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 Other Aquatic Life Research Center, Batu, Ethiopia, 23-27 December 2020.

Editors: *Kefyalew Assefa, Tilahun Cibsa, Kasahun Kitila, Shifera Tadasse, Tadele Geremu, Mezgebu Senbato and Bikila Mengistu*

Oromia Agricultural Research Institute
P.O.Box 81265, Finfinne, Ethiopia

Correct citation: Kefyalew Assefa, Tilahun Cibsa, Kasahun Kitila, Shifera Tadasse, Tadele Geremew, Mezgebu Sanbato and Bikila Mengistu (eds). 2021. Proceedings of Review Workshop on Completed Research Activities of Natural Resource Research Directorate Held at Batu Fishery and Other Aquatic Life, Batu, Ethiopia, 23-27 December 2020. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia.

Organized by:- Communication Affairs Team

Contents

Soil Resource Survey Research

Soil Fertility Assessment and Mapping at Kofele District, West Arsi Zone, Oromia Ethiopia

Husen Namu[1*] and Bekele Abebe[1]
Batu Soil Research Center, P. O. Box 59, Batu, Oromia, Ethiopia.
Corresponding author: E-mail: husunamukurse2016@gmail.com,

Abstract

Soil fertility assessment and mapping is the way of assessing soil nutrients on the basis of soil samples test results and preparing maps at required scale. The study tried to map selected plant nutrients phosphorous, potassium, organic carbon and other soil fertility indicators (pH.EC, CEC) for Kofele district, Oromia, Ethiopia. About 161 soil samples were collected across the district and used to map the whole area. Standard laboratory analyses were followed for every soil parameters. In order to predict values for not sampled locations the Ordinary Kriging interpolation was used by ArcGIS10.1 software. The potassium level in the study site has two classes medium and high which covers 79.98% and 20.02%, respectively. The district has four categories of soilpH but the majority of the area falls in strongly acidic. Generally, the pH of the study were very strongly acidic (5.63% of the area, strongly acidic (63.85% of the area), extremely acidic (0.35%of the area) and moderately acidic (30.16%of the area).The available phosphorus level iscategorized as low, medium and high which is 0.71%, 98.36%, and 0.93%, respectively. The dominating class is medium. Cation Exchange Capacity can also becategorized in three classes namely low (9.14%), moderate(90.84%) and high (0.016%) in soils of the area.Soil Electrical Conductivity is ranged from 0.085 to 0.383 mmhos/cm at 25^{o}Ci.e, are salt free. Soil Organic Matter content ranged from 1.10% to 4.79%namely from low to moderate in rating classes. The organic matter content of soils of the study area are dominated by moderate and low with percent share of 79.73%, 20.27%, respectively. Exchangeable potassium (K) can also be categorized in two classes namely medium 79.98 % and high 20.02% in soil of the area.

*Keywords***:** *Kofele District, Soil Parameters; Soil Fertility; Mapping and Kriging*

Introduction

Soil fertility depletion is considered as the fundamental biophysical cause for declining percapita food production in SSA countries in general and Ethiopia in particular (Sanchez *et al.*,1997). Farmers in most parts of the country actually work hard, in seasons of the year when the rainfall is favorable for their cropping; regardless of their effort they get very little, which does not help them to escape their subsistence way of living. The fault with this agricultural problem is very intricate in nature, the complexity arises from various condition of the country such as the agro-climate, topography of the lands, the soil types and socio-economic status of the farming community and the combination of these; the overall effect of which is finally reflected by soil fertility decline and reduction in yield of crops (Alemayehu *et al.*, 2006).

The issue is to solve the problem, systematic application of scientific methods to assess the fertility status of soils through their physical, chemical and biological properties. Research results have shown that the success in soil management to maintain soil quality depends on understanding of the properties of a given soil. This is a requisite for designing appropriate management strategies and thereby solving many challenges that the Ethiopians are facing in the crop and livestock production sectors and in their efforts towards natural resource management for sustainable development (Wakene, 2001).

Regional Research Institutes and national and regional soil laboratories, have been progress in terms of resources and output, they are currently carrying out research on various areas of soil and water management, fertilizer recommendations, management of problematic soils, and other relevant areas. However, much of these activities are specific to particular areas selected for study and currently cannot be compiled, compared, or accessed at a national level to enable policymakers and other stakeholders to draw conclusions on the status of soil in Ethiopia as a whole and its implications for food production.

Describing the spatial variability across a field was difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced. GIS is a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data (Burrough *et al.*, 1998).GIS can be used in producing soil fertility map of an area that helps to understand the status of soil fertility spatially and temporally, which will help in formulating site–specific balanced fertilizer recommendation. These technologies allow mapping fields accurately and computing complex spatial relationships between soil fertility factors. Numerous studies have been conducted based on geo–statistical analysis to characterize the spatial variability of different properties (Cao *et al.*, 2011; Li XG *et al.*, 2007; Weindorf DC, Zhu Y, 2010; Liu *et al.*, Lin JS *et al.*, 2009 and Haung *et al.*, 2007). Thus, information on spatial variability of soil nutrients is important for sustainable management of soil fertility. Among many Geo–statistical methods, ordinary kriging is widely used to map spatial variation of soil fertility. According (Ismaili Samira *et al.,*2014*),*the ordinary kriging (using either exponential or spherical models) is more accurate for predicting the spatial patterns of the soil properties pH, OM, P, and K than the two other methods (IDW and splines), because it provides a higher level of prediction accuracy (Song *et al.*, 2013). Soil testing provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for optimizing crop yields. Soil fertility maps are meant for highlighting the nutrient needs, based on fertility status of soils and adverse soil conditions which need improvement to realize good crop yields (Verma *et al*., 2005).

Knowledge about an up–to–date status of different soil parameters at different landscapes and mapping their spatial distribution play a vital role in site–specific fertilizer recommendation to enhance production and productivity of the agricultural sector on sustainable basis. However, information on the status and spatial distribution of soil macronutrients are limited for west Arsi zone. Therefore, as part of the regional initiative, this study was conducted with specific objectives to assess and map the status and spatial distribution of soil major nutrients for Kofele district west Arsi Zone. The results of this study are expected to add value to the up–to–date scientific documentation of the status of soil fertility for national soil atlas which is being considered the recommended fertilizer source for maximizing crop yields and further to maintain the sustainable agriculture .

Although Soil fertility assessment and mapping at Kofele district was initiated as response of where and how to use the soil test based crop response studies results, it has more advantage than this to give information about soil fertility status of the district for different users. The objectives of the study were as follows:

- ✓ To identify and classify soil nutrient status of the study area
- ✓ To map soil fertility parameters
- ✓ To avail information on fertilizer application

Materials and Methods

Descriptions of Study Areas

The study was conducted at Kofele district which is found in Oromia Regional State and 272 kilometers far from Finfenne, the capital city of Oromia regional state to south direction. Geographically, Kofele district is located between 6^0 50’55” to 7^0 9’40” North latitudes and 38^0 39' 08" to 39^0 3' 4" East longitudes. With total area coverage of 66097.1 hectares.

Land Use and Vegetation

The main land use systems in the district are mixed (crop–livestock) agricultural system. The major crops produced are wheat (*Triticumaestivum*L.), maize (*Zea mays L,*), barley (Hordeumvulagare L.), potato (Salantumtuberosum), faba beans, (Viciafaba), field peas (Pisumstivum) and enset (*Enseteventricosum*).Besides, other cash crops vegetables are also produced widely. Agriculture is entirely rain fed. There are also different types of natural vegetation, grasses and waterlogged area.

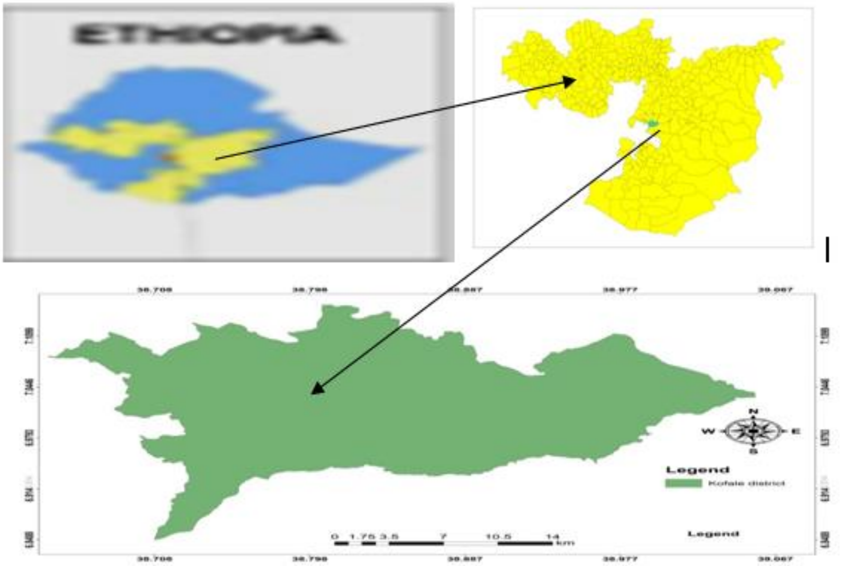


Figure1: Location map study area

Soil Sampling

At the beginning of the study, a preliminary soil survey and field observation were carried out using the topographic map(scale 1:50,000) and satellite image dated January 2016/17.Once the topographic map was interpreted, pre-defined sampling locations were navigated and the exact sampling points were determined by letting the GPS mean position for at least three to five minutes. However, as some pre-defined points were found in unsuitable places for sampling (*e.g.* road, waterway, and household) they were re-located in alternate locations within nearby cropping fields mostly inside a radius of 50 to 100 meters. Each location was recorded with a Garmin Map 70 S GPS using Adindan_UTM_ Zone_37N projected coordinates with 3 to 5 meter accuracy.

After reading the coordinate points and elevation of sampling points, slope gradient (%) of the study area was measured using clinometer by standing in the center of the plot. Then, 10 to 15 sub-samples were taken based on the complexity of topography and heterogeneity of the soil type.In order to address effective root depth of most annual crops, composite soil samples were collected from the top soil (0-20 cm) for chemical analysis. For perennial/tree crops such as fruit trees, coffee, etc sampling depth was extended to 0-50 cm downwards. During collection of sub-samples, maximum care was taken to address variability of the surrounding in terms of the dominant topography and soil type; for those landscapes having uniform topography and homogenous soil type (basically similar soil colour and texture) a minimum of 10 sub-samples were collected and composited within 10 to 50 m distance between each sub-plots using random sampling technique. Accordingly, about 161 points were successfully sampled in the thirty-nine kebeles (or peasant associations) of the District: during the off-season of 2007 E.C cropping season.

Soil Sample Preparation

Sample preparation was made at Batu Soil Research Center. The samples were air-dried and crushed using a mortar and pestle and passed through a 2 mesh sieve.

Soil Laboratory Analysis

Soil properties that were analyzed are texture, pH, ECe, cation exchange capacity (CEC), available P, organic carbon and exchangeable bases were calculated using standard equations. Particle size distribution was analyzed in laboratory by the Bouyoucos hydrometer method using sodium hexameta phosphate as dispersing agent as described by Sahlemedhin and Taye (2000). Organic carbon (OC) was determined using walkley black method. The percent soil organic matter was calculated by multiplying the percent organic carbon by a factor 1.724, considering the fact that organic matter is composed of 58% carbon. Soil pH was measured in a 1:2.5 soil:water suspension potentiometrically by using pH meter and electrical conductivity of a saturated soil paste extracted (ECe) at 25^0c was determined using electrical conductivity meter as described by Reeuwijk (2000).Available p was determined using the standard Olsen extraction method (Okalebo *et al.,* 2002). Total exchangeable bases were determined after leaching soils with ammonium acetate (Thomas, 1990). Amounts of Ca^{2+} and Mg^{2+} in the leachate were measured by atomic absorption spectrophotometer and K^+ and Na^+ were analyzed by flame photometry. Cation exchange capacity (CEC) was determined at soil pH level of 7 after displacement by using 1N ammonium acetate method in which it was thereafter, estimated titrimetrically by distillation of ammonium that were displaced by sodium as described in (Okalebo *et al.,* 2002).

Methods Followed

Selecting Uniform Sampling Area

Soil conditions are influenced by many environmental factors those could be aggravated accordingly through intervention of human beings and natural disasters, therefore while studying soil qualities including fertility status; it is important to investigate the relationship of soil forming factors and others factors. In this study as much as possible it was attempted to comprehensively investigate different factors such as topographic, land use, climate and soils of the area at required scale. The influencing factors were collected from different sources and prepared for further spatial analysis in order to produce spatial layers/ features of the study area. These factors were compared to each other and areas those have almost similar characteristics were grouped in to the same category by using GIS overlay analysis. These categories were used as mapping units and soil samples were collected from these units. Then the district was divided into 161 units as indicated in figure 2 below.

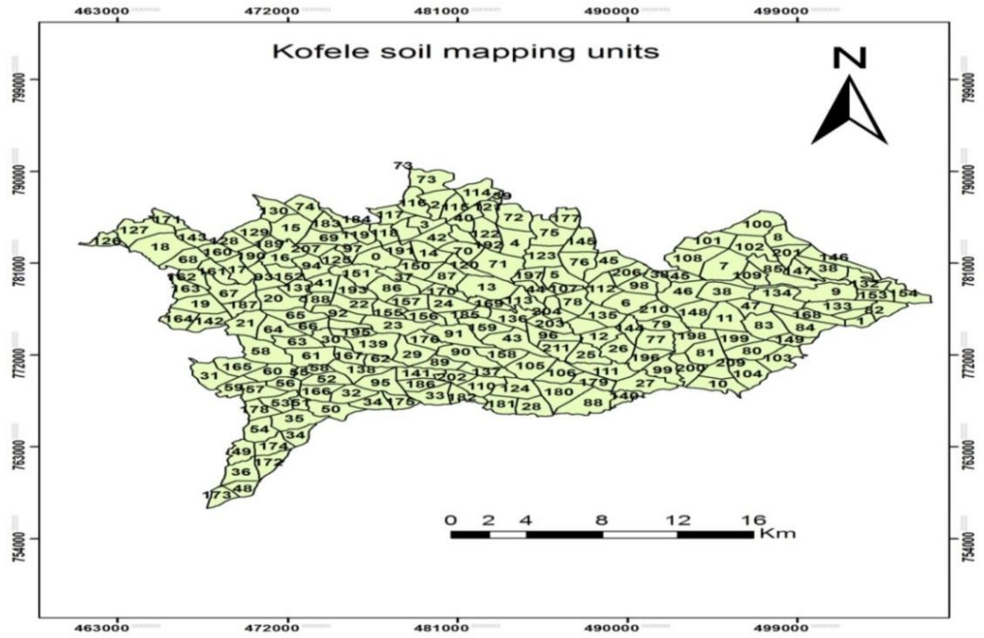


Figure 2. Mapping units

Soil Rating

Based on Booker tropical soil manual 1991 the result of analysis of individual parameters of soils were classified into different categories, i.e. low, medium, high and very high in respect of available contents of each nutrients.

Map Preparation

After data base of samples prepared boost Statistical evaluation and geospatial evaluation were conducted. Then at the end of the activities soil Fertility map of the district was produced for available phosphorous, CEC meq/100 g soil, organic matter (%), available K and soil pH.

Results and Discussion

Soil Reaction (pH)

The soil pH of the study area ranged from 4.022 to 5.86 with average value of 4.87. The soil pH value of the area was low and ranged from extremely acidic (pH <4.5) to moderately acidic (5.6 – 6.0) as per the pH rating category suggested by Johnson (2003) (Figure 3). Based on this, 0.35%, 5.63%, 63.85% and 30.16% of the soils were extremely acidic, very strongly acidic, strongly acidic and moderately acidic in reaction, respectively. The area coverage and percentage share of each categories of soil pH are illustrated in (Table 1). The spatial patterns of the soil pH at Kofele district seems as shown in *(*Figure 3).Thus, it is pertinent to raise the soil pH through liming to increase crop productivity in the study area.

The first reason for the lowest values of soil pH at the study sites could be high rainfall that results in loss of base forming cations through leaching and drain to streams in runoff generated from accelerated erosion. This enhances the activity of $Al3^{+}$ and H^{+} in the soil solution, which reduces soil pH and thereby increases soil acidity. Although soil acidity is naturally occurring in some areas, human activity can change the pH of a soil too; agricultural practices have accelerated the process of soil acidification (Kizilkaya and Dengiz, 2010). Hence, the second reason might be continuous use of ammonium based fertilizers such as diammonium phosphate, (NH4)2HPO4, in such cereal based cultivated fields, which upon its oxidation by soil microbes produce strong inorganic acids. These strong acids in turn provide H^{+} ions to the soil solution that in turn lower soil pH (Abebe and Endalkachew, 2012). Moreover, long-term usage of urea, replacement of ammonium with basic cations and production of hydrogen ion during nitration process, decreases the amount of pH (Juo *et al.,* 1996). Continuous cultivation practices, excessive precipitation and steepness of the topography could also be some of the factors responsible for the reduction of pH in soils at the middle and upper elevation areas (Ahmed, 2002).

Relatively the lowest electrical conductivity (0.085 mmhos/cm at 25^{o}c) was recorded for soils of soil mapping unit 208, whereas the highest value (0.383 mmhso/cm at 25^{o}c) was recorded on soil mapping unit 106. The electrical conductivity of soils of all land units was, however, categorized under low according to Landon (1991). Relatively the lowest EC value recorded for soils of land mapping units could be attributed to the removal of basic cations through erosion with soil and runoff from the relatively sloping land, whereas the highest EC of soil mapping units could be attributed to accumulation of the basic cations because of the vegetation cover as well as low erosion and low disturbance.

Generally, low electrical conductivity recorded in all the land units could be related to the intensive weathering associated with the high rainfall of the area, which removes basic soluble cations by leaching and/or erosion from these soils. This finding is in agreement with the work of Abebe and Endalkachew (2012) who reported that electrical conductivity of soils declined with high amount of rainfall.

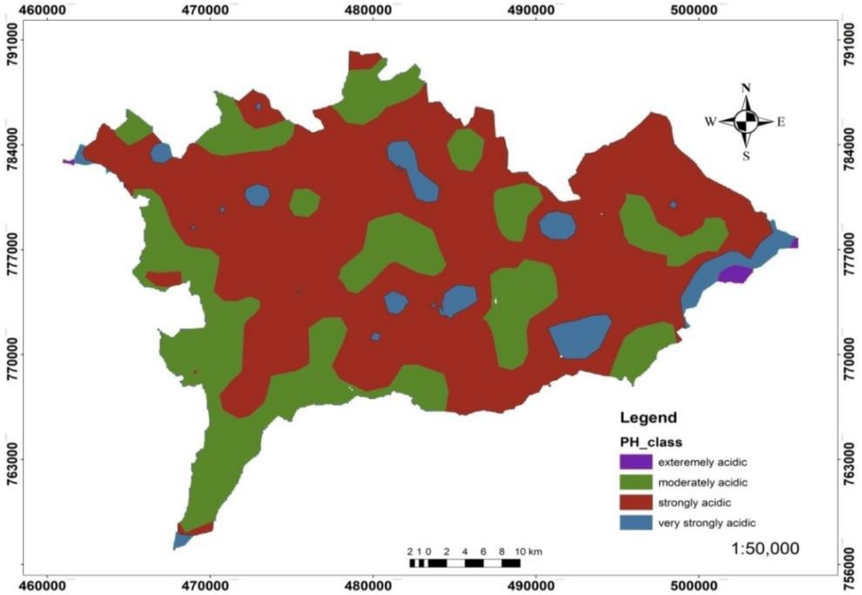


Figure 3. map of soil pH at Kofele district

Soil Texture

The textural class across all mapping units in the study area was silt loam, sandy clay loam, loam and sandy loam with 8.7%, 2.5%, 24.2% and 64.6%, respectively. The high clay content is an indication of complete alteration of weatherable minerals into secondary clays and oxides (Buol *et al.*, 2003).

Soil Organic Matter

Similar to the other soil parameters discussed so far, the organic matter content of soils through the district showed spatial variation. Across the soil mapping units, it ranged from 1.10% to 4.79%. Following organic matter rating suggested by Tekalign (1991), the organic matter content of soils in the district ranged from low to moderate. Accordingly, out of the total sampled mapping units (161), 20.27% and 79.73% soils mapping units were low and moderate in area coverage, respectively as shown in (Table 1).

The most probable source of variation in OM contents among mapping units might be variation in altitude, intensity of cultivation, cropping system and soil management practices. The low levels of OM in the soil of mapping units might be attributed to continuous cultivation with complete removal of crop residue and limited application of organic fertilizers**.** This was in line with the findings of several authors (Duff *et al*., 1995; Grace *et al*., 1995). The intensive cultivation is expected to aggravate rapid oxidation of the small amount of organic matter returned to soils of the cultivated land units. Furthermore, total removal of crop residues for other purposes, such as animal feed, fuel, cash, and construction, is a common practice in the study area. In consent with the findings in this study, Wakene and Heluf (2003) and Alemayehu and Sheleme (2013) demonstrated that intensive cultivation results in rapid oxidation of soil organic matter.

Furthermore, the total removal of crop residues for animal feed and as source of energy was reported as being among the main reasons for low organic matter content in soils of Ethiopia by Sheleme (2011). Yihenew (2002) also confirmed that most cultivated soils of Ethiopia are generally poor in organic matter content.On the other hand, relatively higher (moderate) content of OM was recorded in soils of mapping units (79.73%). This might be due to the fact that wide land mapping units were repeated uses of fertilizers for production of vegetables during off season and their relatively level to gentle slope gradient where the soil moisture storage is better, resulting in better biomass production. Furthermore, the expected impeded drainage related to topography could also slow down the decomposition process. This result is in agreement with the work of Abebe and Endalkachew (2012) in Nitisol of Southwestern Ethiopia.

Available phosphorus

Among mapping units of the study area for available phosphorus content of soils varied from 1.94 ppm to 34.22 ppm. The classification was made according to (Booker Tropical Soil Manual, 1991) that was on the basis of its suitability for agricultural production and it has three classes as indicated in figure 5.

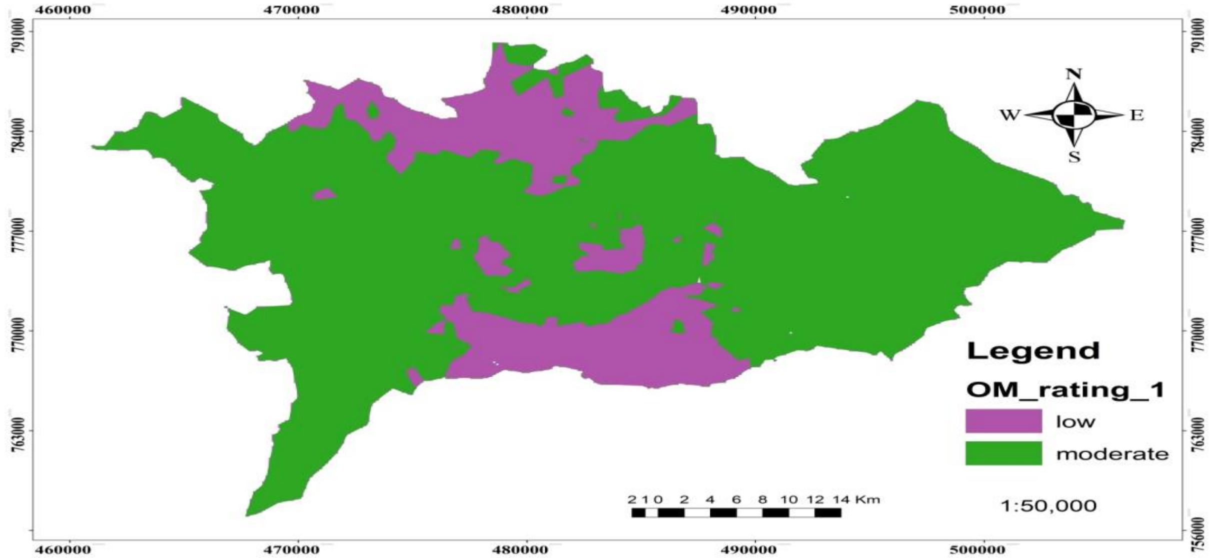


Figure 4. map of soil OM at Kofele district

The available phosphorus level in Kofele district was categorized as low, medium and High which accounts about 0.71%, 98.36%, and 0.93% respectively of mapping units of the study area which illustrated in (Table 1). As per ratings set by (Booker Tropical Soil Manual, 1991) the dominating class is medium which ranges from 5.0 to 15.0 ppm of available phosphorus and accounts about 98.36% of the area where as the least dominant was low which was not more than 0.71% of the area. The map of the available phosphorus for the Kofele district is illustrated in the (Figure 5). The variability in available P contents of soils might be due to different soil management practices, specifically, inherent soil fertility status, type and rate of organic and inorganic fertilizers used in cultivated lands. Besides these factors, variation in parent material, degree of P–fixation, soil pH and slope gradient may also contribute for the difference in available P contents among agricultural soils which in line with the findings of (Usmael *et al.*,2018).

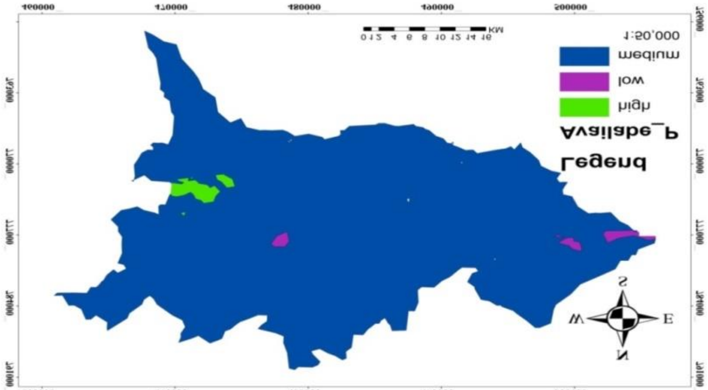


Figure 5. map of Available phosphorus at Kofele district

Cation Exchange Capacity

Measurements of the cation exchange capacity (CEC) show significant soil properties in particular its ability to retain the cation because of their mobility in the soil. The Kofele district soil CEC can be categorized in three classes namely low, moderate and high which accounts 9.14%, 90.84%, and 0.016% land area share as indicated in (Table 1). The spatial patterns of Cation Exchange Capacity are indicated in the (Figure 6).

The variation in CEC values of the studied soils might be the result of observed differences in OM and amount of clay, and soil management practices (intensity of cultivation). The intensive cultivation in the study area, for instance, might have reduced CEC indirectly through its effect on rapid oxidation of the small amount of organic matter in the soil. In line with Alemayehu (2007) and, Fentaw and Yimer (2011) reported that depletion of OM as a result of intensive cultivation contributed to lower CEC of the soils.

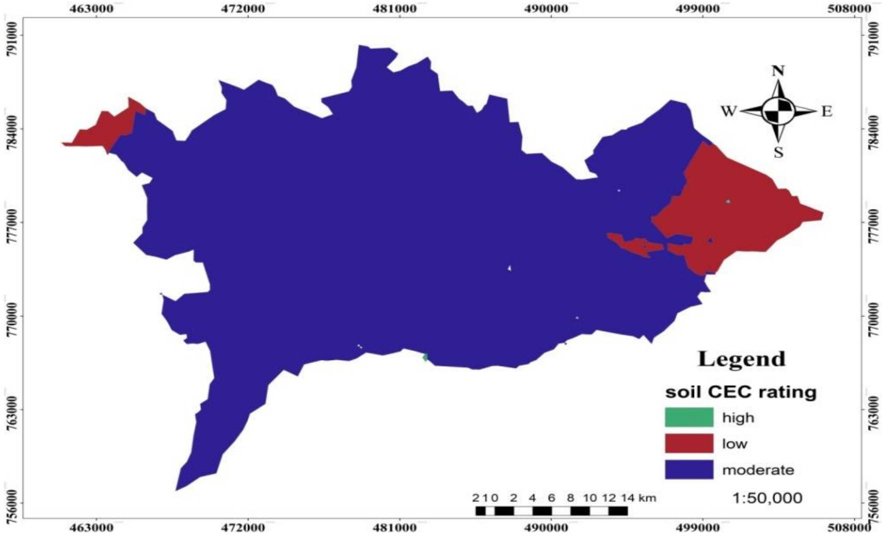


Figure 6. map of CEC at Kofele district

Exchangeable k

The results of laboratory analysis indicates greater values of potassium in the study site than the plant growth limiting ranges of soil potassium level, which ranges from 0.307 to 1.151 (meq/100g of soil). In the some context the Critical values for K that begin to limit plant growth are around 80 to 200 ppm. In case of this study, the status of potassium level in the surface soil of Kofele district are more than the values which limit the growth of crops in the study area. According to FAO (2006) the soil potassium level of study area has two classes' medium and high which accounts 78.98% and 20.02% respectively as indicated in (Table 1). Its spatial pattern varies as indicated in (Figure 7).

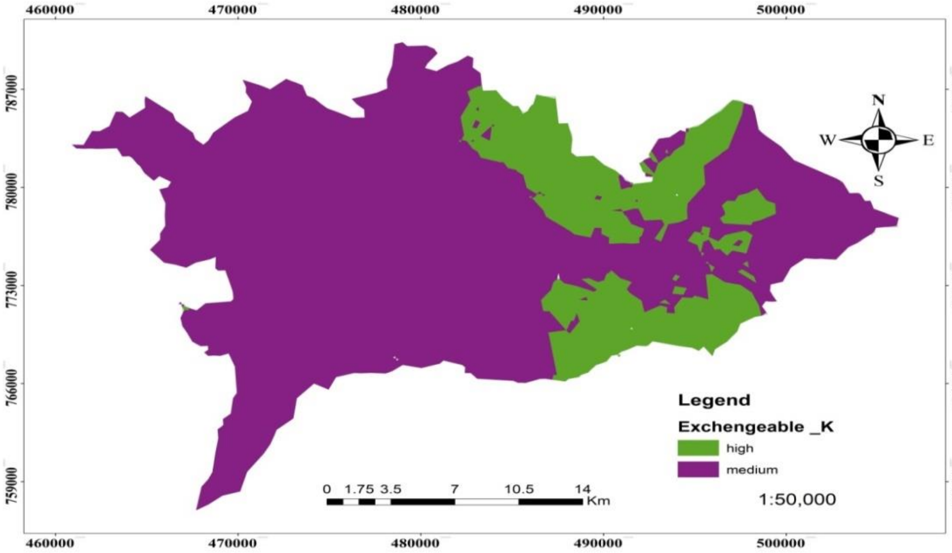


Figure 7. map of Exchangeable K at Kofele district

Table 1. Level and area coverage of each required parameter

Table	Soil parameter	Class	Area_ha	Area-%
1	Av.p	Low	474.60	0.71
		Medium	65014.60	98.36
		High	612.56	0.93
2	Soil CEC	Low	6044.99	9.14
		Medium	60038.4	90.84
		High	10.92	0.016
3	Exchangeable potassium	Medium	52864.30	79.98
		High	13233.20	20.02
4	Organic matter	Low	13394.20	20.27
		Medium	52700.90	79.73
5	Soil pH	Extremely acidic	230.65	0.35
		Very strongly acidic	3723.59	5.63
		Strongly acidic	42198	63.85
		Moderately acidic	19934.20	30.16

Conclusions and Recommendations

A study was undertaken to assess soil fertility status of soils of Kofele district. The fertility status map of soils of the study area was based on physiographic mapping units and physicochemical properties of the soils. Primarily field observation was undertaken in the study area. Soil color, altitude, slope gradient, topography, land use type and soil management history were used to sub-divide the district into different mapping units. Soils of the study area are silt loam, sandy clay loam, loam and sandy loam in textural classes. Generally, sand size fraction followed by silt fraction dominated the study area.

