a sharp material (e.g. axe) (Girmay and Mulugeta, 2010). Tapping is practiced to enhance yield quantity and quality. For instance, tapping activities increased gum arabic yield by 77.42% as compared with untapped trees in Kenya (Wekesa *et al.*, 2009). However, gum arabic production is low in Borana due to there being no artificial tapping activity used and the absence of organized collection in the area (Chikamai, 2003 and Abeje *et al*., 2005). It is also stated that the collectors are unaware of the process of tapping for the production of good quality and quantity gum arabic (Mulugeta *et al*., 2003 and Gizaw, 2006). Therefore, this study is initiated to investigate the effect of different taping materials, tree diameter class and tapping position on gum arabic and incense yield thereby identifying appropriate tapping materials and positions based on stem diameter for selected tree species

Materials and Methods

Description of the study areas

The study was conducted in Dhas and Elwaya districts of the Borana zone. Geographically it is situated between 4º to 6º N latitude and 36º to 42º E longitude (Figure 1). The altitude of the Borana zone ranges from 1,000–1, 700 m above sea level featured by isolated mountains and valleys (Coppock, 1994; McCarthy *et al*., 2002). Elwaya, and Dhas districts are located at a distance of 590 and 730 km South of Finfine (the capital city of the Country), respectively (Teshome et al., 2019 and DDPDO, 2019). Borana is characterized by a semi-arid to arid climate (Kamara *et al*., 2005; Haile *et al*., 2011) and have two distinct rainfall peaks, which demonstrate the bimodal nature of rainfall (Coppock, 1994). The annual mean minimum and maximum temperatures varies from 13.72 to 27.26ºC and 14.63 to 27.33 for Elwaye and Dhas district respectively while the area receives mean annual rainfall of 749.75 and 679.98mm for Elwaya and Dhas district respectively (Figure 2 and 3). The topography consists of isolated mountains, valleys and depressions occupied almost entirely by pastoral and agro-pastoral populations (Coppock, 1994). Thus, Extensive pastoralism (nomadic pastoralism) is the main means of livelihood for the Borana people (Gelagay *et al*., 2007). Cattle, goats, sheep, and camels are important livestock species raised in the area.

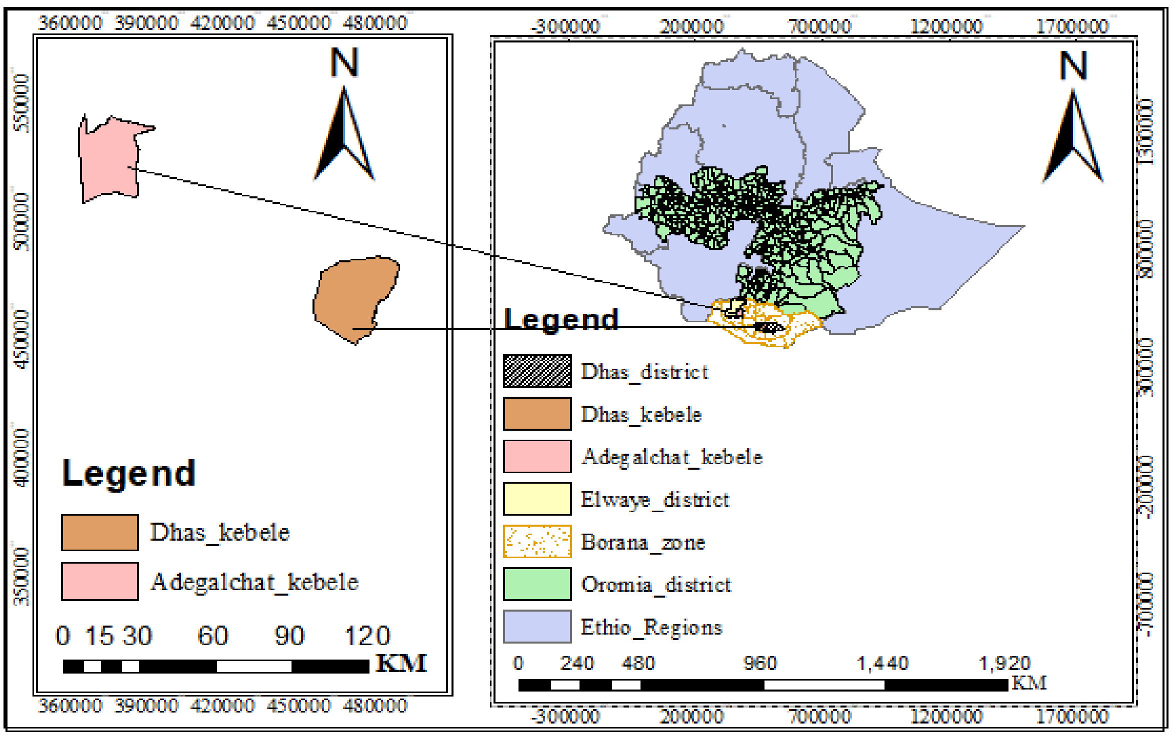


Figure 1: Location of the study area.

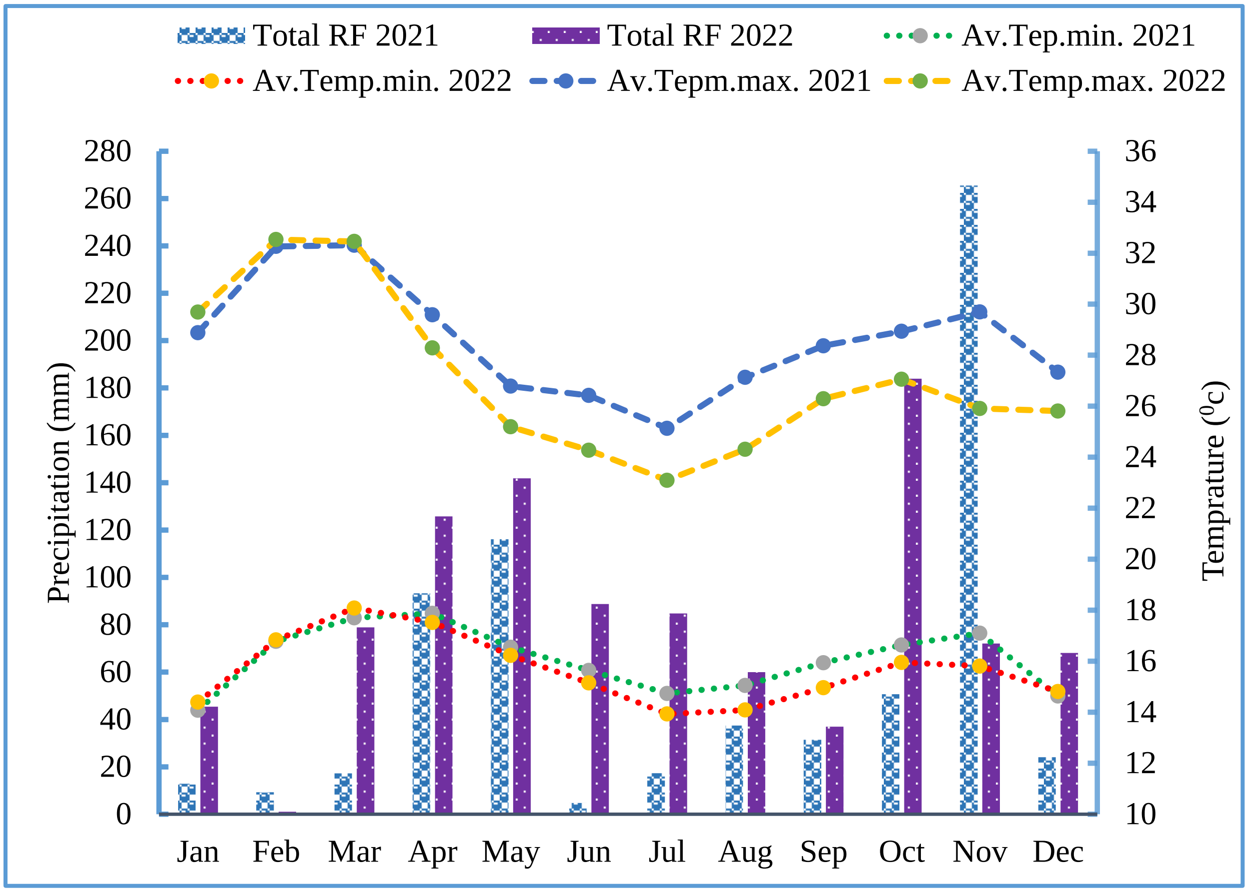


Figure 2: Total rainfall, average maximum and minimum temperature of Dhas District in 2021 and 2022

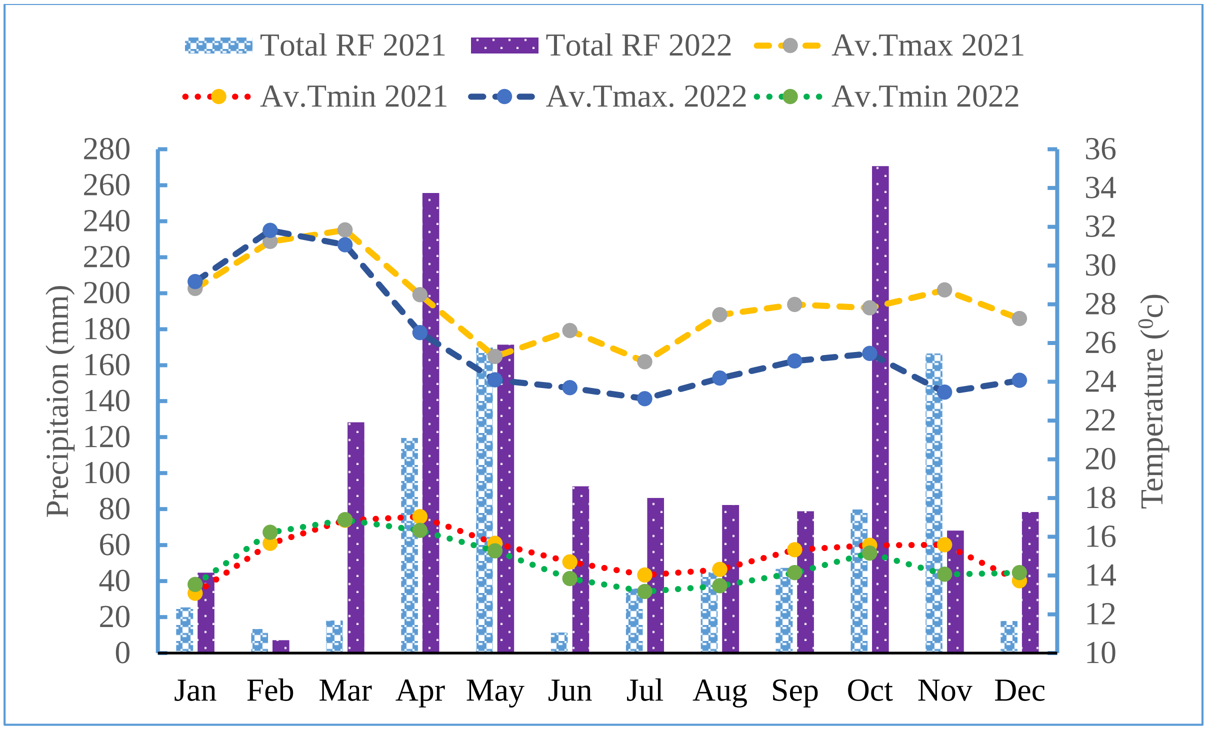


Figure 3. Total rainfall, average maximum and minimum temperature of Elwaya District in 2021 and 2022

Methods

The secondary data were collected and a reconnaissance survey was made in the woodland of the Borana zone and Dhas district (Dhas Kebele) and Elwaye district (Adegelchet Kebele) were selected as a potential areas of gum and incense bearing tree species. Following this, three gum and incense bearing tree species namely; Commiphora corrugate (siltachoo), *Boswellia microphylla* (Ilkabuqis) and *Boswellia neglecta* (Dakkara) were selected for this study. After the site selection of tree species, the sample plot was selected randomly and the experiment was be arranged with 4x3x2 factorial RCBD. The first factor was three different tapping tools namely banga, axe, Sonki and control (no use of tapping materials) as tapping tools had a great influence on the amount of ta/h gum production of *Acacia seyal* variety (Fadl and Gebauer, 2004), and it have a great impact both health and sustainable production. The second factor was the tree diameter class, which was tested in three diameter class levels (5.0-8.0 cm, 8.1-11.0 cm, >11cm) following (Wekesa *et al*, 2009). The third factor was tapping position (height); namely, below DBH (<130cm) and above DBH (>130cm).

The experiment was arranged in a factorial RCBD with three replications where blocks represent replications. The blocks were the three separate stands selected as the unique population of the species distributed at both districts. Each block will have 72 selected trees (samples) that represent the 24 treatments combination. All selected incense bearing tree species were measured for their DBH and classified according to the above stated diameter class. After the diameter was measured by the caliper they were tagged and the GPS point was recorded to identify easily during the collection time. Tapping incisions were made by each selected tapping material in the living bark at the middle part of the tree on the east- and west-facing sides of the trunk. The incision will be done with a length of 10-15cm and a width of 3cm *(*Wekesa *et al*, *2009)*. Three tree samples representing a single diameter class were marked and the total of 72*3 = 216 trees for one tree species and a total of 216*3 = 648 tree samples for all species were covered in this study. The gum and incense yield of each tree species was collected after four weeks following the tapping application and dried at room temperature for 72 hours (Mohammed and Rohle, 2009) and the yield of each tree was determined by weighing on the sensitive balance.

Table 2: Treatments combinations

No	Tapping Material	Diameter Classes (cm)	Height (Position) (cm)
1	Banga	≤8	Above 130cm
2	Axe	8.1 -11	Below 130 cm
3	Sonki	>11	
4	Natural oozing (control)		

Data collection and Analysis

Data recorded during the experiment were, the diameter class of each tree species and gum/incense yield. Finally, data were subjected to analysis of variance using SAS statistical software. The treatment means that were significantly different at a 5% level of significance were separated using the LSD test.

Results and Discussions

Effects of Treatments on Incense Yield of *Commiphora corrugate*

The analysis of variance indicated that frankincense yield differed significantly at ($P < 0.001$) between the different tapping materials and diameter class (Table 2). The analysis of variance also showed there was a significant tapping material and diameter class interaction effect on frank incense yield.

Table 3: Analysis of Variance of tapping data of *Commiphora corrugate*

Source	DF	Sum of Squares	Mean Square	F-Value	P-value
Study Years	1	11.32	11.32	7.94	0.005
Tapping Material	3	72.24	24.08	16.90	< 0.001
Tapping Position	1	3.64	3.64	2.55	0.112
Diameter class	2	457.29	228.64	160.48	< 0.001
Material * Position	3	0.78	0.26	0.18	0.909
Material * Diameter class	6	28.87	4.81	3.38	0.004
Material * Year	3	4.16	1.39	0.97	0.407
Position * Diameter class	2	2.29	1.14	0.80	0.45
Position * Year	1	1.48	1.48	1.04	0.309
DBH * Year	2	12.06	6.03	4.23	0.016
Material * Position * Diameter class	6	9.67	1.61	1.13	0.347
Material * Position * Year	3	0.48	0.16	0.11	0.953
Material * Diameter class * Year	6	16.47	2.74	1.93	0.08
Position * Diameter class * Year	2	0.65	0.32	0.23	0.797
Material * position * Diameter class * Year	6	3.04	0.51	0.36	0.906
Error	148	210.86	1.43		

Tapped trees generally provided a significantly higher yield than untapped trees. Thus, the maximum gain in yield was observed under trees tapped by axe (5.99g/tree) following trees tapped under Sonki (5.01gm/tree) while the lowest gain in yield was observed under untapped trees (4.18gm/tree). This finding confirms similar studies in southern Ethiopia where tapping yielded far more yield than untapped trees (Semegnew *et al.,* 2016). The results of this study clearly show that tree stem diameter (dbh) showed significant differences at ($p < 0.001$) in resin yield between the different tree diameters (Table 3). Accordingly, the yield of frankincense increased with increasing tree size (diameter). Thus, the yield obtained from the <8cm, 8.1-11cm and >11cm dbh trees/diameter class was 3.72, 4.06 and 7.10g per tree, respectively. The highest resin production was obtained from the largest trees (dbh >11cm) over 7g per tree. This result was also consistent with the works of Abbas *et al.,* (2009) in south Sudan that frankincense yield, was obtained from 10 -15cm and 16-20 cm stem diameter being 60% and almost 38% lower than that of stems over 20 cm stem diameter. These results contrast with studies in southern Ethiopia and western Sudan where gum arabic yield increased with increasing tree size /diameter (Ballal *et al*., 2005). This might be due to these tree species being different. Moreover, there is no significant difference ($p > 0.05$) observed in the yield of frank incense among the tapping position of these tree species implying that the tapping position evaluation had no effect on the quantity of frankincense for this tree species in the study sites.

Table 4: Mean ± Std. Error of main effects on frankincense yield of *Commiphora corrugate*

1. Study years	Mean yield (gm/tree)
2022	5.21 ± 0.13 [a]
2021	4.70 ± 0.13[b]
2. Tapping materials	
Axe	5.99 ± 0.18 [a]
Sonki	5.01 ± 0.18 [b]
Banga	4.652 ± 0.16[bc]
Natural oozing	4.18 ± 0.21[c]
3. Tapping position	
Above DBH	4.81± 0.13[a]
Below DBH	5.11±0.13[a]
4. Diameter class	
>11cm	7.10 ± 0.13 [a]
8.1 -11cm	4.06 ± 0.16 [b]
≤8cm	3.72 ± 0.17[b]
CV	39.83
R^2	76.6%

The mean yield of frankincense between tapping materials*diameter class of the study sites is presented in (Table 4). Accordingly, there is a significant difference ($p < 0.01$) in the mean yield of frankincense for all tapping materials*diameter class. Hence, the highest frankincense yield was obtained for axe tapping above the 11cm diameter class (8.62g) followed by banga tapping at tapping above the 11cm diameter class (6.78g) while, the lowest frankincense yield was obtained for Banga tapping at below 8cm diameter class (3.54g/tree) followed by Sonki tapping at below 8cm diameter class (4.1g/tree).