The pH of the soil ranged from 4.022 to 5.86, indicating variation with status of extremely acidic to moderately acidic. However, 0.36%, 5.63%, 63.85% and 30.16% of the soils collected from the mapping units were extremely acidic, very strongly acidic, strongly acidic and moderately acidic respectively in reaction which can affect the availability and solubility of some soil nutrients such as P and thus reduce crop yields. Therefore, appropriate rate of lime needs to be applied or cultivating acid tolerant crops is recommended for all extremely acidic, very strongly acidic, strongly acidic and moderately acidic soils of the study area to obtain optimum crop yields. The electrical conductivity values recorded in soils under the different mapping units indicate that the soils are free from salinity problem currently and in the foreseeable future. Soil OM ranges from 1.1% to

4.79% namely from low to moderate.The plant available P status ranged from 1.94 ppm to 34.22 ppm.But some parts of the agricultural soils of the study area were below the optimum level mainly due to the acidity of the soil reaction. Thus, site specific organic or inorganic P fertilizer sources are recommended to boost the agricultural productivity of the study areas. Low CEC shared 9.14%, moderate CEC shared 90.84% and high shared 0.016% of the total area of the mapping units. Soil EC is ranges 0.085 to 0.383 mmhos/cm i.e. totally salt free. The soil potassium level in the study site has two classes medium and high.

Further calibration and correlation of soil test results with plant response is recommended for site–soil–crop specific fertilizer recommendation with appropriate rate since soil analysis alone cannot go beyond the identification of deficiency, sufficiency or toxicity status of soil nutrients due to complex and dynamic nature of the soil.

Acknowledgment

We would like to acknowledge Oromia Agricultural Research Institute for financial support provided during whole activity. We also provide thanks to Batu Soil Research Center for providing necessary attention and follow up to conduct the research successfully.

References

Abebe Nigussie and Endalkachew Kissi. 2012. Physicochemical characterization of Nitisol in Southwestern Ethiopia and its fertilizer recommendation using NuMaSS, Global Advanced Research Journal of Agricultural Science, 1(4): 66-73.

Ahmed Hussen, 2002. Assessment of Spatial Variability of Some Physcio-chemical Properties of Soils under Different Elevations and Land Use Systems in the Western Slopes of Mount Chilalo, Arsi. (Unpublished MSc thesis), Alemaya University, Alemaya, Ethiopia.

Alemayehu K 2007.Effects of land use and topography on soil properties at Delbo watershed. MSc Thesis, Hawassa University, Ethiopia.P. 64.

Alemayehu Kiflu and Sheleme Beyene. 2013. Effect of different land use systems on selected soil properties in south Ethiopia. *Journal of Soil Science and Environmental Management*, 4(5): 100-107.

Alemayehu M, Yohanes F, Dubale P (2006). Effect of indigenous stone bunding on crop yield at MesobitGendeba. J. Land Degr. 45-54.

Buol SW, Southard RJ, Graham RC, Mc Daniel PA (2003). Soil genesis and classification.5th edition.Iowa State Press, Ames.

Burrough PA, Rachael A, Mc Donnell. *Principles of Geographical Information Systems*. New York, USA: Oxford University Press; 1998.

Cao SK, Chena KL, Cao GC, et al. 2011.The analysis of characteristic and spatial variability for soil organic matter and organic carbon around qinghai lake. *Procedia Environmental Sciences*.Vol;10 (A):678 –684.

Duff, B., P.E. Rasmussen and R.W. Smiley, 1995.Wheat/fallow systems in semi-arid regions of the Pacific,north-west America.pp. 85-109. *In*: Barnett, V. Payne, R. and Steiner, R. (Eds). *Agricultural Sustainability:Economic, Environmental and Statistical Considerations*. New York, USA: John Wiley and Sons, Inc.

Fantaw Y. and Yimer A. 2011.The effect of crop land fall owing on soil nutrient restoration in the Bale Mountain. Sci. Dev. J. 1(1):43-51.

FAO (Food and Agriculture Organization of the United Nations), 2006. Guidelines for soil description. 4th Edition.FAO, Rome.

Grace, P.R., J.M. Oades, H. Keith and T.W. Hancock, 1995.Trends in wheat yields and soil organic carbon in the permanent rotation trial at the Waite Agricultural Research Institute, South Australia. Australian Journal of Experimental Agriculture.35: 857- 864.

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

Huang B, Sun WX, Zhao YC, et al. Temporal and spatial variability of soil organic matter and total nitrogen in an agricultural ecosystem as affected by farming practices. *Geoderma.* 2007;139(3–4):336–345.

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

Juo A, Franzluebbers K., Dabiri A, Ikhile B (1996). Soil Properties and crop performance on kaolinticalison after 15 years of fallow and continuous cultivation. Plant *Soil*, 180: 209-217.

Kizilkaya R, Dengiz O (2010). Variation of land use and land cover effects on some soil physicochemical characteristics and soil enzyme activity. *Zemdirbyste Agriculture*, 97(2): 15-

Landon, J.R. 1991. Booker tropical soil manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. 474p.

Li XG, Li FM, Zed R, et al. Soil physical properties and their relations to organic carbon pools as affected by land use in an alpine pastureland. *Geoderma*. 2007;139(1–2):98–105.

Lin JS, Shi XZ, Lu XX, et al. Storage and spatial variation of phosphorus in paddy soils of China. *Pedosphere*. 2009;19(6):790–798.

Liu ZP, Shao MA, Wang YQ. Spatial patterns of soil total nitrogen and soil total phosphorus across the entire Loess Plateau region of China. *Geoderma*. 2013;197–198:67–78.

Okalebo, J.R.,K.W.Gathua and P.L. Womer. 2002. Laboratory methods of soil and plant analysis: a Working manual, 2nd Ed. TSBF-CIA and SACRED Africa, Nairobi, keenya. 128p.

Sahlemedhin Sertsu and Taye Bekele. 2000. Procedures for soil and plant anlysis. National Soil Research Centre, Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia. 110p.

Samira I, Ahmed D, Lhoussaine M. Soil fertility mapping: comparison of three spatial interpolation techniques. *International Journal of Engineering Research and Technology*. 2014;3(11):134–143.

Sanchez, P.A., Sheperd, K.D., Soul, M.J., Place, F.M., Buresh, R.J., Izac, A.M.N., Mokwunye, A.U, Kwesiga,F.R., Ndirtu, C.G. and Woomer, P.L. 1997. Soil fertility replenishment in Africa.An investment in natural resource capital. pp. 1-46. *In*: Buresh, R.J. Sanchez, P.A. and Calnoun, F. (eds.). *SSSA special publication* No.51.SSSA. Am. Soc. Argon. Madison, Wisconsin, USA. pp: 1-46.

Sheleme Beyene. 2011. Characterization of soils along a toposequence in Gununo area, southern Ethiopia. *Journal of Science and Development*. 1(1): 31-41.

Song G, Zhang L, Wang K, et al. Spatial simulation of soil attribute based on principle of soil science. IEEE; 2013.

Tekalign Tadese. 1991. Soil, Plant, Water, Fertilizer, Animal Manure and Compost Analysis. Working Document No. 13. International Livestock Research Center for Africa (ILCA), Addis Ababa, Ethiopia

TeshomeYitbarek, Heluf Gebrekidan, Kibebew Kibret and Shelem Beyene. 2013. Impacts of lan use on selected physicochemical properties of soils of Abobo area, western Ethiopia. *Agriculture, Forestry and Fisheries*, 2(5): 177-183.

Thomas, G.W. 1990. Exchangeable cations. In: Methods of soil analysis, part 2.(2eds) L.page,R.Miller and R.Keeney, American Society of Agronomy, Midson,WI. pp.159-166.

Usmael Mohammed, Kibebew Kibret (PhD), Muktar Mohammed (PhD) and Alemayehu Diriba. 2018. Soil fertility assessment and mapping of Becheke sub watershed in Haramaya district of East Hararghe Zone of Oromia Region, Ethiopia. *Journal of Natural Sciences Research,* 8(20):22-23.

Van Reeuwijk et al. CCD-coupled X-ray image intensifier. J. Appl. Cryst. *2000*. 33, 1422±1429. J*ournal of Applied. Sep* 29, 2000 - research papers. *1422 S. J.* Verma VK, Patel LB, Toor GS. Spatial distribution of macronutrients in soils of arid tract of Punjab, India. *International Journal of Agriculture and Biology*. 2005;7(2):295–297.

Wakene Negassa and Heluf Gebrekidan, 2003.Forms of phosphorus and status of available micronutrients under different land-use systems of Alfisols in Bako area of Ethiopia.Ethiopian Journal of Natural Resources. 5(1):17-37.

Wakene Negassa. 2001.Assessment of important physicochemical properties of DystricUdalf (DystricNitosols) under different management systems in Bakoarea,Western Ethiopia (Published MSc thesis). Alemaya University, Alemaya, Ethiopia.

Weindorf DC, Zhu Y. Spatial variability of soil properties at Capulin Volcano, Mew Mexico, USA: implications for sampling strategy. *Pedosphere*. 2010;20(2):185–197.

Yihenew G Selassie, Fentanesh Anemut and Solomon Addisu, 2015. The effects of land use types, management practices and slope classes on selected soil physico-chemical properties in Zikre watershed, North-Western Ethiopia. *Environmental Systems Research* 4:3 DOI 10.1186/s40068-015-0027-0.

Yihenew Gebreselassie. 2002. Selected chemical and physical characteristics of soils of AdetResaerch Centre and its testing sites in northwestern Ethiopia. *Ethiopian Journal of Natural Resources*, 4(2): 199-215.

Validation of phosphorous Requirement Map for bread Wheat at Negele Arsi District, West Arsi Zone, Oromia, Ethiopia

Reta Worku[1] and Husen Namu[1]
Batu Soil Research Center, P. O. Box 59, Batu, Oromia, Ethiopia.
Corresponding author: Reta Worku

Abstract

Ethiopia is the largest wheat producer in Sub-Saharan Africa. Despite large area in wheat production, the mean national wheat yield is quite low, primarily those related to a low level of agricultural technology, traditional farming, and lack of improved varieties, soil fertility depletion and blanket fertilizer recommendation. Hence Batu Soil Research Center was produced fertilizer requirement map andvalidate the fertilizer requirement map, field experiments were carried out on ten peasant associations of NegeleArsi district to validate the quality of fertilizer requirement map on some yield components and yield of bread wheat crop. The treatments consisted of Control (unfertilized plot), Blanket (100/100 NPS/Urea), P-map) and P-required (Pc-P0)$P_{f)}$ were laid out with simple adjacent plots and replicated over ten location.The Analysis of Variance indicates that grain Yield and Biomass were significantly ($P<0.05$) influenced by different rate of phosphorus fertilizer application, whereas Harvest index and thousand kernel weight were not significantly ($p<0.05$) influenced by different rate of phosphorus fertilizer application. P-required gave the highest (4194 kg ha^{-1}) grain yield and p-map gave the highest (11050 kg ha $^{-1}$) Biomass yield. The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of P-map gave the highest marginal rate of return (1576.1%) for bread wheat f crop production is recommended for farmers in Negele Arsi district.*

Key words*: Blanket recommendation, P-map, P-required, Arc GIS , validation of fertilizer requirement map.*

Introduction

Wheat (Triticum spp.) is one of the major cereal crops grown in the highlands of Ethiopia and Ethiopia is the largest wheat producer in Sub-Saharan Africa (Efrem *et al.,* 2000).Global wheat production in 2019 was estimated at 765.41million tons (USDA, 2020). It is one of the most important cereals cultivated in Ethiopia, which ranked fourth after teff, maize and sorghum in area and production during 2017-18 cropping season, (CSA, 2018). It covered an area of 1.7 million hectares with a total production of 46.43 million quintals) of the grain production and mean productivity of 27.36 quintals ha^{-1} during 2017-18cropping season (CSA, 2018).

Despite large area in wheat production, the mean national wheat yield is quite low. This low productivity can be ascribed to many factors, primarily those related to a low level of agricultural technology, traditional farming, lack of improved varieties, soil fertility depletion, blanket fertilizer recommendation and soil management techniques (IAR/CIMMYT, 2003).

Fertilizer recommendations, in Ethiopia in general and Negele Arsi district, in particular, are of blanket type and are based on soil color characteristics rather than on soil test results and crop requirements. Such a practice leads to inefficient use of fertilizers by the crop since the amount to be applied can be more or less than the crop requires. As a result, the farmer may not be able to obtain the maximum benefit that is worthy of the money he has spent in purchasing the input. That is where site specific fertilizer recommendations are more comprehensive and beneficial since they can help to tailor fertilizer use more efficiently.

The science of soil-testing for nutrient management and fertilizer recommendations is widely accepted among Soil scientists and agronomists. Nutrient management recommendations should be established through soil test and plant tissue correlation and calibration procedures. Sound soil test calibration is specific for each crop type and they may also differ by soil type, climate, and the crop variety (Sonon and Zhang, 2014) and relates soil test measurement in terms of crop response (Bray, 1945 and 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.

A fundamental assumption of site specific Soil fertility management is that economically optimum application rates of fertilizers determination. Soil fertility map is very important for fertilizer recommendations. To do soil fertility maps and fertilizer requirement maps, composite soil samples should be collected from mapping units and their digital soil fertility maps have to be prepared by using geostatistical interpolations to predict for non-sampled locations based on laboratory results of each parameters (Singh *et al*, 2010). The maps created with commonly used sampling and interpolations procedures may be found marginally to poor-quality in some cases. Therefore planers and users should evaluate map quality at test sites before adoption of maps for the whole recommendation (Mueller *et al*, 2001). Soil fertility Map quality can be evaluated by comparing predicted and observed soil properties. Predicted and measured values can be determined either by with in validation or cross validation analysis.

Validation involves independent sample collection and compares measured and estimated values for every validation points. Cross validation is often used to assess map quality because of it needs no additional resources and data. Cross validation involves removing an observation data from prediction. In some condition the validation of prepared soil fertility maps were done for two consecutive years as well as every year and if variation is significant, the maps should be readjusted by more sample collection (Mueller *et al*, 2001).

Batu Soil Research Center has finalized soil fertility and fertilizer requirement maps for Wheat at NegeleArsi District. The maps were done based on their P_c (phosphorous critical level) and pf (phosphorous factor which rise soil p by one ppm) that were developed by calibration studies conducted for Wheat. These outputs were initially geo referenced and by using ArcGIS10.1 their maps were created by Geo-statistical interpolation mainly Ordinary kriging.

Hence soil nutrient requirement map quality can be evaluated by comparing grain yield and yield component response of fertilizer rate of P-map and fertilizer rate calculated from P requirement (PR) from P-initial, P-critical and P-requirement factor. Hence validation of this map is very important to demonstrate outputs by supporting with field trial. Therefore this activity was conducted with the following objectives:-

- ✓ To validate fertilizer requirement map for bread wheat
- ✓ To introduce soil fertility and fertilizer requirement map at NegeleArsi district

Materials and Methods

Description of the Study Area

The study was conducted at Negele Arsi district, which is located in West Arsi zone of the Oromia Regional State, Ethiopia. The district is located between 7.15°N to 7.75°N latitudes and 38.35°E to 38.95° E longitudes. Its total area coverage is128095.82 hectare and its map is indicated below.

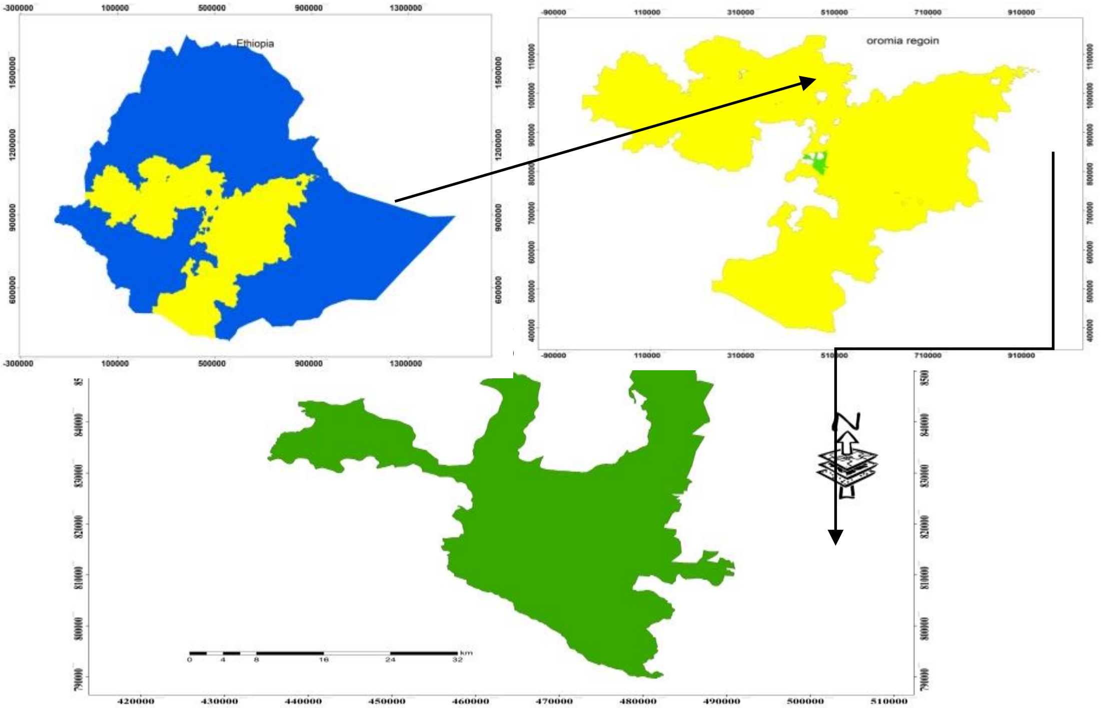


Figure 1. Location Map of NegeleArsi District.

Experimental Materials

Planting material

- ✓ Bread wheat varietyOgolcho

Fertilizer material

- ✓ NPS fertilizer in the form of (19% N, 38% P_2O_5 and 7% S) used as a source of N: P: S and Recommended optimum nitrogen (46 kg N/ha and 69 kg N/ha) for Mollicandosol and Eutricverticsol respectively.

Other materials

- ✓ GPS and ArcGIS
- ✓ DNR Garmin

Methods

The maps were developed through soil sample collected from each mapping units developed at stage of base map preparation. These samples were analyzed for available P atBatu Soil research Center laboratory. These outputs were initially geo referenced and by using ArcGIS10.3, their maps were created by Geo-statistical interpolation mainly Ordinary kriging.

Soil Sampling and Analysis

Based on Mapping units the soil samples were collected, then taken to soil laboratory in order to determine the vales of the required parameters particular phosphorous in ppm. Soil fertility Map quality can be evaluated by comparing predicted and observed soil properties. Predicted and measured values can be determined either by with in validation or cross validation analysis. Validation involves independent sample collection and compares measured and estimated values for every validation points. Accordingly, from bread wheat producing potential Peasant association, those have different rate of fertilizer application and have large area coverage were identified and soil samples were collected to a depth of 0 - 20 cm from willing farmers .

The collected composite soil sample was air dried, ground, and sieved using 2 mm sieve except for organic matter which was 0.02 mm sieve. Then the composite soil sample was analyzed for available phosphorus using standard laboratory procedures at Batu Soil Research Center. After the samples were analyzed in Laboratory based on their coordinate points and related soil phosphorous values and Crop phosphorous critical level i.e. bread wheat the PR (phosphorous requirement for bread wheat) was determined as the following equation.

PR= PC- PO

Then the difference needed for wheat production was mapped by using ArcGIS spatial analyst tool i.e. Interpolation for this case Ordinary Kriging was used in order to predict for un sampled area/locations/. The continuous and classified maps were indicated in the figures below respectively. In order to have the values of phosphorous requirement map for bread wheat as discrete quantitative vector values, the continuous interpolation surface values were classified by defined interval of 2ppm soil phosphorous

Treatments and Experimental Design

The treatments were arranged based on already determined Phosphorous critical and requirement factor for bread wheat crop.Whereas *Pc= 18 ppm and Pf = 4.72ppm and 3.63ppm for Eutricvertic sol and Mollicandosol respectively (Tilahun Firomsa 2017,*unpublished) and P *Applied = (Critical P - Po)* Pf*. The treatments were laid out with simple adjacent plots with ten replications over locations.

The gross plot size will be 10 m x 10 m (100 m^2). Spacing of 1.0 m and 0.5 m was maintained in between adjacent blocks and plots, respectively and harvested from $4m^2$. The details of the treatments are shown in Table 1. Nitrogen fertilizer in the form of Urea (46%N and 69%N) will be used according to the recommended optimum rate for both Dominant soils (*TilahunFiromsa 2017,* unpublished). However the amount of N found in different levels of NPS was deducted.

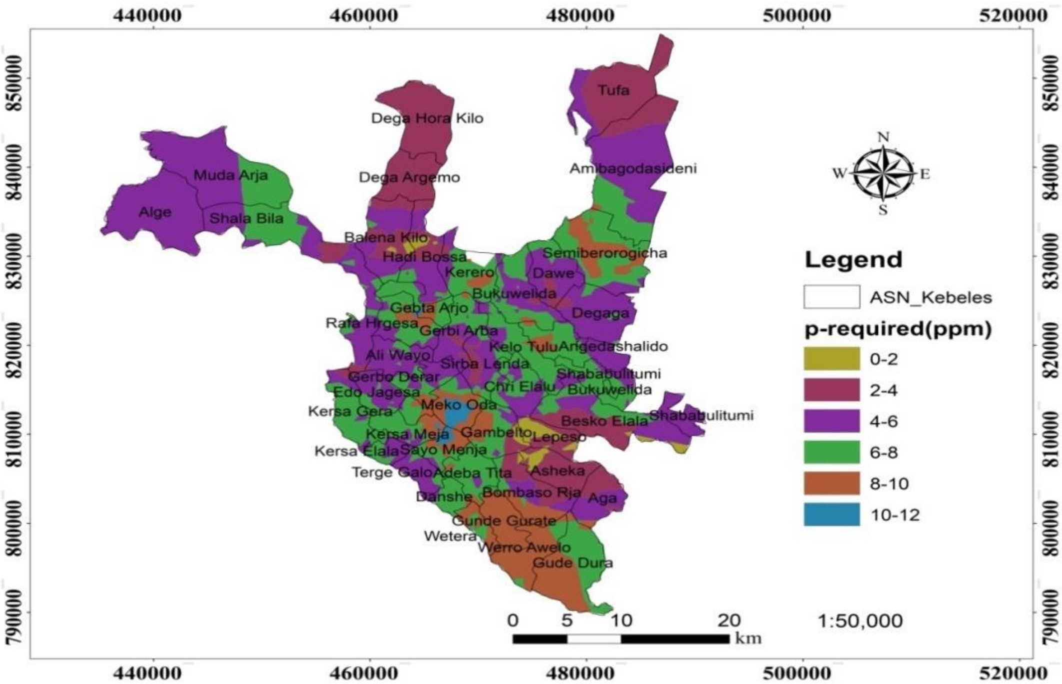


Figure 2. Validated phosphorus requirement map for bread wheat at NegeleArsi District.

Treatments and Experimental Design

The treatments were arranged based on already determined Phosphorous critical and requirement factor for bread wheat crop.Whereas *Pc= 18 ppm and Pf = 4.72ppm and 3.63ppm for Eutricvertic sol and Mollicandosol respectively (Tilahun Firomsa 2017,*unpublished) and P *Applied = (Critical P - Po)* Pf*. The treatments were laid out with simple adjacent plots with ten replications over locations.

The gross plot size will be 10 m x 10 m (100 m^2). Spacing of 1.0 m and 0.5 m was maintained in between adjacent blocks and plots, respectively and harvested from $4m^2$. The details of the treatments are shown in Table 1. Nitrogen fertilizer in the form of Urea (46%N and 69%N) will be used according to the recommended optimum rate for both Dominant soils (*TilahunFiromsa 2017,* unpublished). However the amount of N found in different levels of NPS was deducted.

Table1 : amount of fertilizers treatment used for Validation of fertilizer requirement map of wheat crop in kg/ha.

Sites	**p-required**		**p- map**		**Blanket**		**Control**
	Po (ppm)	P applied *Pc=18,pf=4.72 and3.63 ppm*	Po (ppm)	P applied *Pc=19,pf=4.72*	NPS	Urea	No fertilizer
1	9.92	29.33	10.40	27.59	100	100	0
2	7.56	37.90	10.46	27.37	100	100	0
3	13.68	15.68	11.92	22.07	100	100	0
4	7.90	47.67	12.00	28.32	100	100	0
5	15.64	11.14	10.24	36.63	100	100	0
6	9.48	40.21	10.50	35.40	100	100	0
7	13.00	18.15	11.64	23.09	100	100	0
8	10.64	26.72	9.80	29.77	100	100	0
9	9.96	37.95	9.76	29.91	100	100	0
10	**11.28**	**31.72**	**7.24**	**50.79**	**100**	**100**	**0**

Whereas, po= initial soil phosphorus, Pc= critical soil phosphorous, pf= phosphorous requirement factor, p- map= Predicted application, p-required = actual application

Management of the Experiment

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 2019 using seed rate of 150 kg ha^{-1}. Full dose of Phosphorous 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 was carried out uniformly for all treatments. The crop was harvested at harvest maturity and was sun dried till constant weight before threshing.

Data Collection and Measurement

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}.

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.

Statistical Analysis

The data was subjected to analysis of variance (ANOVA) as per the experimental design using GenStat (15^{th} 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 will be tested. The discarded and selected treatments' using this technique was 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

$$\text{MRR (\%)} = \frac{\text{Change in NB (NBb}-\text{NBa)}}{\text{Change in TCV (TCVb}-\text{TCVa)}} \times 100$$

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 nd Discussion

Yield and Yield Components of Bread Wheat

Analysis of variance indicated that grain yield and biomass of bread wheat with P-required and P-map P fertilizer applications were with similar effects, but significantly different at($P<0.05$)to blanket and control treatments, however Harvest Index was not significantly affected by treatments applied. The highest grain yield (4194kg ha-1) and the highest biomass (11050kg ha-1) were resulted from P-required and p-map application respectively. While the lowest grain yield (1738 kg ha-1) and the lowest biomass (5849kg ha-1) was obtained from without fertilizer application.

Grain yield of bread wheat significantly increased from control to P-required however, grain yield at p-required and P-map was statistically at parity. The highest grain yield at the highest P rates might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to synergetic effect of the three nutrients which enhanced yield components and yield. The Result in line with Saqib Bashir *et al.*, 2015 who reported that Maximum grain yield was recorded for 100 kg P2O5 ha-1 when applied through double band application method as compared to control. Similar results were also obtained by Ali et al., (2004), Kaleem *et al*., (2009) and Khan *et al*., (2010) who found that grain yield of wheat significantly increased with phosphorus application.

Table 2. Grain and biomass yield, harvest index and thousand kernel weight of bread wheat as influenced by different methods of phosphorus rates application

Treatment	GY(kg ha^{-1})	BM(kg ha^{-1})	HI(%)	TKW(g)
P- Required	4194^{a}	10699^{a}	42.37	36.63
P-map	4120^{a}	11050^{a}	41.50	39.12
Blanket	3325^{b}	9025^{b}	41.03	36.94
Control	1738^{c}	5849^{c}	38.93	38.62
LSD (0.05)	446.3	1049.4	NS	NS
CV (%)	14.8	12.6	12	6.9

Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher protected LSD test;; BM= Biomass yield; GY = Grain yield; HI% = Harvest index in percent; Pr = phosphorus required (31.09kg P ha^{-1}); p- map= phosphorus predicted (29.5kg P ha^{-1}), Blanket (100/100 NPS/Urea kg ha^{-1}, control (no fertilizer application)

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 the minimum acceptable rate of return (CIMMYT, 1988). As indicated in Table 3, the partial budget and dominance analysis revealed that the highest net benefit 58115.6 Birr ha-1 was obtained P-map ,while the lowest net benefit 26070Birr ha-1) was obtained from control treatment. Moreover, the highest marginal rate of return of 1576.1% was also obtained from P-map (phosphorus applied from fertilizer requirement map). According to this result, farmer's investment of 1 Birr on P-map treatment on Ogolcho bread wheat benefits 15.761Birr.

Table 3. Partial budget and marginal analysis of treatment applied over ten sites for bread wheat

Treatments	P (kg ha^{-1})	N (kg ha^{-1}	AGY by 10%	G B (Birr ha^{-1}	TVC (Birr	NR (Birr ha^{-1})	MRR %
Control	0	0	1738	26070	0.00	26070	-
Blanket	16.5	46	3325	49875	2973	46902	700.7
P-required	31.09	57.5	4194	61410	4000	57409.9	232
P-map	29.5	57.5	4120	61800	3684.4	58115.6	1576.1

Where, NPS cost = 15.62 Birr kg^{-1}, UREA cost = 14.11 Birr kg^{-1}of N, NPS, Bread wheat grain per ha= 15Birr kg^{-1}, MRR (%) = Marginal rate of return, D= Dominated treatment, Control = unfertilized, AGY= adjusted grain yield, Gross Benefit, TVC= total variable cost, NR Net return

Summary and Conclusion

Ethiopia is the largest wheat producer in Sub-Saharan Africa. Despite large area in wheat production, the mean national wheat yield is quite low, primarily those related to a low level of agricultural technology, traditional farming, and lack of improved varieties, soil fertility depletion and blanket fertilizer recommendation. Site specific Soil fertility management is that economically optimum application rates of fertilizers determination. Soil fertility map is very important for fertilizer recommendations. The Analysis of Variance indicates that grain Yield and Biomass were significantly ($P<0.05$) influenced by different rate of phosphorus fertilizer application, P-required gave the highest (4194 kg ha^{-1}) grain yield and p-map gave the highest (11050 kg ha $^{-1}$) Biomass yield. The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of P-map gave the highest marginal rate of return (1576.1%) for bread wheat of crop production is recommended for farmers in Negele Arsi district.

Reference

Bereket Haileselassie, Dawit Habte, Mehretab Haileselassie, and Gebremedhin Gebremeskel. 2014. Effects of Mineral Nitrogen and Phosphorus Fertilizers on Yield and Nutrient Utilization of Bread Wheat (*Tritcumaestivum*) on the Sandy Soils of Hawzen District, Northern Ethiopia. *Agriculture, Forestry and Fisheries*, 3 (3): 189–98.

Bray, R.H. 1945. Soil-plant relations: II. Balanced fertilizer use through soil tests for potassium and phosphorus. Soil Sci. 60:463-473

Bregh, K., Chew, A., Gugerty, M.K., and Anderson, C.L. 2012. Wheat value chain: Ethiopia. EPAR Brief No. 204.

CIMMYT Economics Program, International Maize and Wheat Improvement Center, 1988. *From agronomic data to farmer recommendations: an economics training manual* (No. 27). CIMMYT.

Corey, R.B. 1987. Soil test procedures: Correlation. p. 15-22. In J.R. Brown (ed.) Soil testing: Sampling, correlation, calibration, and interpretation. SSSA Spec. Publ. 21. SSSA, Madison, WI.

CSA (Central Statistical Agency). 2018. Agricultural sample survey: area and production of major crops, meher season. Vol. I. Addis Ababa, Ethiopia.

Demeke M., Di Marcantonio F., 2013. Analysis of incentives and disincentives for wheat in Ethiopia. Technical notes series, MAFAP, FAO, Rome.

Endalkachew K. (2006). Effects of rates and methods of phosphorus placement on residual soil p, yield and p uptake of wheat in nitosols of kulumsa area, arsi zone. MSc. thesis report.

FAO. 1976. A Framework for Land Evaluation. Soil Resources Management and Conservation Service Land and Water Development Division. FAO Soil Bulletin No.32. FAO-UNO, Rome.

FAO. 2007. Land evaluation towards a revised framework. Land and Water Discussion Paper 6. Rome:

FAOSTAT (Food and Agriculture Organization of the United Nations), 2014. FAOSTAT (Online).Available at *http://www.fao.org/faostat*. Accessed on 10 June, 2018.

Geleta, B., Gorfu, A. and Gebeyehu, G., 1994. Wheat production and research in Ethiopia: constraints and sustainability. *Developing Sustainable Wheat Production Systems*, pp.18-25.

International Food Policy Research Institute (IFPRI) (2010). *Fertilizer and Soil Fertility Potential in Ethiopia*. IFPRI, Washington DC, USA.

Mueller T. G., F. J. Pierce, O. Schaben berger, and D. D. Warncke,2001. MAP QUALITY FOR SITE-SPECIFIC FERTILITY MANAGEMENT.Soil Sci. Soc. Am. J. 65:1547–1558 (2001).

Negassa, A., Shiferaw, B., Koo, J., Sonder, K., Smale, M., Braun, H.J., Gbegbelegbe, S., Guo, Z., Hodson, D.P., Wood, S. and Payne, T.S., 2013. The potential for wheat production in Africa: analysis of biophysical suitability and economic profitability.

Rouse, R.D. 1967. Organizing data for soil test interpretation. p. 115-123. In G.W. Hardy et al. (ed.) Soil testing and plant analysis. Part 1. SSSA. Spec. Publ. 2. SSSA, Madison, WI.

Singh.K.N.Abhishek Rathore,A.K.Tripathi,A.Subba Rao and Salman Khan,2010. Soil Fertility Mapping and its Validation using spatial prediction techniques. Indian Institute of Soil science, Bhopal.

Snoeck.D., Afrifa. A. A., Ofori-Frimpong.K., Boateng.E., and Abekoe.K.M.,2010.Mapping Fertilizer Recommendations for Cocoa Production in Ghana Using Soil Diagnostic and GIS Tools. *West African Journal of Applied Ecology,* vol. **17,** *Department of Soil Science, University of Ghana, Accra, Ghana*

Sonon, L.S. and Zhang, H., 2014. Soil test calibration work in southern USA. *University of Texas A and M university. USA.*

Sys, C., E. Van Ranst, and J. Debaveye. 1991. Land evaluation part I, principles in land evaluation and crop production calculation. Agricultural Publication No. 7. Brussels, Belgium: General Administration for Development Cooperation.

Yesuf Assen, Taye Bekele and and Kefyalew Girma (2005*).Phosphorus Critical Value and Requirement Factor Determination for Tef (Eragrostistef) Production in Ethiopia.* Plant and Soil Sciences Department, Oklahoma State University, Stillwater and National Soil Testing Cente*r,* Addis Ababa, Ethiopia.

Soil Fertility Management Research

Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Maize in Mana District, Jimma Zone, Western Oromia

*Dagne Chimdessa, Gedefa Sori, Garoma Firdisa and Suleiman Aman
Oromia Agricultural Research Institute (IQQO), Bedele Agricultural Research Center
P.O.Box-167, Buno Bedele, Bedele
Corresponding author: dagnechim@gmail.com

Abstract

Periodic assessment of soil fertility status and plant nutrients requirement of a given area has vital role in enhancing sustainable crop production. The study was conducted in Mana district on eleven farmers' fields during 2018 and 2019 main cropping seasons to determine NPS fertilizer rate based on calibrated phosphorus for maize. The treatments consisted of five (0, 25%, 50%, 75% and 100 %) P critical levels (Pc) calculated from NPS fertilizer and previously recommended 100% Pc calculated from DAP fertilizer. The experiment was laid out in RCBD with three replications. Analyzed soil samples were characterized by strongly acidic, very low available phosphorus, low organic carbon content and clay in texture. The analysis of variance among NPS fertilizer rates showed significant differences ($P \leq 0.05$) *for many of the tested maize characters. The shortest (88.6) mean days to 50% tasseling was obtained from 100% Pc from NPS fertilizer, whereas the longest (94.5) days was recorded for the unfertilized plot. The maximum mean biomass yield (30.0 t ha*$^{-1}$*) was recorded for 100% Pc from DAP and grain yield of 6.6 t ha*$^{-1}$ *was recorded from NPS fertilizer, respectively. The lowest mean grain yield (0.8 t ha*$^{-1}$*) was recorded for the treatment with no fertilizer. Economically, the highest net benefit of 19424 ETB ha*$^{-1}$ *with an acceptable MRR of 313% was achieved from use of 100% Pc from NPS. Hence application of 100% Pc from NPS fertilizer is agronomically and economically feasible for maize and recommended for the end users in Mana district. The result also showed that the soils of the study sites had poor chemical fertility and integrated soil fertility management practices can improve the current situation.*

***Key Words**: Nitrogen, NPS rate, Phosphorus, P-critical level*

Introduction

Nutrient mining is a widespread problem in low and medium input agriculture. It causes the exhaustion of nutrient required in moderate to large amounts. That can be particularly severe in the case of N, P, K and S depending on soil nutrient reserves and the amounts replenished. A negative balance can be acceptable for a short period, but, where prolonged, it will lead to soil deterioration. It is expensive to improve depleted soils (FAO, 2006).

Low plant nutrients level in the soils in Ethiopia are caused by crop removal of nutrients from the soil, little or no fertilizer application, and total removal of crop residues from the farmland and burning. Nowadays, due to increasing population pressure and shortage of land, deforestation and cultivation activities are being carried out on steep slopes, which accelerate soil erosion (Tolessa *et.al*., 2001). Moreover, the shortage of land for production of food crops has eliminated the practice of fallowing and crop rotation on the flatter areas. According to FAO (2001) soil fertility management on smallholder farms in the tropics has become a major issue, as a result of continued land degradation and rapid population growth. On the other hand, shortage of grasslands (grazing areas) has forced the farmers to remove crop residues for animal feed. Since the area receives high rainfall, leaching may also cause nutrient losses and soil acidity. Continuous cultivation of the soils for many years without replenishing the nutrients mined has negatively affected the fertility of the soils and availability of nutrients, which has contributed to the declining productivity of maize in the area. Mokwunye *et.al*., (1996) also stated that cultivated highly weathered soils commonly suffer from multiple nutrient deficiencies, and nutrient balances are generally negative. If nutrient loss continues at this alarming rate, it may only be few years before crop yield targets cannot be realized (Smaling, 1990).

In Ethiopia, maize is first in productivity and second in area coverage after teff (CSA, 2010). Despite tremendous yield potential, its productivity remains low as compared to developed countries. The low yield level of this crop was attributed by several factors among which, nutrient management is found the key element in Ethiopia (CIMMYT, 2004). 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)

Similarly, crop productivity can also be limited because of toxicity and/or deficiency of essential plant nutrients. In view of this, Bedele Soil Research Center, the then, Bedele Agricultural Research Center was conducted soil test crop response based Phosphorus calibration study for maze using DAP fertilizer in Mana district; and recommended Phosphorus critical level and requirement factor **(**Dagne *et al*, 2015**).** On the other hand, Ethiopia has realized that agricultural soils commonly suffer from multiple nutrient deficiencies, and nutrient balances are generally negative, and an effort has been made since 2015 to introduce different types of fertilizers among which, NPS fertilizer is one of it. However, the rate and response of the newly introduced NPS fertilizer was not adjusted to the previously calibrated phosphorus using DAP fertilizer for maize. Therefore, the objective of this study was to determine NPS fertilizer rate based on calibrated phosphorus for maize in Mana district, Western Oromia.

Materials and Method

Description of the Study Area

A study was conducted on farmers' fields in Mana district of Jimma zone in 2018 and 2019 main cropping seasons. For this experiment, twelve experimental sites were used, Mana district is located at 07°37’58.4”to 07°54’01.5”N and 036 °37’37.1” to 036 °53’31.5”.

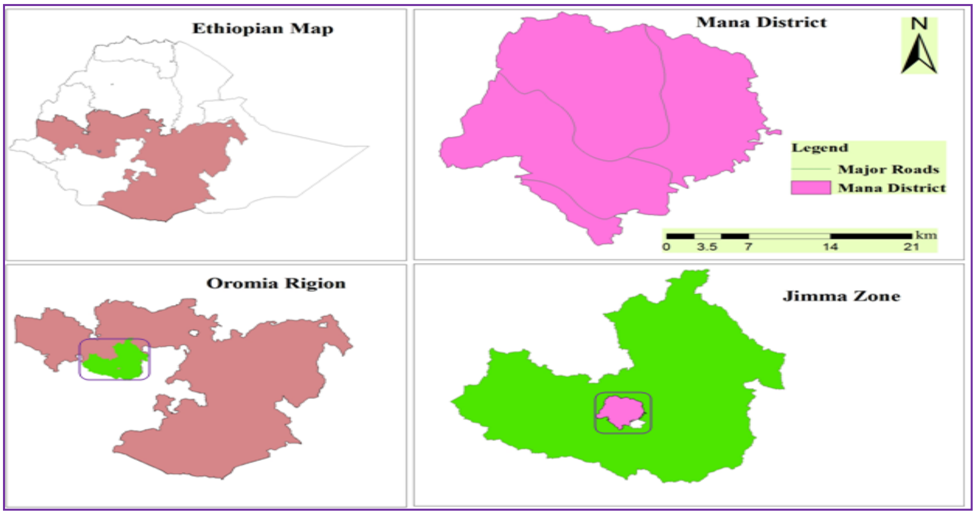
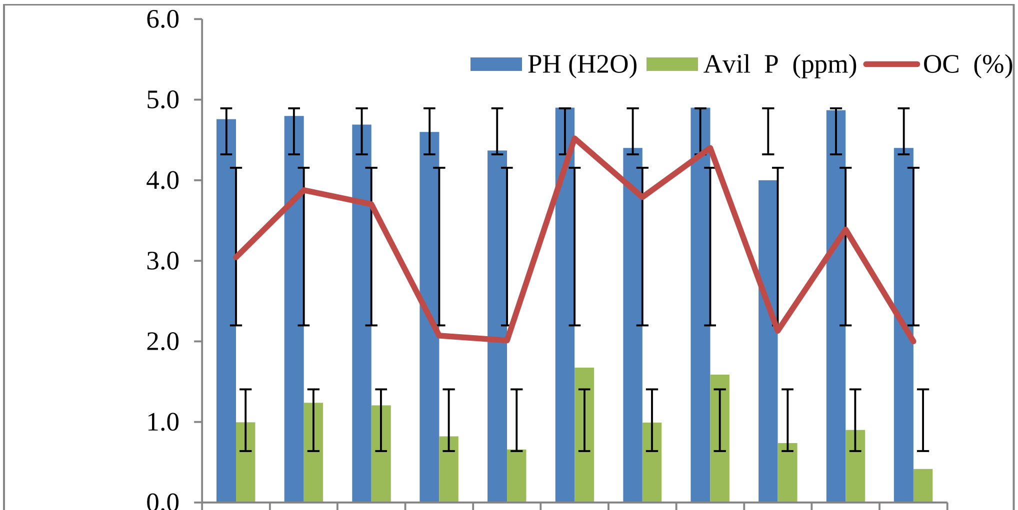


Figure 1. Map of the study area (Mana district)

Soil Sampling and Analysis

Eleven composite soil samples (0-20) cm depth were collected from each experimental sites before planting during site selection to analyze soil pH (H_2O), available P, (%OC), CEC, exchangeable acidity 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 of laboratory analysis indicated that, soil pH was strongly acidic in reaction, low in available P and OC content (Fig 2). The low contents of available P observed in the study area agreed with the results of similar study (Eylachew, 1999). The low available P in most Ethiopian soils can be attributed to P fixation, crop harvest. Soil erosion and low rate of P sources application. The OC content of the soil was low (Berhanu, 1980). Most cultivated land soils of Ethiopia are poor in their organic matter content due to the low amount of organic materials applied to soil and complete removal of biomass from farm land (Yihenew, 2002). As a result, the major source of organic matter in cultivated soils below ground plant biomass has little contribution to increasing OM (Olson *et.al.*, 2014). Soils CEC values were low to moderate and clay in texture (Table 1). The observed CEC values of the soils generally showed similar trend with that of soil OC (Table 1). This implies that CEC was more influenced by OM than clay content (Taye *et.al.*, 2003).



	1	2	3	4	5	6	7	8	9	10	11
PH (H2O)	4.8	4.8	4.7	4.6	4.4	4.9	4.4	4.9	4.0	4.9	4.4
Avil P (ppm)	1.0	1.2	1.2	0.8	0.7	1.7	1.0	1.6	0.7	0.9	0.4
OC (%)	3.0	3.9	3.7	2.1	2.0	4.5	3.8	4.4	2.1	3.4	2.0

Figure 2. Soil pH, available phosphorus and organic carbon status before planting in Mana district during 2018 and 2019 main cropping seasons

Table 1. Soils CEC, exchangeable acidity and textural class status before planting in Mana district during 2018 and 2019 main cropping seasons

Sites	CEC (cmol($^+$)/kg soil)	Ex. Acidity meq/100 g soil)	Textural Class
1	18.3	1.3	Clay
2	18.1	0.9	Clay
3	14.7	0.5	Clay
4	13.3	0.7	Clay
5	11.1	0.7	Clay
6	18.1	1.0	Clay
7	15.8	0.2	Clay
8	15.3	1.1	Clay
9	15.7	0.3	Clay
10	14.1	0.8	Clay
11	16.0	0.7	Clay

Treatments

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 used as a check amounting the total number of treatments to six.

Experimental Design and Procedures

The experiment was laid out in RCBD with three replications. The gross plot size was 12m^2 (3m x4m) that accommodated five maize plants rows. Hybrid maize (BH 661) which is high yielder as compared to other improved maize varieties in the study areas was used as a test crop and planted in rows spacing of 80 cm and 25 cm between plants. 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 maize in Mana district was used as source of N. 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 soil 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, days to 50% tasseling, biomass yield, grain yield, and thousand kernel weight were collected. Data on plant basis was recorded from the three central rows out of the five rows per plot. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD.

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 shelling were estimated by assessing the current local market prices. The price of NPS (1548.87ETB 100 kg-^{1}), 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 maize shelling (1 ETB kg$^{-1)}$) were considered to get the total cost that vary among the treatments. Time elapsed during NPS 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 ETB 6 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 and the marginal rate of return (MRR) were also calculated as per standard manual (CIMMYT, 1988).

Result and Discussion

Mean Days to Tasseling

Mean days to tasseling of maize were non significantly different ($P \leq 0.05$) among NPS fertilizer rates and DAP fertilizer, which were significantly different from the treatment without fertilizer (Table 2).This indicated that physiological maturity of maize was not influenced by NPS fertilizer rates. The highest (94.5) and lowest (88.6) days to tasseling were recorded from un fertilized plot and 100% Pc from NPS, respectively. This is due to the fact that fertilization hastens maturity.

Table 2. Mean days to tasling of maize under different NPS fertilizer rates in Mana district in 2018 and 2019 main cropping seasons

Treatments	Days to Tasseling	
Without fertilizer	94.5a	
25% Pc from NPS + Rec N	89.0 ^{b}	
50% Pc from NPS + Rec N	88.7^{b}	
75% Pc from NPS + Rec N	88.8^{b}	
100% Pc from NPS + Rec N	88.6 ^{b}	
100% Pc from DAP+ Rec N	88.7 ^{b}	
Mean	89.7	
CV (%)	6.5	
LSD	2.8	

Mean followed by the same letters in the column are not significantly different at P≤ 5%. CV = Coefficient of Variation, LSD = Least Significant Difference, Pc= Phos0horus critical level, Rec N = Recommended Nitrogen fertilizer

Mean Biomass and Grain Yields

Mean maize dry biomass and grain yields were significantly influenced by different NPS fertilizer rates ($P<0.05$). Increasing fertilizer levels from 0 to 100% Pc from NPS showed linear and consistent yield increment. The highest above ground dry biomass yield (30.0 t ha^{-1}) followed by 29.6 t ha^{-1} were obtained from 100% Pc from DAP and NPS fertilizer, respectively. However there were statistically similar between the two treatments (Table 3) so that, 100% Pc from DAP and NPS increased maize biomass yield by 21% and 19 % over 75% Pc from NPS fertilizer rate, respectively. Similarly, combined analysis showed that mean grain yield of maize was significant differences ($P \leq 0.05$) among the treatments. Maize grain yield was increased with applied NPS fertilizer rates from (25 % to 100 %) Pc from NPS fertilizer (Table 3).The highest mean grain yield (6.6 t ha^{-1}), followed by (6.5 t ha^{-1}) were obtained from 100% Pc from NPS and DAP fertilizers, respectively. This increment in grain yield with the NPS fertilizer which contained Sulfur is an indicator of low soil fertility level in the study area for maize production. This is in agreement with the findings of (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. This showed that low soil fertility is among the greatest constraints to maize production in Ethiopia (Kelsa *et.al.*, 1992).

Table 3. Mean biomass and grain yields of maize under different NPS fertilizer rates in Mana district in 2018 and 2019 main cropping seasons

Treatments	Biomass Yield ($t\ ha^{-1}$)	Grain Yield ($t\ ha^{-1}$)
Without fertilizer	6.4d	0.8^{d}
25% Pc from NPS + Rec N	19.1^{c}	2.7^{c}
50% Pc from NPS + Rec N	22.3^{bc}	3.6^{b}
75% Pc from NPS + Rec N	24.8^{b}	4.1^{b}
100% Pc from NPS + Rec N	29.6^{a}	6.6^{a}
100% Pc from DAP+ Rec N	30.0^{a}	6.5^{a}
Mean	22.0	4.0
CV (%)	24.1	32.6
LSD	3.8	0.6

Mean followed by the same letters in each column are not significantly different at P≤ 5%. CV = Coefficient of Variation, LSD = Least Significant Difference, Pc= Phos0horus critical level, Rec N = Recommended Nitrogen fertilizer

Mean Thousand Kernel Weight

Analysis of variance showed that there were significant differences ($P \leq 0.05$) among NPS fertilizer rates on thousand kernel weight of maize (Table 4). The highest (474.9 g) and lowest (241.6 g) mean thousand kernel weight were recorded for the treatment with 100% Pc from NPS, and no fertilizer application, respectively. The increment of kernel weight with the highest nutrient content fertilizer could be due to the more plant nutrient availability at grain filling and positive interaction. In agreement with the result, kernel weight is strongly associated with assimilate availability at flowering (Tollenaar and Dwyer, 1999). The final weight of the grains is thus a result of the rate at which the kernel accumulates dry matter and the duration over which this occurs (Housely *et.al.*, 1982). The strong relationships found between grain yield and number of kernels per row and between grain yield and thousand kernels weight were also in agreement with the findings of (Khatun *et.al.*, 1999) who stated that these two yield attributes are the most important components directly related to grain yield in maize.

Table 4. Mean thousand kernel weight of maize under different NPS fertilizer rates in Mana district in 2018 and 2019 main cropping seasons

Treatments	TKW (g)	
Without fertilizer	241.6^{d}	
25% Pc from NPS + Rec N	349.8^{c}	
50% Pc from NPS + Rec N	401.6^{b}	
75% Pc from NPS + Rec N	406.6^{b}	
100% Pc from NPS + Rec N	474.9^{a}	
100% Pc from DAP+ Rec N	461.8^{a}	
Mean	389.4	
CV (%)	14.2	
LSD	40.3	

Mean followed by the same letters in each column are not significantly different at P≤ 5%. CV = Coefficient of Variation, LSD = Least Significant Difference, Pc= Phos0horus critical level, Rec N = Recommended Nitrogen fertilizer, TKW= thousand kernel weight

Effects of NPS Fertilizer Rates on Economic Feasibility

The highest net benefits of 19424 ETB ha^{-1} with MRR of 313% were achieved from use of 100% Pc from NPS. The minimum net benefit was obtained from the treatments with no fertilizer. In conclusion, application of 100% Pc from NPS fertilizer for maize is agronomically and economically feasible (Table 5).

Table 5. Partial budget analysis for NPS fertilizer rates on Maize in Mana district

Treatments	Av. GY (t ha^{-1})	Adj. GY (t ha^{-1})	TVC (ETB)	Gross Benefit (ETB)	Net Benefit (ETB)	D. A	MRR (%)
Without fertilizer	0.8	0.7	2370	4200	1830		-
25% Pc from NPS + Rec N	2.7	2.4	9002.5	14400	5398		54
50% Pc from NPS + Rec N	3.6	3.2	11457	19200	7743		96
75% Pc from NPS + Rec N	4.1	3.7	12781.5	22200	9419		127
100% Pc from NPS + Rec N	6.6	5.9	15976	35400	19424		313
100% Pc from DAP+ Rec N	6.5	5.9	16875	35400	18525	D	-

Av.GY= Average grain yield, Adj.GY= Adjusted grain yield to 10%, TVC= Total Variable Costs, D.A = Dominance analysis, D= Dominated and MRR= Marginal Rate of Return, Pc= Phosphorus critical level, Rec N = Recommended Nitrogen fertilizer

Conclusion and Recommendation

Fertilizer application in relation to initial soil fertility status and crop requirement leads to economic and judicious use of fertilizers. Accordingly, all the studied NPS fertilizer effects on maize yield and yield components showed that NPS fertilizer would be promising to grow maize in the study area, The results of the study revealed that the maximum mean grain yield, the highest net benefit and acceptable MRR were recorded for 100% Pc from NPS fertilizer, whereas the lowest were recorded for the treatment without fertilizer. Accordingly NPS fertilizer 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. In conclusion, based on the data obtained from this study 100% Pc from NPS is agronomically and economically feasible for maize and hence recommended for the end users in Mana district. To sustain and/or improve the current unbalanced fertilizer application and soil mining of the study sites, precautionary actions such as adopting sustainable soil fertility replenishment strategy, soil conservation practices, lime application and avoiding unbalanced fertilizers can help to rebuild the soil conditions to increase crop productivity. Further researches have to be continued to recommend fertilizer types and rate for major crops grown in this region.

Acknowledgment

We acknowledge Oromia Agricultural Research Institute (IQQO) for granting research fund and technical advice.

References

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.

Berhanu Debele, 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, 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.

CIMMYT (International Maize and Wheat Improvement Centre, 2004. Global trends influencing CIMMYT future. Prepared by the Global Trends Task Force in support of strategic planning at CIMMYT. Mexico, D.F.: CIMMYT.

CSA (Central Statistical Agency), 2010.Agricultural Sample Survey for the 2009/2010 crop season. Volume II Report on Area and production of Crops for Private Peasant Holdings (Meher Season) Statistical Bulletin 446.FDRE/CSA, Addis Ababa, Ethiopia.

Dagne Chimdessa, Abdulmalik Mohammed and Gemechu Gerba, 2015. Soil Test Crop Response based Phosphorous Calibration Study for Maize in Mana District of Jimma Zone, Southwest Oromia, Ethiopia. pp. 35-42. Proceedings of Review Workshop on Completed Research Activities of Natural Resource Research Directorate held at Adami Tulu Agricultural research Center, Adami Tulu, Ethiopia 17- 21 November 2015.

Delorite, R.J. and H. L. Ahlgren, 1967. Crop Production. (3rd Eds). Prentice Hall, Inc., Englewood Cliffs, New Jersey.

Eylachew Zewdie, 1999. Selected physical, chemical and mineralogical characteristics of major soil soccurring in Chercher highlands, Eastern Ethiopia. Ethiopian Society of Soil Science. Ethiopian J .Natural Resource 1: 173-185.

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.

FAO (Food and Agriculture Organization), 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16. FAO, Rome

Housely, T. L., A. Kirleis, H. W. Ohm and F. L. Patherson, 1982. Dry matter accumulation in soft red winter wheat seeds. *Crop Sci. J.* 22:290-294.

Kelsa Kena, Tadesse Yohannes and Tesfa Bogal, 1992. Influence of fertilizer and its related management practices on maize grain yield in major producing areas of Ethiopia. pp. 15 104.Proceedings of the First National Maize Workshop of Ethiopia 5-7 may, 1992 Addis Ababa, Ethiopia.

Khatun, F., S. Begum, A. Mothin, S. Yasmin and M.R. Islam, 1999. Correlation coefficient and path analysis of some maize hybrids. Bangladesh. *J. Botany:* 28 (1):9-15.

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

Mokwunye, A. U., A. de Jager and E. M. Smailing, 1996. Restoring and maintaining the productivity of West Africa Soils: Key to sustainable development. International Fertilizer Development Center (IFDC), Muscle Shoals, Alabama. 94p.

Olson, K., Ebelhar, S. A. and Lang, J. M. (2014) Long-Term Effects of Cover Crops on Crop Yields, Soil Organic Carbon Stocks and Sequestration. *Open Journal of Soil Science*, 4, 284-292.

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

Taye Kufa, Mesfin Abebe and Paulos Dubale, 2003. Contribution of organic amendment physico-chemical conditions of coffee nursery media. In: Tilahun Amede and Eylachew Zewdie (Eds.). 2003. Challenges of land Degradation to Agriculture in Ethiopia. *Proceedings of the 6th ESSS Conference, February. 28- March 1, 2002*. Addis Ababa, Ethiopia.

Tollenaar, M. and L. M. Dwyer, 1999. Physiology of maize. *In*: Smith, D. L. and C. Hamel. Crop yield, physiology and process. Springer-Verlag Berlin Heidelberg.

Tolessa Debelle, Tesfa Bogale, Wakene Negassa, Tenaw Worayehu, Minale Liben, Tewodros Mesfin. Birtukan Mekonen and Waga Mazengia, 2001. A review of fertilizer management research on maize in Ethiopia. Enhancing the contribution of maize to food security in Ethiopia. *Proceedings of the second National maize workshop of Ethiopia .12-16 November 2001*, Addis Ababa, Ethiopia.

Yihenew Gebreselssie, 2002. Selected chemical and physical characteristics of soils of Adet Research Center and its testing sites in Northwestern Ethiopian. Society of Soil Science. *Ethiopian J, Natural Resource.* 4: 199-215.

Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Maize in Bedele District, Western Oromia

Dagne Chimdessa and Gedefa Sori
Oromia Agricultural Research Institute (OARI), Bedele Agricultural Research Center
P.O.Box-167, Buno Bedele zone, Bedele
Corresponding author: dagnechim@gmail.com

Abstract

Soil fertility and functioning must be restored to provide sustainable farming systems. Therefore, on farm experiment was conducted for two consecutive years during 2018 and 2019 to determine NPS fertilizer rate based on calibrated phosphorus for maize in Bedele district. The treatments consisted of five (0, 25, 50, 75 and 100 %) P critical levels (Pc) calculated from NPS fertilizer and previously recommended 100% Pc calculated from DAP fertilizer was included as check. The experiment was laid out in RCBD design with three replications. The results of the study revealed that the soil samples analyzed were characterized by strongly acidic, low available Phosphorus, low organic carbon content and clay in texture. The analysis of variance among NPS fertilizer rates showed significant differences ($P \leq 0.05$) for almost all the maize characters tested. The shortest (92.0) mean days to 50% tasseling was obtained from 100% Pc from NPS fertilizer, whereas the longest (98.6) days was recorded for the unfertilized plot. The maximum mean biomass yield (28.7 t ha^{-1}) was recorded for 100% Pc from DAP and grain yield of 8.5 t ha^{-1} was recorded from NPS fertilizer, respectively. Whereas, the lowest mean grain yield (1.3 t ha^{-1}) were recorded for the treatment with no fertilizer. Economic analysis for nutrient management indicated that the highest net benefit of 28244.00ETB ha^{-1} with an acceptable MRR of 271% was achieved from use of 100% Pc from NPS. Hence application of 100% Pc from NPS fertilizer is ergonomically and economically feasible for maize and recommended for the end users in Bedele district. The result also showed that the soils of the study sites had poor chemical fertility and integrated soil fertility management practices can improve the current situation.

***Key Words**: Nitrogen, NPS rate, Phosphorus, P-critical level*

Introduction

In countries with a capacity for excess food production, maintenance of soil fertility is a requirement for both economic and environmental viability of their farming system, People are dependent on soils and, conversely, good soils are dependent on people and the uses they make of the land (Brady and Weil, 2002). Crop yields in the developed world are high and agricultural soils have high fertility status due to intensive use of fertilizers (Mengel and Kirkby, 1996). For many cropping systems in Africa, nutrient balances are negative that indicating soil mining (Bationo *etal*., 1998). Sanchez and Leakey (1997) reported large per hectare losses of N, P and K during the last 30 years in about 100 million hectares of cultivated land in Africa (-700, -100 and -450 kg ha-1 30 years-1 for N, P and K, respectively) in contrast to large positive nutrient balances in North America (+200, +700 and +1000 kg ha-1 30 years-1 for N, P and K, respectively. The balances for NPK, the major plant nutrients, are taken as useful indicators of sustainability of cropping systems (Janssen *etal.*, 1995). On the other hand, Stangel *et al*. (1994) estimated the net losses of essential plant nutrients to be about 50 kg ha^{-1}year-1 in Africa. Similarly, nutrient mining due to sub optimal fertilizer use coupled with unblended fertilizer use favored the emergence of multi nutrient deficiency in Ethiopian soils (Wassie and Shiferaw, 2011) and resulted in stagnant crop production.

In Ethiopia, low soil fertility is one of the factors limiting the yield of crops, including maize.

The low nutrient levels in the soils are caused by crop removal of nutrients from the soil, little or no fertilizer application, and total removal of crop residues from the farmland and burning. Nowadays, due to increasing population pressure and shortage of land, deforestation and cultivation activities are being carried out on steep slopes, which accelerate soil erosion (Tolessa *etal*., 2001). Moreover, the shortage of land for production of food crops has eliminated the practice of fallowing and crop rotation on the flatter areas. According to FAO (2001) soil fertility management on smallholder farms in the tropics has become a major issue, as a result of continued land degradation and rapid population growth. On the other hand, shortage of grasslands (grazing areas) has forced the farmers to remove crop residues for animal feed. Since the area receives high rainfall, leaching may also cause nutrient losses and soil acidity. Continuous cultivation of the soils for many years without replenishing the nutrients mined has negatively affected the fertility of the soils and availability of nutrients, which has contributed to the declining productivity of maize in the area. Mokwunye *et al*. (1996) also stated that cultivated highly weathered soils commonly suffer from multiple nutrient deficiencies, and nutrient balances are generally negative. If nutrient loss continues at this alarming rate, it may only be few years before crop yield targets cannot be realized (Smaling, 1990).In general plant nutrient deficiency is one of the foremost problems hamper the development of an economically successful agriculture (Fageria and Baligar, 2005).

In Ethiopia, maize is first in productivity and second in area coverage after teff (CSA, 2010). Despite tremendous yield potential, it's productivity remains low as compared to developed countries. The low yield level of this crop was attributed by several factors among which, nutrient management is found the key element in Ethiopia (CIMMYT, 2004). 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)

Crop productivity can also be limited because of toxicity and/or deficiency of essential plant nutrients. In view of this, Bedele Soil Research Center, the then, Bedele Agricultural Research Center was conducted soil test crop response based Phosphorus calibration study for maze using DAP fertilizer in Bedele district; and recommended Phosphorus critical level and requirement factor (Dagne *et al*, 2015**).** On the other hand, Ethiopia has realized that agricultural soils commonly suffer from multiple nutrient deficiencies, and nutrient balances are generally negative, and an effort has been made since 2015 to introduce different types of fertilizers among which, NPS fertilizer is one of it. However, the rate and response of the newly introduced NPS fertilizer was not adjusted to the previously calibrated phosphorus using DAP fertilizer for maize.

Objective:

- To determine NPS fertilizer rate based on calibrated phosphorus for maize in Bedele district, Western Oromia.