Table 5: Interaction effects of tapping materials, diameter classes on frankincense yield of *Commiphora corrugate*

Tapping Materials	Diameter class	Mean± *Std. E.* yield (gm/a tree)
Axe	>11cm	8.62±0.26[a]
	8.1 -11cm	4.99±0.36[c]
	≤ 8 cm	4.36±0.3c[d]
Banga	>11cm	6.78±0.27[b]
	8.1 -11cm	3.64±0.28[d]
	≤ 8cm	3.54±0.3[d]
Natural oozing	>11cm	6.68±0.25[b]
	8.1 -11cm	2.97±0.34[d]
	≤ 8cm	2.89±0.46[d]
Sonki	>11cm	6.31±0.29[b]
	8.1 -11cm	4.63±0.32[cd]
	≤ 8cm	4.1±0.31[cd]

Generally, a frankincense or gum tree species can be wounded and the gum or incense yield can be harvested after a month. This means that, in the practical situation of the study area, gum and incense yield can be collected three times in a year. Accordingly, an average of 17.97gm of incense can be harvested per one Commiphora corrugate (Siltachoo) incense tree per year.

Effects of Treatments on Frankincense Yield From *Boswellia Microphylla*

Boswellia microphylla is one of the gum-resin-bearing species in Borana. The frankincense produced from *B. microphylla* trees is a physiological process and as such tapping practices ant atmospheric conditions affect its yield production. The yield obtained from *B. microphylla* in 2021 was lower than that of 2022 and the data of 2021 and 2022 (Table 7); this might be because of the atmospheric temperature variation over the two years. Analysis of variance pointed out that there were significant differences among tapping materials (Axe, Banga, and natural oozing) both in the 2021 and 2022 study years ($F = 4.38$, $p < 0.01$; $F = 37.47$, $P < 0.001$) respectively (Table 5).

Tapping/wounding of the bark generally provided a significantly higher yield than untapped trees or natural oozing. The frankincense yield obtained from *Boswellia microphylla* tapped by Axe was highest (10.76 ± 0.8 gm/tree in 2021 and 43.71 ± 1.97gm/tree in 2022) than those tapped with Banga, Sonki, and natural oozing in both years. The lowest yield was obtained from natural oozing which was 8.32 ± 0.73 gm/tree in 2021 and 14.19 ± 1.97gm/tree in 2022 (Table 6). Tapping by Axe increases the frankincense yield by 17% on average compared to natural oozing. The yield obtained from a tree tapped by Banga and Sonki was not significantly different from each other, however, better than the yield obtained from natural oozing and lower than that of the tree tapped by Axe (Table 6).

Table 6: Analysis of Variance (ANOVA table) of treatments effects on yield of *Boswellia microphylla*

Year	**Source of Variation**	**D. f**	**Sum of Squares**	**Mean Square**	**F- value**	**P- value**
	Materials	3	247.95	82.65	4.38	0.007
	Position	1	12.24	12.24	0.65	0.423
	Diameters Class	2	2196.43	1098.22	58.16	<0.001
Year I	Materials *position	3	33.10	11.03	0.58	0.627
(2021)	Materials * Diameters Class	6	375.21	62.54	3.31	0.006
	Position * Diameters Class	2	85.83	42.92	2.27	0.11
	Materials *position* Diameters	6	137.69	22.95	1.22	0.308
	Error	73	1378.56	18.88		
	Materials	3	15745.40	5248.47	37.47	< 0.001
	Position	1	3574.55	3574.55	25.52	< 0.001
	Diameters Class	2	33177.50	16588.75	118.43	< 0.001
Year II	Materials *Position	3	3774.75	1258.25	8.98	< 0.001
(2022)	Materials * Diameters Class	6	7567.92	1261.32	9.01	< 0.001
	Position * Diameters Class	2	559.82	279.91	2.00	0.14
	Materials *Position *Diameters	6	1732.05	288.68	2.06	0.063
	Error	120	16808.44	140.07		

The effects of tapping potions (the upper and lower part of a tree) on the frankincense yield of *B. microphylla* were evaluated. The effects of tapping potions showed irregular trends. There was no significant difference between the two tapping positions (above and below DBH) in 2021(F= 0.65, $P > 0.05$), however, the two tapping position was a significant difference in 2022 (F= 25.52, $P < 0.001$) (Table5). The frankincense yield of *B. microphylla* obtained from below DBH (33.64 ±1.39 gm/a tree) was greater than that of above DBH (23.67 ±1.39gm/a tree) in 2022(Table 6). Even though there was no statistically different, the yield collected from below DBH was also greater than that collected from Above DBH in 2021.

In terms of diameter classes, a significant difference was observed in frankincense yield of *B. microphylla* among the three diameter classes in both 2021 (F = 58.16, $P < 0.001$) and, 2022 (F=118.43, $P < 0.001$) study years (Table 5). The highest yield was obtained from trees in the largest diameter class (>11cm) in the other classes and the lowest yield was obtained from the smaller diameter class (< 8cm) in both the 2021 and 2022 study years (Table 6). This result is consistent with the studies on *Boswellia papyrifera* pointed out that the highest resin production is obtained from the largest diameter trees than the smallest (Abbas *et al.*, 2009, Elias *et al.*, 2020). This result was in contrast with the works of Semegnew *et al.*, (2016) stated that the highest yield *Acacia senegal* gum Arabic was obtained from trees in the smallest diameter class than the largest classes. This may be due to species variation.

Table 7: Mean yield (gm/a tree) of incense of *Boswellia microphylla*

Tapping Materials	**Year I (2021)**	**Year II (2022)**
Axe	10.76 ± 0.8a	43.71 ± 1.97^{a}
Banga	10.69 ± 1.18ab	29.17± 1.97^{b}
Sunkey	8.26 ± 0.8bc	27.54 ± 1.97^{b}
Natural oozing	7.74 ±1.07c	14.19 ± 1.97^{c}
Tapping Position		
Below DBH	9.12 ± 0.66^{a}	33.64 ±1.39^{a}
Above DBH	8.32 ± 0.73^{a}	23.67 ±1.39^{b}
Diameter Classes		
>11cm	15.16 ± 0.69 a	47.81 ±1.71^{a}
8.1 -11cm	8.42 ± 0.84b	27.46 ± 1.71^{b}
≤ 8cm	2.54 ± 0.98c	10.69 ± 1.71^{c}
CV	45.25	33.21
R^2	71.9	79.9%

There was no significant interaction effect observed among the tapping materials, tapping position, and diameter classes. The significant interaction effects were detected between tapping materials and diameter class in both 2021 and 2022 study years; (F= 3.31, *P*< 0.01) and (F= 9.01, *P*< 0.001) respectively (Table 5). The highest frankincense yield of *B. microphylla* (21.08gm/Tree) was recorded from a tree >11cm diameter class tapped with Axe while the lowest yield (2.33 gm/tree) was recorded from natural oozing trees with < 8cm diameter class in 2021 (Table 7).

Table 8: Interaction effects of tapping materials and diameter class on frankincense yield of *Boswellia microphylla*

Tapping Material	Diameter Classes	Mean yield (gm/a tree)	
		Year II (2021)	Year II (2022)
Axe	>11cm	21.08 ±1.32^{a}	71.05 ± 3.42a
	8.1 -11cm	8.59 ±1.32^{cd}	48.75 ± 3.42b^{b}
	≤ 8cm	2.69 ± 1.54^{e}	11.325 ± 3.42^{cd}
Banga	≥11cm	14.38 ± 1.54^{b}	53.825 ± 3.42^{b}
	8.1-11cm	12.38 ± 1.98^{bc}	23.092 ± 3.42^{cd}
	≤ 8cm	2.47 ± 2.51^{e}	10.592 ± 3.42^{cd}
Sunkey	>11cm	14.91 ± 1.37^{b}	42.196 ± 3.42^{b}
	8.1 -11cm	6.63 ± 1.32^{d}	27.613 ± 3.42^{cd}
	≤8cm	2.70 ± 1.45^{e}	12.821 ± 3.42^{cd}
Natural oozing	>11cm	10.34 ±1.32^{c}	24.175 ± 3.42^{c}
	8.1-11cm	6.08 ± 1.98^{de}	10.375 ± 3.42^{cd}
	≤8 cm	2.33 ± 2.17^{e}	8.017 ± 3.42^{d}

In general, gum and incense yield can be collected three times in a year in the study area and an average of 81.71gm of incense can be harvested per one *Boswellia microphylla* (Ilkabuqis) incense tree per year using axe.

Effects of treatments on Incense Yield of *Boswellia neglecta*

The effects of tapping material, tapping diameter classes, and tapping height on the Yield of *Boswellia neglecta* were conducted in 2021 and 2022 at two sites (Adegelchet and Dhas) in Borana woodland. Analysis of variance revealed that there was no significant difference in the mean yield of two study locations and study years. Significant differences were observed among tapping materials ($P < 0.001$), diameter classes ($p < 0.001$), and between tapping positions ($P<0.01$) (Table 8).

Table 9: Analysis of Variance (ANOVA table) of treatments effects on *Boswellia neglecta*

Source of Variations	DF	Sum Sq	Mean Sq	F value	Pr (>F)
Location	1	1.22	1.22	0.34	0.560
Year	1	0.75	0.75	0.21	0.647
Tapping Materials	3	356.09	118.70	33.27	< 0.001***
Tapping Position	1	25.76	25.76	7.22	0.008**
Diameter classes	2	616.08	308.04	86.35	< 0.001***
Location*Year	1	52.54	52.54	14.73	< 0.001***
Location*Material	3	20.34	6.78	1.90	0.131
Location*Position	1	6.70	6.70	1.88	0.172
Year*Position	2	26.42	13.21	3.70	0.026*
Mat*Position	3	6.59	2.20	0.62	0.605
Location*Diameter class	1	1.81	1.81	0.51	0.478
Year*Diameter class	2	23.08	11.54	3.23	0.041
Material*Diameter class	3	108.23	36.08	10.11	< 0.001***
Position*Diameter class	6	227.95	37.99	10.65	< 0.001***
Location*Position	2	20.53	10.27	2.88	0.058
Location*Year*Material	3	45.17	15.06	4.22	0.006**
Location*Year*Position	1	0.01	0.01	0.00	0.970
Location*Material*Position	2	50.52	25.26	7.08	0.001**
Year*Material*Position	3	18.76	6.25	1.75	0.157
Location*Year*Diameter class	6	28.70	4.78	1.34	0.240
Location*Material*Diameter class	2	2.22	1.11	0.31	0.733
Year*Material*Diameter class	3	7.76	2.59	0.73	0.538
Location*Position*Diameter class	6	19.58	3.26	0.92	0.485
Year*Position*Diameter class	2	5.62	2.81	0.79	0.456
Material*Position*Diameter class	6	64.51	10.75	3.01	0.008**
Location*Year*Material*Position	2	17.04	8.52	2.39	0.094
Location*Year*Material*Diameter class	5	14.97	2.99	0.84	0.523
Location*Year*Position*Diameter class	2	5.49	2.74	0.77	0.465
Location*Material*Position*Diameter class	4	15.69	3.92	1.10	0.358
Year*Material*Position*Diameter class	6	20.28	3.38	0.95	0.462
Location*Year*Material*Position*Diameter class	2	3.67	1.84	0.51	0.599
Error	208	742.01	3.57		

The result of this study indicated incense yield of *B. neglecta* better under natural oozing. The yield obtained from natural oozing was significantly highest (6.155gm/tree) as compared to other tapping materials. The results would suggest that there is no impact of tapping trees on the frankincense yield *B. neglecta*. We found small worms in the natural oozing which may be contributing to high yielding under natural oozing. However, only a few individual trees/arcs of the area give the products. In the case of diameter classes similar to other species, the highest resin production was obtained from the largest diameter class trees (dbh >11cm) over 6.16 gm per tree (Table 9) and the lowest yield was obtained from smaller size trees (2.07gm/tree). The position of tapping had a significant effect on the resin production of *B. neglecta.* Trees produced a higher resin yield of 4.42 gm/tree above DHB than below DBH which was about 3.62gm/tree. The results in lined with the findings of a study by Abbas *et al*., (2009) found the resin yield of *B. papyrifera* was highest at tapping above 150 cm from the base of trees.

Table 10: Mean ± Std. Error effects of main treatments on Incense yield of ***Boswellia neglecta***

Treatments	**Levels**	**Mean Yield (gm/a tree)**
Tapping Materials	Natural oozing	6.155±0.238[a]
	Axe	3.386±0.257[b]
	Sonki	3.246±0.242[b]
	Banga	3.072±0.263[b]
Diameter Classes	> 11cm	6.33±0.19[a]
	8.1 - 11 cm	3.49±0.23[b]
	≤ 8 cm	2.07±0.23[c]
Tapping Position	Above DBH	4.42±017[a]
	Below DBH	3.62±017[b]
CV		43.27
R^2		79.8%

There was a significant interaction effect of tapping material, Tapping position, and diameter class on the frankincense yield of *B. neglecta* (F=3.01, *P*<0.01). The highest yield was recorded under natural oozing collated from the above position of a tree (above DBH) of a tree DBH greater than 11cm (13.47 ± 0.50 gm/tree); followed by natural oozing from below DBH of similar diameter class (7.65± 0.52gm/tree)(Table 10). The frankincense yield of *B. neglecta* obtained from a tree diameter class greater than 11cm tapped at the above DBH position by Axe was (7.10 ± 0.60 gm/tee) the best next to the yield obtained from natural oozing. The lowest frankincense yields were obtained from the above DBH position of smaller diameter trees tapped by Banga (1.46±0.771), Sonki (1.56 ± 0.64), and Axe (1.61 ± 0.66). Generally, there was a significant and positive correlation between tree diameter size and frankincense yields of *B. neglecta* trees.

Table 11: Mean ± Std. Error Incense yield of Tapping Materials*Tapping Position*DBH class for *Boswellia neglecta*

Tapping Materials	Diameter Classes	Tapping Position	Yield (gm/ a tree)
Natural oozing	> 11cm	Above DBH	13.47 ± 0.50[a]
Natural oozing	> 11cm	Below DBH	7.65± 0.52[b]
Axe	> 11cm	Above DBH	7.10 ± 0.60[b]
Natural oozing	8.1- 11cm	Above DBH	6.66 ± 0.51[b]
Sonki	> 11cm	Below DBH	5.54 ± 0.62[bc]
Banga	> 11cm	Below DBH	4.34 ± 0.50[c]
Axe	> 11cm	Below DBH	4.29 ± 0.56[c]
Banga	> 11cm	Above DBH	4.279 ± 0.47[c]
Sonki	> 11cm	Above DBH	4.17 ± 0.51[c]
Natural oozing	8.1 - 11cm	Below DBH	4.04 ± 0.71[cd]
Sonki	8.1 -11cm	Below DBH	3.09 ± 0.56[cd]
Banga	8.1 -11cm	Above DBH	3.07 ± 0.68[cd]
Natural oozing	≤8cm	Above DBH	2.79 ± 0.55[cd]
Axe	8.1 -11cm	Below DBH	2.77 ± 0.59[cd]
Banga	8.1 -11cm	Below DBH	2.63 ± 0.67[cd]
Sonki	8 .1-11cm	Above DBH	2.59 ± 0.68[cd]
Axe	8.1 - 11cm	Above DBH	2.59 ± 0.76[cd]
Sonki	≤ 8cm	Below DBH	2.36 ± 0.55[cd]
Natural oozing	≤ 8cm	Below DBH	2.32 ± 0.68[cd]
Banga	≤ 8cm	Below DBH	2.25 ± 0.75[cd]
Axe	≤8cm	Below DBH	1.87 ± 0.64[d]
Axe	≤ 8cm	Above DBH	1.61 ± 0.66[d]
Sonki	≤ 8cm	Above DBH	1.56 ± 0.64[d]
Banga	≤ 8cm	Above DBH	1.46±0.771[d]

Gum and incense yield can be collected three times in a year in the study area. As a result, an average of 18.47gm of incense can be harvested per one *Boswellia neglecta* (Dakkara) incense tree per year through natural oozing.

Conclusions and Recommendations

Commiphora corrugate, *Boswellia microphylla and Boswellia neglecta* are among the frankincense gum-resin-bearing tree species naturally grown in Borana rangelands. Frankincense from these species is collected from natural exudates and has no tapping at all. The producers are mainly herdsmen, women, and children, and they do the collection side by side with herding and other activities. A key result in the present study was found that tapping of *Commiphora corrugate* and *Boswellia microphylla* increases frankincense yield by 17% on average compared to natural oozing. The maximum yield was observed under trees tapped by Axe when compared to Banga, Sonki, and natural oozing. However, the resin production from *Boswellia neglecta* was highest under natural oozing compared to tapping. We found small worms in the natural oozing which may be contributing to better yield under natural oozing. In the case of diameter classes, the highest frankincense yields were obtained from large-size trees (dbh >11cm) for all species. In generally, gum and incense yield can be collected three times in a year in the study area. Accordingly, an average of 17.97gm, 81.71gm and 18.47gm of incense can be harvested per one of *Commiphora corrugate* (siltachoo) and *Boswellia microphylla* (Ilkabuqis) per year using axe and Boswellia neglecta (Dakkara) tree through natural oozing per year respectively. Therefore, to get better yield from *Commiphora corrugate* and *Boswellia microphylla* species Axe was the better and should be taken as the recommended tool for tapping, and tapping at lower parts of the stem of larger size trees provides a better yield of frankincense. For *Boswellia neglecta* highest yield was obtained from natural oozing, consequently, more studies are needed on the contributions of the worms natural found in the natural oozing. Moreover, further research should be done on long-term tapping effects on yields, trees healthy, and vulnerability to insect damage.