Materials and Method

Description of the Study Area

A study was conducted in Bedele district on twelve farmers' fields in 2018 and 2019 main cropping seasons. Bedele district is located at 08^{o}14’28.6” to 08^{o}37’52.8”N and 036^{o}13’22.0” to 036^{o}35’09.1” E with altitude ranging from 1013 to 2390 masl. The 18 years weather information at nearby study area (Ethiopian Meteorology Agency Bedele District Branch) indicated that a uni-modal rainfall pattern with average annual rain fall of 1945 mm. The rainy seasons cover 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 25.8.0°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 Dimmaa*” 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)

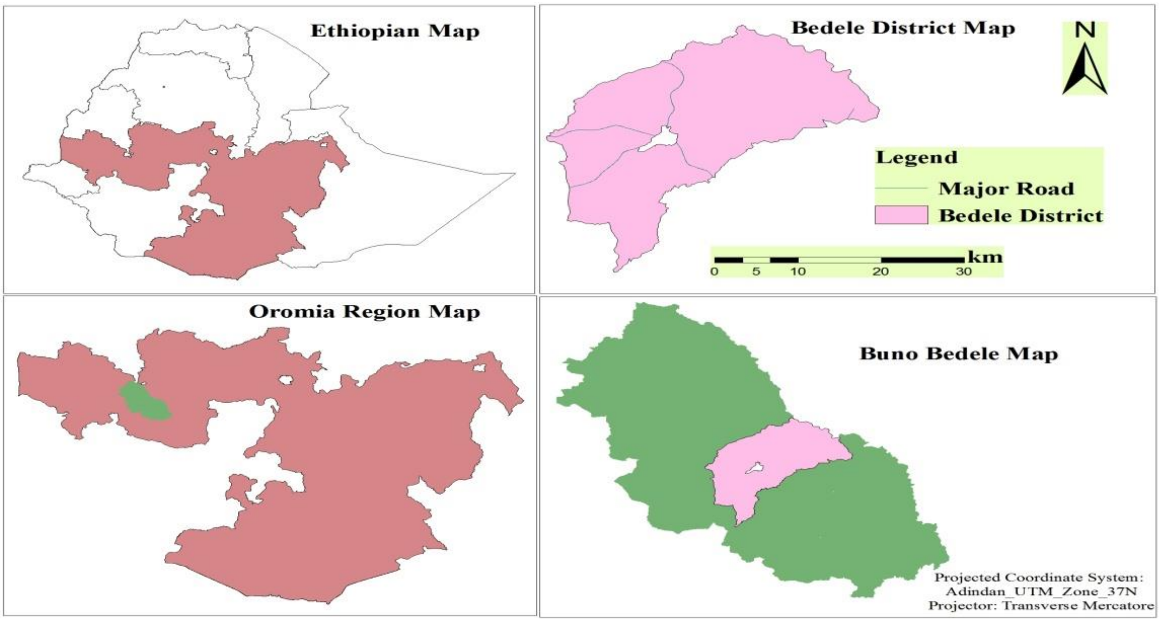


Figure 1. Map of the Study Area (Bedele district)

Soil Sampling and Analysis

During site selection twelve composite surface soil samples (0-20) cm depth were collected from each experimental sites before planting to analyze soil pH (H_2O), available P, (%OC), CEC, Exchangeable acidity and textural class. The collected soil samples were prepared and analyzed following standard laboratory procedures at soil analysis laboratory of, Bedele Agricultural Research Center.

Analysis result showed that, soil pH was strongly acidic in reaction, low in available P and OC content (Fig 2). The low contents of available P observed in the study area agreed with the results of similar study (Eylachew, 1999). The low available P in most Ethiopian soils can be attributed to P fixation, crop harvest. soil erosion and low rate of P sources application. The OC content of the soil was low (Berhanu, 1980). Most cultivated land soils of Ethiopia are poor in their organic matter content due to the low amount of organic materials applied to soil and complete removal of biomass from farm land (Yihenew, 2002). As a result, the major source of organic matter in cultivated soils below ground plant biomass has little contribution to increasing OM (Olson *etal* 2014).

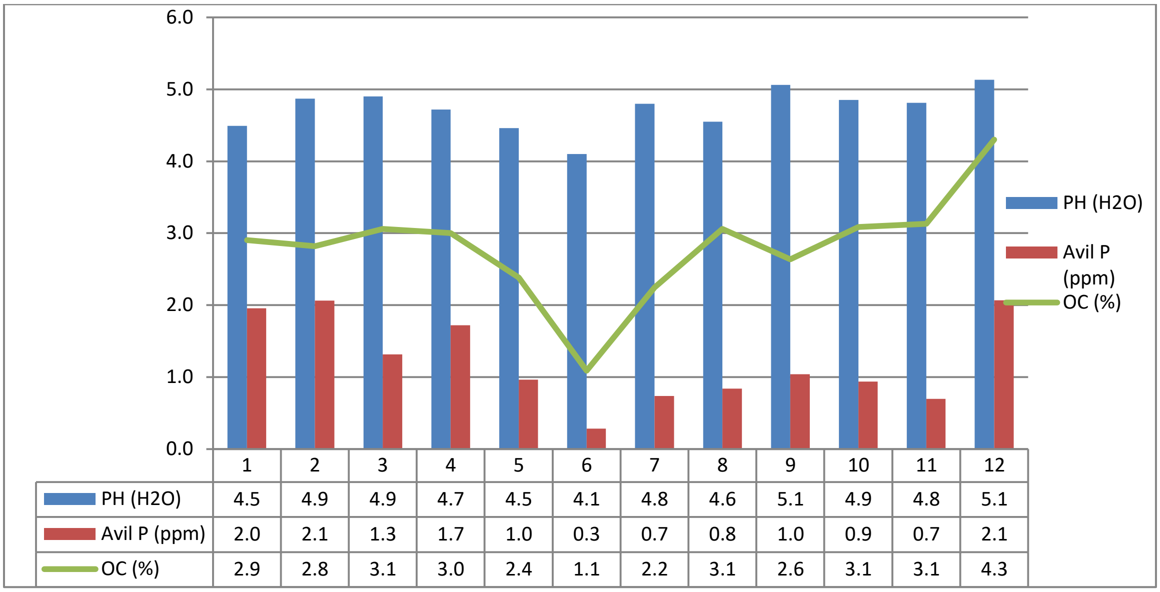


Figure 2. Soil pH, Available Phosphorus and Organic Carbon Status Before Planting in Bedele District

Soils CEC values were low to moderate and clay in texture (Table 1). The observed CEC values of the soils generally showed similar trend with that of soil OC (Table 1). This implies that CEC was more influenced by OM than clay content (Taye *etal*, 2003).

Table 1. Soil CEC, Exchangeable Acidity and Textural Class Status Before Planting in Bedele District

Sites	CEC (cmol(+)/kg soil)	Ex. Acidity meq/100 g soil)	Textural Class
1	14.5	0.3	Clay
2	18.9	0.2	Clay
3	20.2	0.2	Clay
4	16.9	0.3	Clay
5	15.3	1.0	Clay
6	17.5	1.9	Clay
7	13.7	0.5	Clay
8	16.6	0.6	Clay
9	18.0	0.6	Clay
10	15.7	0.3	Clay
11	11.9	0.5	Clay
12	16.7	0.9	Clay

Treatments

The field experiment involved five treatments (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. The total numbers of treatments were six.

Experimental Design and Procedures

The experiment was laid out in RCBD with three replications. The gross plot size was $12m^2$ (3m x4m) that accommodated five maize plants rows. Hybrid maize (BH 661) which is high yielder as compared to other improved maize varieties in the study area was used as a test crop in the district, which was planted in rows with spacing of 80 cm between rows and 25 cm among plants within a row. 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 correction factor. Recommended N; (92 kg N ha^{-1}) determined during Phosphorus calibration study for maize in Bedele district was used as source of N. 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 soil exchangeable acidity. 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.

Finally, days to 50% tasseling, biomass yield, grain yield, and thousand kernel weight were collected. Data on plant basis was recorded from the three central rows out of the five rows per plot. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD.

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 shelling 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 shelling (1 ETB $kg^{-1)}$) were considered to get the total cost that vary among the treatments. Time elapsed during NPS 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 ETB 6.00 $kg^{-1,}$. 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 and the marginal rate of return (MRR) were also calculated as per standard manual (CIMMYT, 1988).

Result and Discussion

Mean Days to Tasling of Maize (BH 661) under Different NPS Fertilizer Rates

The analysis of variance for days to tasseling revealed non-significant differences (P ≤ 0.05) among NPS fertilizer rates and DAP fertilizer, which were significantly different from un fertilized treatment (Table 2).This indicated that Physiological maturity of maize was not influenced by NPS fertilizer rates. The longest (98.6) and shortest (92.0) days to tasseling were recorded from un fertilized plot and 100% Pc from NPS in Bedele District, respectively.

Table 2: Mean days to Tasling of Maize (BH 661) Under Different NPS Fertilizer Rates in Bedele District in 2018 and 2019 Cropping Seasons

Treatments	Days toTessling (days)
Without fertilizer	98.6^{a}
25% Pc from NPS + Rec N	93.5^{b}
50% Pc from NPS + Rec N	93.2^{b}
75% Pc from NPS + Rec N	92.2^{b}
100% Pc from NPS + Rec N	92.0^{b}
100% Pc from DAP+ Rec N	92.1^{b}
Mean	93.6
CV (%)	6.7
LSD (5%)	2.9

Mean followed by the same letters in the column are not significantly different at P≤ 5%. LSD = Least Significant Difference, CV = Coefficient of Variation, Pc= Phos0horus critical level, NPS= Nitrogen, Phosphorus and Sulfur, Rec N = Recommended Nitrogen fertilizer,

Mean Biomass and Grain Yields of Maize (BH 661) Under Different NPS Fertilizer

Table 3 Presents the means of maize biomass and grain yields as influenced by different rates of NPS fertilizer. Analysis of variance indicated significant differences ($P<0.05$) among the treatments. Above ground dry biomass yields of maize consistently increased with applied NPS fertilizer rates from (0 to 100 %) Pc from NPS. Significantly the highest above ground dry biomass yield (28.7 t ha^{-1}) was obtained from the treatment of 100% Pc from DAP fertilizer, but statistically similar with 100% Pc from NPS fertilizer. The treatment100% Pc from DAP and NPS fertilizer increased maize biomass yields by 49 and 47% over the treatment 75% Pc from NPS fertilizer, respectively. Similarly, maize grain yield was increased with increasing NPS fertilizer rates (Table 3). 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). The highest grain yield (8.5 t ha^{-1}) followed by (8.0 t ha^{-1}) were obtained from 100% Pc from NPS and DAP fertilizers, respectively. This yield increment in grain yield with the NPS fertilizer which contained Sulfur is an indicator of low soil fertility level in the study area for maize production. This is in agreement with the findings of (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. This showed that low soil fertility is among the greatest constraints to maize production in Ethiopia (Kelsa *etal*, 1992). Sulfur interaction with nitrogen is very common, and S requirements of crops are enhanced with the increase of N in the growth medium. The main reason for the interaction of S with N may be a significant increase in growth of plants with N addition, which may cause dilution of Sulfur in plants (Wilkinson *etal*., 2000).Sulfur is an important component of two amino acids, cysteine and methionine, which are essential for protein formation. Since animals cannot reduce sulfate, plants play a vital role in supplying essential S-containing amino acids to them (Streeter and Barta, 1984).

Table 3: Mean Biomass and Grain Yields of Maize (BH 661) Under Different NPS Fertilizer

Treatments	Biomass yield (t ha^{-1})	Grain yield (t ha^{-1})
Without fertilizer	5.1^{d}	1.3^{e}
25% Pc from NPS + Rec N	16.6^{c}	5.3^{d}
50% Pc from NPS + Rec N	19.3^{b}	6.1^{c}
75% Pc from NPS + Rec N	19.3^{b}	6.9^{b}
100% Pc from NPS + Rec N	28.4^{a}	8.5^{a}
100% Pc from DAP+ Rec N	28.7^{a}	8.0^{a}
Mean	19.6	6.1
CV (%)	20.2	25.8
LSD (5%)	2.4	0.7

Mean followed by the same letters in each column are not significantly different at P≤ 5%. LSD = Least Significant Difference, CV = Coefficient of Variation, Pc= Phos0horus critical level, NPS= Nitrogen, Phosphorus and Sulfur, Rec N = Recommended Nitrogen fertilizer

Mean Thousand Kernel Weight of Maize (BH 661) Under Different NPS Fertilizer Rates

Thousand kernel weight is one of the most important parameter that influenced the maize yield. There were comparable differences among treatments in case of thousand kernel weight (Table 4). The highest (441.8 g) and lowest (217.3 g) mean thousand kernel weight were recorded for the treatment with 100% Pc from DAP, and no fertilizer application. The highest thousand kernel weight was recorded for 100% Pc from DAP and followed by100% Pc from NPS fertilizer. However there were statistically similar between (the two treatments in thousand kernel weight (Table 4). In general, these increment of kernel weight with the highest nutrient content fertilizer, could be due to the more plant nutrient availability at grain filling and positive interaction . In agreement with the result, kernel weight is strongly associated with assimilate availability at flowering (Tollenaar and Dwyer, 1999). The final weight of the grains is thus a result of the rate at which the kernel accumulates dry matter and the duration over which this occurs (Housely *etal*,1982). The strong relationships found between grain yield and number of kernels per row and between grain yield and thousand kernels weight were also in agreement with the findings of (Khatun *etal*, 1999) who stated that these two yield attributes are the most important components directly related to grain yield in maize.

Table 4. Mean Thousand Kernel Weight of Maize (BH 661) under Different NPS Fertilizer

Treatments	TKW (g)
Without fertilizer	217.3^{d}
25% Pc from NPS + Rec N	332.5^{c}
50% Pc from NPS + Rec N	376.5^{bc}
75% Pc from NPS + Rec N	398.1^{ab}
100% Pc from NPS + Rec N	431.4^{a}
100% Pc from DAP+ Rec N	441.8^{a}
Mean	366.3
CV (%)	19.5
LSD (5%)	52.1

Mean followed by the same letters in the column are not significantly different at P≤ 5%. LSD = Least Significant Difference, CV = Coefficient of Variation, Pc= Phos0horus critical level, NPS= Nitrogen, Phosphorus and Sulfur, Rec N = Recommended Nitrogen fertilizer, TKW= thousand kernel weight

Effects of NPS Fertilizer Rates on Economic Feasibility of Maize Production

The results of economic analysis for nutrient management are indicated in (Table 5). The highest net benefit of 28244.00 ETB ha^{-1} with an acceptable marginal rate of return (MRR) of 271% was achieved from use of 100% Pc from NPS, whereas the minimum net benefit was obtained from the treatments with no fertilizer. In conclusion, application of 100% Pc from NPS fertilizer for maize is agronomical and economically feasible.

Table 5: Partial Budget Analysis for NPS Fertilizer Rates on Maize in Bedele District

Treatments	Av. GY (t ha^{-1})	Adj. GY (t ha^{-1})	TVC (ETB)	Gross Benefit (ETB)	Net Benefit (ETB)	D.A	MRR (%)
Without fertilizer	1.3	1.2	2920.00	7200.00	4280.00		-
25% Pc from NPS + Rec N	5.3	4.8	12142.50	28800.00	16657.50		134
50% Pc from NPS + Rec N	6.1	5.5	13987.00	33000.00	19013.00		128
75% Pc from NPS + Rec N	6.9	6.2	15531.50	37200.00	21668.50		172
100% Pc from NPS + Rec N	8.5	7.7	17956.00	46200.00	28244.00		271
100% Pc from DAP+ Rec N	8.0	7.2	18305.00	43200.00	24895.00	D	-

Av.GY= Average grain yield, Adj.GY= Adjusted grain yield to 10%, TVC= Total Variable Costs, D.A = Dominance analysis, D= Dominated and MRR= Marginal Rate of Return, Pc= Phos0horus critical level, NPS= Nitrogen, Phosphorus and Sulfur, Rec N = Recommended Nitrogen fertilizer

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, all the studied NPS fertilizer effects on maize yield and yield components showed that NPS fertilizer would be promising to grow maize in the study area, The results of the study revealed that the maximum mean grain yield, the highest net benefit and acceptable MRR were recorded for 100% Pc from NPS fertilizer, whereas the lowest were recorded for the treatment without fertilizer. Accordingly NPS fertilizer 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. In conclusion, based on the data obtained from this study 100% Pc from NPS is agronomically and economically feasible for maize and hence recommended for the end users in Bedele district.

Acknowledgment

We acknowledge Oromia Agricultural Research Institute (IQQO)) for granting research fund and technical advice

References

Bationo, A., Lompo, F. and Koala, S. (1998) Research on Nutrient Flows and Balances in West Africa: State-of-the- Art. In: Smaling, E.M.A., Ed., *Nutrient Balances as Indicators of Production and Sustainability in Sub-Saharan African Agricultural, Agriculture, Ecosystems & Environment*, **71**, 19-36.

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

Berhanu Debele, 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia

Brady, N. C. and R. R. Weil, 2002. The Nature and Properties of soils (13thed). Pearson Education, Asia. 960p.

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

CIMMYT(International Maize and Wheat Improvement Centre, 2004. Global trends influencing CIMMYT‟sfuture. Prepared by the Global Trends Task Force in support of strategic planning at CIMMYT. Mexico, D.F.: CIMMYT. Season) Statistical Bulletin 446.FDRE/CSA, Addis Ababa, Ethiopia

CSA (Central Statistical Agency), 2010.Agricultural Sample Survey for the 2009/2010 crop season. Volume II Report on Area and production of Crops for Private Peasant Holdings (Meher Season) Statistical Bulletin 446.FDRE/CSA, Addis Ababa, Ethiopia

Dagne Chimdessa, Abdulmalik Mohammed and Gemechu Gerba, 2015. Soil Test Crop Response based Phosphorous Calibration Study for Maize in Bedele District of Iluababor Zone, Southwest Oromia, Ethiopia. pp. 28-34. Proceedings of Review Workshop on Completed Research Activities of Natural Resource Research Directorate held at Adami Tulu Agricultural research Center, Adami Tulu,Ethiopia 17- 21 November 2015

Delorite, R.J. and H. L. Ahlgren,1967. Crop Production. (3rd ed). Prentice Hall, Inc., Englewood Cliffs, New Jersey.

Eylachew Zewdie, 1999. Selected physical, chemical and mineralogical characteristics ofmajor soil soccurring in Chercher highlands, Eastern Ethiopia. Ethiopian Society of Soil Science. *Ethiopian J .Natural Resource* 1: 173-185.

Fageria, N. K. and V. C. Baligar, 2005. Growth components and zinc recovery efficiency of upland rice genotypes. *Agron J.* 40:1211–1215.

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, (2nd ed). Lewis Publishers, Boca Raton, Florida.290p.

Housely, T. L., A. Kirleis, H. W. Ohm and F. L. Patherson, 1982. Dry matter accumulation in soft red winter wheat seeds. *Crop Sci. J.* 22:290-294.

Janssen DM, Stoorvogel JJ, Shipper RA (1995). Using sustainability indicators in agricultural land Use analysis: An example from Costa Rice. Netherlands Journal of Agricultural Scienc*e* 43:61-81.

Kelsa Kena, Tadesse Yohannes and TesfaBogal, 1992. Influence of fertilizer and its related management practices on maize grain yield in major producing areas of Ethiopia. pp. 15-104.Proceedings of the First National Maize Workshop of Ethiopia 5-7 may, 1992 Addis Ababa, Ethiopia.

Khatun, F., S. Begum, A. Mothin, S. Yasmin and M.R. Islam, 1999. Correlation coefficient and path analysis of some maize hybrids. Bangladesh. *J. Botany:* 28 (1):9-15.

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

Mokwunye, A. U., A. de Jager and E. M. Smailing, 1996. Restoring and maintaining the productivity of West Africa Soils: Key to sustainable development. International Fertilizer development Center (IFDC), Muscle Shoals, Alabama. 94p.

Olson, K., Ebelhar, S. A. and Lang, J. M. (2014) Long-Term Effects of Cover Crops on Crop Yields, Soil Organic Carbon Stocks and Sequestration. *Open Journal of Soil Science*, 4, 284-292.

Sanchez AP, Leakey RB (1997). Land use transformation in Africa: three determinants for balancing food security with natural resource utilization. Agronomy Journal 7:15 23.

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

Stangel, P., C. Pieri and U. Mokwunye,1994. Maintaining nutrient status of soils: macro nutrients. pp.171-197. In: Green land, D.J. and I. Szabolcs (eds). Soil resilience and Sustain able land use. Willingford, UK: CAB International.

Streeter, J. G. and A. L. Barta. 1984. Nitrogen and minerals. In: *Physiological basis of crop growth and development*, M. B. Tesar, Ed., 175–200. Madison,

Taye Kufa, Mesfin Abebeand Paulos Dubale, 2003. Contribution of organic amendment tophysico-chemical conditions of coffee nursery media. In: Tilahun Amede and Eylachew Zewdie (eds.). 2003. Challenges of land Degradation to Agriculture in Ethiopia. *Proceedings of the 6th ESSS Conference, February. 28- March 1, 2002*. Addis Ababa, Ethiopia.

Tollenaar, M. and L. M. Dwyer, 1999. Physiology of maize. *In*: Smith, D. L. and C. Hamel. Crop yield, physiology and process. Springer-Verlag Berlin Heidelberg.

Tolessa Debelle, Tesfa Bogale, Wakene Negassa, Tenaw Worayehu, Minale Liben, Tewodros Mesfin. Birtukan Mekonen and Waga Mazengia, 2001. A review of fertilizer management research on maize in Ethiopia. Enhancing the contribution of maize to food security in Ethiopia. *Proceedings of the second National maize workshop of Ethiopia .12-16 November 2001*, Addis Ababa, Ethiopia.

Wassie H, 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.

Wilkinson, S. R., D. L. Grunes, and M. E. Sumner. 2000. Nutrient interactions in soil and plant nutrition. In: *Handbook of soil science*, M. E. Sumner, Ed., Boca Raton, FL: CRC Press.

Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Maize in Dabo Hana District, Western Oromia

*Dagne Chimdessa, Gedefa Sori, Dechassa Mengistu and Amanuel Kajela
Oromia Agricultural Research Institute (OARI), Bedele Agricultural Research Center
P.O.Box-167, Buno Bedele zone, Bedele
Corresponding author: dagnechim@gmail.com

Abstract

The secret of ensuring food security for the ever increasing population is strongly linked to the productivity of soils. In view of this ,on farm experiment was conducted in Dabo Hana district in 2018 and 2019 cropping seasons to determine NPS fertilizer rate based on calibrated phosphorus for maize. The treatments consisted of five (0, 25, 50, 75 and 100 %) P critical levels (Pc) calculated from NPS fertilizer and previously recommended 100% Pc calculated from DAP fertilizer was included as check. The experiment was laid out in RCBD design with three replications. laboratory analyzed soils data were characterized by strongly acidic, very low available Phosphorus, low organic carbon content and silty clay loam to clay in texture. The analysis of variance among NPS fertilizer rates showed significant differences ($P \leq 0.05$) for almost all the maize characters tested. The shortest (89.0) mean days to 50% tasseling was obtained from 100% Pc from NPS fertilizer, whereas the longest (97.1) days was recorded for the unfertilized plot. The maximum mean biomass yield (31.0 t ha^{-1}) and grain yield of (8.7 t ha^{-1}) were recorded for 100% Pc from NPS fertilizer. Whereas, the lowest mean grain yield (1.8 t ha^{-1}) was recorded for the treatment with no fertilizer. Economic analysis for nutrient management indicated that the highest net benefit of 27340.00ETB ha^{-1} with an acceptable MRR of 263% was achieved from use of 100% Pc from NPS. Hence application of 100% Pc from NPS fertilizer is agronomically and economically feasible for maize and recommended for the end users in Dabo Hana district. The result also showed that the soils of the study sites had poor chemical fertility and integrated soil fertility management practices can improve the current situation.

***Key Words**: Nitrogen, NPS rate, Phosphorus, P-critical level*

Introduction

Efficient management of soil is vital for economic growth and development. African soil nutrient balances are often negative due to low level of fertilizer inputs, and soil nutrient depletion is a major reason for decreasing or stagnation of agricultural productivity (Sanchez *et al*, 1997). Mbah (2006) indicated that soil fertility is a major overriding constraint that affects all aspects of crop production. On another hand, estimated essential plant nutrients loss in Africa was approximately 50 kg ha^{-1}year^{-1}(Janssen et al., 1995). Mokwunye *et al*. (1996) also stated that cultivated highly weathered soils commonly suffer from multiple nutrient deficiencies, and nutrient balances are generally negative. If nutrient loss continues at this alarming rate, it may only be few years before crop yield targets cannot be realized (Smaling, 1990).

In Ethiopia, low soil fertility is one of the factors limiting the yield of crops, including maize. The low nutrient levels in the soil are caused by crop removal of nutrients from the soil, little or no fertilizer application, and total removal of crop residues from the farmland and burning. Nowadays, due to increasing population pressure and shortage of land, deforestation and cultivation activities are being carried out on steep slopes, which accelerate soil erosion (Tolessa *et al*., 2001). Moreover, the shortage of land for production of food crops has eliminated the practice of fallowing and crop rotation on the flatter areas. According to FAO (2001) soil fertility management on smallholder farms in the tropics has become a major issue, as a result of continued land degradation and rapid population growth. On the other hand, shortage of grasslands (grazing areas) has forced the farmers to remove crop residues for animal feed. Since the area receives high rainfall, leaching may also cause nutrient losses and soil acidity. Continuous cultivation of the soils for many years without replenishing the nutrients mined has negatively affected the fertility of the soils and availability of nutrients, which has contributed to the declining productivity of maize in the area.

As the case in other regions in Africa, 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 (Astatke et al., 2004; Wassie et al., 2010; Wassie and Shiferaw, 2011) and resulted in stagnant crop production. On the other hand Inorganic fertilizers overcome soil fertility problems and responsible for increasing large part of world‟s food production (Sanchez and Leakey, 1997). Increment of crop yield from 30 to 50% has resulted from application of commercial fertilizers (Vlek, 1990; Stewart et al., 2005). This implies that using chemical fertilizer plays significant role in increasing food production to meet the demand of the growing world population. Therefore, adequate nutrient management is among the most important factors in sustaining crop production and productivity.

In Ethiopia, maize is first in productivity and second in area coverage after teff (CSA, 2010). Despite tremendous yield potential, it's productivity remains low as compared to developed countries. The low yield level of this crop was attributed by several factors among which, nutrient management is found the key element in Ethiopia (CIMMYT, 2004). 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)

The productivity of soils can also be limited because of toxicity and/or deficiency of essential plant nutrients. In view of this, Bedele Soil Research Center, the then, Bedele Agricultural Research Center was conducted soil test crop response based Phosphorus calibration study for maze using DAP fertilizer in Dabo Hana district; and recommended Phosphorus critical level and requirement factor**.** On the other hand, Ethiopia has realized that agricultural soils commonly suffer from multiple nutrient deficiencies, and nutrient balances are generally negative, and an effort has been made since 2015 to introduce different types of fertilizers among which, NPS fertilizer is one of it. However, the rate and response of the newly introduced NPS fertilizer was not adjusted to the previously calibrated phosphorus using DAP fertilizer for maize.

Objectives:

- To determine NPS fertilizer rate based on calibrated phosphorus for maize in Dabo Hana district, Western Oromia.

Materials and Method

Description of the Study Area

On farm experiment was conducted on twelve sits for two consecutive years during 2018 and 2019 in Dabo Hana district. Dabo Hana district is located at 08^{o}30’28.7” to 08^{o}41’34.6”N and 036 ^{o}26’19.2” to 036 ^{o}30’41.1” E with altitude ranging from 1791 to 1990 masl; 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 25.8.0°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 Dimmaa*” 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)

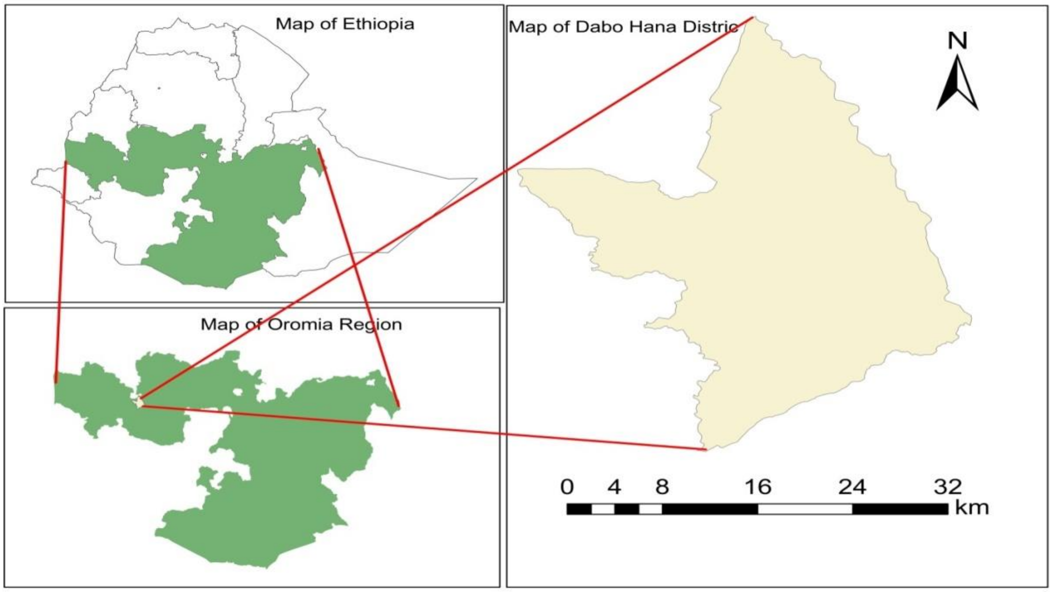
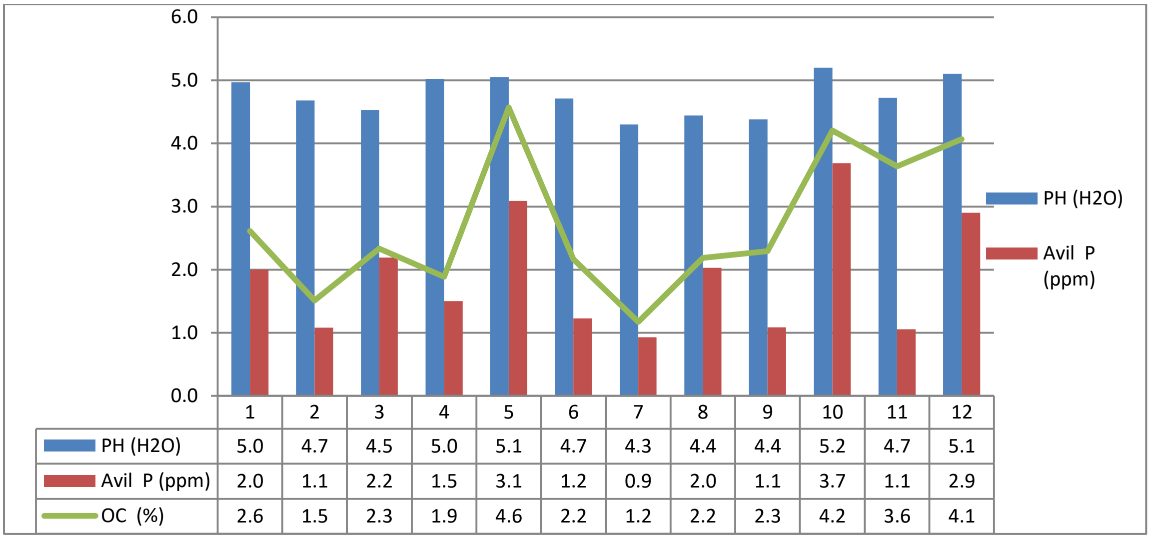


Figure 1. Map of the Study Area (Dabo Hana district)

Soil Sampling and Analysis

Twelve composite surface soil samples (0-20) cm depth were collected from each experimental sites before planting to analyze soil pH (H_2O), available P, (%OC), CEC, exchangeable acidity and texture during site selection. The collected soil samples were prepared and analyzed following standard laboratory procedures at soil analysis laboratory of, Bedele Agricultural Research Center.

Laboratory analysis result indicated that, soil pH was strongly acidic in reaction, low in available P and OC content (Fig 2). The low contents of available P observed in the study area agreed with the results of similar study (Eylachew, 1999). The low available P in most Ethiopian soils can be attributed to P fixation, crop harvest. soil erosion and low rate of P sources application. The OC content of the soil was low (Berhanu, 1980). Most cultivated land soils of Ethiopia are poor in their organic matter content due to the low amount of organic materials applied to soil and complete removal of biomass from farm land (Yihenew, 2002). As a result, the major source of organic matter in cultivated soils below ground plant biomass has little contribution to increasing OM (Olson *et.al* 2014).



	1	2	3	4	5	6	7	8	9	10	11	12
PH (H2O)	5.0	4.7	4.5	5.0	5.1	4.7	4.3	4.4	4.4	5.2	4.7	5.1
Avil P (ppm)	2.0	1.1	2.2	1.5	3.1	1.2	0.9	2.0	1.1	3.7	1.1	2.9
OC (%)	2.6	1.5	2.3	1.9	4.6	2.2	1.2	2.2	2.3	4.2	3.6	4.1

Figure 2. Soil pH, Available Phosphorus and Organic Carbon Status Before Planting in Dabo Hana District

Soils CEC values were low to moderate and and soil textural class was ranged from Silty clay loam to clay (Table 1). The observed CEC values of the soils generally showed similar trend with that of soil OC (Table 1). This indicated that CEC was more influenced by OM than clay content (Taye *etal*, 2003).

Table 1. Soil CEC, Exchangeable Acidity and Textural Class Status Before Planting in Dabo Hana District

Sites	CEC(cmol(+)/kg soil)	Ex. Acidity meq/100 g soil)	Textural Class
1	17.8	0.1	Loam
2	15.3	0.4	Sity clay loam
3	16.3	0.5	Silty clay loam
4	17.6	0.3	Silty clay loam
5	15.1	0.3	Silty loam
6	15.5	0.4	Silty loam
7	18.9	1.6	Clay
8	14.7	0.3	Clay
9	15.0	0.4	Clay
10	19.3	0.1	Clay
11	21.9	0.2	Clay
12	17.2	0.4	Clay Loam

Treatments

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. The total numbers of treatments were six.

Experimental Design and Procedures

The experiment was laid out in RCBD with three replications. The gross plot size was $12m^2$ (3m x4m) that accommodated five maize plants rows. Hybrid maize (BH 661) which is high yielder as compared to other improved maize varieties in the study areas was used as a test crop, that was planted in rows with spacing of 80 cm between rows and 25 cm among plants within a row. 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 correction factor. Recommended N; (138 kg N ha^{-1}) determined during Phosphorus calibration study for maize in Dabo Hana district was used as source of N. 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 in the soil. 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. Finally, days to 50% tasseling, biomass yield, grain yield, thousand kernel weight were collected. Data on plant basis was recorded from the three central rows out of the five rows per plot. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD..

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 shelling 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 shelling (1 ETB $kg^{-1)}$) were considered to get the total cost that vary among the treatments. Time elapsed during NPS 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 ETB 6.00 $kg^{-1,}$. 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 and the marginal rate of return (MRR) were also calculated as per standard manual (CIMMYT, 1988).

Result and Discussion

Mean Days to Tasling of Maize (BH 661) Under Different NPS Fertilizer

The result of combined analysis showed that mean days to tasling of maize were non significant differences ($P \leq 0.05$) among NPS fertilizer rates and DAP fertilizer, which were significantly different from the treatment without fertilizer (Table 2).This indicated that Physiological maturity of maize was not influenced by NPS fertilizer rates. The highest (96.7) and lowest (89.0) days to tasling were recorded from un fertilized plot and 100% Pc from NPS, respectively.

Table 2. Mean Days to Tasling of Maize (BH 661) Under Different NPS Fertilizer Rates in Dabo Hana District in 2018 and 2019 Cropping Seasons

Treatments	Days to tasseling (days)
Without fertilizer	96.7^{a}
25% Pc from NPS + Rec N	91.4^{b}
50% Pc from NPS + Rec N	90.3^{b}
75% Pc from NPS + Rec N	89.9^{b}
100% Pc from NPS + Rec N	89.0^{b}
100% Pc from DAP+ Rec N	89.6^{b}
Mean	91.1
CV (%)	6.3
LSD (5%)	2.6

Mean followed by the same letters in the column are not significantly different at P≤ 5%. LSD = Least Significant Difference, CV = Coefficient of Variation, Pc= Phos0horus critical level, NPS= Nitrogen, Phosphorus and Sulfur, Rec N = Recommended Nitrogen fertilizer.

Mean Biomass and Grain Yields of Maize (BH 661) Under Different NPS Fertilizer

Mean above ground dry biomass yields of maize were significantly ($P<0.05$) increased with applied NPS fertilizer rates from (0 to 100 %) Pc from NPS. However there were statistically at par between (100% Pc from NPS and 100% Pc from DAP (Table 3). All applied NPS fertilizer rates yielded significantly more than the treatment without fertilizer. The highest above ground dry biomass yields (31.0 t ha^{-1}) followed by (30.3 t ha^{-1}) were obtained from 100% Pc from NPS and 100% Pc from DAP fertilizer, respectively. 100% Pc from NPS and DAP fertilizers increased maize biomass yield by 44% and 41% over 75% Pc from NPS fertilizer rate, respectively. 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).

The result of combined analysis showed that NPS fertilization on maize grain yield was found to be significant (Table 3).The grain yield was increased consistently with NPS rates where the maximum grain yield (8.7 t ha^{-1}) was obtained from the application of the highest NPS fertilizer rate 100% Pc from NPS followed by (8.3 t ha^{-1}) which was obtained from 100% Pc from DAP fertilizer and the minimum (1.8 t ha^{-1}) was from the control plot. This increment in grain yield with the NPS fertilizer which contained Sulfur is an indicator of low soil fertility level in the study area for maize production. This is in agreement with the findings of (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. This showed that low soil fertility is among the greatest constraints to maize production in Ethiopia (Kelsa *etal*, 1992).

Table 3. Mean Biomass and Grain Yields of Maize (BH 661) Under Different NPS Fertilizer Rates in Dabo Hana District in 2018 and 2019 Cropping Seasons

Treatments	Biomass Yield (t ha^{-1})	Grain Yield (t ha^{-1})
Without fertilizer	7.8^{d}	1.8^{e}
25% Pc from NPS + Rec N	16.8^{c}	4.4^{d}
50% Pc from NPS + Rec N	21.1^{b}	6.1^{c}
75% Pc from NPS + Rec N	21.5^{b}	7.1^{b}
100% Pc from NPS + Rec N	31.0^{a}	8.7^{a}
100% Pc from DAP+ Rec N	30.3^{a}	8.3^{a}
Mean	21.4	6.0
CV (%)	25.5	15.7
LSD (5%)	3.6	0.5

Mean followed by the same letters in each column are not significantly different at P≤ 5%. LSD = Least Significant Difference, CV = Coefficient of Variation, Pc= Phos0horus critical level, NPS= Nitrogen, Phosphorus and Sulfur, Rec N = Recommended Nitrogen fertilizer

Mean Thousand Kernel Weight of Maize (BH 661) Under Different NPS Fertilizer

The result of analysis of variance showed that there were significant differences ($P \leq 0.05$) among NPS fertilizer rates on thousand kernel weight of maize (Table 4). The highest (480.7 g) and lowest (272.2 g) mean thousand kernel weight were recorded for the treatment with 100% Pc from NPS, and no fertilizer application, respectively. In general, these increment of kernel weight with the highest nutrient content fertilizer, could be due to the more plant nutrient availability at grain filling and positive interaction . In agreement with the result, kernel weight is strongly associated with assimilate availability at flowering (Tollenaar and Dwyer, 1999) The final weight of the grains is thus a result of the rate at which the kernel accumulates dry matter and the duration over which this occurs (Housely *etal*,1982). The strong relationships found between grain yield and number of kernels per row and between grain yield and thousand kernels weight were also in agreement with the findings of (Khatun *etal*, 1999) who stated that these two yield attributes are the most important components directly related to grain yield in maize.

Table 4. Mean Thousand Kernel Weight of Maize (BH 661) Under Different NPS Fertilizer Rates in Dabo Hana District in 2018 and 2019 Cropping Seasons

Treatments	TKW (g)
Without fertilizer	272.2^{d}
25% Pc from NPS + Rec N	342.7^{c}
50% Pc from NPS + Rec N	400.0^{b}
75% Pc from NPS + Rec N	407.3^{b}
100% Pc from NPS + Rec N	480.7^{a}
100% Pc from DAP+ Rec N	473.2^{a}
Mean	396.0
CV (%)	6.6
LSD	17.3

Mean followed by the same letters in the column are not significantly different at P≤ 5%. LSD = Least Significant Difference, CV = Coefficient of Variation, Pc= Phos0horus critical level, NPS= Nitrogen, Phosphorus and Sulfur, Rec N = Recommended Nitrogen fertilizer, TKW= thousand kernel weight

Effects of NPS Fertilizer Rates on Economic Feasibility of Maize Production

The results of economic analysis for nutrient management are indicated in (Table 5). The highest net benefit of 27340.00 ETB ha^{-1} with MRR 263% was achieved from use of 100% Pc from NPS fertilizer. The minimum net benefit was obtained from the treatment with no fertilizer. In conclusion, application of 100% Pc from NPS fertilizer for maize is agronomicaly and economically feasible.

Table 5. Partial Budget Analysis for NPS Fertilizer Rates on Maize in Dabo Hana District

Treatments	Av. GY (t ha^{-1})	Adj. GY (t ha^{-1})	TVC (ETB)	Gross Benefit (ETB)	Net Benefit (ETB)	MRR (%)
Without fertilizer	1.8	1.6	3360.00	9600.00	6240.00	-
25% Pc from NPS + Rec N	4.4	4.0	12056.50	24000.00	11943.50	66
50% Pc from NPS + Rec N	6.1	5.5	15381.00	33000.00	17619.00	171
75% Pc from NPS + Rec N	7.1	6.4	17145.50	38400.00	21254.50	206
100% Pc from NPS + Rec N	8.7	7.8	19460.00	46800.00	27340.00	263
100% Pc from DAP+ Rec N	8.3	7.5	20029.00	45000.00	24971.00	-

Av.GY= Average grain yield, Adj.GY= Adjusted grain yield to 10%, TVC= Total Variable Costs, D.A = Dominance analysis, D= Dominated and MRR= Marginal Rate of Return, Pc= Phos0horus critical level, NPS= Nitrogen, Phosphorus and Sulfur, Rec N = Recommended Nitrogen fertilizer

Conclusion and Recommendation

The use of right amount of fertilizer based on crop requirement has a significant importance for sustainable crop production. Accordingly, all the studied NPS fertilizer effects on maize yield and yield components showed that NPS fertilizer would be promising to grow maize in the study area, The results of the study revealed that the maximum mean grain yield, the highest net benefit and acceptable MRR were recorded for 100% Pc from NPS fertilizer, whereas the lowest were recorded for the treatment without fertilizer. Accordingly NPS fertilizer 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. In conclusion, based on the data obtained from this study 100% Pc from NPS is agronomical and economically feasible for maize and hence recommended for the end users in Dabo Hana district.

Acknowledgment

We acknowledge Oromia Agricultural Research Institute (IQQO)) for granting research fund and technical advice.

References

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

Berhanu Debele, 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, 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.

CIMMYT International Maize and Wheat Improvement Centre,2004. Global trends influencing CIMMYT "sfuture. Prepared by the Global Trends Task Force in support of strategic planning at CIMMYT. Mexico, D.F.: CIMMYT.

CSA (Central Statistical Agency), 2010.Agricultural Sample Survey for the 2009/2010 crop season.Volume II Report on Area and production of Crops for Private Peasant Holdings (Meher Season) Statistical Bulletin 446.FDRE/CSA, Addis Ababa, Ethiopia

Delorite, R.J. and H. L. Ahlgren,1967. Crop Production. (3rd ed). Prentice Hall, Inc., Englewood Cliffs, New Jersey.

Eylachew Zewdie, 1999. Selected physical, chemical and mineralogical characteristics ofmajor soil soccurring in Chercher highlands, Eastern Ethiopia. Ethiopian Society of Soil Science. *Ethiopian J .Natural Resource* 1: 173-185.

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, (2nd ed). Lewis Publishers, Boca Raton, Florida.290p.

Housely, T. L., A. Kirleis, H. W. Ohm and F. L. Patherson, 1982. Dry matter accumulation in soft red winter wheat seeds. *Crop Sci. J.* 22:290-294.

Janssen DM, Stoorvogel JJ, Shipper RA (1995). Using sustainability indicators in agricultural land Use analysis: An example from Costa Rice. Netherlands Journal of Agricultural Science 43:61-81.

Kelsa Kena, Tadesse Yohannes and TesfaBogal, 1992. Influence of fertilizer and its related management practices on maize grain yield in major producing areas of Ethiopia. pp. 15-104.Proceedings of the First National Maize Workshop of Ethiopia 5-7 may, 1992 Addis Ababa, Ethiopia.

Khatun, F., S. Begum, A. Mothin, S. Yasmin and M.R. Islam, 1999. Correlation coefficient and path analysis of some maize hybrids. Bangladesh. *J. Botany:* 28 (1):9-15.

Mbah, C. N. (2006). Influence of organic wastes on plant growth parameters and nutrient uptake by maize (Zea mays L.). *Nigerian Journal of Soil Science*, *16*(1), 104-108.

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

Mokwunye, A. U., A. de Jager and E. M. Smailing, 1996. Restoring and maintaining the productivity of West Africa Soils: Key to sustainable development. International Fertilizer Development Center (IFDC), Muscle Shoals, Alabama. 94p.

Olson, K., Ebelhar, S. A. and Lang, J. M. (2014) Long-Term Effects of Cover Crops on Crop Yields, Soil Organic Carbon Stocks and Sequestration. *Open Journal of Soil Science*, 4, 284-292.

Palm, C. A., Myers, R. J. K., & 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).

Sanchez AP, Leakey RB (1997). Land use transformation in Africa: three determinants for balancing food security with natural resource utilization. Agronomy Journal 7:15-23.

Sanchez P.A., Shepherd K.D., Soule M.J., Place F.M., Buresh R.J., Izac A.-M.N., Mokwunye A.U., Kwesiga F.R., Ndiritu C.G., Woomer P.L. (1997). Soil fertility replenishment in Africa. An investment in natural resource capital, in: Buresh R.J.,

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

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

Taye Kufa, Mesfin Abebeand Paulos Dubale, 2003. Contribution of organic amendment tophysico chemical conditions of coffee nursery media. In: Tilahun Amede and Eylachew Zewdie (eds.). 2003. Challenges of land Degradation to Agriculture in Ethiopia. *Proceedings of the 6th ESSS Conference, February. 28- March 1, 2002*. Addis Ababa, Ethiopia.

Tollenaar, M. and L. M. Dwyer, 1999. Physiology of maize. *In*: Smith, D. L. and C. Hamel. Crop yield, physiology and process. Springer-Verlag Berlin Heidelberg.

Tolessa Debelle, Tesfa Bogale, Wakene Negassa, Tenaw Worayehu, Minale Liben, Tewodros Mesfin. Birtukan Mekonen and Waga Mazengia, 2001. A review of fertilizer management research on maize in Ethiopia. Enhancing the contribution of maize to food security in Ethiopia. *Proceedings of the second National maize workshop of Ethiopia .12-16 November 2001*, Addis Ababa, Ethiopia.

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

Wassie H, 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, 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

Verification of Soil Test Crop Response Based Phosphorous Recommendation for Maize in Darimu District, Iluababor Zone, Western Oromia

*Dagne Chimdessa, Gedefa Sori, Garoma Firdissa and Habtamu Girma
Oromia Agricultural Research Institute (OARI), Bedele Agricultural Research Center
P.O.Box-167, Buno Bedele, Bedele
Corresponding author: dagnechim@gmail.com

Abstract

Verification of soil test crop response based calibrated phosphorous for maize was conducted in Darimu district, Western Oromia in 2019. The aim of the study was to verify the recommended nitrogen fertilizer (138 kg N ha^{-1}), determined P-critical level (10 ppm) and P- requirement factor (7.49) for maize during soil test crop response based phosphorus calibration study in the district. The treatments consisted of without fertilizer (T1), blanket recommendation (100/100 DAP/urea kgha^{-1}) (T2) and STCRBPR that were arranged in simple adjacent plots (10 m x10 m) and replicated over eleven sites. Analyzed initial soil samples collected before sowing indicated that strongly acidic in reaction, very low available phosphorus, low organic carbon content and clay in texture. The analysis of variance among treatments showed significant differences ($P \leq 0.05$) on maize biomass and grain yields. The maximum mean grain yield (7.4 t ha^{-1}) was recorded for STCRBPR, whereas the lowest (1.1 t ha^{-1}) was recorded for the treatment without fertilizer. The highest marginal rate of return 220% was obtained from STCRBPR, where by application of STCRBPR is agronomically and economically feasible and recommended as profitable for maize production in Darimu district. The result also showed that the soils of the study sites had poor chemical fertility and integrated soil fertility management practices can improve the current situation.

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

Introduction

Soil fertility depletion presents a major challenge to bring about increased and sustainable productivity in order to feed the ever increasing population of the country. It is caused by crop removal of nutrients from the soil, little or no fertilizer application, and total removal of crop residues from the farmland and burning. Nowadays, due to increasing population pressure and shortage of land, deforestation and cultivation activities are being carried out on steep slopes, which accelerate soil erosion (Tolessa *et.al.*, 2001). Moreover, the shortage of land for production of food crops has eliminated the practice of fallowing and crop rotation on the flatter areas.

According to FAO (2001) soil fertility management on smallholder farms in the tropics has become a major issue, as a result of continued land degradation and rapid population growth. On the other hand, shortage of grasslands (grazing areas) has forced the farmers to remove crop residues for animal feed. Since the area receives high rainfall, leaching may also cause nutrient losses and soil acidity. Continuous cultivation of the soils for many years without replenishing the nutrients mined has negatively affected the fertility of the soils and availability of nutrients, which has contributed to the declining productivity of maize in the area. Mokwunye *et.al.,* (1996) also stated that cultivated highly weathered soils commonly suffer from multiple nutrient deficiencies, and nutrient balances are generally negative. If nutrient loss continues at this alarming rate, it may only be few years before crop yield targets cannot be realized (Smaling, 1990). It is also expensive to improve depleted soils (FAO, 2006).

On the other hand, soil test crop response based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops and fertilizer schedules should therefore be based on the magnitude of crop response to applied nutrients at different soil fertility levels (Santhi *et al.,* 2003*).* Having this concept, soil test crop response based phosphorus calibration study was conducted in Darimu district on maize for three years. Thus formula comprises phosphorus critical level (10 ppm), phosphorus requirement factor (7.49) and nitrogen (138 kg ha^{-1}) were determined based on initial soil phosphorus (Dagne *et al,* 2019). Even though, critical phosphorus level and phosphorus requirement factor and nitrogen were determined during P calibration study, further verification trial was needed to have confidence on the significances of determined fertilizer rate over blanket recommendation practiced by farming community of the area and control one. Therefore, the objective of this study was to verify P critical level and P- requirement factor as well as N for maize.

Materials and Method

Description of the Study Area

Verification of soil test crop response based phosphorous recommendation for maize was conducted in Darimu district on eleven farmers' fields in 2019 cropping season. Darimu district is located at $08^0$37′00″ to $08^0$38′09″ N and 035^0 24′27″ to $035^0$25′40″E with altitude ranged from 700 to 1800 masl. Rainfall pattern is uni-modal with mean annual rainfall and a temperature of the district is ranging from 792 to 1192 mm, 18 to $31C^0$, respectively. The rainy season covers April to October and the maximum rainfall is received in the months of June, July and August. 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 Diimaa*" 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)

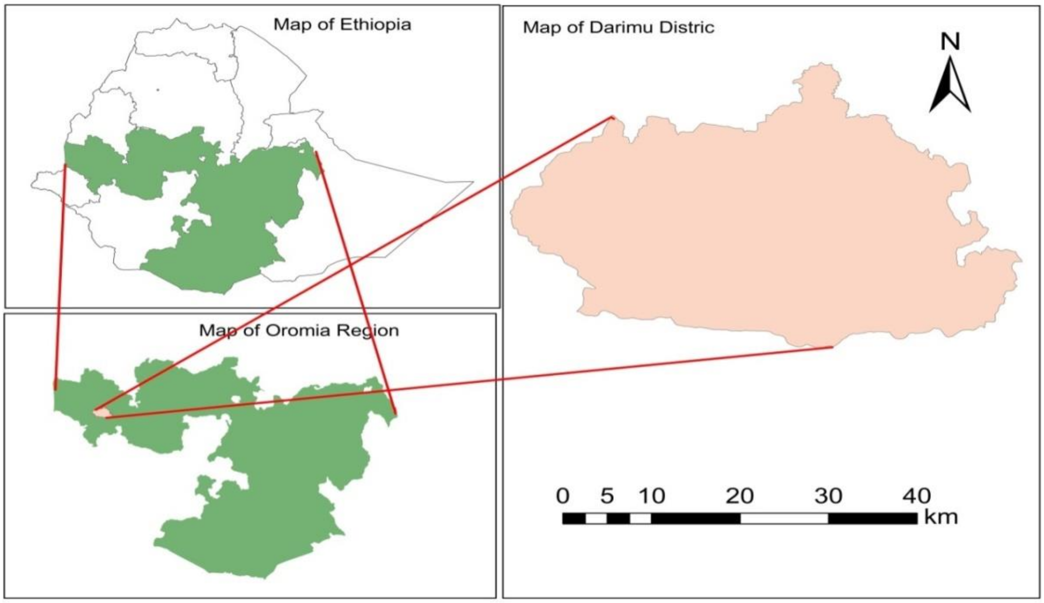


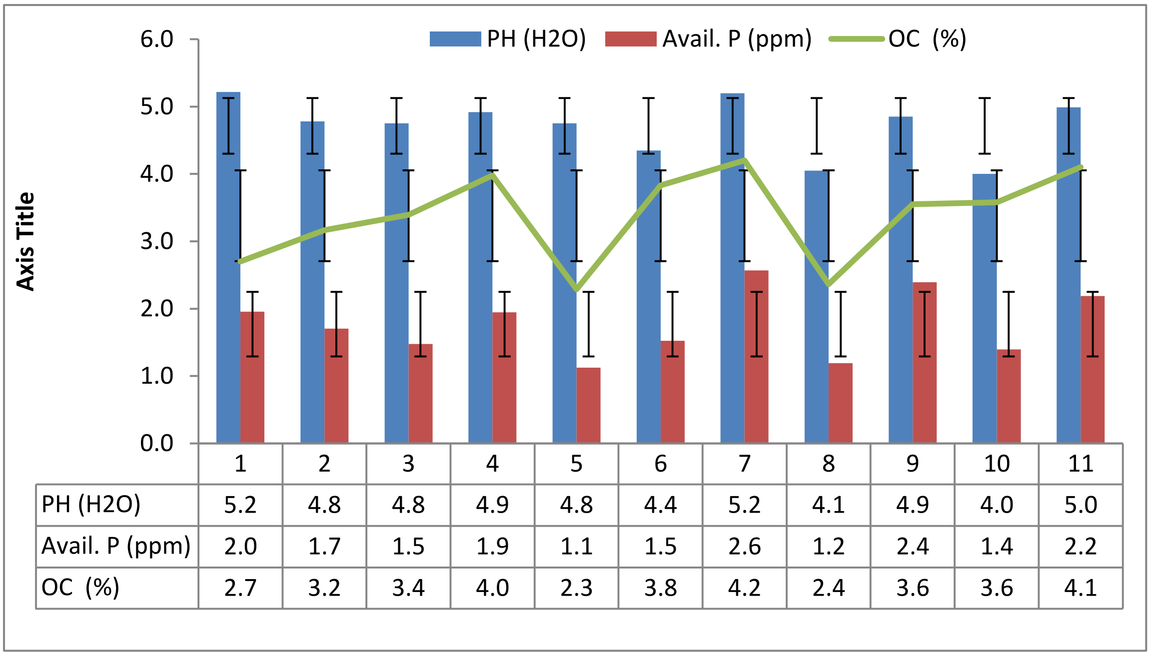
Figure 1. Map of the study area (Darimu district)

Soil Sampling and Analysis

During site selection composite surface soil samples (0-20) cm depth were collected from each experimental sites before planting to analyze soil pH (H_2O), available P, (%OC), CEC, exchangeable acidity 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 of soil analysis indicated that, soil pH was strongly acidic in reaction, low in available P and OC content (Fig 2). The low contents of available P observed in the study area agreed with the results of similar study (Eylachew, 1999). The low available P in most Ethiopian soils can be attributed to P fixation, crop harvest. Soil erosion and low rate of P sources application. The OC content of the soil was low (Berhanu, 1980). Most cultivated land soils of Ethiopia are poor in their organic matter content due to the low amount of organic materials applied to soil and complete removal of biomass from farm land (Yihenew, 2002). As a result, the major source of organic matter in cultivated soils below ground plant biomass has little contribution to increasing OM (Olson *et.al.*, 2014).

Figure 2. Soil pH, available phosphorus and organic carbon



	1	2	3	4	5	6	7	8	9	10	11
PH (H2O)	5.2	4.8	4.8	4.9	4.8	4.4	5.2	4.1	4.9	4.0	5.0
Avail. P (ppm)	2.0	1.7	1.5	1.9	1.1	1.5	2.6	1.2	2.4	1.4	2.2
OC (%)	2.7	3.2	3.4	4.0	2.3	3.8	4.2	2.4	3.6	3.6	4.1

Status before Planting in Darimu district

Soil CEC ranged from low to moderate and soil textural classes were clay loam to clay. The observed CEC values of the soils generally showed similar trend with that of soil OC (Table 1). This implies that CEC was more influenced by OM than clay content (Taye *et.al.*, 2003).

Table 1. Soils CEC, exchangeable acidity and textural class status before planting in Darimu district during 2019 main cropping season

Sites	CEC (cmol(+)/kg soil)	Ex. Acidity meq/100 g soil)	Textural Class
1	23.70	0.12	Clay Loam
2	21.27	0.28	Clay Loam
3	21.34	0.50	Clay
4	24.35	0.12	Clay
5	23.43	0.32	Clay
6	22.24	0.52	Clay
7	21.51	0.28	Clay
8	19.04	1.52	Clay
9	19.53	0.28	Clay
10	13.63	1.88	Clay
11	18.33	0.24	Clay

Treatments, Experimental Design and Procedures

The treatments consisted of unfertilized plot (T1), blanket recommendation (100/100 DAP/urea kgha^{-1}) (T2) and P-required (Pc-Po)*Pf) that were arranged in simple adjacent plots (10m x10m) and replicated over eleven sites. Hybrid maize (BH 661) which is high yielder as compared to other improved maize varieties in the study areas was used as a test crop that was planted in rows with spacing of 80 cm between rows and 25 cm among plants within a row.

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 on maize in Darimu district was used as source of N for STCRBPR. The experimental fields were prepared 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 soil exchangeable acidity. 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. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD.

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 trashing 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 maize trashing (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. Maize yield was valued at an average field price of 6 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 and the marginal rate of return (MRR) were also calculated as per standard manual (CIMMYT, 1988).

Result and Discussion

Mean Grain Yield

There were significant differences ($P \leq 0.05$) among treatments in maize grain yield. The maximum mean grain yield (7.4 t ha^{-1}) was recorded from the application of STCRBPR (soil test crop response based phosphorus recommendation), whereas the lowest (1.1 t ha^{-1}), was recorded from the unfertilized plot (Table 2). This high increment of yield with simple management of nutrient is an indicator of low nutrient content in the soil. STCRBPR increased maize grain yield over blanket recommendation fertilizer application, which indicated that maize productivity in the study area was reduced due to high demand for external nutrient inputs. This indicated that unbalanced fertilization. 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). Soil of the study area is characterized by low P and organic carbon content (Table 1). Most cultivated land soils of Ethiopia are poor in their organic matter content due to the low amount of organic materials applied to soil and complete removal of biomass from farm land (Yihenew, 2002). As a result, the major source of organic matter in cultivated soils below ground plant biomass has little contribution to increasing OM (Olson *et.al.*, 2014). Three different crop response categories to fertilizer application have been identified, namely responsive, fertile non-responsive and degraded non-responsive to indicate yield variability in small scale farming (Kihara et al., 2016).

Table.2: Mean grain yield of maize in Darimu district during 2019 main cropping season

Treatments	Grain Yield (t ha^{-1})
Without Fertilizer	1.1^{c}
Blanket Recommendation	3.4^{b}
STCRBPR	7.4^{a}
Mean	3.9
CV(%)	11.9
LSD	0.4

Mean followed by the same letters in the column are not significantly different at $P \leq 5\%$, CV = Coefficient of Variation, LSD = Least Significant Difference, STCRBPR= Soil Test Crop Response Based Phosphorus Recommendation

Economic Feasibility of Maize Production

The highest net benefit of 21051 ETB $ha^{-1}$with an acceptable marginal rate of return (MRR) of 220%, were achieved from use of STCRBPR. The minimum net benefit was obtained from the treatments without fertilizer (Table 3).

Table 3. Partial budget analysis for verification of STCRBPR on maize in Darimu district during 2019 main cropping season

Treatments	Av. GY (t ha^{-1})	Adj. GY (t ha^{-1})	TVC (ETB)	Gross Benefit (ETB)	Net Benefit (ETB)	D.A	MRR (%)
Without Fertilizer	1.1	1.0	2700	6000	3300		
Blanket Recommendation	3.4	3.1	12401	18600	6199		30
STCRBPR	7.4	6.7	19149	40200	21051		220

Av.GY= Average grain yield, Adj.GY= Adjusted grain yield to 10%, TVC= Total Variable Costs, D.A = Dominance analysis, D= Dominated and MRR= Marginal Rate of Return, Blank. Rec =Blanket Recommendation, Far. Prac = Farmers' Practice, STCRBPR= Soil Test Crop Response Based Phosphorus Recommendation

Conclusion and Recommendation

Routine soil analysis for 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 Darimu district. The significant differences maximum mean grain yield (7.4 t ha^{-1}) was recorded for STCRBPR, whereas the lowest (1.1 t ha^{-1}) was recorded for un fertilized treatment. STCRBPR increased maize grain yield over blanket fertilizer recommendation, which indicated that maize productivity in the district was reduced due to high demand for external nutrient inputs. Fertilizer application of STCRBPR had the highest net benefit with an acceptable MRR. Therefore, STCRBPR is agronomically and economically feasible for maize and hence, determined P-critical level (10 ppm), P- requirement factor (7.49) and nitrogen (138 kg N ha^{-1}) recommended for maize in Darimu district. Further, demonstration and training should be conducted in the farming community to popularize the technology in the district.

Acknowledgments

We acknowledge Oromia Agricultural Research Institute (IQQO) for granting research fund.