Acknowledgments
The authors express their gratitude to Oromia Agricultural Research Institution for funding the projects and appreciate the staff of Yaballo Pastoral and Dryland Research Centre for helping and facilitating the fieldwork activities. The authors also gratefully appreciate pastoral communities in Adegelchet and Dhas Kebeles for supporting and guarding the experiment on the field throughout the lifetime of the activity.

References

Abbas, H.A., Kamal, E.M., and Idris, M.A., (2009). Effect of Position of Tapping, Tree Stem Diameter and Tapping Tools on Frankincense Yield of Boswellia Papyrifera in South Kordofan State, Sudan, Forests, Trees and Livelihoods, 19:1, 19-26, Doi: 10.1080/14728028.2009.9752651. Http://Dx.Doi.Org/10.1080/14728028.2009.9752651

Abdulla, A.M., (2013). Contribution of Non-timber Forest Products to Household Food Security: The Case of Yabello Woreda, Borana Zone, Ethiopia. Food Science and Quality Management, 20, 1–13. https://doi.org/10.1016/j.biocon.2006.06.020.

Abeje, E., Demel, T., and Håkan H., (2005). The Socio-Economic Importance and Status of Populations of Boswellia Papyrifera (Del.) Hochst. In Northern Ethiopia: The Case of North Gonder Zone.‖ Forests, Trees and Livelihoods 15(1):55–74. doi: 10.1080/14728028.2005.9752507.

Adefires, W., Demel T., Mulugeta, L., and Masresha, F., (2012). Diversity, Regeneration Status, and Population Structures of Gum and Resin Producing Woody Species in Borana, Southern Ethiopia.‖ Forests, Trees and Livelihoods 21(2):85–96. doi: 10.1080/14728028.2012.716993.

Adefires, W., and Abdile, M., (2008). Assessment of the Resources Base and Socioeconomic Importance of Gum-Resources of Selected Zones in Somali Regional State.

Adefires, W., Mulugeta, L., Masresha, F., and Demel, T., (2011). Socio- Economic Importance of Gum and Resin Resources in the Dry Woodlands of Borana, Southern Ethiopia. Forests, Trees and Livelihoods 20(2–3):137–55. doi: 10.1080/14728028.2011.9756703.

Ballal, M.E., Siddig, E.A., Fadl, E.L., and Luukkanen, M.A., (2005). Gum Arabic Yield in differentially managed *Acacia senegal* stands in western Sudan. *Agro-forestry Forum*, 63: 237-245.

Chikamai, N., (2003). *Review and synthesis on the state of knowledge of Boswellia species and commercialization of frankincense in the drylands of Eastern Africa.*

Coppock, D.L., (1994). The Borana Pleatue of Southern Ethiopia: Synthesis of Pastoral Research, Development and Change, 1980-91. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia, p. 393.

DDPDO, (2019). Dhas District Pastoral and Development Office (DDPDO) Annual Report. Borbor, Dhas, Ethiopia.

Elias, C., Abrham, A., Ambachew, G., Kibruyesfa, S., Tatek, D., (2020).Tapping height and season affect frankincense yield and wound recovery of Boswellia papyrifera trees, *Journal of Arid Environments*, Volume 179, 104176, ISSN 0140-1963, https://doi.org/10.1016/j.jaridenv.2020.104176.

Eshetu, A., (2002). Regeneration status, soil seed banks and socio- economic importance of *Boswellia papyrifera* in two woredas of northern Gondar zone, Ethiopia. MSc thesis, Swedish university of agricultural sciences, Sweden.

Fadl, K.E., and Gebauer, J., (2004). Effect of different tapping tools and different tapping positions on 'talh gum' yield of *Acacia seyal* var. *seyal* in South Kordofan, Sudan. A full paper online publication of the Conference on International Agricultural Research for Development, 1-6, http:// www. tropentag.de.

Gelagay, A., Teshale, S., Amsalu, W., Esayas, G., (2007). Prevalence of contagious caprine pleuropneumonia in the Borana pastoral areas of Ethiopia. Small Rumin. Res. 70 (2), 131–135.

Girmay, F., Mulugeta, L., (2010). Production, handling and quality control. In: Lemenih, M. and Kassa, H. (eds), Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia. CIFOR, Bogor, Indonesia, 47-67.

Girmay, F., (2000). The Status of Gum Arabic and Resins in Ethiopia.‖ Pp. 29–31 in Proceedings of the Meeting of the Network for Natural Gums and Resins in Africa (NGARA)., edited by B. N. Chikamai. NGARA, Nairobi. Kenya.

Gizaw, A.W., (2006). *Population status and socio-economic importance of gum and resin bearing species in Borana Lowlands, southern Ethiopia*. Msc. thesis submitted to the school of graduate studies, Addis Ababa University, department of Biology Ethiopia.

Haile, A., Ayalew, W., Kebede, N., Dessie, T., Tegegne, A., (2011). Breeding strategy to improve Ethiopian Borana cattle for meat and milk production. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 26. ILRI, Nairobi, Kenya.

Jiregna, G., Lisanework, N., and Heluf, G., (2007). Potential, Distribution, Ethno-Botany and Tapping Procedures of Gum Producing Acacia Species in the Somali Region, Southeastern Ethiopia. East African Journal of Sciences 1(1):69–78.

Kamara, A., Kirk, M., Swallow, B., (2005). Property rights and land use change: implications for sustainable resource management in Borana, Southern Ethiopia. J. Sustain. Agric 25, 41–61.

McCarthy, N., Kamara, A., Kirk, M., (2002). The effect of environmental variability on livestock and land use management: the Borana plateau, Southern Ethiopia. Socioeconomics and Policy Research Working Paper 35. ILRI. (International Livestock Research Institute), Nairobi, Kenya, and IFPRI (International Food Policy Research Institute), Washington, DC, USA, p. 35.

Mohammed, H.M., Rohle, H., (2009). Effect of tree density and tapping techniques on Productivity of gum talha from *Acacia seyal* var. *seyal* in South Kordofan, Sudan. Deutscher Tropentag 2004. Conference on International Research on Food Security, Natural Resource Management and Rural Development. University of Hamburg, 2009 October; 6-8.

Mulugeta, L., (2005). Production and Marketing of Gums and Gum Resins in Ethiopia. In: Chikamai, B., Casadei, E. (Eds), Production and Marketing of Gum Resins: Frankincense, Myrrh and Opoponax. NGARA Publication Series 5. Network for Natural Gums and Resins in Africa, Nairobi., 55–70.

Mulugeta, L., Tarekegn, A., and Mats, O., (2003). Gum and Resin Resources from Some Acacia, Boswellia and Commiphora Species and Their Economic Contributions in Liban, South-East Ethiopia.‖ Journal of Arid Environments 55(3):465–82. doi: 10.1016/S0140-1963(03)00053-3.

Mulugeta, L., and Habtemariam, K., (2011). Opportunities and Challenges for Sustainable Production and Marketing of Gums and Resins in Ethiopia. CIFOR, Bogor, Indonesia.

Semegnew, T., Mulugeta, L., Brehane, M., Galgalo, D., and Prema, K., (2016). Effect of Tapping Intensity and Tree Diameter on Gum Arabic Yield of *Acacia Senegal* (L) Wild in Southern Ethiopia. 2. 229-238.

Tadesse, W., Desalegn, G., and Alia, R., (2007). Natural gum and resin bearing species of Ethiopia and their potential applications

Tadesse, W., Feleke, S., Eshete, T., (2004). Comparative study of traditional and new tapping method on frankincense yield of Boswellia papyrifera. Ethiopian Journal of Natural Resources 6: 287-299.

Teshome, D., Sori, T., Sacchini, F., Wieland, B., (2019). Epidemiological investigations of contagious caprine pleuropneumonia in selected districts of Borana zone, Southern Oromia, Ethiopia. Trop. Anim. Health Prod. 51 (3), 703–711.

WBISPP (Woody Biomass Inventory and Strategic Planning Project), (2005). Forest Resources of Ethiopia. Ministry of Agriculture and Rural Development. Addis Ababa.

Wekesa, C., Makenzi, P., Chikamai, B.N., Lelon, J.K., Luvanda, A.M., Muga, M., (2009). Gum arabic yield in different varieties of Acacia senegal (L.) Willd in Kenya. Afri. J. of Plant Sci., 3(11): 263-276. Nairobi, Kenya.

Yasin, M., and Salah, S., (2014). The Role of Indigenous Gums and Resins in Pastoralists' Livelihood Security and Climate Change Adaptation in Garba Tula Area of Northern Kenya.‖ Future Agricultures Consortium as Part of the Early Career Fellowship Programme. 1–20.

Assessment of Wild edible fruit plants in West Hararghe Zone, Oromia Region, East Ethiopia

Alemayehu Diriba, Wasihun Gizaw and Shimelis Dekeba
Mechara Agricultural Research Center, Oromia Agricultural Research Institute, Ethiopia
Corresponding Author: *alemayhudiriba@gmail.com*

Abstract

Wild edible fruit plants are essential standing in all parts of the world as a subsidiary food basket on daily basis. They are means of survival for rural communities with food and feed consumption, especially during times of drought, famine, shocks, and risks. This study intended to identify, and document scientific data, to get the constraint and opportunity potential of Wild edible fruit plants. Implementation through assessed species, partly used, habitat, mode of uses, flowering months, fruiting months, and factors of threats of wild edible fruits plants. Structured and semi-structured questionnaire interviews, key informant guided, and species quantification along 18 transact lines on 60 sampled quadrants were used to collect data in the west Hararghe zone at Daro-Lebu, Chiro, and Gumbi Bordode Weredas on six PAs. A total of 120 randomly selected sample households were interviewed for data collection. Both quantitative and qualitative data analyses were made. Descriptive analyses were made to analyze the data using SPSS version 16.0. The study embraced a total of 55 Wild edible fruit plants In addition to food values, these plants provide diverse benefits to the existing community including income, fuel wood, fencing, construction, medicine, and fodder. The top five highly impersonated wild edible fruit plant species by respondents were Psidium guajava, Mimusops kummel, Carissa spinarum L., Rosa abyssinica, Ficus sycomorus, and Oncoba spinosa forssk. However, most of them were threatened by anthropogenic factors through misconception utilities. The threat factors such as land degradation and grazing, clearing of forests for agriculture, fire, timber and charcoal, Stem, leaves, root, and bark harvest. To alleviate, the entire threat of wild edible fruit plant species; a community-based forest management system, awareness creation, and growing of wild edible fruit plant species at farms and homesteads level, is mandatory for any forest resource users. The other point is the absence of seedlings and saplings under wild edible fruit plant species in its habitat is an indicator of a regeneration problem. Therefore; the most threatened and unregenerated wild edible fruit plant species of the study areas priority should be given to the critical collection, domestication, in-situ and ex-situ conservation, and promotion of on-farm cultivation in the form of agroforestry systems. Further investigation should be considered on the collection, nutrient content analyses, in-situ and ex-situ conservation, wise utilization, and popularization of Wild edible fruit plants through forest management. These are vital points to be deliberated forward.

Keywords: Threat factors, Forest, anthropogenic effect, Wild edible fruit plants

Introduction

Wild edible fruit plants refer to species that are neither cultivated nor domesticated, which are available from their wild natural habitat and used as sources of food (Beluhan and Ranogajec, 2010). Even though the primary dependence of most agricultural societies on staple crop plants such as wheat, maize, and rice, the conventional eating of wild edible plant products is used as food. In human history continues until the present day observed over worldwide are more than 7,000 wild edible plant species (Grivetti and Ogle, 2000). Wild edible fruit plants are closing food gaps and play an important role in maintaining livelihood security for many people in developing countries during seasonal food shortages, as emergency food aid (Afolayan and Jimoh, 2009; Teshome and Sebsebe, 2002). Moreover, the indigenous Wild edible fruit plants are adapted to the local culture and environment welfare through natural growing manner with a minimum requirement of external inputs and maintenance such as management, fertilizer, and pesticides are the main advantage (Ruffo *et al.*, 2002). Even though Wild edible fruit plants can easily be integrated into sustainable farming systems by the majority of the rural population, they are still not treasured as cultivated fruit trees, such as mango, avocado, Papaya, and orange due to lack of scientific support. Many countries have given priority to the documenting of Wild edible fruit plants and the associated indigenous knowledge. Countries such as India, Mexico, Bolivia, Spain, and Turkey have in-depth Ethnobotanical information on Wild edible fruit plant's utility. By contrast, in Ethiopia conducted on Wild edible fruit plants utilities and dietary analyses were shallow and addressed only an insignificant portion of the country (Rashid *et al*., 2008).

Therefore; traditional knowledge of wild plants, generally in Africa and particularly in Ethiopia is endangered of being lost, as habits, value systems, and the natural environment change (Ruffo *et al.*, 2002). This study also reflected that the endangered of Wild edible fruit plants is due to more anthropogenic factors, such as land degradation and grazing, clearing of forest for Agriculture, fire, timber and charcoal, Stem, leaves, root, and bark harvest. These factors might be occurred as a result of care failure knowledge especially among the new generations, modernization, and urban dwellers to preserve Wild edible fruit plants to be valuable for future generations. So it needs to be conserved and maintained through sustainable utilization without jeopardizing it for future generations (Demel *et al.*, 2010).

In general, regardless of their importance, Wild edible fruit plants are faced with serious threats of anthropogenic and environmental factors in the country due to agricultural expansion, overgrazing/overstocking, deforestation, and urbanization (Addis, 2009; Asfaw, 2009; Teklehaymanot and Giday, 2010). In Ethiopia, where more than 80% of the population is rural, the people have depended on their traditional knowledge of the utility of Wild edible fruit plants with shallow form without exhaustive documentation of their contribution, management, and utilization in their surroundings. This is particularly true in study areas and in the rural population of West Hararghe Zone, where rural communities of the area depend on Wild edible fruit plants for various purposes such as supplementary food, feed during bad times, and income and medicine with barely.

However, there are no any researches so far done, on Wild edible fruit plants in the study area to be as the impetus for policymakers, NGOs, and end users to sustain utilization and management without jeopardizing the future generation. Therefore; the study intended to identify and document Wild edible fruit plants associated with Ethnobotanical knowledge of indigenous communities on part used, habitat, perception, threat factors, related to utility and management as well as constraint and opportunity potentials as to be input for West Hararghe community and other related areas of the country.

General Objective

- To assess Wild edible fruit plants in the West Hararghe zone, Oromia Region

Specific objectives

- To identify Wild edible fruit plants in the study area
- To document scientific information and utilization of commonly used Wild edible fruit plants
- To know the constraint and opportunity potential of Wild edible fruit plants in combating food insecurity for rural communities.

Materials and Methods

Selection of the study area

Before the socio-economic survey, all Weredas' of the Zone which have the potential on growing edible fruit trees and shrub species could be identified. Based on the information gathered, three potential Weredas from each agroecology zones could be selected. From three selected Weredas (Daro-Lebu, Chiro, and Gumbi-Bordode), from each Wereda, two PAs were selected. A total of six kebele (Metegudesa and Jilbo PA from Daro-Lebu Wereda, Halewagora, and Nejabas PA from Chiro Wereda and Burqaberkele and Legarba PA from Gumbi-Bordode Wereda could be selected and used for the socio-economic survey.

Description of the study areas

The study was carried out in the west Hararghe zone, at three Weredas (Namely Daro-Lebu, Chiro, and Gumbi-Bordode). From each of the selected Weredas; 2 PAs and over 6 PAs were selected to obtain all necessary information about edible fruit tree and shrub species of the study areas. Daro-Lebu Wereda **is** one of Wereda of West Hararghe zone in Oromia Regional State. It is located at 80 15'00" N-80 43'00" N latitudes and 400 17'00" E- 400 45'00" E longitudes. The Wereda is bordered by Habro in the northeast, East Arsi Zone, in the south-west, Hawi Gudina Wereda, in the north, Anchar Wereda, in the north, and Boke Wereda in the east. Daro-Lebu Wereda located at a distance of 118km and 478km from the Zonal town is Chiro and Addis Ababa; respectively. The average altitude is (1147-2300 m.a.s.l.). The basic agro-climatic conditions are Weyina-dega (44%) and Kola (56%). Mechara Agricultural Research Center receives on average during the belg rainy season (February 26, March 90, April 157, and May 128mm) and the kiremt rainy season (June 101, July 144, August 158, and September 127mm). The mean annual temperature is 21°C with a mean annual minimum temperature of 15°C and a maximum of 28°C Mechara Agricultural Research Center while, (Wasihun, 2021 unpublished). The farming system of Daro-Lebu Wereda is mixed farming. The main types of crops grown were Cash and cereal crops such as chat, coffee and teff, barley, maize, sorghum, etc. respectively.

-Lebu had rapid population changes which demanded expanding of agricultural land, fuel wood consumption, and residential area (DLW report.2014). The woreda had a total human population of 364613 of which 186097 (51.04%) are male and 178514.04 (48.96%) are female. Out of the total population, 13.56 % are urban dwellers (CSA, 2015). Population density is 82.53 persons per square kilometer and had a total area of 441788.7 hectares (4417.95/km2). The land use pattern of Wereda that cultivable land 86.8 %, pasture (1.8%), forest (4.14%), and remaining (7.26%) is considered mountainous and swampy.