References

Berhanu Debele, 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, 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, 2016. Soils Characteristics in Maize Based Farming System of Western Oromia, Ethiopia. *Journal of Energy and Natural Resources*. 5 ; 37

Dagne Chimdessa, Gedefa Sori, Alemayehu Abdeta and Garoma Firdissa, 2019. Soil Test Crop Response Based Phosphorus Calibration Study for Maize in Darimu District of Iluababor Zone, Southwest Oromia, Ethiopia. PP. 67-74. Proceeding of Workshop on Completed Research Activities of Natural Resource Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Oromia, Ethiopia, 07-12 October 2019.

Eylachew Zewdie, 1999. Selected physical, chemical and mineralogical characteristics of major soil soccurring in Chercher highlands, Eastern Ethiopia. Ethiopian Society of Soil Science. *Ethiopian J .Natural Resource* 1: 173-185.

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.

FAO (Food and Agriculture Organization), 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16. FAO, Rome

FAO, (Food and Agriculture Organization), 2008.Efficiency of soil and fertilizer phosphorus use Reconciling changing concepts of soil phosphorus behavior with agronomic information. Bulletin 18.

Kihara J, Nziguheba G, Zingore S, Coulibaly A, Esilaba A, Kabambe V and Huising J (2016) Understanding variability in crop response to fertilizer and amendments in sub-Saharan Africa. Agriculture, Ecosystems and Environment 229, 5–18.

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

Mokwunye, A. U., A. de Jager and E. M. Smailing, 1996. Restoring and maintaining the productivity of West Africa Soils: Key to sustainable development. International Fertilizer Development Center (IFDC), Muscle Shoals, Alabama. 94p.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of available phosphorous in soils by extraction with sodium bicarbonate. *USA Circular J.* 939: 1-19.\

Olson, K., Ebelhar, S. A. and Lang, J. M. (2014) Long-Term Effects of Cover Crops on Crop Yields, Soil Organic Carbon Stocks and Sequestration. *Open Journal of Soil Science*, 4, 284-292.

Palm, C. A., Myers, R. J. K., & 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).

Santhi R., Natesan R., Seh'akumari G., 2003. Soil test based fertilizer recommendation under IPNS for aggregatum onion in Inceptisols of Tamil Nadu Department of Soil Science and Agricultural Chemi~try. Tamil :'\jadu Agricultural Lniversity Coimhatore Ml 003. India

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

Taye Kufa, Mesfin Abebeand Paulos Dubale, 2003. Contribution of organic amendment tophysico-chemical conditions of coffee nursery media. In: Tilahun Amede and Eylachew Zewdie (Eds.). 2003. Challenges of land Degradation to Agriculture in Ethiopia. *Proceedings of the 6th ESSS Conference, February. 28- March 1, 2002.* Addis Ababa, Ethiopia.

Tolessa Debelle, Tesfa Bogale, Wakene Negassa, Tenaw Worayehu, Minale Liben, Tewodros Mesfin. Birtukan Mekonen and Waga Mazengia, 2001. A review of fertilizer management research on maize in Ethiopia. Enhancing the contribution of maize to food security in Ethiopia. *Proceedings of the second National maize workshop of Ethiopia .12-16 November 2001,* Addis Ababa, Ethiopia.

Yihenew Gebreselssie, 2002. Selected chemical and physical characteristics of soils of Adet Research Center and its testing sites in Northwestern Ethiopian. Society of Soil Science. *Ethiopian J, Natural. Resource.* 4: 199-215.

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

Chalsissa Takale, Temesgen Chimdessa*, Garamu Bayata, Olifan Fikadu and Chaltu Regasa

Oromia Agricultural Research Institute, Nekemte Soil Research Center, Soil fertility improvement and problematic soils research team. P.O. Box 587, Nekemte, Ethiopia

*Corresponding author email: temesgenchimdessa468@gmail.com

Abstract

The use of fertilizers without first testing the soil is like taking medicine without consulting a physician. Therefore, soil test crop response-based fertilizer calibration study can give farmers a service leading to the better and more economic use of fertilizers and better soil management practices. Because of this, a field experiment was conducted on farmers' fields in the Jima Arjo district of Oromia Regional State, Ethiopia to determine the economic rate of N, critical P-concentration, and P- requirement factors. The trial was conducted on eight experimental sites/farmers' field in the first year of the experiment (2017/18 cropping season) to determine the economic rate of N and on twenty farmers field in the second and third years during 2018/19 and 2019/20 cropping season to determine phosphorus critical level and requirement factor. In the first year, the treatments were factorial combined of four levels of phosphorus (0, 10, 20, 40 kg/ha) and four levels of nitrogen (0, 46, 92, and 138 kg/ ha), while, the treatments in the second and third years were five levels of P (0, 10, 20, 30, and 50 kg/ha). The treatments in all years of experiments were laid out as a randomized complete blocked design (RCBD) with three replications. Representative soil samples were taken before planting and analyzed following standard procedures. The soil pH of the experimental fields less than 5.5 was limed before the setup of the experiment. The results of the study revealed that the soil reaction pH (H2O) of the experimental sites ranged from 4.6 to 5.9. The lowest (2165.8 kg/ha) mean grain yield of the crop was obtained from the control (without fertilizers application) and the highest (4779.7 kg/ha) mean grain yield was recorded from the application of 138 kg N/ha and 40 kg P/ha. However, the partial budget analysis showed that 92 kg/ha of N was economically optimal for the production of bread wheat in the district. The study results also indicated that the P- critical value (13ppm) and P-requirement factor (9.1Kg P/ha) were determined for the phosphorus fertilizer recommendation in the study area. Thus, the farmers in the study area could be advised to use soil test crop response-based fertilizer recommendations to increase the production of bread wheat in Jima Arjo district.

Key words: Bread wheat, Fertilizer, Jima Arjo, Phosphorus

Introduction

Bread wheat (Triticum Aestivum L.) is one of the most staple food crops in the world and it is one of the most important cereals cultivated in Ethiopia. It stands fourth in both area coverage and total annual production, and second in yield per hectare next to maize (CSA, 2017). Bread wheat grain is used for making bread, porridge, soup and consumed as roasted and boiled forms. Moreover, the straw of bread wheat is an important feed for livestock, thatching roofs, and bedding (Bekele *et al.,* 2017).

In spite of its tremendous importance, its production in Ethiopia as well as in Oromia region has faced immense production constraints affecting both its yield potential and industrial quality. Among these constraints mainly farmers are using low yielding local varieties and declining soil fertility (Jemmal, 1994). Continuous cropping and applications of suboptimal rates of mineral fertilizers have aggravated the decline in soil fertility and crop yield (Zeleke, G., G *et al.* 2010). In high lands of Jima Arjo District, wheat production is too low and even less than half of its potential that could be obtained through using improved varieties (JADADO, 2019).

Land productivity could improve only if, the soil fertility problems were improved. Phosphorous is the most yield limiting of soil supplied elements and soil P tends to decline when soils are used for agriculture (David, M.E. and J.T. David, 2012). Studies have demonstrated that nitisol and vertisols areas of Ethiopian highlands are marginally to severely deficient in P (Regassa, H. and G. Agegnehu, 2011). To overcome the soil fertility problem, farmers use mainly chemical fertilizers. For instance, more than 80% of the farmers in mid-altitude areas use chemical fertilizers (Abdissa, G., *et al*., 1999).

In Ethiopia, 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 (Zeleke *et al.,* 2010 and Bekele *et al.,* 2002). 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.

In Jima Arjo district, there is no any visible recommendation of NP fertilizer rate for bread wheat as well as for other crops except the blanket recommendation. Determining the appropriate NP fertilizer rate hence necessary for maximizing economic yields. Even farmers don't apply NP fertilizers as per the blanket recommendation, rather they use less than the blanket recommendation rates. These all demand research works to study to determine their optimal rates for achieving the potential production of bread wheat in the target areas (Litke *et al.,* 2017; Kumar *et al.,* 2018). Currently, soil fertility research improvement is agreed with respect to site specific fertilizer recommendation in the country (Ethio SIS, 2015). This field experiment was conducted with the basic assumption that fertilizer recommendations typically depend on crop response experiments in which spatial variability has been minimized for every independent variable affecting crop yield except for the nutrient in question (Kastens *et al.*, 2003). Therefore, the aim of this study was to determine the economic rate of N and to determine critical P concentration and P requirement factors for bread wheat production in Jima Arjo district.

Materials and Methods

Descriptions of Study Area

Location

The study was conducted in Jima Arjo district, East Wollega Zone of Oromia regional state, which capital town located at 378 kilometers far from Finfinnee (Addis Ababa) to the west direction. Geographically Jima Arjo district is located between 80 33’ to 80 55’N latitudes and 360 22’ to 360 44’E longitudes and has a total area of 77,258 hectares (Figure 1). Elevation of the District ranges from 1500 to 2600 meters above sea level.

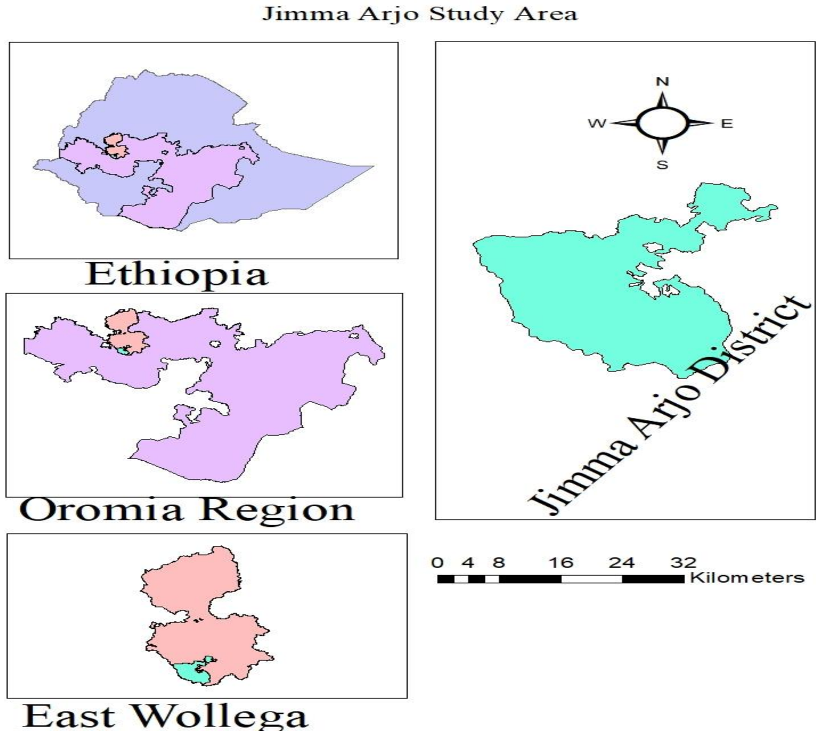


Figure 1: Location map of Jima Arjo district

Agro Climate, Soil Type and Topography

According to the agro-climatic classification of Ethiopia by MoA (2005), the study area can be grouped in to three major physiographic units based on their elevation. Rainfall of the study area is characterized by unimodal with monthly rainfall rising steadily from March to a peak at August and then descends gradually to the month of December. Months from May to September are when the area receives more rain (76.3% of the total rain of the area). The mean annual rainfall of the study area recorded for 19 years at Nekemte Metrological agency is 1855.3 mm. April to September are the months of high rainfall. The lowest mean monthly rainfall (14.1 mm) was recorded in the month of January while the highest 332 mm rainfall recorded in August. The maximum and minimum mean temperature of the study area is 10 ^{0}C to 23 ^{0}C respectively. The average annual temperature is 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 m a.s.l. 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).

Site Selection for the Experiment

The study was conducted on farmers' fields across Jima Arjo District. The specific Experimental sites in the district were selected based on ranges of phosphorus contents (high, medium and low), willingness of farmers to provide land and initiative to implement the activity and accessibility for supervision and vicinity to the road. During experimental site selection, composite soil samples was collected in a zigzag method from farmers field and analyzed for soil pH and available P in order to identify the extents of soil acidity and level of phosphorus in the soil to select actual experimental sites. Accordingly, the experiment was done on 8 farmer's field for optimum N fertilizer determination and 20 farmers' field for phosphorus critical level and requirement factor determination.

Experimental Procedure, Design and Treatments

The trial was done for three consecutive year (2017/18- 2019/20 cropping season). In 2017/18 cropping season, optimum N determination and in 2018/19 and 2019/20 cropping season, Pc and Pf were determined. The experiment was laid out in randomized complete block design (RCBD) with three replications. The treatment was consisted four levels of P (0,10,20 and 40) kg/ha and four levels of N (0,46,92 and 138) kg/ha during N determination trial. While, the treatments in the second and third years of the experiment was included five levels of P (0,10,20,30 and 50 kg/ha). Gross plot size was 3m x 4m. Land preparation was done using the local ox plow. Wheat variety of "*Danda'a*" was used and sown in a row with a rate of 150 kg/ha. N was split-applied (1/3 at planting and the remaining about three weeks after planting). Partial budget analysis for optimum N fertilizer was done following the procedures described in CIMMYT (1998). The mean grain yield data of wheat were employed in the analyses. Furthermore, the grain yield obtained from each treatment were adjusted down by 10% in order to narrow down the possible yield gap that may happen due to difference in field management. The average prices of relevant inputs required to do the partial budget analyses were collected from different sources.

After 21 days of sowing, composite soil samples were collected at 0-20 cm depth using auger from each treatment and replications separately, and the samples were subjected to laboratory analysis using Olsen method. With continuous field management, all important field agronomic data were collected. Based on soil available Phosphorus analyzed before and after planting (available P values in samples collected from unfertilized and fertilized plots) data, p requirement factor was calculated that enables one to determine the quantity of P required per hectare to raise the soil test by 1 mg kg^{-1} and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level. For the determination of critical values of P, the Cate-Nelson diagram method (Nelson and Anderson, 1977) was used, where soil P values were put on the X-axis and relative yield values on the Y-axis, and scatter points were divided into two populations. Hence soil and yield data from 20 sites of all treatments with their replications were used for such analysis.

Data Analysis

Agronomic and soil data was properly managed on the MS excel computer. The collected data was subjected to the analysis of variance using the SAS 9.0 (SAS Institute, 2004). Means separation was done using least significant difference (LSD).

Results and Discussion

Soil pH and Available Phosphorus

The soil reaction of the experimental sites before planting ranged from 4.6 -5.9 (table 1). Accordingly, the soils were very strongly to moderately medium acidic in reaction (Chude *et al.*, 2005). According to (Thomas and Hargrove, 1984), the suitable pH range for wheat crop is between 5.5 and 7.0. Continuous cultivation and long-term application of inorganic fertilizers led to low soil pH and aggravated the losses of basic cations from highly weathered soils. Moreover, the acidic nature with low soil pH obtained from the whole sites may be attributed to the fact that the soils were derived from weathering of acidic igneous granites and leaching of basic cations such as K, Ca and Mg from the surface soil. The maximum and minimum values of available P were 19.66 and 2.33 ppm, respectively (table 1). Most of available phosphorus contents of soil categorized under low status according to the critical level set by Ethio SIS (2015). Therefore, the soil of the study area needs the application of P containing fertilizers.

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

Sites	pH (H2O)	AV. P (ppm)
1	5.0	5.04
2	5.0	4.74
3	4.8	2.33
4	5.1	6.37
5	4.8	2.58
6	5.0	3.67
7	5.1	7.18
8	4.6	3.90
9	5.2	4.20
10	5.8	12.41
11	5.3	5.26
12	5.3	4.87
13	5.9	19.66
14	5.5	10.23
15	5.5	7.67
16	5.2	4.27
17	5.4	4.23
18	5.6	8.97
19	5.4	5.09
20	5.6	11.11

Yield Responses to N and P Fertilizer Rates During Optimum N determination trial

The main and interaction effects of both P and N fertilizer rates shows highly significant difference ($P<0.05$) for bread wheat grain yield with grand mean of 3757.37 kg/ha. The lowest (2165.8 kg/ha) mean grain yield of the crop was obtained from the control (without fertilizers application) and the highest (4779.7 kg/ha) mean grain yield was recorded from the application of 138 kg N/ha and 40 kg P/ha. Except 46 N Kg/ha with zero level of P fertilizer, all the rest produce significant mean grain yield as compared to the control. This result signifies that the existence of positive interaction of P and N fertilizers for the production of bread wheat, and the responsiveness to the application of high-level of phosphorus fertilizer. However, the maximum mean grain yield obtained was showed no significant difference from mean grain yield obtained from application of 92 N and 20 kg P each in Kg/ha (Table 2). Previous research output reported by Desta (1978), Mesfin (1980) and Asnake and Tekalign (1991) supported this result. Kefyalew *and* Tilahun (2018) also found that, grain yield of bread wheat significantly increased with increasing rate of N and P fertilizer application.

Table 2. Interaction effect of N and P rates on grain yield of bread wheat (kg/ha)

N (Kg/ha)	P (kg/ha)				*Mean*
	0	10	20	40	
0	2165.8^{f}	3330.5^{de}	3731.9^{bcd}	4156.3^{abc}	*3346.125*
46	2758.0^{ef}	3695.2^{bcd}	3607.8^{cd}	3558.9^{cd}	*3404.975*
92	3860.2^{bcd}	3913.6^{bcd}	4162.1^{abc}	4154.1^{abc}	*4022.5*
138	3631.0^{cd}	4213.0^{abc}	4399.8^{ab}	4779.7^{a}	*4255.875*
Mean	*3103.75*	*3788.075*	*3975.4*	*4162.25*	*3757.369*
LSD (5%)	**733.5**				
CV (%)	**11.74**				

Optimum N Fertilizer Rate determination

Partial budget analysis was used to determine economically optimum rates of N. Economic analysis using partial budget analysis showed that fertilizer rates of 92 kg N/ha was economically optimal for production of bread wheat in Jima Arjo District with gaining a net benefit of twenty four thousands four hundred fifty eight birr and thirty four cents (24458.34 birr) (Table 3). Therefore, recommended rate of Nitrogen for bread wheat production across the district is 92 kg/ha.

.

Table 3. Summary of partial budget analysis for economic fertilizer recommendation

Trt	N (Kg/ha)	P (Kg/ha)	GY (qt/ha)	AGY (Qt/ha)	GFB (birr/ha)	FC (birr/ha)	TSC (birr/ha)	HBC (birr/ha)	TVC (birr/ha)	NB (birr/ha)	change in NB	change in TVC	MRR (%)
1	0	0	21.91	19.72	15775.83	0.00	985.99	394.40	1380.39	14395.44			
2	0	10	33.23	29.91	23924.97	646.00	1495.31	598.12	2739.43	21185.54	6790.09	1359.05	499.62
3	0	20	36.70	33.03	26420.67	1292.00	1651.29	660.52	3603.81	22816.86	1631.33	864.37	188.73
4	0	40	40.63	36.57	29252.34	2584.00	1828.27	731.31	5143.58	24108.76	1291.90	1539.77	83.90
5	46	0	27.94	25.15	20116.44	1100.00	1257.28	502.91	2860.19	17256.25	-6852.51	-2283.39	300.10
6	46	10	37.13	33.42	26735.13	1746.00	1670.95	668.38	4085.32	22649.81	5393.55	1225.14	440.24
10	92	10	39.79	35.81	28651.50	2846.00	1790.72	716.29	5353.01	23298.49	1825.80	883.02	206.77
11	92	20	42.54	38.29	30630.51	3492.00	1914.41	765.76	6172.17	24458.34	1159.85	819.16	141.59
13	138	0	37.38	33.64	26915.85	3300.00	1682.24	672.90	5655.14	21260.71	-1624.35	-1782.06	91.15
14	138	10	42.94	38.64	30914.91	3946.00	1932.18	772.87	6651.05	24263.86	3003.14	995.92	301.55
15	138	20	44.55	40.09	32073.03	4592.00	2004.56	801.83	7398.39	24674.64	410.78	747.34	54.97
16	138	40	48.00	43.20	34560.00	5884.00	2160.00	864.00	8908.00	25652.00	977.36	1509.61	64.74

While Trt = Treatment; ha = hectare; qt = Quantal; GY = Grain yield; AGY = Adjusted Grain yield; Gross field benefit; FC = Fertilizer cost; TSC = Total Service cost; HBC = Harvesting and bagging cost; TVC = Total variable cost NB = Net benefit and MRR = Marginal rate of return

Remark: - Dominated treatments are not included in the table

Yield Responses to P Fertilizer Rates During Phosphorus Critical and Requirement factor determination trial

The analysis of variance revealed that, the application phosphorus fertilizer rates showed highly significant ($p \leq 0.01$) affects grain and biomass yield of bread wheat. Comparison of means among application levels showed that the highest mean grain (4257.7 kg/ha) and biomass (12838.0 kg/ha) yield were recorded at the highest recognized rates of phosphorus.

Table4. Main effects of Phosphorus fertilizer rates on grain and biomass yields of bread wheat

P (kg/ha)	Grain yield (Kg/ha)	Biomass yield (Kg/ha)
0	2043.5^{c}	6173.0^{d}
10	3073.8^{b}	7082.0^{cd}
20	3535.0^{b}	8962.0^{bc}
30	3642.7^{b}	10181.0^{ab}
40	4257.7^{a}	12838.0^{a}
Significance	***	***
LSD (5%)	604.43	2759.3
CV (%)	10.03	16.76

Critical P Level Determination

Cate-Nelson diagram method was used, where soil P values were put on the X-axis and relative grain yield values on the Y-axis and scatter points were divided into four populations. Then, moving a cross over the data points until a minimum number are positioned in the first and third quadrants. Hence, the scattered plot showed that 13 ppm was critical phosphorus level for bread wheat production in Jima Arjo District (Figure 2). It means, the soil test phosphorus value (by Olsen method) above this critical phosphorus level, wheat grain yield of the District could not respond.

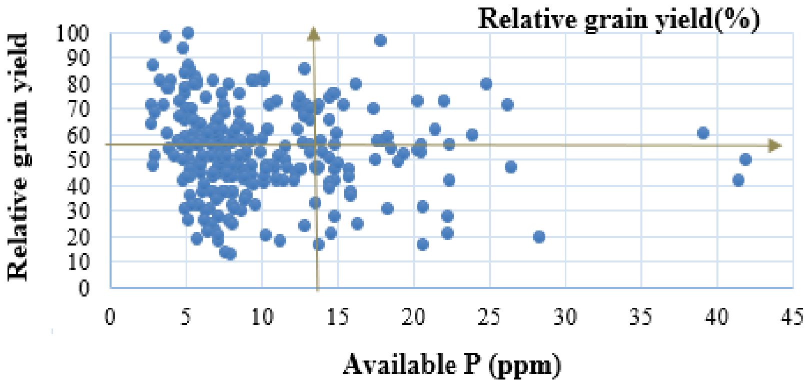


Figure 2. Relative grain yield Vs P Olsen plot chart for P critical level determination

Phosphorus Requirement Factor Determination

Calculated phosphorus requirement factor (Pr), for bread wheat production at Jima Arjo area was 13 kg/ha (Table 5). It means, the amount of P in kg needed to raise the soil test Phosphorus by 1 ppm. These Phosphorus requirement factor enables to determine the quantity of P required per hectare to raise the soil test by 1 ppm, and to determine the amount of fertilizer required per hectare to bring the level of available Phosphorus above the critical level.

Table 5. Determination of Phosphorus requirement factor (Pf) for bread wheat productionin Jima Arjo District

P rates (Kg/ha)	Average of P (ppm)	P increased over Control	P requirement Factor (Kg P applied/ ppm P of soil)
0	10.40		
10	11.94	1.54	6.50
20	12.09	1.69	11.82
30	13.27	2.87	10.46
40	15.56	5.15	7.76
Mean		**2.81**	**9.13**

Conclusion and Recommendation

The study was conducted on the farmers field in Jima Arjo district with the objective to determine optimum level of nitrogen fertilizer rate and to determine Phosphorus critical value (Pc) and Phosphorus requirement factor (Pf) for bread wheat production in the district. The main and interaction effects of both P and N fertilizer rates shows highly significant difference ($P<0.05$) for bread wheat grain yield. Accordingly, the highest (4779.7 kg ha^{-1}) mean grain yield of bread wheat was obtained from the combined rates of 138 kg N ha^{-1} and 40 kg ha^{-1} of P. The analysis of variance revealed that, the application phosphorus fertilizer rates showed highly significant ($p < 0.05$) affects grain and biomass yield of bread wheat. Application of 40 kg P ha^{-1} gave significantly higher grain and biomass yield. In addition, the critical available soil P concentration (13 ppm) and the average P requirement factor (9.1 ppm) have been established for the district. Partial budget analysis indicated that 92 kg/ha of N fertilizer rates was economically optimal for production of Bread wheat in Jima Arjo District with gaining a net benefit of twenty four thousands four hundred and fifty eight birr (24,458.34 birr). Farther verification of the result on farmers field could be a pre request before disseminating the technology to the user.

References

Abdissa *et al.*,1999. Maize seed systems study in western Shewa and eastern Wellega zones of Oromia region, CIMMYT Technical paper, Addis Ababa, Ethiopia: ILRI

Bekele, T., G. Gorfu, Y. Assen and S. Sertsu, 2002. Results of Phosphorous Soil Test Calibration Study in Hetosa Werede, Arsi zone: *Proceeding of the Workshop on phosphorous soil test calibration Study.* Addis Ababa, Ethiopia: EIAR

Chude, V.O., Jayeoba, O. J. and Oyebanyi, O.O. 2005. Hand book on soil acidity and use of agricultural lime in crop production. Published by *NSPFS Nigeria.* Pp 7-24..

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

CSA (Central Statistical Agency), 2017. Report on: Area and Production of Major Crops (Private Peasant Holdings, Meher Season) Statistical Bulletin, 532, Addis Ababa, Ethiopia.

David, M.E. and J.T. David, 2012. Modeling an Improvement in phosphorous utilization in Tropical Agriculture. *Journal of Sustainable Agriculture, 36: 18-35.*

Ethio SIS (Ethiopian Soil Information System), 2015. http:// www.ata.gov.et/ highlighted-deliverables/ ethiopian-soil-information-system-ethiosis/. Accessed 15 March 2015.

Geremew Bayata, Siraj Hasan, Berhanu Deressa, Muluneh Yadeta and Mitiku Wakjira, 1998. Land Use Study of Jima Arjo Woreda. Nekemte, Ethiopia. Pp. 1 – 55.

Jemmal Mohammed, 1994. Performance of wheat genotypes under irrigation in Awash valley, Ethiopia. *African Crop Science Journal, 2: 145-151.*

Jima Arjo District Agricultural Development Office (JADADO). 2019. Annual Report for the year 2018-2019. (unpublished report). Jima Arjo District Agricultural Development Office. Arjo, Ethiopia.

Kefyalew Assefa and Tilahun Firomsa, 2018. Phosphorus Critical Level and Optimum Nitrogen Rate Determination on Bread Wheat for Sustainable Soil Fertility Management and Economical Production at Lume Area of Oromia Region, Ethiopia. *Journal of Biology, Agriculture and Healthcare, ISSN 2224-3208 (Paper) ISSN 2225-093X (Online) Vol.8, No.1, 2018 26*

Kumar, V., Chauhan, R.K., Srivastava, S., Singh, J. and Kumar, P. (2018). Contamination, enrichment and translocation of heavy metals in certain leafy vegetables grown in composite effluent irrigated soil. *Archives of Agriculture and Environmental Science, 3(3): 252-260. https://doi.org/10.26832/24566632.2018.030307*

Litke, L., Gaile, Z. and Ruža, A. (2017). Nitrogen fertilizer influence on winter wheat yield and yield components depending on soil tillage and forecrop. In Research for Rural Development. *International Scientific Conference Proceedings (Latvia).* Latvia University of Agriculture.

Muleta Ebisa. 2009. Land Use/Land Cover Dynamics and Soil Degradation Assessment Using Remote Sensing and GIS: A Case Study of Jima Arjo Woreda (Western Ethiopia). MSc Thesis Addis Abeba University.

Nelson, L.A. and R.L. Anderson, 1977. Partitioning soil test- crop response probability. In soil testing: Correlating and interpreting the analytical results, ed T.R. Peck, 19-39. Madison, WI: *American Society of Agronomy.*

Regassa, H. and G. Agegnehu, 2011. Potentials and limitations of acid soils in highlands of Ethiopia: A review. In Barley research and development in Ethiopia edited by B. Mulatu and S. Grando, 103-112. ICARDA, Aleppo, Syria

Roy, R. N., Finck, A., Blair, G. J, and Tandon, H. 2006. Plant nutrition for food security. A guide for integrated nutrient management. FAO Fertilizer and Plant Nutrition Bulletin 16: 368.

SAS (Statistical Analysis System) Institute. 2004. SAS/STAT user’s guide. Proprietary software version 9.00. SAS Institute, Inc., Cary, NC.

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 Levels on Yield and Yield components Based on Calibrated Phosphorus for Maize at Dugda District, East Shewa Zone, Oromia, Ethiopia

Tilahun Abera[1*], Tilahun Firomsa[1], Abdurhman Husen[1] and Amante Lema[1]
Batu Soil Research Center, P. O. Box: 59, Batu, Oromia, Ethiopia.
Corresponding author: email-tileabera3@gmail.com

Abstract

Nutrient deficiencies are the most important problems influencing maize production in the mid and low altitude sub-humid agro-ecologies of Ethiopia due to limited use of commercial inputs and lack of soil fertility enriching rotations or fallows. Due to this on-farm study of blended NPS fertilizer for maize was conducted in Dugda District, East Shewa Zone of Oromia, during the main cropping seasons of 2018-2019. The main objective of the study was to assess the effect of of blended NPS fertilizer rates on yield and yield components of Maize variety (MHQ 138) and to determine economically appropriate rate of blended NPS fertilizer for optimum maize crop production at Dugda District. The treatments were arranged based on already determined Phosphorous critical(Pc) and phosphorus requirement factor(Pf) and consisting of 100% Pc from TSP(Tripple supper phosphate) fertilizer, 100%, 75%, 50%, 25% Pc from blended NPS fertilizer and control (no fertilizer application).Applied Phosphorus = (Critical P - Po) Pf. Whereas Pc= 10 ppm and Pf = 4.68 ppm. The experiment was laid out in randomized complete block design (RCBD) with three replications. Inter and intra row spacing was 0.75 x 0.25m respectively. The results of the study revealed that, different rates of phosphorus critical from blended NPS and TSP fertilizers did not significantly ($p < 0.05$) influenced ear height, number of rows per ear and thousand kernels weight of maize crop at study area. However, plant height, biomass yield, grain yield, harvest index and cob weight were highly significantly ($p < 0.01$) influenced by different rates of phosphorus critical from blended NPS and TSP fertilizers. The highest (2008 cm) plant height, the highest(6123 kg ha^{-1}) grain yield, and the highest (52.67 kg ha^{-1}) cob weight were recorded by application of the highest 100% Pc (168 kg ha^{-1}) while the highest (20.14 tone ha^{-1}) biomass yield and the highest (32.77 %) harvest index were recorded by 100 pc TSP and 75% PC NPS; respectively. The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of 100 Pc NPS (168 kg NPS ha^{-1}) is profitable which gave the highest (35073 Birr) net return with acceptable (102%)marginal rate of return and recommended for farmers in Dugda district and other areas with similar Agro-ecological conditions*

Key words: - *Applied phosphorus, NPS, Phosphorous critical (Pc) level, phosphorus requirement factor (Pf), Maize Yield and Yield components*

Introduction

Maize (*Zea mays* L.) is an important cereal crop of the World. It is a member of grass family poaceae and is highly cross pollinated crop most people regard maize as a breakfast cereal. However, in a processed form it is also found as fuel (ethanol) and starch. Starch in turn involves enzymatic conversion into products such as sorbitol, dextrine, sorbic and lactic acid, and appears in household items such as beer, ice cream, syrup, shoe polish, glue, fireworks, ink, batteries, mustard, cosmetics, aspirin and paint (Du Plessis, 2003).

Global Maize production in 2018 was estimated at 1147 million t from 193 million ha area harvested with average yield of 5924 kg ha^{-1}. However, in Ethiopia maize production in 2018 was estimated at 7360201 t from 2235872 ha area harvested with average yield of 3293 kg ha^{-1}(FAOSTAT, 2018). According to this report despite the large area under maize in Ethiopia, the national average yield of maize is 80% far below the world's average yield. Moreover, according to Taffese *et al*. (2012) who reported that the averaged cereals production from CSA data for over the years of 2004/05–2007/08 were 12,062,972 metric tons from a total area harvested of 8,230,211 ha. Accordingly this report showed that among cereals average maize production in these years was estimated at 3,314,286 t from 1,595,238 ha area harvested with average yield of 2077.6 kg ha^{-1}

The low productivity of maize is attributed to many factors like declining of soil fertility, poor agronomic practice, limited use of input, frequent occurrence of drought and insufficient technologies (Tsedeke *et al*., 2015). However, Successful maize production depends on the correct application of production inputs that will sustain the environment as well as agricultural production. These inputs are adapted cultivars, plant population, soil tillage, fertilization, weed, insect and disease control, harvesting, marketing and financial resources (Du Plessis, 2003).

According to the report of Stewart *et al*., (2005) 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 and estimated that at least 30 to 50% of crop yield increment is attributable to application of commercial fertilizers. Even though, low soil fertility 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 yield unless sufficient nutrients are available (Delorite and Ahlgren, 1967).

Like in other developed 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.

Due to these, Ethiopia has been moving from blanket recommendations to diversification and away from DAP and Urea, which have long been the only type of fertilizer imported for grain crops to blended fertilizers such as NPS. However, the rate of this fertilizer was not determined by researchers particularly for the study area and Maize production. Therefore, this research activity were proposed to assess the effect of rates of blended NPS on yield and yield components of maize crop; to determine economically appropriate rate of blended NPS fertilizer for maize crop production.

Materials and Methods

Description of the Study Site

The field experiment was conducted at Dugda district of East Shoa Zone, on farmers field during 2019/2020 cropping season. It was part of the former woreda of Dugda Bora what was divided between Bora and Dugda woredas. Part of the East Shewa Zone located in the Great Rift Valley, Dugda Bora is surrounded by Lake Zway in the southeastern direction; by AdamiTullu and Jido Kombolcha from south, in the west by the Southern Nations, Nationalities and Peoples Region, from the northwest by Southwest Shewa Zone, from the north by the Awash River which separates it from Ada'a Chukala, from the northeast by Koka Reservoir which separates it from Adama, and on the east by the Arsi Zone (Figure 1). The altitude of this District ranges from 1500 to 2300 meters above sea level; (WikiMiniAtlas).

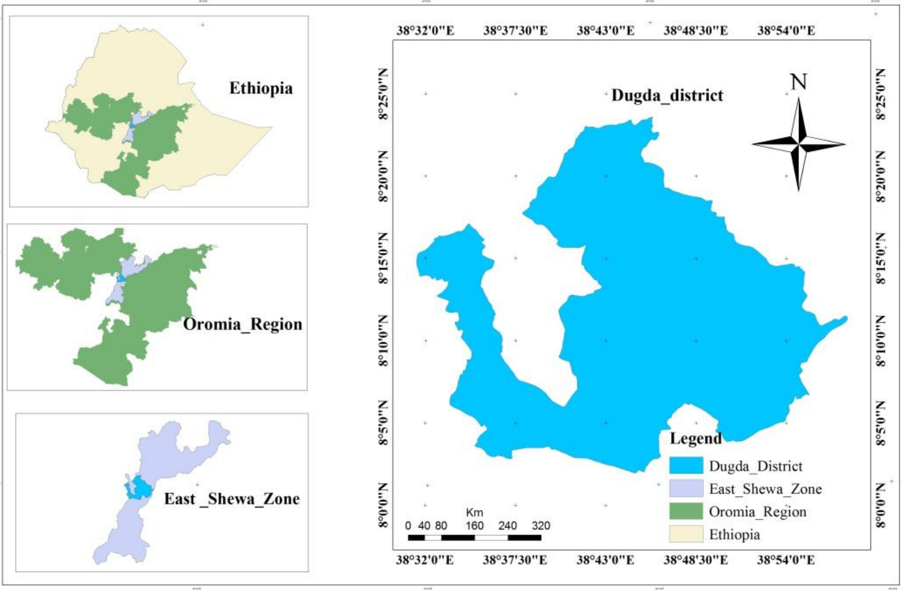


Figure 1. Location map of Dugda District

Treatments and Experimental Design

The treatments were prepared on the bases of already determined Phosphorous critical and requirement factor and consisting of 100% Pc from TSP (Triple supper phosphate) fertilizer, 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application). The experiment was laid out in a randomized complete block design (RCBD) with three replications. Phosphorus fertilizer was calculated and applied according to the formula of ***Applied P*** = (Critical P - Po)* Pf. Whereas ***Pc= 10 ppm and Pf = 1.41-4.68(3.05) ppm*** (EIAR, 2017). The gross plot size was 4.5*2.5 (11.25m^2) accommodating 6 rows and 10 plants per row. Spacing of 75 cm and 25 cm were maintained in between inter rows; respectively. The outermost one row from each side of a plot were considered as border, thus the Net plot size was 0.75 m*0.25 m*4 rows*10 plants (7.5 m^2). Nitrogen fertilizer used source was form Urea (46%N) at the recommended optimum rate of 46 kg ha^{-1}. However the amount of nitrogen found in different levels of blended NPS was deducted.

Partial budget Analysis

The economic analysis was carried out by using the methodology described in CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on ha basis in Ethiopian Birr. 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, TSP and Urea and the application costs). Cost of stalk yield was not included in the calculation in the benefit since the farmers in the area do not use it.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 x 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:-

$$\text{MRR }(\%) = \frac{\text{Change in NB (NBb}-\text{NBa)}}{\text{Change in TCV (TCVb}-\text{TCVa)}} \times 100$$

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.

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.

The fertilizer cost was calculated for the cost of each fertilizer of NPS (Birr 14.54 kg^{-1}), N/Urea (Birr 10.60 kg^{-1}) and TSP (Birr 24.5 kg^{-1}) during sowing time. The average open price of maize at Meqi market was Birr 7 kg^{-1} in October 2019 during harvesting time. The application cost of NPS and two times urea application were 300 birr ha^{-1}.

Data to be collected

Plant height (cm): Was measured as the height from the soil surface to the base of the tassel of five randomly taken plants from the net plot area at physiological maturity.

Number of rows per ear: was recorded from the count of five randomly taken ears in the central net plot area.

Ear length: was measured from 10 randomly selected Ears per plot at harvesting time.

Ear height (cm): Was measured from ground level to the node bearing the top useful ear.

Number of kernels per cob: The mean number of kernels per cob was recorded as an average of five randomly taken ears from the net plot area.

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.

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: was harvested from the three central rows excluding plants from either ends. Grain yield was adjusted at 12.5% moisture content.

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.

Data Analysis

The data was subjected to analysis of variance (ANOVA) as per the experimental design using GenStat (15thedition) software (GenStat, 2012). The Least Significance Difference (LSD) at 5% level of probability was used to determine differences between treatment means.

Result and Discussion

Ear height, Number of rows per Ear and Thousand kernels weight

The analysis of variance revealed that different rates of phosphorus critical from blended NPS and TSP fertilizers did not significantly ($p < 0.05$) influence ear height, number of rows per ear and thousand kernels weight of maize crop at study area (Table 2).

Plant Height

The analysis of variance indicated that different rates of phosphorus critical (Pc) from blended NPS and TSP fertilizers have highly significantly ($p < 0.01$) influenced plant height of maize crop (Table 2). Decreasing the amount of phosphorus critical from hundred to the lowest rates of blended NPS significantly decreased plant height. However there were no statistically significant difference between application of 100% phosphorus critical from NPS and 100% phosphorus critical from TSP fertilizers. The maximum application rate of 100% Pc (168 kg NPS ha^{-1}) resulted in the highest (2008 cm) plant height. Where as no fertilizer application has recorded the shortest plant height (184.2 cm) (Table 2). This result is parallel with Dagne (2016) who reported that application of Togo blended fertilizer NPKSBZn (26:11:11:3.5:0.15:0.6) kg ha $^{-1}$ with micro nutrient Cu+Zn (5+5 L ha^{-1}) increased plant height of maize by 66.81% over control plot and 6.11% over recommended NP fertilizers at Kejo farmers field.

Table 2. Yield & its components of maize as influenced by different rates of phosphorus critical

Treatment	EH (cm)	NRPE	PH (cm)	BM (t ha^{-1})	GY (kg ha^{-1})	HI (%)	TKW (gm)	Cob wt. (kg ha^{-1})
100%Pc TSP	14.94	12.83	2003^{ab}	20.14^{a}	5185^{bc}	25.97^{b}	31.69	50.83^{ab}
100%Pc NPS	15.14	13.64	2008^{a}	18.95^{ab}	6123^{a}	32.46^{a}	30.36	52.67^{a}
75%Pc NPS	14.36	13.08	197.8^{b}	18.10^{bc}	5951^{ab}	32.77^{a}	29.90	51.69^{ab}
50%Pc NPS	14.58	12.44	200.4^{b}	17.47^{bc}	5432^{abc}	31.01^{ab}	29.22	50.42^{a}
25%Pc NPS	14.86	12.94	188.1^{c}	16.47^{cd}	5037^{c}	30.75^{ab}	28.34	50.63^{bc}
Control	14.64	12.36	184.2^{c}	15.25^{d}	2185^{d}	14.49^{c}	30.17	51.76^{c}
LSD (0.5)	NS	NS	6.503	1.9258	874.2	5.795	NS	481.3
CV (%)	2.90	4.10	1.80	5.20	9.60	11.4	7.20	11.7

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, PH= plant height, EH=ear height, NRPE=number of row per ear, BM= biomass, t= tones; GY= grain yield, TKW = thousand kernel weight, HI= harvested index CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant.

Biomass Yield

The analysis of variance indicated that different rates of phosphorus critical (Pc) from blended NPS and TSP fertilizers had highly significant ($p < 0.01$) influence on plant biomass yield of maize crop. Biomass yield has been increasing as the rate of phosphorus critical increased from the lowest rates to the highest phosphorus critical application (100% Pc) of blended NPS. However there were no statistically significant difference between application of 100% phosphorus critical from NPS and 100% phosphorus critical from TSP fertilizers. The maximum application rate of 100% Pc from TSP fertilizer (139 kg TSP kg ha^{-1}) resulted in the highest (20.14 t ha^{-1}) biomass yield. Whereas control, no fertilizer application, recorded the lowest biomass (15.25 t ha^{-1} (Table 2). The result was also in conformity with report of Tagesa and Alemayo (2020) whom reported that biomass yield of maize increased with increasing NP fertilizer application in a consistent manner and the highest biomass yield (19.748 t ha^{-1}) was reported from application of the highest rate of (200/92 NPS/N kg ha^{-1}).

Grain Yield

The analysis of variance indicated that different rates of phosphorus critical (Pc) from blended NPS and TSP fertilizers have highly significant ($p < 0.01$) influence on grain yield of maize crop. Grain yield has been increasing as the rate of phosphorus critical increased from the lowest rates to the highest phosphorus critical application (100% Pc) of blended NPS. The maximum application rate of 100% Pc from NPS fertilizer (168 kg NPS kg ha^{-1}) resulted in the highest (6123 Kg ha^{-1}) grain yield.While no fertilizer application recorded the lowest grain yield of (2175 kg ha^{-1} (Table 2). This result is in line with Mikuannet and Kiya (2020) who reported maximum mean grain yield (9 t ha^{-1}) from plots treated with 150 kg NPS ha^{-1}.

Harvest Index

The analysis of variance indicated that different rates of phosphorus critical (Pc) from blended NPS and TSP fertilizers have highly significantly ($p < 0.01$) influenced harvest index of Maize crop. Harvest index has been relatively increasing as the rate of phosphorus critical increased from the lowest rates to the highest phosphorus critical application (100% Pc) of blended NPS. The maximum application rate of 100% Pc from NPS fertilizer (168 kg NPS kg ha^{-1}) resulted in the highest (32.46%) harvest index.While no fertilizer application has recorded the lowest harvest index of (14.49 %) (Table 2). This result is in parallel with Tagesa and Alemayo (2020) that reported maximum harvest index of (43.96 %) from plots treated with 200/92 kg NPS/N ha^{-1}. Whereas, the lowest (26.66%) harvest index was recorded from the control plot.

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 that means 100% marginal rate of return (MRR) was 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 35073 Birr ha^{-1} was obtained in the treatment that was treated with 100 % PC blended NPS while the lowest net benefit 13766 Birr ha^{-1} was obtained in the control treatment.

Table 3. Partial budget and marginal analysis for blended NPS, TSP and supplemented N rates of maize crop.

Treatment	NPS/TSP (kg ha^{-1})	Urea (kg ha^{-1})	Adjusted grain yield (less10%) (kg ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net return (Birr ha^{-1})	MRR (%)
Control	0	0	1,967	13,766	-	13,766	0
25%Pc NPS	42	100	4,533	31,733	1,895	29,838	848
50%Pc NPS	84	100	4,889	34,222	2,460	31,762	341
75%Pc NPS	126	100	5,356	37,491	2,966	34,525	546
100%Pc NPS	168	100	5,511	38,575	3,502	35,073	102
100% Pc TSP	139	100	4,667	32,666	4,341	28,324	D

Where, NPS cost = 14.54 Birr kg^{-1}, TSP cost = 24.50 birr kg $^{-1}$, UREA cost = 10.60 Birr kg^{-1}of N, Maize grain per ha = 7 Birr kg^{-1}, NPS and Urea application cost = 300 Birr ha^{-1}, MRR (%) = Marginal rate of return, D= Dominated treatment, Control = unfertilized, TSP= Triple supper phosphate, NPS= blended NPS fertilizer.

Conclusion and Recommendation

Despite the large area under maize in Ethiopia, the national average yield of maize is 80% far below the world's average yield. The low productivity of maize is attributed to many factors like declining of soil fertility, poor agronomic practice, limited use of input, frequent occurrence of drought and insufficient technologies. However, successful maize production depends on the correct application of production inputs that will sustain the environment as well as agricultural production. These inputs are adapted cultivars, plant population, soil tillage, fertilization, weed, insect and disease control, harvesting, marketing and financial resources.

Some researchers reported that, 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 and estimated that at least 30 to 50% of crop yield increment is attributable to application of commercial fertilizers. However, the usual blanket fertilizer rate application 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. Due to these Ethiopia has been moving from blanket recommendations to diversification and away from DAP and Urea to blended fertilizers such as NPS.However, the rate of this fertilizer was not determined by researchers particularly for the study area. Hence, field experiment was carried out to determine economically appropriate rate of blended NPS fertilizer for maize crop production at Dugda district, on a farmer's field during 2018/2019 cropping season.

The experiment was conducted on already determined Phosphorous critical and requirement factor and consisting of 100% Pc from TSP(Triple supper phosphate) fertilizer, 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application) and laid out in a randomized complete block design (RCBD) with three replications .Phosphorus fertilizer was applied according to the formula of ***Applied P*** = (Critical P - Po)* Pf. Whereas ***Pc= 10 ppm and Pf = 1.41-4.68(3.05) ppm.***
The analysis of variance revealed that different rates of phosphorus critical from blended NPS and TSP fertilizers did not significantly ($p <0.05$) influence ear height, number of rows per ear and thousand kernels weight of maize crop at study area. However, plant height, biomass yield, grain yield, harvest index and cob weight were highly significantly ($p <0.01$) influenced by different rates of phosphorus critical from blended NPS and TSP fertilizers. The highest (2008 cm) plant height, the highest(6123 kg ha^{-1}) grain yield, and the highest (52.67 kg ha^{-1}) cob weight were recorded by application of the highest 100% Pc (168 kg ha^{-1}) while the highest (20.14 tone ha^{-1}) biomass yield and the highest (32.77 %) harvest index were recorded by 100 pc TSP and 75% PC NPS respectively. The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of 100 Pc NPS (168 kg NPS ha^{-1}) are profitable which gave the highest (35073 Birr) net return with acceptable (102%)marginal rate of return and recommended for farmers in Dugda district and other areas with similar Agro-ecological conditions

References

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. 2016. Blended Fertilizers Effects on Maize Yield and Yield Components of Western Oromia, Ethiopia. *Agriculture, Forestry and Fisheries,* 5(5): 151-162.

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

Du Plessis, J., 2003. *Maize production* (pp. 1-38). Pretoria, South Africa: Department of Agriculture.

FAOSTAT (Food and Agriculture Organization of the United Nations), 2018. FAOSTAT (Online). Available at *http://www.fao.org/faostat*.Accessed on 10 October, 2020.

GenStat. 2012. GenStat Executable Release 15.2.Lawes Agricultural 425 Trust, Rothamstead Experimental Station, Harpenden, Clarendon 426 Press, London

Mekuannent and Kiya. 2020. Response of growth, yield and yield components of hybrid maize (Zea mays L.) varieties to newly introduce blended NPS and N fertilizer rates at Haramaya, Eastern Ethiopia. *Cogent Food & Agriculture*, (00), p.1771115.

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

Taffesse, A.S., Dorosh, P. and Gemessa, S.A., 2012. Crop production in Ethiopia: Regional patterns and trends. *Food and agriculture in Ethiopia: Progress and policy challenges*, pp.53-83.

Tagesa and Alemayo. 2020. Effect of Blended NPS Fertilizer Supplemented with Nitrogen on Yield Components and Yield of Maize (Zea mays L.) in Kachabirra District, Kembata Tambaro Zone, Southern Ethiopia: *International Journal of Research in Agricultural*

Tsedeke Abate, Bekele Shiferaw, Abebe Menkir, Dagne Wegary, Yilma Kebede, Kindie Tesfaye, Menale Kassie , Gezahegn Bogale, Berhanu Tadesse &Tolera Keno. 2015. Factors that transformed maize productivity in Ethiopia.

Determination of NPS Rates for Yield and Yield Components Based on Calibrated Phosphorus for Teff (Eragrostis tef (Zucc.) in Lume District, East Shoa Zone, Oromia, Ethiopia

Tilahun Abera[1*], Tilahun Firomsa[1], Abdurhman Husen[1], Amante Lema[1] and Chali Hundesa[1]
Batu Soil Research Center, P. O. Box 59, Batu, Oromia, Ethiopia
Corresponding author email adress: - tileabera3@gmail.com

Abstract

*Teff (Eragrostis tef (Zucc.) Trotter) is the major cereal crop in Ethiopia as well as in Oromia but its productivity is hampered by low and declining soil fertility resulting in loss of essential plant nutrients such as phosphorus. With this fact the study was conducted on the effect of blended NPS fertilizer rates on yield and yield components of teff in Lume District of East Shewa Zone, Oromia, during the main cropping seasons of 2018-1920. The aim of the study was to assess the effect of rates of blended NPS on yield and yield components of Teff variety (Boset) as well as to determine economically appropriate rate of blended NPS fertilizer for maize crop production for farmers of Lume district. The treatments were arranged based on already determined Phosphorous critical and phosphorus requirement factor and consisting of 100% Pc from DAP fertilizer, 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application). **Applied P**= (Critical P - Po)* Pf. Whereas Pc= 13 ppm and Pf = 3.65 ppm. The experiment plots were laid out in randomized complete block design (RCBD) with three replications. The analysis of variance showed that different rates of phosphorus critical from blended NPS and TSP fertilizers have shown highly significance at $p < 0.01$ on plant height, biomass yield and grain yield. However, harvest index had shown no significance ($p < 0.05$) influence due to application of different rates of phosphorus critical from blended NPS and TSP fertilizers. The highest (90.43 cm) plant height, the highest (2800 kg ha^{-1}) grain yield, and the highest (12.17 ton ha^{-1}) biomass yield were recorded by application of the highest 100% Pc (137 kg ha^{-1}). The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of 100% Phosphorus critical from NPS fertilizer (168 kg NPS ha^{-1}) is profitable which gave the highest (47048 Birr) net return with the highest acceptable (938%) marginal rate of return and recommended for farmers in Lume district and other areas with similar Agro-ecological conditions*

Key words: *- Applied phosphorus, blended NPS, teff, phosphorous critical (Pc) phosphorus requirement factor (Pf) 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 ("*Injera*") a big flat bread or pan cake, 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 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 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: to assess the effect of rates of blended NPS and supplemental N fertilizer on growth, yield components and yield of teff; to determine economically appropriate rate of blended NPS fertilizer for teff crop production

Materials and Methods

Description of the Experimental Site

The experiment was conducted on farmer's field in Lume District, East Shewa Zone of Oromia Regional State in Central Ethiopia. Mojo is the capital town of Lume district located at 73 kilometers from Finfine (Addis Ababa) to the East. Geographically Lume district is located between 80 27'00" to 80 49'00" North and 390 5'00" to 390 16'00" East with total area coverage 67514.73hectares. The elevation ranges from 1590 to 2512 meters above sea level, whereas the average elevation is 1909 meters above sea level.

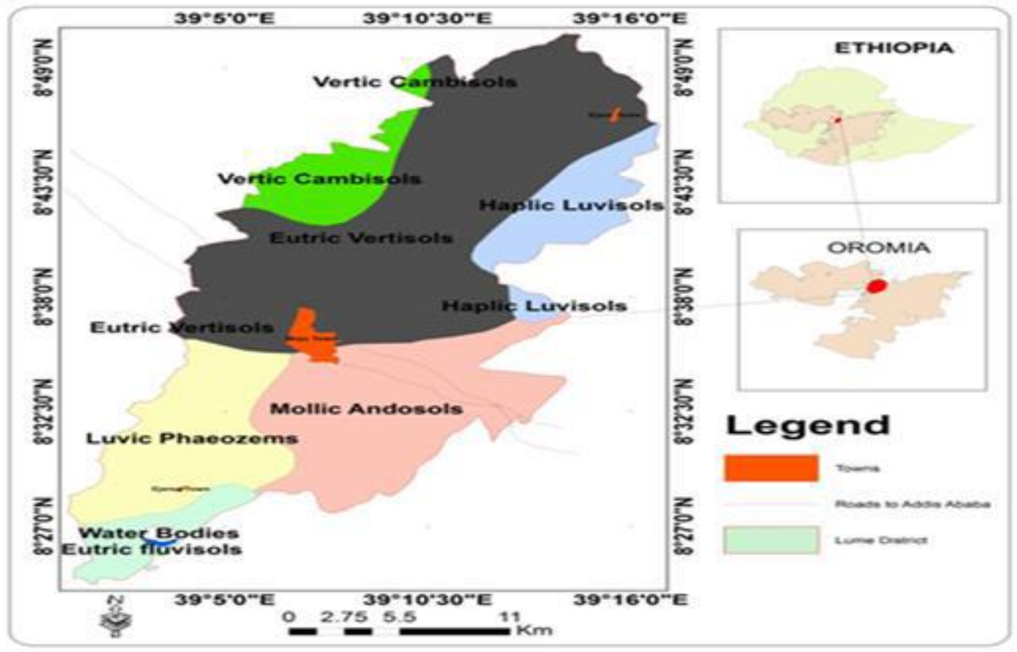


Figure 1. Location Map of Lume District

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)

Treatments and Experimental Design

The treatments were arranged based on already determined Phosphorous critical and requirement factor and consisting of 100% Pc from DAP fertilizer, 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application). ***Applied Phosphorus***= (Critical P - Po)* Pf. Whereas ***Pc= 13 ppm and Pf = 3.65 ppm*** (Kefyalew *et al*., 2017). The experiment was laid out in randomized complete block design (RCBD) with three replications.The gross plot sizes were 3 m x 4 m (12 m^2) and harvested from (4 m^2).Nitrogen fertilizer in the form of Urea (46%N) was used according to the recommended optimum rate of 46 kg N ha^{-1} (Kefyalew *et al*., 2017).

Management of the Experiment

The experimental fields were prepared following the conventional tillage practice which includes four times plowing before sowing of the crop. As per the specification of the design, field layouts were prepared; the land were leveled and made suitable for crop establishment. Sowing was done in mid July 2018/ 2019 using seed rate of 30 kg ha^{-1}. Full dose of NPS and TSP as per the treatment and one-third of N alone were applied at sowing time. The remaining two-third of N alone was top dressed at the mid-tillering crop stage. While conducting the experiment all others necessary agronomic management practices were carried out uniformly for all treatments.

Data Collection and Measurement

Yield Components and Yield

Plant height (cm) Plant height was measured from the soil surface to the tip of panicle from 10 randomly tagged plants from the net plot area at physiological maturity

Aboveground dry biomass yield:The aboveground 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: Thegrain 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.

Result and discussion

Plant Height

The analysis of variance indicated that different rates of phosphorus critical (Pc) from blended NPS and TSP fertilizers have highly significantly ($p < 0.01$) influenced plant height of Teff crop (Table 2).Decreasing the amount of phosphorus critical from hundred to the lowest rates of blended NPS significantly decreased plant height. However there were no statistically significant difference between application of 100% phosphorus critical from NPS and 100% phosphorus critical from TSP fertilizers. The maximum application rate of 100% Pc/137 kg NPS ha^{-1}) resulted in the highest (90.43 cm) plant height.While no fertilizer application has recorded the shortest plant height (66.20 cm). However there were significant variation between the highest (100% Pc NPS), (100% Pc TSP) and 75% Pc. This implies that the plant might be achieved its optimum application at the second highest (75% Pc/ 103 kg NPS ha^{-1}rate of fertilizer application. The result is in agreement with the finding of (Yared *et al*., 2020) who recorded the highest (105.72 cm) plant height by combined application of (150/69 kg ha^{-1}) of blended NPS and nitrogen fertilization, respectively. While the lowest plant height

(77.95 cm) was recorded by the control plot. The result is also in parallel with Tashome *et al*., 2019 who reported the highest (126.33 cm) plant height by combined application of 100/138 kg ha^{-1} blended NPSZnB and nitrogen fertilizers, respectively.

Table 1. Plant height, biomass yield and grain yield of teff as influenced by different rates of blended NPS and TSP fertilizers.

Treatments	PH(cm)	BM (ton ha^{-1})	GY (kg ha^{-1})	HI %
100%PC TSP	85.80^{ab}	10.04^{b}	2455^{ab}	24.48
100%PC NPS	90.43^{a}	12.17^{a}	2800^{a}	23.01
75%PC NPS	85.96^{ab}	10.49^{b}	2513^{ab}	23.74
50%PC NPS	81.93^{bc}	10.12^{b}	2490^{ab}	24.81
25%PC NPS	75.63^{c}	10.01^{b}	2242^{b}	22.41
Control	66.20^{d}	6.29^{c}	1387^{c}	22.02
LSD (0.05)	8.28	899.30	370.80	NS
CV (%)	4.00	3.60	6.20	3.14

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, PH= plant height, BM= biomass, GY= grain yield, HI= harvested index, CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant, TSP= Triple super phosphate.

Biomass Yield

The analysis of variance indicated that different rates of phosphorus critical (Pc) from blended NPS and TSP fertilizers had highly significant ($p < 0.01$) influence on plant biomass yield of Teff crop. Biomass Yield has been increasing as the rate of phosphorus critical increased from the lowest rates to the highest phosphorus critical application (100% Pc) of blended NPS. The maximum application rate of 100% Pc from NPS fertilizer (137 kg NPS ha^{-1}) resulted in the highest (12.17 tone ha^{-1}) biomass yield.While no fertilizer application has recorded the lowest biomass yield (6.29 tone ha^{-1}) (Table 2). 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}). Moreover, the result is concurrent with the finding of (Yared*et al*., 2020) who recorded the highest 10.038 tone ha^{-1}) biomass yield by application of the highest (150 kg ha^{-1}) of blended NPS fertilization. While the lowest biomass yields (5.222 ton ha^{-1}) was recorded by the control plot.

Grain Yield

The analysis of variance indicated that different rates of phosphorus critical (Pc) from blended NPS and TSP fertilizers have highly significantly ($p < 0.01$) influenced grain yield of Teff crop. Grain Yield has been increasing as the rate of phosphorus critical increased from the lowest rates to the highest phosphorus critical application (100% Pc) of blended NPS. However there were no statistically significant difference between the highest (100 % Pc NPS/TSP) application from the preceding rates of 75 % Pc and 50% Pc of NPS rates. The maximum application rate of 100% Pc from NPS fertilizer (137 kg NPS kg ha^{-1}) resulted in the highest (2800 kg ha^{-1}) grain yield. While no fertilizer application has recorded the lowest grain yield of (1387 kg ha^{-1} (Table 2). The highest (100 % Pc/137) application of NPS enhanced Teff grain yield by 14% and 101% over the highest (100% Pc/113 kg ha^{-1}) application of Triple supper phosphate fertilizer and control plot respectively.

The result is in parallel with the finding of (Kinfe *et al*., 2019) who reported that application of blended NPS fertilizer significantly influenced teff grain yield and recorded the highest (2269.80 kg ha^{-1}) grain yield by application of 150 kg NPS ha^{-1}. The result is also 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.

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 that means 100% marginal rate of return (MRR) was 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 47048 Birr ha^{-1} was obtained in the treatment that was treated with (100% PC/ 137 kg ha^{-1}) blended NPS while the lowest net benefit 24966 Birr ha^{-1} was obtained in the control treatment.

Table 3. Partial budget and marginal analysis for blended NPS, TSP and supplemented N rates of Teff crop.

Treatment	fertilizers (kg ha^{-1})	Urea (kg ha^{-1})	Adjusted grain yield down wards by 10% (kg ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net return (Birr ha^{-1})	MRR %
Control	0	0	1,248	24,966	-	24,966	0
25%Pc NPS	34	100	2,018	40,356	1,858	38,498	728
50%Pc NPS	68	100	2,241	44,820	2,356	42,464	796
75%Pc NPS	103	100	2,262	45,234	2,854	42,380	D
100%Pc NPS	137	100	2,520	50,400	3,352	47,048	938
100% Pc TSP	113	100	2,210	44,190	4,132	40,058	D

Where, NPS cost = 14.54 Birr kg^{-1}, TSP cost = 24.50 birr kg $^{-1}$, UREA cost = 10.60 Birr kg^{-1}of N, Teff grain per ha = 20 Birr kg^{-1}, NPS and Urea application cost = 200 Birr ha^{-1}, MRR (%) = Marginal rate of return, D= Dominated treatment, Control = unfertilized, TSP= Triple supper phosphate, NPS= blended NPS fertilizer.

Conclusion and Recommendation

Teff (*Eragrostis tef*) is an ancient tropical cereal that has its center of origin and diversity in the northern Ethiopian highlands and used for centuries as the principal population meal called Injera. It contains higher amount of iron, calcium, phosphorus, copper, and thiamine as compared to other cereal grains. Teff proteins have no gluten in nature, free of gliadin, and could be suitable for use in the diet of patients suffering with celiac disease. However, with these types of importance its productivity is very low and might be due to declining in loss of essential plant nutrients such as phosphorus from soil. Moreover, in Ethiopia including the study area inorganic fertilizers have been supplementing for crops only from DAP and urea in the form of blanket recommendation. That means without considering agro-ecology, environmental effects, spatial and temporal soil fertility variations which is economically inefficient by increasing production costs and environmental hazards. So soil test based crop response and site specific P fertilizer application with new blended NPS fertilizer have been considering as essential to improve the trend and increase teff crop yield. Therefore, the treatments were arranged based on already determined Phosphorous critical and phosphorus requirement factor and consisting of 100% Pc from DAP fertilizer, 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application). Applied P = (Critical P - Po)* Pf. Whereas Pc = 13 ppm and Pf = 3.65 ppm. The experiment plots were laid out in randomized complete block design (RCBD) with three replications. The analysis of variance showed that except harvest index different rates of phosphorus critical from blended NPS and TSP fertilizers have highly significantly ($p < 0.01$) plant height, biomass yield and grain yield. The highest (90.43 cm) plant height, the highest (2800 kg ha^{-1}) grain yield, and the highest (12.17 kg ha^{-1}) biomass yield were recorded by application of the highest 100% Pc (137 kg 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 100% Phosphorus critical from NPS fertilizer (168 kg NPS ha^{-1}) is profitable which gave the highest (47048 Birr) net return with the highest acceptable (938%) marginal rate of return and recommended for farmers in Lume district and other areas with similar Agro-ecological conditions.