Chiro Wereda is located in the West Hararghe Zone of the Oromia National Regional state at about 324 km East of Finfinne, the capital city of the Oromia regional state. The capital town of the Wereda is Chiro, which is also the capital town of the Zone. Normally the Wereda is divided into three major agro-ecological zones. These are Lowland with 22 kebele, Midland with 13 kebele, and highland altitude with 4 kebele. The Wereda bordered Mieso in the North, Gemechis in the South, Guba-koricha in the West, and Tulo in the East. Mixed farming is the dominant practice in the Wereda (98%) and the rest is of the pastoral production system (2%). The Wereda is founded at an average altitude between (1100-2500 m.a.s.l.). From the total land area/topography of the Wereda, 45% is plain and 55% is a steep slope. The Wereda is mainly characterized by steep slopes and mountains with rugged topography, which is highly vulnerable to erosion problems.

The Wereda has a maximum and minimum temperature of 23 ^{0}C and 12 ^{0}C respectively and maximum and minimum rainfall of 1800 mm and 900 mm respectively (2003 E.C data from Office of Agriculture of the Wereda). The rainfall type is bimodal and erratic. The main rainy season is from June to September for the highland and midland areas and from March to April for the lowland. The short rainy season is from March to May for the highland and midland and for the lowland around July. The amount of rainfall is relatively adequate in the highland and midland than in the lowland.

Soil types of Wereda are sandy soil, clay soil (black soil), and loamy soil types that are 25.5%, 32%, and 42.5%; respectively according to 2003 E.C. data from the Office of Agriculture and Rural Development. The soil types vary with the topography mainly black soils are observed in the highland and midlands, while one can see red soil in the lowland areas. The total land area of the Wereda is 70,912.8 hectares out of which 31659.1 hectares is cultivated land, 30667.4 hectares is uncultivated land, 8104.3 hectares is covered by forest, and 482 hectares is grazing land. Shortage of land is common in the Wereda. Among the main reasons is the increasing population density at a very alarming rate and land fragmentation due to the high number of children in the household. The average land holding status in the area is 4 (0.5-0.25 ha)

Gumbi-Bordode Wereda is found in the West Hararghe Zone of the Oromia National Regional state at about 300 km East of Finfinne, the capital city of Oromia regional state, and at the longitude, 09^o 13’ 05.2” North and 040^o 45’ 27.7” East. The capital town of distract is Bordode, which is located at 65 km North of Chiro, the capital town of the zone. The Wereda has only one major agroecological zone which is lowland. In the Wereda more of the farming community is agro-pastoralist covering 98% and 2% is pastoral community. The Wereda is founded at an average altitude of 1310 m.a.s.l. Almost about 95% of the Wereda has plain topography (data from the Office of Agriculture).

The Wereda has a maximum and minimum temperature of 28 ^{0}C and 16 ^{0}C respectively and maximum and minimum rainfall of 750 mm and 500 mm respectively (2003 E.C data from Office of Pastoral and Agro-pastoral Development of the Wereda). The rainfall type is mono-modal and erratic. The main rainy season is from mid-June to mid-August and the amount of rainfall is inadequate. In the Wereda there are sandy soil, clay soil (black soil), and loamy soil types covering 10%, 75%, and 15%, respectively that data from the Office of Agriculture and Rural Development.

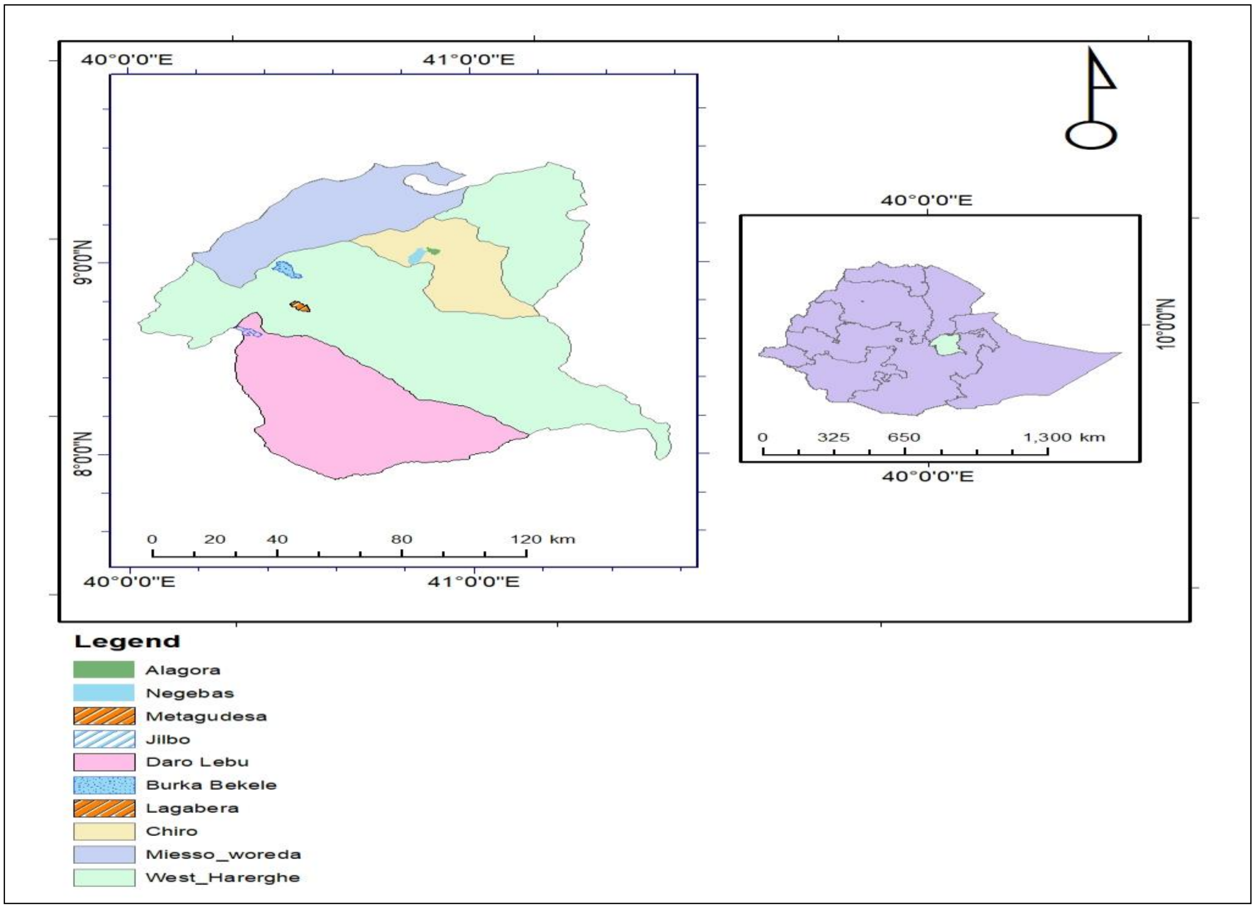


Figure1. Study area Map

Method of Data Collection

Socioeconomic Survey

The socioeconomic survey involved various data collection techniques, such as key informant interviews, semi-structured questionnaires, focus-group discussions, and field observations. Semi-structured interviews were used with 120 respondent households that were randomly selected from 3 selected Weredas of the zone. From each of the selected Weredas; 2 PAs were selected to obtain all necessary information about Wild edible fruit plants of the study areas. This is an effective method that can even be used with children or illiterate people (Sinha, 2003). All sampled households were asked independently the same question to freely name orally all the Wild edible fruit plants they know as it comes into their memory. During the survey took place; different socio-economic factors (age, household size, sex, education, etc…) of the respondents were identified. In addition to the household interviews, important information was collected from key informants. These key informants were those living in the study area for a long time and who have a good understanding of Wild edible fruit plants

The collected data were providing an overview of the socio-economic and biophysical environment of the study areas. As well, field visits and vegetation inventory was applied at each of the study areas/Kebele along the border of the natural forest near the study area to cross-check the reality and to observe the potential of all wild edible fruit plants for more information. By using the above various data collection techniques, necessary data were collected to know indigenous knowledge of rural communities on utilization, role in food security, opportunity, constraints, perception, and factors of the threat of wild edible fruit plants of the study area.

Vegetation Inventory

Inventories on vegetation coverage of wild edible fruit plants of the study area were carried out, to obtain information on the type, trend, and production potential based on their existence and retrieval of sapling and seedling regeneration. The inventory was based on (Huxley and Houten, 1997) procedures that 'shrub' used to describe woody perennial plants that remain low and produce multiple shoots from the base, while 'trees' refers to woody perennial plants that produce one main trunk or bole and a more or less distinct and elevated crown.

Inventories on vegetation coverage of wild fruit plants in the study area were conducted by systematic transect sampling. Two agroecology zones (midland and lowland) in each of the study areas, with 3 parallel lines, 200 m apart between each transect line and with an interval of 200m distance were laid. On each transect line, 20×20 m (400 m^2) quadrants were implemented. Therefore; in this study 18 transect lines and 60 quadrants were laid out over all the study areas. On each plot/quadrant, all Wild edible fruit plants were documented by their vernacular name, later converted to the scientific name using a tree identification manual. The density of Wild edible fruit plants on each plot/quadrant was expressed by counting stems and converting the number to a per hectare basis that over all of the study area coverage was about (2.4 ha). Data on the estimated quantity of edible fruit plants' products expected from each tree/shrub were collected by interviewing the collectors. According to Pancel (1993), the number of edible parts expected from each plant species of a certain size class could be estimated by asking the same question of several collectors. Following this method, in this study, 12 collectors participated from both agroecology zone, to obtain the real identification of edible parts of the various trees and shrubs on each plot.

Data analysis

The collected data were analyzed employing descriptive statistics, with Microsoft Excel and SPSS (Statistical Package for Social Sciences, version 16) to meet the objectives based on the given parameters.

Results and Discussion

Characteristics of Sample Household

Because of the country's cultural significance, men constituted the majority of the respondents in this study. Thus, 120 (91=76%) of the total responses were male, while the remaining (29=24%) were female. The survey result showed that the highest percentage of the respondents' age was found between 31-45 years (53%); while the lowest percentage was 66-70 years (5%) (Table 1). This indicated that the respondents were at a mature, adult age stage for data quality. The survey result showed that only 48% of the respondents were educated, while 52% were uneducated. The result of the household size of respondents indicated that the highest household size was 2-4 (59%); while the lowest household size was 10-12 (12%). The result of the agroecological zone of the study areas observed that (67%) was midland, while (33%) was lowland coverage.

The other main point is the result of farmland size showed that the highest percentage of farmland size was 0.13 ha (37%); while the lowest percentage was 2.5 ha (7%). This indicated that farmers suffered from farmland shortage. Generally; socio-economic scenarios have an indirect impact on wild edible fruits neither managing nor destroying. For example; according to the respondents' responses; during the bad time, Wild edible fruit plants were eaten as food and feed. On the other hand; as a result of farmland shortage; there is the distraction of Wild edible fruit plants for agricultural expansion.

Table 1-Socio-economics of respondents' information

Sex	Frequency	Percent
Men	91	76
Women	29	24
Total	120	100
Age		
18-30	22	18
31-45	64	53
46-65	28	23
66-70	6	5
Total	120	100
marital status		
Married	112	93
Widowed	6	5
Devour	2	2
Total	120	100
Educational status		
Non-educated	62	52
primary school	56	46
secondary school	2	2
Total	120	100

Average land holding in hectares	Frequency	Percent
0.025 ha	28	23
0.125 ha	11	9
0.13 ha	44	37
0.25 ha	11	9
0.5 ha	13	11
1 ha	8	7
2.5 ha	5	4
Total	120	100
Agroecology zone		
midland	80	67
lowland	40	33
Total	120	100
household size		
10-12	14	12
2-6	71	59
7-9	35	29
Total	120	100

Qualitative Description of Respondents on Wild Edible Fruit Plants

The respondents were asked crosscheck questions that were listed in (Table 2) below. The respondents were gotten from different sources those are from natural forests, river banks, farm boundaries, and postural lands. The result of Wild edible fruit plants observed that the highest percentage source of Wild edible fruit plants was collected from the natural forest (34.2%); while the lowest source was collected from postural lands (9.2%). The infusing factors of Wild edible fruit plants utilization were listed by respondents. The result of infusing factors of wild edible fruits indicated that the highest percentage (23.4%) was observed from supplementary food, feed, and income; while the lowest percentage (10%) was observed from Tradition and hunger of children during keeping of livestock (Table 2). This study in agreement with the other findings elsewhere indicates the supplemental role of Wild edible fruit plantss needed during food gaps and famine (Abera, M. (2022).

The role of Wild edible fruit plants in ecological and environmental values indicated that the highest value (35.1%) was observed from maintaining weather conditions and sustaining ecological balance, while the lowest value (16.6%) was recorded from attracting rainfall and making a green environment (Table 2). The result of opportunities in utilizing Wild edible fruit plants indicated that the highest value (67.7%) was observed under the ability to grow naturally; while the lowest value (2%) was under income opportunity (Table 2). The result of the limitation of Wild edible fruit plants indicated that the highest value (37%) was observed deforestation and overgrazing; the lowest observation (8%) was obtained from "Some of them have invasiveness manner" (Table

2). The result of the trend of wild edible fruit plant production over the last 10 years observed that the highest value (90.8) was recorded as "decreasing"; while the lowest value (1.7) was observed as a "no change" alternative (Table 2). The result on the perception of respondents in utilizing Wild edible fruit plants indicated that the highest value (41.7) was observed in "Seedlings have to be planted on farms and reduce deforestation"; while the lowest value (28.3%) was observed under "protected and sustained for future" (Table 2). Some farmers are practiced limited management actions (growing in farms and homesteads). This is an indication of the community understands the value and brings under control Wild edible fruit plants However, the management practices are limited compared to other staple food plants. Moreover, Wild edible fruit plants gathered in natural environments without care of the management and exposed to anthropogenic threats, which are deterioration of forest products, being choice/alternative food, cultural ignorance and lack of awareness about the nutritional value of the products could make them being ignored for management. This study in line with Fentahun and Hager (2008) reports a lower level of management for Wild edible fruit plants (Tebkew et *al.*, 2014).

Table 2. Qualitative description of respondents about wild edible fruits across the study areas

1	**Source of Wild edible fruit plants**	**Frequency**	**Percent**
	Natural forests	50	34.2
	Around river area	33	27.5
	Around farm boundary	26	21.7
	On pasture land	11	9.2
	Total	120	100
2	Influencing factors to use Wild edible fruit plants		
	It is sweaty, Medicinal, and has no side effect	13	11.7
	Supplementary food, feed& income	26	23.4
	Supplementary food, feed& income during hanger	25	22.5
	Tradition and hunger of children during keeping livestock	12	10.8
	Total	76	100
3	Role of Wild edible fruit plants in ecological and environmental values		
	Attract rainfall and make a green environment	19	16.6
	Improve soil and water conservation	34	28.3
	Maintain climate change	24	20.0
	Maintain weather conditions and sustain ecological balance	32	35.1
	Total	120	100
4	Opportunities in utilizing Wild edible fruit plants		
	Ability to grow naturally	65	67.7
	Income opportunity	2	2.0
	Self-distribution	29	30.2
	Total	96	100
5	Constraints in utilizing Wild edible fruit plants		
	Climate change	13	11
	Deforestation and overgrazing	44	37
	Some of them have an invasiveness manner	9	8
	Lack of enough information	14	12
	Agricultural expansion	40	33
	Total	120	100
6	The trend of Wild edible fruit plants production over the last 10 years		
	Increasing	9	7.5
	Decreasing	109	90.8

	No change	2	1.7
	Total	120	1
7	Perception of respondents in utilizing Wild edible fruit plants		
	All people should conserve those trees/shrubs	36	30.0
	Have to be protected and sustained for future	34	28.3
	Seedlings have to be planted on farms and reduce deforestation	50	41.7
	Total	120	10

Diversity of Wild Edible Fruit Plants Across the Study Area

The study revealed that about 55 wild edible fruit tree/shrub species were identified and documented based on important parameters. The results of the habit of Wild edible fruit plants were highly dominated by shrub species and followed by tree species, and the remaining were herbaceous. Species richness observation of Wild edible fruit plants in the study areas was poor based on the Shannon diversity index (0.01): A total of 55 wild edible plant species were recorded in 3 Weredas on 6 PAs (Table 3).

In Daro-Lebu Wereda at Jilbo PA; observation of wild fruit plants showed that the highest percentage (11.8, 8.5 and 7.8%) were recorded under *Mimusops kummel*, *Psidium guajava*, and *Vangueiria arisepala*, respectively; while the lowest percentage (0.7%) was under *Myrica salicifolia.Rich*, *Capparis decidua*, *Rubus apetalusPoir.*, *Acokanthera schimperi*, *Rhus glutinosa* and *Acokanthera schimperi* with similar figures (Table 3). In Metagudesa PA; observation of wild fruit plants indicated that the highest percentage (15.9, 13.5, 13.5, and 12.7) were verified under *Mimusops kummel*, *Rosa abyssincia*, *Psidium guajava*, and *Syzygium guineense*; respectively; while the lowest percentage (0.8%) was under *Tamarindus indica*, *Myrica salicifolia. Rich*n and *Rubus apetalus* with similar figures (Table 3).

In the other study area in Chiro Wereda at Halewagora PA; observation of Wild edible fruit plants indicated that the highest percentage (12.7, 12, and 11.7%) were under *Oncoba spinosa Forssk.*, *Acacia seyal Del.* and *Carissa spinarum L.*, respectively; while the lowest percentage (0.7%) was under *Cordia africana*, *Mimusops kummel*, *Rytigynia neglecta*, *Physalis micrantha*, *Myrica salicifolia. Rich* and *Piper nigrum* with similar figures (Table 3). In Nejabas PA; observation of wild fruit plants indicated that the highest percentage (11.4, 7.9 and 7.1) were under *Carissa spinarum L.* and *Acacia seyal Del.*, *Oncoba spinosa Forssk.* and *Rubus apetalus Poir.*; respectively; while the lowest percentage (0.7%) was under *Myrica salicifolia.Rich, Celosia anthelminthica, Rhus natalensis Krauss*, *Rhoicissus tridentata*, and *Albizia grandibracteata* with similar figures (Table 3).

In the other study area in Gumbi-Bordode Wereda at Burqabarkele PA; observation of Wild edible fruit plants indicated that the highest percentage (9.7, 9.2, and 8.2%) were noted under *Opuntia ficus-indica/cactus, Ficus sycomorus* and *Ziziphus spina-*, respectively; while the lowest percentage (0.5%) was under *Lex mitis*, *Oncoba spinosa Forssk*., *Combretum molle* and *Allophylus abyssinicus* with similar figure (Table 3). In Legarba PA; observation of wild fruits indicated that the highest percentage (8.8, 77.5.9, and 7) were illustrated under *Mimusops kummel*, *Psidium guajava*, *Cordia sinensis Lam* and *Rhus natalensis Krauss*, *Ficus sycomorus*; respectively; while the lowest percentage (0.4%) was under *Acacia seyal Del.*, *Oncoba spinosa Forssk. Euclea racemosa, Grewia bicolour*, *Rubus apetalus*, *Syzygium guineense* and *Physalis micrantha Link* with similar figures (Table 3).

Table 3: Observation frequency of Wild edible fruit plants by study areas

No.	Scientific name	Family name	*Gumbi-Bordode Wereda* Burqabarkele PA		Legarba PA		Chiro Wereda Halewagora PA		Nejabas PA		Daro-Lebu Wereda Jilbo PA		Metagudesa PA		total
			F	%	F	%	F	%	F	%	F	%	F	%	
1	*Puntia ficus-indica*	*Cactaceae*			4	1.8									4
2	*Carissa spinarum L.*	*Apocynaceae*	11	5.6	15	6.6	16	11.3	16	11.4	6	3.9	7	5.6	71
3	*Hypoestes aristata*	*Acanthaceae*	9	4.6											9
4	*flavescens*	*Tiliaceae*											1	0.8	1
5	*Piper nigrum*	*Piperaceae*					1	0.7	1	0.7					2
6	*Balanites aegyptiaca*	*Balantiaceae*	2	1.0											2
7	*Toddalia asiatica*	*Rutaceae*									1	0.7			1
8	*Portulaca quadrifida.*	*Portulacaceae*									3	2.0	3	2.4	6
9	*Myrica salicifolia.Rich*	*Loganiaceae*	3	1.5	7	3.1	1	0.7	1	0.7	1	0.7	1	0.8	14
10	*Physalis micrantha*	*Solanaceae*					1	0.7							1
11	*Vangueiria arisepala*	*Rubiaceae*					10	7.0	7	5.0	12	7.8	6	4.8	35
12	*Celosia anthelminthica.*	*Amaranthaceae*	1	0.5	14	6.1			1	0.7	2	1.3			18
13	*Rhus natalensis Krauss*	*Anacardiacea*	5	2.6	17	7.5	2	1.4	1	0.7					25
14	*Rhoicissus tridentate*	*Vitaceae.*	1	0.5					1	0.7					2
15	*Grewia tenax (Forssk.)*	*Tiliaceae*	12	6.2	14	6.1									26
16	*Salvadora persica*	*Salvadoraceae*	1	0.5	1	0.4									2
17	*Annona reticulata L.*	*Annonaceae*									1	0.7			1
18	*Syzygium guineense*	*Myrtaceae*	2	1.0	1	0.4					17	11.1	16	12.7	36
19	*Capparis decidua*	*Capparidaceae*									1	0.7			1
20	*Rosa abyssincia*	*Rosaceae*	4	2.1	5	2.2	11	7.7	9	6.4	13	8.5	17	13.5	59
21	*Rubus apetalus Poir.*	*Rosaceae*			1	0.4	3	2.1	10	7.1	1	0.7	1	0.8	16
22	*Momordica foetida*	*Cucurbitaceae*									1	0.7			1
23	*Albizia grandibracteata*	*Leguminosae-*							1	0.7					1
24	*Phoenix reclinata Jacq*	*Arecaceae*	4	2.1											4
25	*Capsicum chinense*	*Solanaceae*							3	2.1					3
26	*Ficus sur (F. Capensis)*	*Moraceae*							4	2.9					4
27	*Grewia bicolour*	*Tiliacea*	6	3.1	1	0.4									7

28	*Ficus sycomorus*	*Anacardiacea*	18	9.2	16	7.0					10	6.5	3	2.4	47
29	*Boscia salicifolia*	*Capparidaceae*	3	1.5											3
30	*Berchemia discolor*	*Rhamnaceae*	5	2.6											5
31	*Oncoba spinosa Forssk*	*Flacourtiaceae*			4	1.8	3	2.11		0.7	5	3.3	3	2.4	16
32	*Dovyalis abyssinica*	*Flacourtiacea*											2	1.6	2
33	*Cordia sinensis Lam*	*Boraginaceae*	8	4.1	17	7.5									25
34	*Meriandra benegalensis*	*Verbenaceae*			4	1.8									4
35	*Lex mitis*	*Ebenaceae*	1	0.5	5	2.2	6	4.2	2	1.4	2	1.3	2	1.6	18
36	*Rytigynia neglecta*	*Rubiaceae*					1	0.7							1
37	*Grewia schweinfurthii*	*Tiliaceae*	4	2.1							1	0.7			5
38	*Grewia ferruginea*	*Tiliaceae*	7	3.6	3	1.3					1	0.7			11
39	*Mimusops kummel*	*Sapotaceae*	13	6.7	20	8.8	1	0.7	6	4.3	18	11.8	20	15.9	78
40	*Myrsine africana L.*	*Myrsinaceae*			1	0.4									1
41	*Embelia schimperi*	*Myrsinaceae*					14	9.9	9	6.4	3	2.0			26
42	*Acokanthera schimperi*	*Sterculiaceae*	2	1.0			3	2.1			1	0.7			6
43	*Euclea racemosa*	*Ebenaceae*	1	0.5	1	0.5			1	0.7	1	0.7	8	6.3	12
44	*Ziziphus spina-*	*Rhamnaceae.*	16	8.2	15	6.6									31
45	*Tamarindus indica*	*Fabaceae*	3	1.5	5	2.2			2	1.4	3	2.0	1	0.8	14
46	*Oncoba spinosa Forssk.*	*Flacourtiaceae*	1	0.5	1	0.4	18	12.7	11	7.9	6	3.9	9	7.1	46
47	*Acacia senegal (L.)*	*Fabaceae*	3	1.5											3
48	*Rhus glutinosa*	*Anacardiaceae*									1	0.7			1
49	*Combretum molle*	*Combretaceae*	19	9.7	13	5.7	13	9.2	6	4.3	9	5.9	4	3.2	64
50	*Osyris quadripartita*	*Santalaceae*					2	1.4							2
51	*Cordia Africana*	*Boraginaceae*	2	1.0	1	0.4	17	12.0	16	11.4					36
52	*Acacia seyal Del.*	*Fabaceae*	3	1.5	7	3.1	1	0.7	4	2.9	3	2.0			18
53	*Allophylus abyssinicus*	*Anacardiacea*	1	0.5	2	0.9	3	2.1	7	5.0	11	7.2	3	2.4	27
54	*Acacaia seyal del.***	*Fabaceae*	10	5.1											10
55	*Psidium guajava*	*Myrtaceae)*	12	6.2	20	8.8	14	9.9	18	12.9	18	11.8	17	13.5	99
Total			195	100	228	100	142	100	140	100	153	100	126	100	984

F= frequency,%=percent, PA=Peasant Association

Operational Description of Wild edible fruit plants on Adaptation, Part Used, Habitat, Mode of use, Flowering and Fruiting Months

The respondents were asked crosscheck questions that were listed in (Table 4) below. The respondents answered the questionnaires about wild edible fruits about habituate, part used habitat, mode of use, flowering, and fruiting months. In these processes; the adaptation result of wild fruits showed that the highest percentage (72%) was found from wild habituation; while the lowest percentage (16%) was from both wild /domestic habituation (Table 4). In terms of part used of the wild fruits revealed that the highest percentage (98.2%) of part used was got from the fruit and this result coincides with Sintayo and Zebene (2020), their study findings in a different part of Ethiopia reported that most of the Wild edible fruit plants' parts used were fruits; while the lowest percentage (1.8%) was got from /leaf/bark/root (Table 4). This study is in line with the work of Adal *et al.*, 2004 that fruit uses accounted for 80% of wild edible food.

But, this is contrasted with the finding of Tilahun, T. and Mirutse, G. (2010) studied in southern Ethiopia, that most Wild edible fruit plants were used as vegetables by harvesting their leaves, young twigs, and upper parts (leaf and stem). The other disagreement finding of this study reported by [Ali *et al.*, 2008] was that most of the edible plant parts were leaves that were consumed after cooking. The result on the habitat of wild edible fruit" species observed that the highest percentage (73.2%) was indicated from shrubs species; while the lowest percentage (3.6%) was got from herb species (Table 4). This study is in line with (Ameni *et al.*, 2003; Balemie *et al.,* 2004) that the most harvested wild edible fruits were recorded from shrubs than other categories.

The result on the mode of use of Wild edible fruit plants indicated that the highest percentage (96.4%) was used fresh; while the lowest percentage (3.6%) was gotten undercooked (Table 4). This study agrees with the findings of Kebu, B., and Fasil, K. (2006), who reported that raw fruits contain the largest percentage of raw edible fruits. Raw edible fruits might be a good source of nutrients that does not lose their nutrients fresh; while boiled or cooked, some essential nutrients might be lost. The other results on flowering and fruiting months of wild edible fruits observed that the highest percentage (35.7% and 14.4%) months were April and July, and October and November, respectively; while the lowest percentage (1.8% and 7.1%) months were flowered in February, September, July, February, and April, respectively (Table 4). In the parameters, in which Wild edible fruit plants correlated and related with adaptation, part used, habitat, mode of use, flowering, and fruiting months were well stated and counted in (Appendix Table 1).

Table 4: Structural descriptions of wild edible fruits in percent on habituate, part used, habitat, mode of use, flowering months, and fruiting months

Adaptation of the species	**Frequency**	**Percent**	**Flowering Months**	**Frequency**	**Percent**
Wild	46	72.0	April and July	20	35.7
wild /domestic	9	16.1	April and May	7	12.5
Total	56	100.0	February	1	1.8
Part of the species used			February and April	2	3.6
Fruit	55	98.2	January	3	5.4
Fruit/leaf/bark/root	1	1.8	Januaryand February	2	3.6
Total	56	100.0	June	4	7.1
Habitat of the species			March	2	3.6
Herb	2	3.6	May	15	26.8
Shrubs	41	73.2	Total	56	100.0
Tree	13	23.2	Fruiting month		
Total	56	100.0	October& November	8	14.3
Mode of uses			June	6	10.7

as it is		54	96.4	April	4	7.1
as it is/cooked		2	3.6	February	4	7.1
	Total	56	100.0	January	4	7.1
				July	4	7.1
				March	4	7.2
				May	4	7.2
					4	7.1

Regeneration Trend and Species diversity of Wild edible fruit plants in the study areas

In Daro-Lebu Wereda at Metegudesa PA, the surveillance of Wild edible fruit plants revealed that the highest percentage (30.8%) occurred under *Psidium guajava* species; while the lowest percentage (5.1%) was under *Vangueiria arisepala* species (Table 5a). On the other hand; an indicator of regeneration trend results with saplings and seedlings of wild edible fruits revealed that the highest percentage (62.1%) occurred under *Psidium guajava* species; while the lowest percentage (8.3%) occurred under *Mimusops kummel*, species (Table 5a). At Jilbo PA; in Daro-Lebu Wereda likewise; the results on observation of Wild edible fruit plants revealed that the highest percentage (26.2%) occurred under *Rosa abyssinica* species; while the lowest percentage (4.8%) occurred under *Carissa spinarum L.* species (Table 5a). Similarly; an indicator of regeneration trend results with saplings and seedlings of wild edible fruits revealed that the highest percentage (62.1%) occurred under *Psidium guajava* species; while the lowest percentage (8.3%) occurred under *Mimusops kummel*, species (Table 5a).

In Chiro Wereda at Nejabas PA; the results of observation of Wild edible fruit plants revealed that the highest percentage (24.3%) has occurred under *Carissa spinarum L;* while the lowest percentage (2.7%) happened under *Cactaceae* species (Table 5b). On the contrary; the indicator of regeneration trend results with saplings and seedlings of wild edible fruits revealed that the highest percentage (43.8%) was observed under *Carissa spinarum L.* species; while the lowest percentage (16.7%) occurred under *Acacia seyal del.* species. On the other hand; the species that hadn't any indicator of regeneration trend results with saplings and seedlings of wild edible fruits trees/shrubs were occurred under *Opuntia ficus-indica/cactus*, *Allophylus abyssinicus* and *Myrica salicifolia.Rich* species (Table 5b).

Whereas at Halewagora PA; in Chiro Wereda the same as other study areas; the results on observation of Wild edible fruit plants discovered that the highest percentage (18.8%) was observed under *Carissa spinarum L.* species; while the lowest percentage (4.2%) occurred under *Oncoba spinosa Forssk.* and *Rhus natalensis Krauss* species (Table 5b). Similarly; an indicator of regeneration trend results with saplings and seedlings of Wild edible fruit plants revealed that the highest percentage (57.9%) was observed under *Carissa spinarum L.* species; while the lowest percentage (37.5%) was observed under *Rhus natalensis Krauss* species (Table 5b). Likewise; the species that hadn't any indicator of regeneration trend results with saplings and seedlings of wild edible fruits plant was observed under *Opuntia ficus-indica/cuctus* species (Table 5b).

In Gumbi-Bordode Wereda, at Legarba PA; the results of observation of Wild edible fruit plants revealed that the highest percentage (14.6%) has occurred under *Rhus natalensis Krauss* and *Lex mitis* species; while the lowest percentage (2.4%) was observed curred under *Toddalia asiatica*, *Syzygium guineense* and *Euclea racemosa* species (Table 5c). On the contrary; the indicator of regeneration trend results with saplings and seedlings of wild edible fruit plants revealed that the highest percentage (57.1%) occurred under *Acokanthera schimperi* species; while the lowest percentage (8.3%) occurred under *Mimusops kummel*, species (Table 5c).

Whereas at Burqabarkele PA; in Gumbi-Bordode Wereda similarly; the results on observation of Wild edible fruit plants discovered that the highest percentage (18%) occurred under *Grewia tenax* species; while the lowest percentage (5%) resulted under *Balanites aegyptiaca* species (Table 5c). likewise; an indicator of regeneration trend result with saplings and seedlings of wild edible fruits revealed that the highest percentage (50.9%) occurred under *Grewia tenax* species; while the lowest percentage (13%) resulted under *Euclea racemosa* species (Table 5c). Likewise; the species those hadn't any indicator of regeneration trend result with sapling and seedlings of Wild edible fruit plants /shrubs occurred under *Ficus sycomorus* and *Cactaceae* species; respectively (Table 5c).

Table 5a. Observation of species and Sapling trends of a given tees/shrubs in **Daro-Lebu**
Table 5b-Observation of species and Sapling trends of a given tees/shrubs in **Chiro** Wereda,

Observation of species			Sapling trends of a given tees/shrubs in Nejabas PA, from 3 transect lines and 9 quadrants			
Scientific name	*Frequency*	*Percent*	*Scientific name*	*Number sampled trees*	*Tot*	*Percent*
Carissa spinarum L.	*9*	*24.3*	*Carissa spinarum L*	*16*	*58*	*27.6*
Lex mitis	*7*	*18.9*	Cactaceae	*0*	*8*	*0.0*
Cactaceae	*5*	*13.5*	*Embelia schimperi*	*14*	*32*	*43.8*
Acacia seyal Del.	*4*	*10.8*	*Acacia seyal Del.*	*2*	*12*	*16.7*
Euphorbia abyssinica/cuctus	*3*	*8.1*	*Lex mitis*	*19*	*54*	*35.2*
Allophylus abyssinicus	*2*	*5.4*	*Oncoba spinosa Forssk.*	*1*	*4*	*25.0*
Myrica salicifolia	*1*	*2.7*	*Allophylus abyssinicus*	*0*	*3*	*0.0*
Myrsine africana L.	*1*	*2.7*	*Myrsine africana L.*	*4*	*10*	*40.0*
Oncoba spinosa Forssk.	*1*	*2.7*	*Myrica salicifolia*	*0*	*2*	*0.0*
Total	*37*	*100.0*	*Number of transacts=3* *Number of quadrants=9*			

observation of species			Sapling trends of a given tees/shrubs in shrubs in, Halewagora PA, from 3 transect lines and 9 quadrants			
Scientific name	*Frequency*	*Percent*	*Scientific name*	*Number sampled trees*	*Total*	*Percent*
Carissa spinarum L.	*9*	*18.8*	*Carissa spinarum L.*	*66*	*114*	*57.9*
Rhus natalensis Krauss	*7*	*14.6*	*Embelia schimperi*	*83*	*147*	*56.5*
Rosa abyssincia	*2*	*4.2*	*Lex mitis*	*51*	*101*	*50.5*
Lex mitis	*6*	*12.5*	*Acokanthera schimperi*	*8*	*16*	*50.0*
Embelia schimperi	*6*	*12.5*	*Rosa abyssincia*	*7*	*15*	*46.7*
Acokanthera schimperi	*4*	*8.3*	*Allophylus abyssinicus*	*5*	*12*	*41.7*
Oncoba spinosa Forssk	*2*	*4.2*	*Acacia seyal Del.*	*11*	*29*	*37.9*
Cactaceae	*3*	*6.3*	*Rhus natalensis Krauss*	*9*	*24*	*37.5*

Acacia seyal Del.	*5*	*10.4*	*Cactaceae*	*0*	*14*	*0.0*
Allophylus abyssinicus	*3*	*6.3*	*Number of transacts=3*			
Total	*48*	*100*	*Number of quadrants=9*			

The absence of seedlings and saplings under any wild edible plant species in its habitat is an indicator of the regeneration problem. However, this scenario might be occurred due to different factors. Relevant biotic factors can be human activities, grazing, deforestation dispersal agents, and competition. Nevertheless, the exact points of factors of threat for Wild edible fruit plants in the study area are well stated in the following portion and in (Appendix 1-Table 2 Wereda, from 3 transect lines and 12 quadrants in both PA.)

Observation of species			Sapling trends of a given tees/shrubs in Metagudisa PA				
Scientific name	Frequency	Percent	Scientific name	Number of sampled	Total	percent %	
Observation of species			Sapling trends of a given tees/shrubs in Metagudisa PA				
Scientific name	Frequency	Percent	Scientific name	Number of sampled trees/shrubs	Total	percent %	
Psidium guajava	*12*	*30.8*	Psidium guajava	59	95	62.1	
Carissa spinarum L.	*6*	*15.4*	Rosa abyssincia	47	84	56.0	
Oncoba spinosa Forssk.	*6*	*15.4*	*Oncoba spinosa Forssk.*	*49*	89	55.1	
Allophylus abyssinicus	*5*	*12.8*	*Allophylus abyssinicus*	*32*	63	50.8	
Mimusops kummel	*4*	*10.3*	*Carissa spinarum L.*	*8*	19	42.1	
Syzygium guineense	*3*	*7.7*	*Mimusops kummel*	*1*	12	8.3	
Vangueiria arisepala	2	5.1	Number of transacts=3				
Total	39	100.	Number of quadrants=12				
Observation of species			Sapling trends of a given tees/shrubs Jilbo PA, from 3 transect lines and 11 quadrants				
Scientific name	*Frequency*	*Percent*	*Scientific name*	*Number sampled trees*	*Total*	*Percent*	
Rosa abyssinica	*11*	*26.2*	*Psidium guajava*	*59*	*95*	*62.1*	
Psidium guajava	*8*	*19.0*	*Carissa spinarum L.*	*9*	*15*	*60.0*	
Oncoba spinosa Forssk.	*7*	*16.7*	*Rosa abyssincia*	*47*	*84*	*56.0*	
Allophylus abyssinicus	*7*	*16.7*	*Oncoba spinose*	*49*	*89*	*55.1*	
Mimusops kummel	*6*	*14.3*	*Allophylus abyssinicus*	*32*	*63*	*50.8*	
Carissa spinarum L.	*2*	*4.8*	*Mimusops kummel*	*1*	*12*	*8.3*	
Total	*42*	100	*Number of transacts=3* Number of quadrants=11				

Table 5C. Observation of species and Sapling trends of a given tees/shrubs in **Gumbi-Bordode** Wereda, from 3 transect lines and 9 quadrants in Both PA

Observation of species				*Sapling trends of a given tees/shrubs in,* ***Legarba PA***			
Scientific name	*Frequency*	*Percent*		*Scientific name*	*Number sampled trees*	*Total*	*Percent*
Rhus natalensis Krauss	*6*	*14.6*		*Acokanthera schimperi*	*4*	*7*	*57.1*
Lex mitis	*6*	*14.6*		*Celosia anthelminthica.*	*9*	*17*	*52.9*
Carissa spinarum L.	*4*	*9.8*		*Rhus natalensis Krauss*	*25*	*49*	*51.0*
Mimusops kummel	*4*	*9.8*		*Grewia tenax (Forssk.)*	*14*	*28*	*50.0*
Acokanthera schimperi	*4*	*9.8*		*Lex mitis*	*18*	*36*	*50.0*
Grewia tenax (Forssk.)	*3*	*7.3*		*Myrica salicifolia.Rich*	*17*	*41*	*41.5*
Grewia bicolour	*3*	*7.3*		*Rhus natalensis Krauss*	*2*	*5*	*40.0*
Myrica salicifolia.Rich	*2*	*4.9*		*Vangueiria arisepala*	*2*	*5*	*40.0*
Vangueiria arisepala	*2*	*4.9*		*Grewia bicolour*	*8*	*20*	*40.0*
Celosia anthelminthica.	*2*	*4.9*		*Acokanthera schimperi*	*7*	*18*	*38.9*
Oncoba spinosa Forssk.	*2*	*4.9*		*Carissa spinarum L.*	*11*	*29*	*37.9*
Toddalia asiatica	*1*	*2.4*		*Syzygium guineense*	*1*	*4*	*25.0*
Syzygium guineense	*1*	*2.4*		*Mimusops kummel*	*1*	*12*	*8.3*
Euclea racemosa	*1*	*2.4*					
Total	*41*	*100*		*Number of transacts=3*			
				Number of quadrants=9			
observation of species				Sapling trends of a given tees/shrubs **Burqaberkele PA**			
Scientific name	*Frequency*	*Percent*		*Scientific name*	*Number sampled trees*	*Total*	*Percent*
Grewia tenax (Forssk.)	*8*	*18*		*Grewia tenax (Forssk.)*	*28*	*55*	*50.9*
Cactaceae	*6*	*14*		*Celosia anthelminthica.*	*10*	*22*	*45.5*
Grewia ferruginea	*5*	*11*		*Grewia ferruginea*	*11*	*26*	*42.3*
Grewia schweinfurthii	*4*	*9*		*Grewia schweinfurthii*	*8*	*19*	*42.1*
Euclea racemosa	*4*	*9*		*Boscia salicifolia*	*5*	*12*	*41.7*
Celosia anthelminthica.	*3*	*7*		*Grewia bicolour*	*7*	*17*	*41.2*
Grewia bicolour	*3*	*7*		*Mimusops kummel*	*3*	*13*	*23.1*
Ficus sycomorus	*3*	*7*		*Balanites aegyptiaca*	*1*	*5*	*20.0*
Boscia salicifolia	*3*	*7*		*Euclea racemosa*	*3*	*23*	*13.0*
Mimusops kummel	*3*	*7*		*Ficus sycomorus*	*0*	*4*	*0.0*
Balanites aegyptiaca	*2*	*5*		*Cactaceae*	*0*	*33*	*0.0*
Total	*44*	*100*		*Number of transacts=3*			
				Number of quadrants=10			

Major Factors of threat for Wild edible fruit plants in the study areas

High population pressure, agricultural growth, energy consumption, and inefficient natural resource utilization are the major threats to wild edible fruit plants. So the threat to wild edible fruit plants in the research areas was (land degradation and grazing, forest removal for agriculture, fuel wood, charcoal, and timber, and harvesting of stems, leaves, and bark. The result on major threats of wild edible fruit plants showed that the highest percentage (45%) was observed with the Clearing of forest for Agriculture; while the lowest percentage (5.70%) was recorded with Stem, leaves, and bark harvest (Table 6 and Appendix 1-Table 2). Furthermore, construction, settlement, and unwise utilization are the common threat to Wild edible fruit plants The result of this study is consistent with the reports of (Tebkew *et al.,* 2014) that high population growth, agricultural land demand, lack of alternative fuel energies and plantations, resource use interest conflict between local communities.

Generally; wild edible fruit plants gathered in the natural environments without care of management which is a deterioration of forest products, being unfamiliar food, public ignorance and nonexistence of consciousness may make them violated for exclusive. These scenarios are being exposed to threats of Wild edible fruit plants as a result of the anthropogenic effects. This study in line with (Tebkew *et al*., 2014) reported that a lower level of management and undermine were given for wild edible fruit plants

Table 6- Major threats to wild edible fruit plants in the study areas

Threat factors		Frequency	Percent (%)
1	Land degradation and grazing	414	42.3
2	Clearing of forest for Agriculture	440	45.0
3	Fire, timber, and charcoal	68	6.9
4	Stem, leaves, and bark harvest	56	5.7
Total		978	100.

Association between Socio-Economic Factors and Wild edible fruit plants' parameter

Age correlated positively with household size (p<0.006) which is statistically significant, and the other negatively correlated that Land hold size with Age (p<-0.004), and Education status with household size (p <0.031) which showed statistically significant in (Table 7). A positive correlation indicated that both variables are increased with each other. In this situation, as age ranges rise or drop concurrently, household size increases or decreases (Table 7). On the other hand, a negative correlation indicates that as one variable decreases, the other increases. Therefore; when lands hold size increases; age categories decrease; and when education status increases; household size decreases (Table 7).

Shrubs correlated with fruits; direct uses correlated with trees and shrubs; food correlated with fruit, shrubs, and direct uses; feed correlated with fruit and direct uses; income correlated with fruit and direct uses; pasture correlated with fruit, trees, shrubs, direct uses, food and income; farmers correlated with fruits, shrubs, direct uses, food, income, and pasture; young collectors correlated with fruits, trees, shrubs, direct uses, food, income, pastures, and farmers; men collectors correlated with fruits, direct uses, food, income, pastures, and farmers and young; women collectors correlated with fruits, shrubs, direct uses, food, income, pastures, farmers, young and men; elder collectors correlated with feed are highly significant (P<0.0001) and positively associated under the operational description of Wild edible fruit plants based on a given parameter (Table 8). On the other hand, Land degradation correlated with farmers; forest clear for Agriculture correlated with fruit, trees, direct uses, food, income, pastures, farmers, young and women; fire and charcoal correlated with women are highly significant (P<0.001) and positively associated under factors of threat for Wild edible fruit plants based on the given parameters (Table 8).

Table 7- Pearson Correlation between socio-economic factors. (N = 120)
**. significant at the 0.01 level. *. significant at the 0.05 level; ^{NS}, not significant

Correlation with:	Sex	Age	Household size	Land hold size
Age	-0.006^{NS}			
Household size	-0.031^{NS}	0.251**		
Land hold size	-0.054^{NS}	-0.319*	-0.06^{NS}	
Education status	-0.083^{NS}	0.079^{NS}	-0.198*	-0.02359 ^{NS}

Table 8- Pearson Correlation Coefficients and relationship within the wild edible fruits variable.

Variables		Part used	Habitat		use mode	Purpose of utilization				More inspired by		Collected by			
		Fruit	tree	shrubs	Direct	food	feed	medicine	income	pasture	farmers	young	men	women	elder
Habitat	Tree	0.477**													
	Shrubs	0.681***	-0.176^{NS}												
Use mode	Direct	0.992***	0.450**	0.716***											
Purpose of utilization	Food	0.951***	0.455**	0.728***	0.952***										
	Feed	0.515***	-0.022^{NS}	0.399**	0.501***	0.322*									
	Medicine	0.112^{NS}	0.087^{NS}	-0.033^{NS}	0.111^{NS}	-0.119^{NS}	0.284**								
	Income	0.706***	0.464**	0.361**	0.680***	0.575***	0.487**	0.150^{NS}							
More inspired by	Pastures	0.971***	0.515***	0.645***	0.955***	0.952***	0.472**	0.014^{NS}	0.696***						
	Farmers	0.949***	0.493**	0.616***	0.920***	0.941***	0.421**	0.014^{NS}	0.574***	0.937***					
Collected by	Young	0.911***	0.546***	0.576***	0.904***	0.944***	0.303**	-0.081^{NS}	0.594***	0.950***	0.893***				
	Men	0.794***	0.478**	0.428**	0.801***	0.680***	0.380**	0.475**	0.488**	0.690***	0.720***	0.626***			
	Women	0.879***	0.422**	0.708***	0.923***	0.872***	0.396**	0.079^{NS}	0.559***	0.849***	0.764***	0.815***	0.719***		
	Elder	0.488**	0.122^{NS}	0.234^{NS}	0.463***	0.318*	0.524***	0.316**	0.377**	0.388**	0.462***	0.223^{NS}	0.441**	0.308**	

Factor of threat	Land degrading	0.493**	-0.162^{NS}	0.409**	0.468**	0.450**	0.313**	0.147^{NS}	0.104^{NS}	0.468**	0.515***	0.482**	0.425**	0.339**	0.260^{NS}
	Forest clearing for agriculture	0.757***	0.625***	0.428**	0.736***	0.750***	0.322*	-0.116^{NS}	0.774***	0.778***	0.736***	0.690***	0.472**	0.625***	0.391**
	Fire & Charcoal	0.235^{NS}	0.019^{NS}	0.424**	0.356**	0.293*	-0.007^{NS}	0.017^{NS}	0.027^{NS}	0.183^{NS}	0.059^{NS}	0.250^{NS}	0.281*	0.610***	-0.082^{NS}

***, Correlation is significant at the 0.001 level; **. significant at the 0.01 level. *. significant at the 0.05 level; ^{NS}, not significant

Conclusion and Recommendation

Wild edible fruit plants have a considerable character in complementary food provision, income generation, modification, and nutritional security in different parts of the country. Furthermore, the species are versatile, thus significant in supplementary food delivery, fodder, fuel-wood, income generation, biodiversity conservation, and nutritional security in various regions at the bad and good times among others. However, the species are underutilized and threatened by misconception factors of anthropogenic pressure in natural ecosystems. The misconception factors are land degradation and grazing, clearing of forest for agriculture, fire, timber and charcoal, Stem, leaves, root, and bark harvest. Consequently, a community-based forest management system, awareness creation, and growing of wild edible fruit plants on farms and homesteads level are mandatory for any users to save such kinds of delusion problems. Therefore; the absence and the lowest number of seedlings and saplings under the sampled quadrant of Wild edible fruit plants in its habitat is an indicator of a regeneration problem. In this study, imperfection and threatened species might be occurred due to misconceptions about utilities across Wereda. Those are *Mimusops kummel* is the lowest regeneration species in Daro-Lebu Wereda. Cactaceae */cactus, Allophylus abyssinicus and Myrica salicifolia* and *Ficus sycomorus species* are *the* absence of seedlings and saplings under the sampled quadrants in Chiro and Gumbi-bordode Weredas; respectively. Generally; supporting and promoting indigenous knowledge of farmers to wards encourage domestication, and in-situ and ex-situ conservation through awareness creation, value addition, and commercialization of Wild edible fruit plants are mandatory. All these arguments should help to maximize the multidimensional advantage of communities; while contributing to the sustainable utilization of wild edible fruit plant species eco-friendly. Specifically; the most threatened and under-regenerated Wild edible fruit plant species of the study area priority should be given to the critical collection, domestication, in-situ and ex-situ conservation, and promotion of on-farm cultivation in the form of agroforestry systems. The research gap should be focused on nutrient analysis, collection and in-situ and ex-situ conservation, genetic improvement, fruit processing, and analysis of the economic contribution of Wild edible fruit plant species.

Acknowledgements

The authors would like to express their gratitude to IQQO for supporting this research project. We are also grateful to Mechara Agricultural Research Center and all of the workers, particularly the Agroforestry team members, for their diligent efforts in making the work a success.

References

Abera, M. (2022) Ethnobotanical Study of Wild edible fruit plants and Their Indigenous Knowledge in Sedie Muja Wereda, South Gondar Zone, Northwestern Ethiopia. American Journal of Plant Sciences, 13, 241-264.

Adal H. Traditional use, management and conservation of useful plants in dryland parts of North Shoa Zone of the Amhara National Region: An Ethnobotanical Approach. M.Sc. Thesis, Addis Ababa University, Addis Ababa; 2004.

Addis, G. (2009). Wild and Semi-Wild edible fruit plants of Hamar and Xonso (South Ethiopia) with emphasis on their ethnobotany and nutritional composition of selected species. Ph.D. thesis, Addis Ababa University.

Afolayan, A. and Jimoh, F. (2009). Nutritional quality of some wild leafy vegetables in South Africa. International Journal of Food Science and Nutrition 60 (5): 424-431.
Ameni G. (2003). An ethnobotanical survey on plants of veterinary importance in two Werdas of Southern Tigray, Northern Ethiopia, SINET: Ethiop. J. Sci.; 26:123- 136.
Asfaw, Z. (2009). The future of wild food plants in southern Ethiopia: Ecosystem conservation coupled with enhancement of the roles of key social groups. Acta Horticulturae 806: 701-707.
Assefa, A., & Abebe, T. (2014). Ethnobotanical study of wild medicinal trees and shrubs in Benna Tsemay District, Southern Ethiopia. J Sci Dev, 2(1), 17-33.
Balemie K, Kelbessa E, Asfaw Z. (2004). Indigenous medicinal plant utilization, management and threats in Fentalle area, Eastern Shewa, Ethiopia. Ethiop. J. Biol. Sci.; 3:37- 58.
Beluhan, S. and Ranogajec, A. (2010). Chemical composition and non-volatile components of Croatian wild edible mushrooms. Food Chemistry 124: 1076-1082.
CSA. Ethiopian Housing and Population Survey. 2015.
Demel Teketay., Feyera Senbeta., Maclachlan, M., Bekele, M. and Barklund, P. (2010).Edible Wild Plants in Ethiopia. Addis Ababa University Press, 575pp.
Fentahun M, Hager H (2008). Wild edible fruit species cultural domain, informant species competence and preference in three Weredas of Amhara region, Ethiopia.
Grivetti, L. and Ogle, B. (2000). Value of traditional foods in meeting macro and micronutrient needs: the wild plant connection. Nutr. Res. Rev. 13: 31-46. managementunit, SIDA, Nairobi, Kenya. Pp 766.
Kebu, B. and Fasil, K. (2006) Ethnobotanical Study of Wild edible fruit plants in Derashe and Kucha Weredas, South Ethiopia. Journal of Ethnobiology and Ethnomedicine, 2, 53-75. https://doi.org/10.1186/1746-4269-2-53
Ruffo, C.K., Birnie A. &Tengnäs B. 2002.Edible wild plants of Tanzania. Regional land
Sintayo Demise and Zebene Asfaw.2020. Ethnobotanical Study of Wild Edible Plnats in Adola Wereda, Souther Ethiopia. International Journal of Research and Analytical Review,Volume7,Issue 2, p 212-227.
Tebkew M, Asfaw Z, Zewudie S. Underutilized Wild edible fruit plants in the Chilga Wereda, northwestern Ethiopia: focus on wild woody plants. Agric Food Secur. 2014;3:12.
Teklehaymanot, T. and Giday, M. (2010). Ethnobotanical study of Wild edible fruit plants of Kara and Kewego semipastoralist people in Lower Omo River valley, Debub Omo Zone, SNNPR, Ethiopia. Journal of Ethnobiology and Ethno medicine 2010, 6: 23.
Tilahun, T. and Mirutse, G. (2010) Ethnobotanical Study of Wild edible fruit plants of Kara and Kwego Semi-Pastoralist People in Lower Omo River Valley, Debub Omo Zone, SNNPR, Ethiopia. Journal of

Evaluation of Growth performance of Moringa stenopetala provenance at Daro Lebu and Hawi Gudina districts, West Hararghe Zone, Oromia, East Ethiopia.

Shimelis Dekeba, Alemayehu Diriba, Mosisa Mezgebu and Wasihun Gizaw
Mechara Agricultural Research Center, Mechara, Ethiopia
Corresponding Author: shimedekeba@gmail.com

Abstract
*Six Moringa stenopetala provenances (*Abay Filklik, Arbaminch, Gofa, Wolayita, Konso, and Babile) *were examined for survival and growth parameters at Daro Lebu district at Mechara and Hawi Gudina district at Hawi Gudina site July 2019. This study was undertaken with a randomized complete block design with four replications. At age of three years; survival rate, tree height, diameter at breast height (DBH) over bark, root collar diameter, canopy diameter (RCD), and fresh leaf biomass were assessed. The result indicated that at the Mechara site, there were significant (P < 0.001) among provenances; in their survival, height, root collar diameter, and fresh leaf biomass, but DBH and canopy diameter did not show statistical difference. At Hawi Gudina, there was a significant difference only in fresh leaf biomass between provenances. Survival at the Mechara site ranged from 50% for (M.gofa and M.wolayita) to 83.33% for M.babile ; while at the Hawi Gudina site survival ranged from 91.67% for M.abay Filiklik to 100% for (M.konso, M.arbaminch, and M.wolayita) provenances. At the Mechara site, M.abay Filiklik demonstrated superior mean height (2.53 m) followed by M.babile (2.09 m) and M.wolayita (1.2 m) is the shortest provenance. At Hawi Gudina site, M.arbami demonstrated superior mean height (2.32m) followed by M.konso (2.3 m) and M.babile(1.57 m) were the shortest provenance. M.gofa demonstrated superior RCD (99.17 mm) followed by M.babile (98 mm), while M.wolayita (61.09 mm) showed the lowest performance at Mechara site. While, at Hawi Gudina site, M.arbaminch demonstrated superior RCD (138.67mm) followed by M.konso (135.42 mm); while M.babile (107.09 mm) showed the lowest performance. At Mechara site, M.babile demonstrated superior fresh leaf biomass (1.61 kg) followed by M.gofa (1.59), while M.wolayita (0.48 kg) showed the lowest performance. At Hawi Gudina site, M.gofa demonstrated superior fresh leaf biomass (3.11 kg) followed by Wolayita (2.91 kg), while M.babile (1.34 kg) showed the lowest performance. Owing to superior growth performances attained, M.babile, M.gofa, and M.konso be recommended for Mechara and similar agro-ecology, while M.arbaminch, M.gofa, and M.konso for Hawi Gudina and similar agro-ecology.*

Keywords: Moringa provenance, survival rate, growth, Leaf fresh biomass, Mechara, Hawi Gudina

Introduction

Moringa stenopetala belongs to the family Moringaceae which is represented only by a single genus Moringa. The genus Moringa is represented by 14 different species to which *M.stenopetala* belongs (Yisehak et al., 2011). *M. stenopetala* grows in the wild in elevations between 1,000 and 1,800 m (Mark, 1998) but from personal observations, the species grows as high as 2200 m.a.s.l and as low as 300 m (herbarium sources) in Ethiopia. Moringa is drought resistant and can be grown in a wide variety of poor soils, even barren ground, with soil pH between 4.5 and 9.0. The species is easy to reproduce and its growth is very fast that have raised growing interest due to its social, economic, and environmental importance which can benefit humans and animals nutritionally, economically, and as an energy source. Moringa is an important food source in many countries. *Moringa stenopetala* leaves are the staple food of the Konso people in Ethiopia (Ezekiel et al., 2014).

M. stenopetala is often referred to as the East African Moringa tree because it is native only to southern Ethiopia and northern Kenya (Mark, 1998). Though it grows in many other parts of the tropics, it is not as widely known as its close relative, *M. oleifera* of India but often considered generally more desirable than *M. oleifera* (Yisehak et al., 2011). According to Edwards et al., 2000, *M. stenopetala* is a tree 6-12 m tall; trunk: more or less 60 cm in diameter at breast height; crown: is strongly branched sometimes with several branches; thick at base; bark: white to pale gray or silvery, smooth; wood: soft; leaves: up to 55 cm long; inflorescence: pubescent, densely many-flowered panicles 60 cm long. The optimum light for germination of all Moringa species is half shade. Seeds could be planted about 2 cm deep in soil that is moist but not too wet. Sprouting occurs normally in 1-2 weeks. It can be allowed to grow for shade (6-15 m) or kept low (about 1-1.5 m) for easier harvesting (Yisehak et al., 2011).

The cultivation of Moringa stenopetala in Ethiopia occurs mainly in the zones and special districts such as South Omo, Gamo Gofa, Kaffa, Sheka, Bench Maji, Wolaita, Dawaro, Bale, Borena, Sidama, Burji, Amaro, Konso and Derashe (Edwards et al., 2000). Perennial types of Moringa are best with many production constraints, such as a relatively long period to bear fruit, non-availability of planting materials, and the requirement for long rainy periods in regions where water is scarce and vulnerable to pests and diseases (Price, 1985; Endeshaw, 2003; Moges, 2004). Various indigenous fodder trees and shrubs rich in condensed tannins including *M.stenopetala* is considered nutritionally potential feed supplements under the smallholder farming system in the tropics (Yisehak et al., 2010).

In Ethiopia, it is grown as a backyard crop in the southern parts of the Rift Valley and adjoining lowlands for its edible leaves, flowers, and tender pods. The leaf of Moringa is a very popular vegetable in Southern Nations and Nationalities and Peoples Regional State of Ethiopia and is valued for its special flavor. It is grown as a backyard tree to make it accessible for daily use in more than six million households in Southern Ethiopia (Endeshaw, 2003). Moringa has attracted enormous attention from ethnobotanists and plant genetic resource conservationists due to its widespread use in agriculture and medicine.Among the wide range of uses it provides are human food, fuel wood, livestock forage, medicine, dye, water purification, soil, and water conservation, quality of cooking oil, green manure, and the tree is used as a source of income for Moringa growers (Demeulenaere, 2001; Jiru et al., 2006; Morey, 2010; Melesse et al., 2011).

M. stenopetala is particularly important as a human food because the leaves, which have high nutritional value (Abuye et al., 2003), appear towards the end of the dry season when few other sources of green vegetables are available. The leaves contain high amounts of essential amino acids and vitamins A and C (Abuye et al., 2003). Although Moringa is fast-growing, drought tolerant and easily adapted to poor soil and arid conditions, it has not received significant research attention to select and develop potential ecotypes that might be valuable both as horticultural and medicinal crops (Tenaye et al., 2009). Nowadays, some rural households in Hararghe area use Moringa for veterinary and other utilities.

The need for the *M. stenopetala* is increasing by livelihood as a result of its utility however, it's not accessible in case of the limited amount of species and lack of identification more adaptation provenance is supported with research in the study area. Despite its more significant contributions to livelihood, *M. stenopetala* has not been given due research on provenance in the study area to establish and expanded its species. In the study area, there are gaps between the amount of Moringa contribution and the needs of livelihood because of not giving attention to the expanded amount of *M. stenopetala* with its usage. The knowledge about genetic improvement, proper management, and utilization of this valuable multipurpose tree species is limited. One of the means to overcome the problems is to evaluate different provenances of this species to identify the provenances that maximize productivity. Hence, the present study is initiated to evaluate different *Moring stenopetala* provenances and select the best-adapted provenance in Western Hararghe Zone.

Background information of the Study Species, *Moringa stenopetala*

Favorable Condition for *Moringa Stenopetala* Growth

M. stenopetala can be grown at elevations from 390 - 2,200 meters. It grows best in areas where annual temperatures are within the range of 25 - 35°C, but can tolerate 15 - 48°. Plants can tolerate light frosts; even heavier frosts do not always kill the plant since it can sprout from the base. It prefers a mean annual rainfall in the range of 500 - 1,500 mm but tolerates 200 - 2,800 mm. Grows best in a sunny position, but tolerates light shade. It prefers well-drained soil with a high groundwater table, but it can also withstand dry conditions well, and consequently, it is found in both wetlands and dry areas. It prefers a pH in the range of 6 - 8, tolerating 5- 9. Plants are very drought tolerant; remaining green and continuing to grow even during the exceptionally long dry seasons (Fern, 2018).

Importance of *Moringa stenopetala*

Alley cropping/Intercropping *Moringa stenopetala*

With their rapid growth, long taproot, few lateral roots, minimal shade, and a large amount of biomass yield of high protein content. Moringa trees are one of the best MPT candidates for use in alley cropping systems. Traditionally, the species is grown in mixed multi-story stands with food crops. For instance, around Arba Minch, farmers plant in their home gardens mostly 5 and sometimes up to 15 Moringa trees per 0.1 ha. Farmers practice permanent multistoried cultivation with *M. stenopetala* at the uppermost level, papaya, coffee, and bananas in the upper-middle level; cassava, maize, and sugar cane in the lower-middle level, and cotton and pepper in the lowest level (Yisehak *et al.*, 2011).

Socio-Economic Values of *Moringa stenopetala*

The economic status of an individual in low lands of southern Ethiopia is closely associated with the number of *Moringa stenopetala* (Haleko) trees they have in their backyard. For example, when a young man proposes marriage in the former administrative region of Gamo Goffa of South Ethiopia, the girl's (bride) family enquires whether or not they would be husband has Haleko trees on his farm (Endeshaw, 2003). Demeulenaere (2001) observed in some parts of southern Ethiopia, especially among the Konso people, that the abundance of Moringa species in the garden or on farmland was an indication of the social status of the owner among the society. The one with many Moringa trees in the garden or on farmland had higher social status and was also considered a prosperous person. Among the various uses of *M. stenopetala* are animal feed, fertilizer, honey production, life fencing, medicinal (traditional), and pollution control (Yisehak *et al.*, 2011).

Season and Planting Method of *Moringa Stenopetala*

Moringa is propagated either by stem (limb) cuttings or by seed. In perennial types, limb cuttings 100-150 cm in length with a diameter of 14-16 cm are planted *in situ* during the rainy season. Elite trees are cut down, leaving a stump with a 90 cm head from which 2 to 3 branches are allowed to grow. From these shoots, cuttings 100 cm long and 4 to 5 cm in diameter are selected and used as planting material (Bezabeh, 1993; Teketay, 1995).

The branch cuttings are planted in pits of 60x60x60 cm at a spacing of 5x5 m, during the months from June to August. The monsoon rains during the period facilitate easy rooting and further growth. While planting, one-third of the cutting should be kept inside the pit. Under moderate clay situations, watering should be done just to optimum levels to avoid root rot. The seeds of annual Moringa may be directly dibbled in the pit to ensure accelerated and faster growth of the seedlings. The best-suited season for sowing the seeds is March to August under Southern Ethiopian conditions. The time of sowing has to be strictly adhered to because the flowering phase should not coincide with the rainy seasons, which results in heavy flower shedding. A plant spacing of 2.5x2.5 m between rows and plants should be adopted, giving a plant population of 1600 plants ha^{-1}. The seed germinates 10 to 12 days after sowing. The seed requirement per hectare is 625 g. When planted in a single row along with irrigation channels, a spacing of 2 m is sufficient. Treatment of Moringa seeds with Azospirillum cultures at the rate of 100 g per 625 g of seeds before sowing resulted in early germination and increased seedling vigor, growth, and yield. The most common method of propagating *M. stenopetala* is by direct sowing without pre-treatment of seed. But standard nursery-raised seedlings are also commonly used. Removing the spongy seed coat improves germination. In a nursery, it needs 7-10 days to germinate. Use of wide polythene is advised as the bulgy root requires large enough space (12 cm diameter flat). In about 3 months the seedlings will be ready for planting. Some farmers occasionally propagate the species by using branch-sized cuttings (Yisehak *et al.,* 2011).

Origin of *Moringa Stenopetala*

M. stenopetala is often referred to as the East African Moringa tree because it is native only to southern Ethiopia and northern Kenya (Mark, 1998). Though it grows in many other parts of the tropics, it is not as widely known as its close relative, *Moringa oleifera* of India but often considered generally more desirable than it.

Materials and Methods

Trial Site, Seed Sources, and Experimental Design

Climatic Description of the Study Area

The trial was conducted at Mechara Agricultural Research Center (on station). The center is located 431 Km west of Addis Ababa capital city of Ethiopia at 1780 m a.s.l and Hawi Gudina sub station that found south of Daro Lebu woreda at 70 km away from Mechara Daro Lebu woreda town. The elevation of Hawi Gudina is 1453 m.a.s.l. Rainfall pattern in both locations is bi-modal; Mechara Agricultural Research Center receives on average during *the belg* rainy season (February 26, March 90, April 157, and May 128mm) and *kiremt* rainy season (June 101, July 144, August 158, and September 127mm) and also Hawi Gudina receive on average during *belg* rainy season (February 32, March 31, April 145 and May 328mm) and *kiremt* rainy season (June 26, July 168, August 46 and September 98mm figure1). The average annual rainfall amount is 1120 mm at Mechara Agricultural Research Center and 992mm at Hawi Gudina (Figure

2). The mean annual temperature is 21°C with a mean annual minimum temperature of 15°C and a maximum of 28°C Mechara Agricultural Research Center while, at Hawi Gudina mean annual temperature is 23°C with a mean annual minimum temperature of 16°C and a maximum of 20°C (Wasihun, 2021 unpublished).

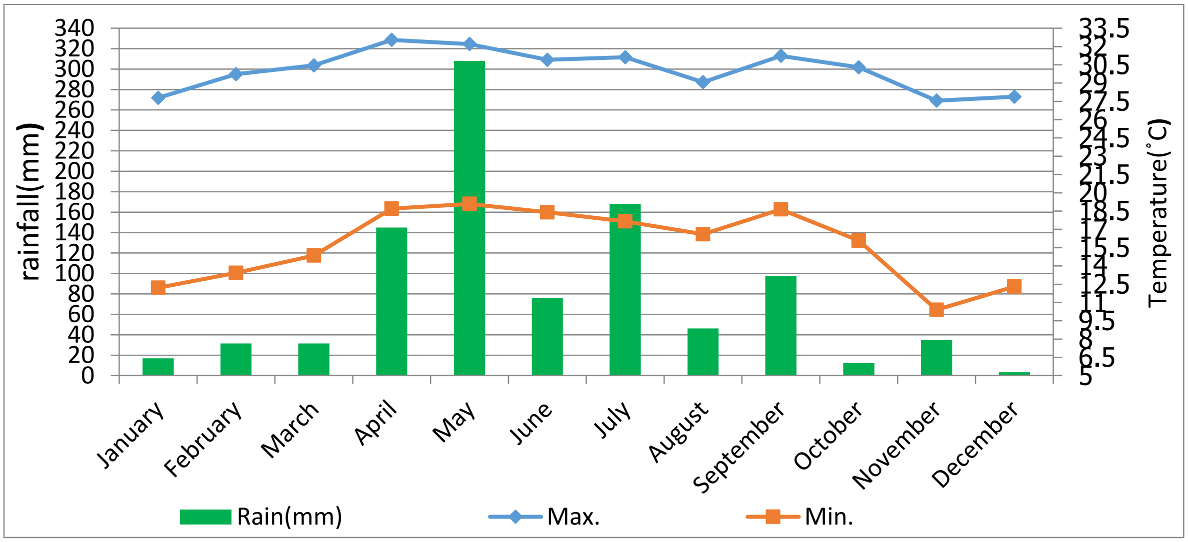


Figure 1. Mean monthly rainfall amount, mean minimum temperature, and Mean Maximum Temperature at Hawi Gudina

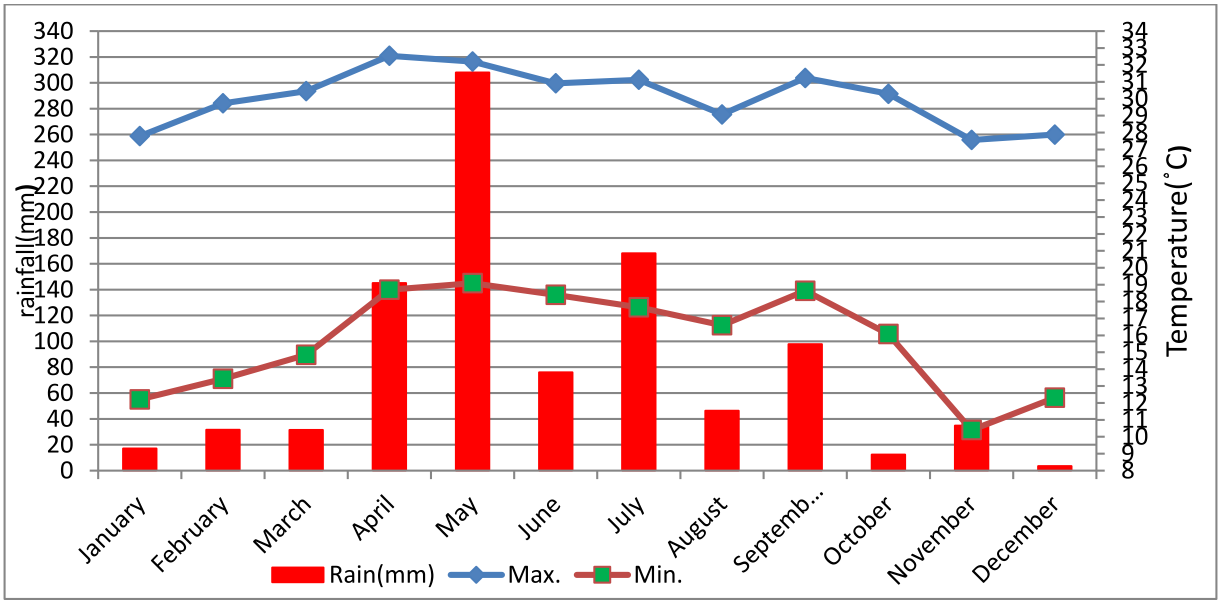


Figure 2. Mean monthly rainfall amount, mean minimum temperature, and Mean Maximum Temperature at Mechara

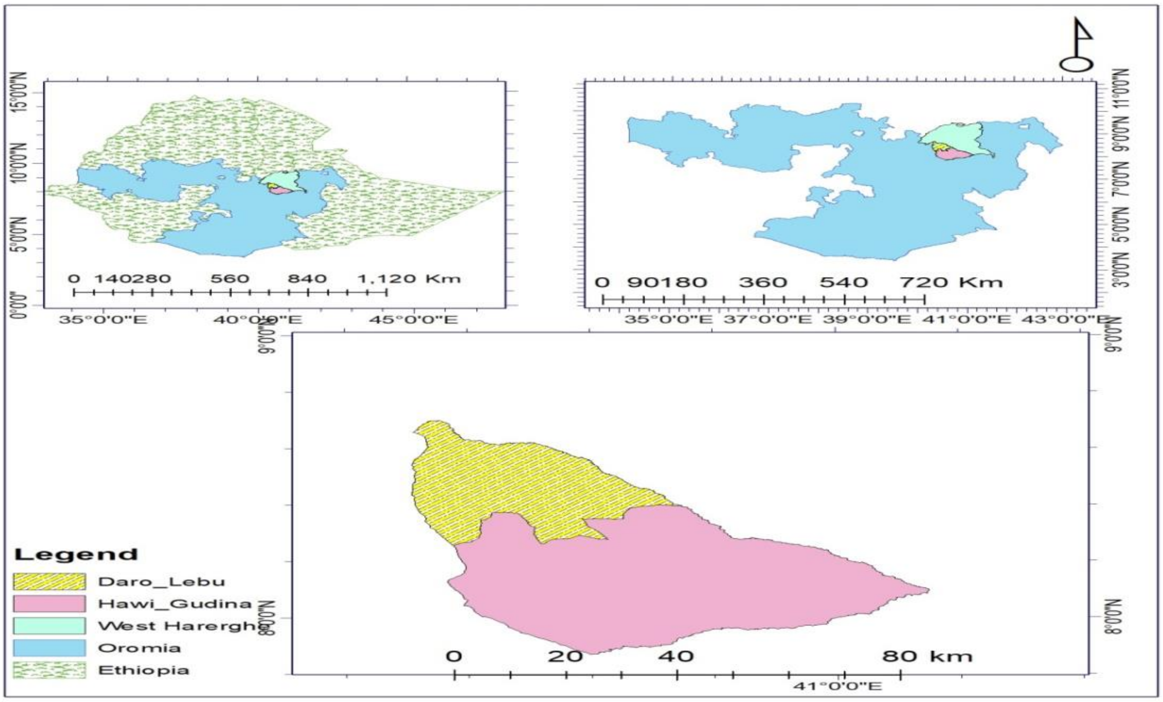


Figure 3. Map of the study area

Seed Source (provenance) and Procedure of Treatment

Six (6) *M. stenopetela* provenances were studied in both sites which were brought from, Abay Filklik, Arbaminch, Gamo Gofa, Wolayita, Konso, and the local (Babile). Potted seedlings of the provenances were raised with polythene tubes at Mechara nursery using standard cultural techniques (Forest Division, 1982). The trial sites were manually cleared and land tilled followed by pitting (pit size: 30 x 30 cm). before seedling planting. Planting was done in July 2019 at Mechara and Hawi Gudina sites respectively. Weeding was done three times during the rainy season and once during the dry season

Experimental Design

Randomized Complete Block Design (RCBD) was used for the six provenances of *M. stenopetala* (treatment species) with four replications. The sizes of the plots were 4m*2m = (8m2) and per plot six (6) trees were planted with 2m*2m spacing. The spacing between plots and blocks was 3m. Sixteen (16) plots at one trial site were prepared while 96 trees were planted at total areas of 25m*17m = (425m2) on each trial site.

Data Collection

The assessment was carried out in 3rd year after planting for variables such as; survival, root collar diameter 30 cm above the ground (RCD), height (H), canopy diameter, diameter at breast height (DBH), and leaf biomass. Leaf biomass production was measured at the final assessment. Height was measured using calibrated height measuring pole and the canopy was measured using a tape meter while RCD and DBH were measured using a caliper.

Data Analysis

The collected data were analyzed with analysis of variance (ANOVA) following the General Linear Model (GLM) procedure using Statistical Analysis Systems (SAS Inst. Inc., 1991). The important variation, mean separation using LSD of result indicator was conducted at 5 % point of the significance level.

Results and Discussion

Survival Rate

Survival rate was significantly different between provenances ($p < 0.05$) at the Mechara site; while at the Hawi Gudina site, there was no significant difference (Tables 1 and 2). Survival at the Mechara site ranged from 50% for M.Gofa and M.wolayita to 83.33% for M.babile; while at the Hawi Gudina site survival ranged from 91.67% for M.abay Filiklik to 100% for M.konso, M.arbaminch, and M.wolayita. All provenances in both sites except the two at the Mechara site had survival above 66%. The insignificant differences among provenances at the Hawi Gudina site may imply all provenances have performed similarly.

Table 1. Means of survival rate, height, Diameter at breast height, Root collar diameter, Canopy diameter, and Fresh leaf Biomass increment for *M . stenopetela* provenance trial at age 3 at Mechara site

Provenances	SR (%)	H(m)	DBH (mm)	RCD (mm)	CNP(m)	FLB (kg)
M.abay Filiklik	66.67(13.61) bc	2.53(0.27) a	30.84(2.88)	90.75(13.21) a	0.95(0.2)	0.72(0.03) bc
M.arbaminch	75(9.62) ab	1.57(0)d	18.59(9.2)	85.42(1.39) a	1.25(0.38)	0.79(0.05) bc
M.babile	83.33(0)a	2.09(0.09) b	28.75(2.5)	98(4.74) a	1.03(0.22)	1.61(0.23) a
M.gofa	50(19.25) d	1.78(0.24) cd	27.29(9.92)	99.17(6.31) a	1.38(0.36)	1.59(0.58) a
M.konso	56.25(4.17) cd	1.97(0.25) bc	32.67(9.52)	85.58(14.84) a	1.29(0.31)	0.98(0.43) b
M.wolayita	50(0)d	1.2(0.23) e	29.38(7.08)	61.09(7.04) b	0.77(0.15)	0.48(0.21) c
Mean	63.54	1.86	27.92	86.67	1.11	1.03
PV	0.0006	<.0001	0.227	0.0004	0.051	0.0004
LSD	14.37	0.309	11.839	13.918	0.4162	0.477
CV	15	11.047	28.14	10.66	24.83	30.791

*Values in parenthesis are standard errors. Means with of the same letter within the same column are not significantly different. Significant ($P < 0.05$) ns = Not significant ($P > 0.05$). SR=Survival Rate, H=Height, DBH= Diameter at Breast Height, RCD= Root Collar Diameter, CD=Canopy Diameter, and FLB=Fresh Leaf Biomass.

Table 2. Means of survival, height, Diameter at breast height, Root collar diameter, Canopy diameter, and Fresh leaf Biomass increment for *M. stenopetela* provenance trial at age 3 at Hawi Gudina site.

Provenances	SR (%)	H(m)	DBH (mm)	RCD (mm)	CNP (m)	FLB (kg)
M.abay Filiklik	91.67(9.62)	2.07(0.28)	52.71(20.87)	105(17.71)	2.15(0.29)	2.03(0.42) [bc]
M.arbaminch	100(0)	2.32(0.32)	43.92(7.67)	138.67(14.43)	2.04(0.23)	2.72(0.53) [ab]
M.babile	95.83(8.34)	1.57(0.21)	41.04(8.64)	107.09(24.28)	1.61(0.13)	1.34(0.44) [c]
M.gofa	95.83(8.34)	2.25(0.18)	39.5(10.06)	126(32.87)	2.14(0.42)	3.11(0.69) [a]
M.konso	100(0)	2.3(0.45)	39.92(15.47)	135.42(32.25)	1.89(0.4)	2.71(0.17) [ab]
M.wolayita	100(0)	2.2(0.8)	33.25(26.78)	107.25(29.71)	1.95(0.57)	2.91(1.07) [ab]
Mean	97.22	2.12	41.72	119.9	1.96	2.47
PV	0.3759	0.22	0.6271	0.2557	0.1576	0.018
LSD	9.55	0.670	23.004	38.07	0.445	1.006
CV	6.52	20.99	36.58	21.07	15.05	27.05

*Means of individual provenance with standard error in parenthesis. The means of the same letter within the same column are not significantly different. Significant ($P < 0.05$) ns = Not significant at ($P > 0.05$). SR=Survival Rate, H=Height, DBH= Diameter at Breast Height, RCD= Root Collar Diameter, CD=Canopy Diameter, and FLB=Fresh Leaf Biomass.

Height Growth

The highest height (2.53m) was scored by the provenance from M.abay Filiklik and the shortest (1.2 m) by the Wolayita provenance for Mechara. At Hawi Gudina the highest one is Arbaminch (2.32 m) and the shortest one is Babile (1.57) provenance respectively. The differences in height growth within a site could be attributed to variations in adaptability among provenances while the between site differences in growth relate to agro climate differences between the two sites. Generally, the provenances showed good performance in height development at Hawi Gudina.

Diameter at Breast Height

There was no significant difference among the provenances in DBH at both sites. Though there were not significant, the M.konso (32.67) tree provenance had the greatest mean DBH followed by M.abay Filiklik (30.84) (Table 1) at Mechara while the greatest mean DBH for Hawi Gudina is M.abay Filiklik (52.71) and the least DBH is for M.wolayita (33.25) provenance. Although there is no significant variation in DBH at the Hawi Gudina site all provenances showed good performance in DBH development. All provenances gave comparable diameters when measured at year three.

Root Collar Diameter

Root collar diameter (RCD) was significantly different between coppice levels ($p < 0.05$) only at Mechara sites, which ranged between M.wolayita 61.09 mm and 99.17 mm for M.gofa provenance (Table 1). Though there is no significant difference in RCD at the Hawi Gudina site; the highest RCD was recorded for M.arbaminch (138.67 mm) provenance (Table 2). The differences in RCD development within a site could be attributed to variations in adaptability among provenances, but generally, the provenances at the Hawi Gudina site showed good performance in RCD development.

Canopy Diameter

At both sites, provenances did not differ significantly in canopy diameter. Canopy diameter at the Mechara site ranged from 0.77 m for M.wolayita to 1.38 m (Table 1) for M.gofa and 1.61 m for M.babile to 2.15 m for M.abay Filiklik (Table 2) provenance respectively.

Fresh Leaf Biomass

Fresh leaf biomass was significantly different between provenances ($p < 0.05$) at both sites (Tables 1 and 2). Fresh leaf biomass at the Mechara site ranged from 0.48 kg for M.wolayita to 1.59 kg for M.gofa and, while for the Hawi Gudina site 1.34 kg for M.babile to 3.11 kg for M.wolayita provenance, respectively. Most provenances grown at the Hawi Gudina site showed high production of fresh leaf biomass than those grown at the Mechara site. This could be due to agroecological variation between these sites. The lowest fresh leaf biomass at the Mechara site was recorded from M.wolayita; while the Hawi Gudina site was recorded for M.babile provenances. This poor performance could probably be due to poor genetic adaptations influenced by climatic conditions in this area.

Conclusions and Recommendations

In Ethiopia, moringa is grown as a backyard crop in the southern parts of the Rift Valley and adjoining lowlands for its edible leaves, flowers, and tender pods. The leaf of Moringa is a very popular vegetable in Southern Nations and Nationalities Peoples Regional State of Ethiopia and is valued for its special flavor. Knowledge about genetic improvement, proper management, and utilization of this valuable multipurpose tree species is limited. One of the means to overcome the problems is to evaluate different provenances of this species to identify the provenances that maximize productivity. Hence, the present study is initiated to evaluate different *Moring stenopetala* provenances and select the best-adapted provenance in Western Hararghe Zone. There was a significant difference between provenances in their survival, height, root collar diameter, and fresh leaf biomass, but DBH and canopy diameter did not show statistically significant variation at the Mechara site. The current study has shown statistically significant variation among moringa provenances in their survival, height, root collar diameter, and fresh leaf biomass, but DBH and canopy diameter did not show statistically significant variation at the Mechara site. At Hawi Gudina, there was a significant difference between provenances only in fresh leaf biomass. The study reveals that at Mechara the most promising provenances are M.babile, M.gofa, and M.konso whereas at Hawigudina, M.arbaminch, M.gofa, and M.konso. The authors have recommended M.babile, M.gofa, and M.konso provenance for Mechara and similar agro-ecology, while M.arbaminch, M.gofa, and M.konso provenances for Hawi Gudina and similar agro-ecology for further production. The research should focus on genetic improvement, and nutrient analysis and evaluate the compatibility of these provenances with other crops in the agroforestry systems.

Acknowledgements

Researchers are very grateful to IQQO for providing funding for this research project. We are also grateful to Mechara Agricultural Research Center and all of the workers, particularly the Agroforestry team members, for their diligent efforts in making the project a success.

References

Abuye, C., Urga, K., Knapp, H., Selmar, D., Omwega, A. M. and Imungi, J. K. (2003), "A compositional study of Moringastenopetalaleaves", East African Medical Journal, Vol. 80.

Bezabeh, K., 1993. Other medicinal uses of Moringastenopetala.Agrofor. Today, 5: 18-18. CWS. 2000. Moringa: The Miracle Tree. CSA, Dakar, Senegal.

Demeulenaere, E. 2001.Moringastenopetala, a subsistence resource in the Konso district. Proceedings of the International Workshop Development Potential for Moringa Products, October 29-November 2, 2001, Dar-Es-Salaam, Tanzania, pp: 2-29.

Edwards, S., M. Tadesse, S. Demissew and I. Hedberg. 2000. Flora of Ethiopia and Eritrea, Volume 2, Part 1: Magnoliaceae to Flacourtiaceae. Addis Ababa University, Ethiopia, Uppsal, Sweden, pp: 660.

Endeshaw, H.G. 2003.Promoting the Miracle Tree of Hope.Ethiopian Herald. Addis Ababa University, Ethiopia.

Ezekiel, E., Shabani, A. O. C., Yonika, M. N., & Mathew, A. M. (2014). Survival, growth and biomass production of Moringa oleifera provenances at Gairo inland plateau and Ruvu Coastal Region in Tanzania. African Journal of Plant Science, 8(1), 54–64. https://doi.org/10.5897/ajps12.158

Fern, K. (2018). Tropical plants database, Ken Fern. tropical. theferns. info.

Jiru, D., Sonder, K., Alemayehu, L., Mekonen, Y., & Anjulo, A. (2006). Leaf yield and nutritive value of Moringa stenopetala and Moringa oleifera accessions: Its potential role in food security in constrained dry farming agroforestry system. Proceedings of the Moringa and other highly nutritious plant resources: Strategies, standards and markets for a better impact on nutrition in Africa, Accra, Ghana, 16-18.

Mark, E.O. 1998. Research on applied uses of Moringastenopetala.FAO Technical Bulletin No.4. http://www.berfingen.info/akababi/simon.htm.

Melesse, A., Tiruneh, W., & Negesse, T. (2011). Effects of feeding Moringa stenopetala leaf meal on nutrient intake and growth performance of Rhode Island Red chicks under tropical climate. Tropical and subtropical agroecosystems, 14(2), 485-492.

Moges, Y. (2004). Recommeneded Agroforestry/Multipurpose trees for Borana lowlands, Middleland and their production techniques. Forestry Research Center, Dryland Forestry research project coordinator. Addis Ababa, Ethiopia.

Price, M.L., 1985. Fruits and others: Articles the moringa tree. Tropical seeds.

Teketay, D. (1995). The effect of temperature on the germination of Moringa stenopetala, a multipurpose tree. Tropical Ecology, 36(1), 49-57.

Tenaye, A., E. Geta and E. Hebana, 2009. A multipurpose cabbage tree (Moringastenopetala): Production, utilization and marketing in SNNPR, Ethiopia. ActaHorticulturae, 806: 115-120.

Yisehak, K., D. Belay and G. Janssens, 2010. Indigenous fodder trees and shrubs: Nutritional and ecological aspects. 14th European Society of Veterinary and Comparative Nutritrition. ESVCN, Zurich, Swizerlands.

Yisehak, K., Solomon, M., & Tadelle, M. (2011). Contribution of Moringa (Moringa stenopetala, Bac.), a highly nutritious vegetable tree, for food security in south Ethiopia: a review. Asian Journal of Applied Sciences, 4(5), 477-488.

SAS Inst. Inc., 1991