References

Costanza, S.H., Dewet, J.M.J. and Harlan, J., 1979. Literature review and numerical taxonomy ofEragrostistef (T'ef). *Economic Botany, 33*(4):413-424.

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 (EragrostisTef). *Memorias, red-alfalagrotech, comunidadeuropea, 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

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, 3(6), ISSN (Online): 2394-1375.

Kinfe Tekulu, Tsadik Tadele, Tewolde Berhe, Weldegebreal Gebrehiwot, Gebresemaeti Kahsu, Solomon Mebrahtom, Goitom Aregawi and Gidena Tasew. 2019. Effect of vermicompost and blended fertilizers rates on yield and yield components of Tef (Eragrostistef (Zucc.) Trotter).*Journal of Soil Science and Enviromental Management.* 10(6):130-141.

Mohammed MIO, Mustafa AI, Osman GAM. 2009. Evaluation of wheat breads supplemented with Teff (Eragrostistef (ZUCC.) Trotter) grain flour. Aust J Crop Sci.; 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):101-103.

Spaenij-Dekking L, Kooy-Winkelaar Y. and Koning F. 2005.The Ethiopian Cereal Teff in Celiac Disease. N Engl J Med.; 353(16):1748-1749.

TeshomeMesfin, Wassie Haile, and SofiyaKassa. 2019. Effects of Nitrogen and Blended Fertilizers on Yield and Yield Components of tef (Eragrostistef (Zucc.) Trotter in Central Highlands of Ethiopia.*International Journal of Advances in Agricultural Science and Technology*. 6 (8): 15-64.

WakjiraTesfahun. 2018. Tef Yield Response to NPS Fertilizer and Methods of Sowing in East Shewa, Ethiopia. *Journal of Agricultural Sciences–Sri Lanka, 13*(2):162-173.

YaredTesfaye, YibekalAlemayehu 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,* 12(02):10168-10180.

Determination of NPS fertilizer rates on growth, yield and yield components of maize (Zea mays L.) in Shashemene District, West Arsi Zone, Oromia

Amante Lemma[1*], Tilahun Abera[1], Abdurhman Husen[1] and Tilahun Firomsa[1]
Batu Soil Research Center, P.O.Box: 59, Batu, Ethiopia
Corresponding author: amentegashu@gmail.com

Abstract

Depilation of soil fertility from year to year due to natural and human made factors is a serious constraint for crop production in Ethiopia. Therefore, the application of actual balanced recommended fertilizer rates based on soil and crop type is one of the best agronomic practices to maximize production. A field experiment was conducted for two consecutive cropping seasons to evaluate the effect of newly introduced NPS fertilizer rates on growth, yield and yield components of maize. The six treatments used for the field experiment were control (without fertilizer), 25 % pc, 50% pc, 75 % pc, 100% pc from NPS and 100% pc from TSP. The treatments were laid out in RCBD design with three replications. The results of the study revealed that application of 100 % Pc from NPS fertilizer with 46 kg urea ha^{-1} gave a maximum mean of above ground biomass yield (35.32 ton/ha) and plant height (251.1 cm). The highest mean grain yield (8766 kg ha^{-1}) was obtained by application rate of 75 % Pc from NPS with 46 kg urea ha^{-1} and the lowest mean grain yield was obtained from control(without application of fertilizer). According to partial budget analysis, the highest net benefit (60,156 ETB) with marginal rate of return (649 %) was obtained from the application of 75 % Pc from NPS fertilizer with recommended 46 kg urea ha. Therefore, this treatment produced maximum grain yields, together with the best economic benefit and could be recommended for the farmers in the study area to maximize maize production.

Keywords: *Blended fertilizer, control, grain yield, biomass, net benefit, marginal rate of return.*

Introduction

Maize (Zea mays L.) is an important crop in many parts of the developing world. It occupies the third place after wheat and rice (Food and Agriculture Organization of the United Nations (FAO, 2016). Supplying nutritious, safe, and affordable food to a growing population is one of the far most burning issues currently facing Africa to fulfill food security in the region (AGRA, Africa Agriculture Status Report, 2013). However, there are a number of factors which are responsible for the low production and productivity of maize. Among these factors, inappropriate crop nutrition management and poor soil fertility are the most important factors responsible for low yield of maize. One of the major problems constraining the development of an economically successful agriculture is nutrient deficiency (Mekuannet and Kiya, 2020).

Maize is the most important staple food crop in terms of calorie intake in rural Ethiopia (Berhane *et al*. 2011). In Ethiopia, maize grows from moisture stress areas to high rainfall areas and from lowlands to the highlands (Kebede *et al*., 1993). According to CSA (2016/17) among cereals, maize is the first and second crop in terms of area coverage and production followed by and next to teff with area coverage of 2,111,518.23ha and production of 71,508,354.11quintals. Therefore, considering its importance in terms of wide adaptation, total production and productivity, maize is one of the high priority crops to feed the increasing population of the country.

In many parts of Africa including Ethiopia, repeated cultivation of land with inappropriate farming methods is causing severe depletion of nutrients and soil organic matter, posing a serious threat to agricultural productivity and sustainability. Declining soil fertility from time to time due to natural and human made factors are serious bottle necks for crop production in Ethiopia. Besides, lack of appropriate fertilizer blends and lack of micronutrients in fertilizer blends are the national problem which is major constraints to crop productivity (Mekuannet and Kiya, 2020). Nutrient deficiencies are the most important problems influencing maize production in the mid and low altitude sub-humid agro-ecologies of Ethiopia due to limited use of commercial inputs and lack of soil fertility enriching rotations or fallows (Ransom *et al*., 1993).

Reduction of soil fertility from year to year due to natural and human made factors is a serious constraint for crop production in Ethiopia. An overview of Ethiopia's fertilizer sub-sector shows that fertilizer was introduced in the1960s by higher learning institutions through limited laboratory and research activities (Murphy, 1968). In the early 1970s nationwide on-farm demonstrations trials were conducted and as a result of these works a blanket rate of 100 kg ha^{-1} DAP or 50 kg ha^{-1} Urea + 100 kg DAP ha^{-1} were recommended irrespective of crop and soil types (NFIU,1993). However, according to the soil fertility map made over 150 districts, most of the Ethiopian soils lack many nutrients N, P, K, S, Ca, Ma, Cu, Zn and B (EthioSIS, 2013).

Application of essential plant nutrients in optimum quantity and right proportion, through correct method and time of application, is the key to increased and sustained crop production. Therefore, application of actual balanced recommended fertilizer rates based on soil and crop type is one of the best agronomic practices to maximize production (Mekuannet and Kiya, 2020). Even though new blended fertilizers such as NPS (19% N, 38% P_2O_5 and 7% S) are currently being used by the farmers in Ethiopia however its effect on yield components and yield of maize are unknown. Therefore, this research activity was designed with the following objectives.

Objectives

- To assess the effect of NPS fertilizer rates on growth, yield and yield components of maize production in the study district
- To determine economically appropriate NPS fertilizer rate for maize crop production

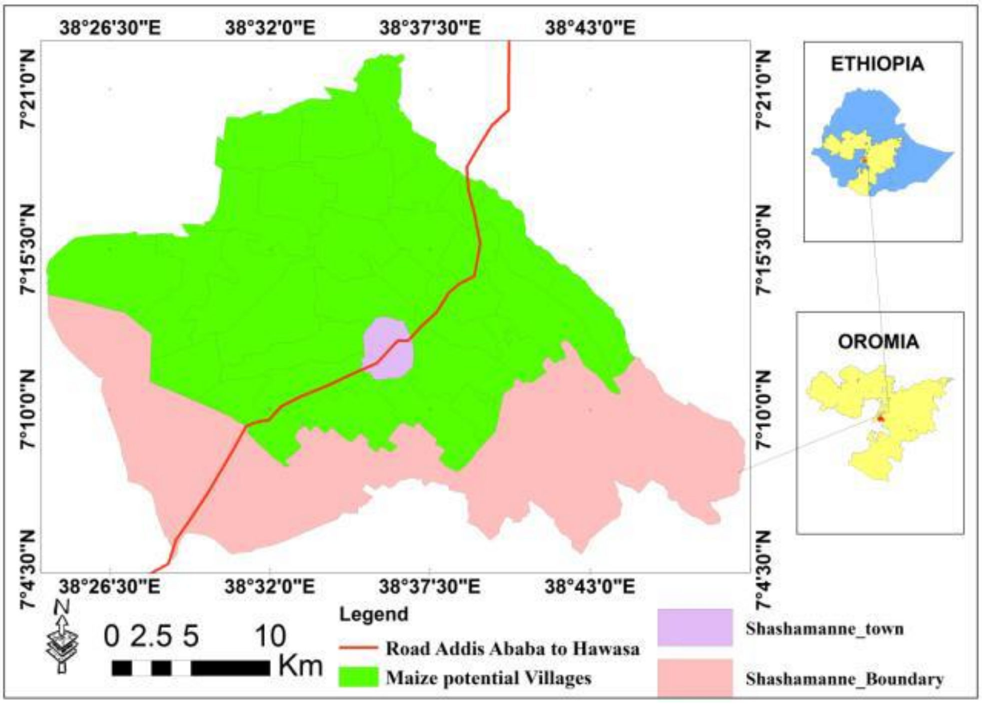
Materials and Methods

Description of the study area

An experiment was executed under rain fed conditions for two consecutive seasons (2017/18 and 2018/19) under main cropping season on farmers' field in Shashamane District, West Arsi Zone of Oromia, Ethiopia. Shashamane District is located at 70^{o}04'50" to 70^{o}22'45" N latitude and 380^{o}23'00" to 380^{o}48'00" E longitude with about150 miles above sea level and 240 km far from Addis Ababa.

Experimental materials

Planting material: Maize variety BH-660, NPS fertilizer (19%N: 38%P_2O_5: 7%S), TSP and urea (46% N) were used for the study purpose.



Figur 1. Location map of Shashamane District

Soil sampling and analysis

Before sowing, soil samples were taken randomly to a depth of 0-20cm in a zigzag pattern to make one composite soil sample of the experimental field. The collected composite soil sample was air dried, grounded, and sieved using 2mm sieve except for total nitrogen and organic matter. Small quantity of this 2 mm sieved soil material allowed passing through 0.2 mm sieve for soil organic carbon (OC) and total nitrogen. Then the composite soil sample was analyzed for its soil texture, soil pH, organic carbon, total nitrogen, available phosphorus, and cation exchange capacity (CEC) using standard laboratory procedures at Batu Soil Research Center.

Organic carbon was determined by Walkley and Black oxidation method (Walkley and Black, 1934). Total nitrogen was analyzed by Micro-Kjeldhal digestion method with sulphuric acid (Jackson, 1962). Cation exchangeable capacity (CEC) was determined by leaching the soil with neutral 1N ammonium acetate (FAO, 2008). Available phosphorus was determined by the Olsen's method using a spectrophotometer (Olsen *et al.*, 1954). Soil pH was measured in water at soil to water ratio of 1:2.5 (Van Reeuwijk, 1992). Soil texture was analyzed by Bouyoucous hydrometer method (Bouyoucous, 1951) and Available S was determined using turbid metric method (Chesnin and Yien, 1951).

Treatments and experimental design

The treatments were based on already determined phosphorous critical and requirement factor and consisting of 100% Pc from TPS fertilizer, 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application). $Applied\ P = (Critical\ P - P_o) * Pf$. *Whereas* $Pc = 35$ *ppm and* $Pf = 1.14$ *ppm* (Tilahun *et al.*, 2015). The experiment was laid out in randomized complete block design (RCBD) with three replications. Inter and intra row spacing was 0.75 x 0.3 m respectively. The gross plot size was 6 x 3 m (18 m^2) accommodating 8 rows and 10 plants per row. The spacing between blocks and plots was 1.0 and 0.5 m, respectively. Nitrogen fertilizer in the form of urea (46 % urea) was used according to the recommended optimum rate of 46 kg N ha^{-1} (Kefyalew *et al.*, 2016). However the amount of nitrogen found in NPS fertilizer was subtracted.

Management of the experiment

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 during the main cropping season (May). All the required amount of blended NPS fertilizer as per the treatment and half of urea alone were applied at sowing time. Full dose of NPS and the remaining half of urea alone were 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 Measurements

Plant height (m): it was determined by measuring the height of 10 randomly sampled plants from ground level to the base of the tassel at physiological maturity.

Ear height (cm): it was recorded from 10 randomly taken plants by measuring the height of the stem from ground level to the point of attachment of upper most ears at physiological maturity.

Number of rows per ear: about 10 ears were taken randomly from the net plot area, and then their rows were counted at harvest and the average was recorded.

Thousand kernels weight (g): about 1,000 kernels were randomly taken and counted from the bulk of threshed kernels in each net plot area, and then weighed using sensitive balance.

Above-ground dry biomass yield (t ha^{-1}): plants were harvested from the net plot area, weighed using field balance and recorded biomass yield at harvest.

Grain yield (t ha^{-1}): grain yield from the net plot area was weighed and finally, it was converted into hectare basis.

Harvest index: it was calculated as the ratio of grain yield to the total above-ground dry biomass yield per plot × 100.

Statistical Data Analysis

Growth parameters, yield components, and yield of maize data were analyzed by using Gen Stat, 2012 (15th edition) statistical software. For significant treatment effects, mean separation was done using the least significance difference (LSD) test at 5% level of significance.

Partial Budget Analysis

The partial budget analysis were carried out by using the methodology described in Centro Internacional de Mejoramiento de Maiz y Trigo/International Maize and Wheat Improvement Center (CIMMYT) (1988) in which prevailing market prices for inputs at sowing and outputs at harvesting were used.

Result and Discussion

Plant Height (cm)

The mean of plant height and the analysis of variance were showed in Table 1. The mean of plant height of maize was significantly different ($p \leq 0.001$) among treatments. However, the mean values of plant height for application of 100 % Pc, 75 % Pc and 50 % Pc from NPS ha^{-1} of NPS fertilizer rates, was not significant statistically. Application of 100 % Pc, 75 % Pc and 50 % Pc from NPS ha^{-1} NPS fertilizer increased the plant height as compared to the application of 100 % Pc from TSP ha^{-1}, 25% Pc from NPS ha^{-1} and control. Similarly, application of 100 % Pc from TSP ha^{-1} and 25% Pc from NPS ha^{-1} fertilizers also significantly increased plant height as compared to the control. Ingeneral, application of 100 % Pc, 75 % Pc and 50 % Pc from NPS ha^{-1} NPS fertilizer increases the mean values of plant height linearly, but statistically did not bring about a significant difference in plant height. Similar result was reported by Mekuannet and Kiya, (2020) that plant height of maize increased with fertilizer.

Table 1. Main Effect of NPS on Yield and Yield Component of Maize in Shashemenne District

Treatments	NPS/TSP (kg/ha)	PH (cm)	EH (cm)	NRPE	BM (ton/ha)	GY (kg/ha)	HKW (gm)	HI (%)
Control	0	213.7^{c}	17.48^{d}	11.19^{c}	21.49^{c}	2932^{e}	30.49^{d}	18.53^{c}
25% Pc (NPS)	37	234.7^{b}	18.19^{c}	12.33^{b}	24.55^{c}	6712^{d}	30.92^{d}	27.39^{a}
50% Pc (NPS)	73	246.9^{a}	20.45^{a}	13.55^{a}	31.35^{b}	8206^{ab}	33.75^{ab}	26.41^{a}
75% Pc (NPS)	110	248.9^{a}	19.85^{b}	13.56^{a}	30.51^{b}	8766^{a}	34.46^{a}	28.73^{a}
100% Pc (NPS)	146	251.1^{a}	19.47^{b}	13.51^{a}	35.32^{a}	7849^{bc}	33.69^{b}	22.24^{b}
100%Pc (TSP)	121	226.2^{b}	18.21^{c}	13.43^{a}	28.35^{b}	7454^{c}	31.54^{c}	26.30^{a}
LSD (0.05)	-	9.45	0.4644	0.5	3.147	592.039	0.73	3.540
CV (%)	-	2.2	1.3	2.2	6.1	4.7	1.2	7.8

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, PH= plant height, EH=ear height, NRPE=number of row per ear, BM= biomass, GY= grain yield, TKW = thousand kernel weight, HI= harvested index, CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant, Pc = phosphorus critical, Pf = phosphorous requirement factor, Po = initial soil phosphorus.

On the other hand the least plant height in unfertilized plots might have been due to low soil fertility level in the study area. In conformity with the results obtained from this study, plant growth and development may be retarded significantly if any of nutrient elements is less than its threshold value in the soil or not adequately balanced with other nutrient elements (Landon, 1991). Thus, the results indicate that blended fertilizers application has enhanced the maize vegetative growth.

Ear Height and Number of Rows per Ear

The mean values and analysis of variance of treatments of ear height and number of rows per ear revealed significant difference ($p \leq 0.05$) among the treatments (Table 1). The maximum ear height was recorded from application of 50% Pc from NPS ha^{-1} fertilizer and followed by applications of 75 % Pc and 100 % Pc from NPS ha^{-1} respectively. Similarly, application of 100 % Pc from TSP ha^{-1} and 25 % Pc from NPS ha^{-1} increased ear height over the control. The ear length increment with the blended fertilizer application might be attributed to good photo assimilate supply. The maximum assimilate supply should be available during maize grain filling. The highest mean number of rows per ear recorded for application of 100 % Pc from TSP, 100 % Pc, 75 % Pc and 50 % Pc from NPS ha^{-1}, and the lowest number of rows per ear was recorded for control and followed by application of 25% Pc from of NPS ha^{-1}.

Above Ground Biomass Yield (ton/ha)

Based on the mean values and analysis of variances, above ground biomass yield was significantly influenced among the treatments. But, above ground biomass yield was not affected significantly by application of 100 % Pc from TSP, 75 % Pc and 50 % Pc from NPS fertilizer ha^{-1}. Higher above ground biomass yield (35.32 t ha^{-1}) was obtained by applying 100% Pc from NPS while lowest above ground biomass yield (24.55 t ha^{-1} and 21.49 t ha^{-1}) was obtained by applying 25% Pc from NPS ha^{-1} and control respectively. This result is in agreement with Mekuannet and Kiya, (2020).

Gain Yield (kg ha^{-1})

According to the mean values and analyses of variances showed in table 1, the grain yield was significantly influenced by application of different rate of NPS blended fertilizer. Therefore, the highest grain yield (8766 kg ha^{-1}) was obtained by applying 75% Pc from NPS ha^{-1} with recommended urea (46 kg ha^{-1}) and followed by application of 50% Pc from NPS (8206 kg ha^{-1}). While the lowest grains yield (2932 kg ha^{-1}) was recorded for control control (without fertilizers). The low yield in unfertilized plots might have been due to reduced leaf area development resulting in lesser radiation interception and, consequently, low efficiency in the conversion of solar radiation (Dagne, 2016). This result was in line with Onasanya *et al*., 2009 and Mekuannet and Kiya, 2020) who found that grain yield was affected by interaction of phosphorus with urea and application of different rates of blended NPS and urea fertilizer.

Hundreds Kernels Weight (gm)

The results of analysis of variance (table 1) showed that there were significant differences ($P \leq 0.05$) among treatments for hundreds kernel weight of maize. The highest hundreds kernel weight was recorded for the application of 75% Pc from NPS ha^{-1} with recommended urea (46 kg ha^{-1}), whereas the lowest hundreds kernel weight (30.49 gm and 30.92 gm) was observed for application of the control and 25% Pc from NPS ha^{-1} respectively.

Harvest Index (%)

Analysis of variance showed that harvest index was significantly influenced ($P \leq 0.05$) between the treatments (table 4). The highest HI (28.73%) was obtained by application of 75% Pc from NPS ha^{-1}, followed by application of 25% Pc from NPS (27.39 %) and 50% Pc from NPS ha^{-1}, while the least HI (18.53%) was obtained from control.

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, between 50 and 100% marginal rate of return (MRR) was the minimum acceptable rate of return (CIMMYT, 1988). All costs and benefits were calculated on hectare basis in Birr and the concepts used in the partial budget analysis were the mean grain yield of each treatment, the field price of maize grain, and the gross field benefit ha^{-1} (the product of field price and the mean yield for each treatment). As indicated in table 2, the partial budget and dominance analysis showed that the highest net benefit 60,156 Birr ha^{-1} was obtained in the treatment that was treated with 75% Pc from NPS ha^{-1} and recommended urea (46 kg urea ha^{-1}) while the lowest net benefit 21,355 Birr ha^{-1} was obtained in the control treatment.

Table 2. Partial Budget and Marginal Analysis

Treatment	NPS/TSP (kg ha^{-1})	Urea (kg ha^{-1})	Adjusted grain yield down wards by 10% (kg ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost(Birr ha^{-1})	Net benefit (Birr ha^{-1})	MRR (%)
Control	0	0	2,669	21,355	-	21,355	0
25%Pc NPS	37	100	6,041	48,326	1,892	46,428	1321
50%Pc NPS	73	100	7,385	59,083	2,423	56,662	1955
75%Pc NPS	110	100	7,889	63,115	2,955	60,156	649
100%Pc NPS	146	100	7,064	56,513	3,487	53,030	D
100% Pc TSP	121	100	6,709	53,669	4,321	49,344	D

Where, NPS cost = 14.54 Birr kg^{-1}, TSP cost = 24.50 birr kg $^{-1}$, UREA cost = 10.60 Birr $kg^{-1}$of N, Maize grain per ha = 8 Birr kg^{-1}, NPS and Urea application cost = 300 Birr ha^{-1}, MRR (%) = Marginal rate of return, D= Dominated treatment, Control = unfertilized, TSP= Triple supper phosphate, NPS= blended NPS fertilizer.

Conclusion

The current study was initiated with the objectives to assess the effect of blended NPS fertilizer rates on growth, yield and yield components of maize production and to determine economically appropriate NPS fertilizer rate for maize crop production in Shashamane District. The results of the study revealed that most of the parameters were significantly affected by application rates of NPS fertilizer. Analysis of variance showed that there was a significance difference between the treatments in above ground biomass yield, grain yield, ear height and HKW. Application of 100% Pc from NPS fertilizer with recommended urea (46 kg ha^{-1}) gave a maximum mean of above ground biomass yield (35.32 ton/ha) and plant height (251.1 cm). The highest mean grain yield (8766 kg ha^{-1}) was obtained by application rate of 75% Pc from NPS with recommended urea (46 kg ha^{-1}) and the lowest mean grain yield was obtained from control (without application of fertilizer). According to partial budget analysis, the highest net benefit (60,156 ETB) with marginal rate of return (649 %) was obtained from the application of 75% Pc from NPS fertilizer with recommended urea (46 kg ha^{-1}). Therefore, this treatment produced a maximum grain yield, together with the best economic benefit and recommended for the farmers in the study area instead of using blanket recommendation.

Acknowledgements

The author would like to acknowledge Oromia Agricultural Research Institute for financial support; Batu Soil Research Center for providing research facilities like supply of inputs and logistic. I would also like to express my sincere thanks to Soil Fertility Improvement Team members of the Center for participation in conducting this assessment. Last not least, I am thankful for Agriculture and Natural Resource Bureau, and the farmers of Shashamane district who allowing me to use their land for this study.

References

Mekuannet Belay & Kiya Adare,(2020). Response of growth, yield components, and yield of hybrid maize (*Zea mays* L.) varieties to newly introduced blended NPS and N fertilizer rates at Haramaya, Eastern Ethiopia, Cogent Food & Agriculture, 6: 1771115, Online Journal homepage: https://www.tandfonline.com/loi/oafa20.

FAO (Food and Agriculture Organization of the United Nations). (2016). Food and agriculture data, Italy, Rome. Online. FAO. Retrieved October 14, 2019, from http://www.fao.org/faostat/en/#data/QC/visualize. AGRA, Africa Agriculture Status Report. (2013). Focus on Staple Crops. Nairobi, Kenya.

Channabasamma, A., Habsur, N.S., Bangaremma, S.W. and Akshaya, M.C., 2013. Effect of nitrogen and sulphur levels and ratios on growth and yield of maize. *Molecular Plant*

Dagne Chimdessa.2016. Blended Fertilizers Effects on Maize Yield and Yield Components of Western Oromia, Ethiopia. *Agriculture, Forestry and Fisheries,* 5(5): 151-162. *Breeding*, 4(37):292-296.

Doswell,C.R.,R.L. Pahwal and R.P. Cantrell,1996. Maize in the third world. west view press,Colorado, USA., PP268.

EARO. 2000. Research Strategy for Maize. Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia

EthioSIS (Ethiopian Soil Information System). 2013. Soil analysis report. Agricultural Transformation Agency (Unpublished)NFIU (1993). Results of NPK fertilizer trials conducted on major cereal crops (1988-1991) Addis, Ababa Ethiopia. ADD/NFIU Joint Working Paper No. 43, FOA.

Ignaciuk, A., and Mason-D'Croz, D. (2014) "Modelling Adaptation to Climate Change in Agriculture", OECD Food, Agriculture and Fisheries Papers, No. 70, OECD Publishing.

Mathews, B. W; J. P. Tritschler II and S.C. Miyasaka. 1998. Phosphorus management and sustainability. *Crop Sci.,* 39: 395-399.

Mulatu K., G. Bogale, B. Tolessa, Y. Desalegne and A. Afeta. 1992. Maize production trends and research in Ethiopia. In: B. Tolessa and J.R. Ransom (ed.). Proceedings of the First National Maize Workshop in Ethiopia. CIMMYT/IAR, Addis Ababa.

Murphy, H. F. (1968). A report on fertility status and other data on some soils of Ethiopia. Experimental Station Bulletin No. 44. Hailesilassie College of Agriculture. Oklahoma State University, 551P.

Price, C.A., 1970. *Molecular Approaches to Plant Physiology,* McGraw-Hill., N.Y.

Ransom, J.K., Short, K. and Waddington, S. 1993. Improving Productivity of Maize in Stress Environments. In: Benti T. and Ransom, J.K. (eds.). Proceedings of the First National Maize Workshop of Ethiopia, 5-7 May 1992, Addis Ababa, Ethiopia. IAR/ CIMMYT, Addis Ababa. pp. 30-33.

Tilahun T., Minale L., Alemayehu A. and and Abreham M. (2006). Maize fertilizer response at the major maize growing areas of northwest Ethiopia, Proceedings of the 1st Annual Regional Conference on Completed Crop Research Activities,14 to 17 August 2006 Amhara Regional Agricultural Research Institute Bahir Dar, Ethiopia.

Tisdale, S.L., W.L.Nelson, J.D. Beaton and J. L.Havlin. 1993. Soil Fertility and Fertilizers. 5th edn. MacMilln Company, New York. pp. 634.

Uchida, R., 2000. Essential nutrients for plant growth: nutrient functions and deficiency symptoms. *Plant Nutrient Management in Hawaii's soils*, pp.31-55.

Wassie Haile and Shiferaw Boke (2011). Response of Irish Potato (Solanum tuberosum) to the Application of Potassium at Acidic Soils of Chencha, Southern Ethiopia. International Journal of Agricultural Biology 13: 595–598.

R.O. Onasanya, O.P. Aiyelari, A. Onasanya, S. Oikeh, F.E. Nwilene and O.O. Oyelakin, (2009). Growth and Yield Response of Maize (*Zea mays* L.) to Different Rates of Nitrogen and Phosphorus Fertilizers in Southern Nigeria, *World Journal of Agricultural Sciences,* 5 (4): 400-407

Determination of NPS Rates on Yield and Yield Components of Bread Wheat at Lume District, East Shoa Zone, Oromia, Ethiopia

Tilahun Abera[1*], Tilahun Firomsa[1], Abdurhman Husen[1], Amante Lema[1], and Chali Hundesa[1]
Batu Soil Research Center, P. O. Box 59, Batu, Oromia, Ethiopia
Corresponding author: Tilahun Abera, email- 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, on-farm study was conducted in lume District of East Shewa Zone of Oromia, during the main cropping seasons of 2018-2020. The aim of the study was to assess the effect of rates of NPS fertilizer on yield and yield components of bread wheat (Qubsa) as well as to determine economically appropriate rate of NPS fertilizer for bread wheat crop production for farmers of lume district. The treatments was based on already determined Phosphorous critical and requirement factor and consisting of 100% Pc from TSP fertilizer, 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application). Applied Phosphorus = (Critical P - Po) Pf. Whereas Pc= 19 ppm and Pf = 4.72 ppm (Kefyalew et al., 2017). The experiment was laid out in randomized complete block design (RCBD) with three replications. The analysis of variance indicated that, except thousand kernels weight all tasted parameters of bread wheat were significantly ($p<0.05$) influenced by treatment applied. Plant height, and grain yield were highly significantly ($p <0.01$) influenced by 100 % Pc/263 kg ha^{-1} of NPS fertilizer but harvest index was significantly ($p < 0.05$) affected by 75% Pc/197 kg ha $^{-1}$ of NPS fertilizer. However, spike length and biomass yield were significantly ($p <0.05$) and highly significantly ($p <0.01$) influenced by 100% Pc/217 kg ha^{-1} TSP, respectively. The highest (121 cm) plant height, the highest(54.04) seed per spike, and the highest (4702 kg ha^{-1}) grain yield were recorded by 100 % Pc/263 kg ha^{-1} of blended NPS. But the highest (10.66 cm) seed per spike and the highest (10.25 tone ha^{-1}) biomass yield were recorded by application of the highest 100% Pc/217 kg ha^{-1} TSP. However the highest (40.24%) harvest index was recorded by 75% Pc/197 kg ha-1 of NPS. Moreover, from all tasted parameters the lowest values were recorded by control plots. The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of 75% P from NPS (197 kg NPS ha^{-1}) is profitable which gave the highest (35610 Birr) net return with acceptable (526%) marginal rate of return and recommended for farmers in Lume district and other areas with similar Agro-ecological conditions*

Key words: - *Applied phosphorus, bread wheat, NPS, Phosphorous critical (Pc) phosphorus requirement factor (Pf), Yield components, 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). Global demand for wheat is increasing partly on its adaptability and high yield potential but also on the gluten protein fraction which confers the viscoelastic properties that allow dough to be processed into bread, pasta, noodles, and other food products (Shewry, 2009).

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).

Global wheat production in 2018 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 5315270 tons from 1789372 ha area harvested with average yield of 2971 kg ha^{-1} (FAOSTAT, 2019). According to this report despite the large area under wheat in Ethiopia, the average yield of wheat is 19.38 % far below the world's average yield.

Soil degradation, depletion of soil essential nutrients and blanket recommendation of only DAP and Urea fertilizers are among the major factors limiting sustainable cereal production including wheat in the Ethiopian highlands. Therefore, 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 successful crop production.

According to (Kefyalew, 2010) the effect of fertilizer use on the value of agricultural production and yield is positive. However, the magnitude with which the value of production responds to a change in fertilizer use is low. Besides this the smaller marginal effects of fertilizer use might be due to problems arising from applying below recommended rates and failure to use the two nutrients in proper combination. 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 were deficient in N, P, Zn and K. Therefore, this study was undertaken with the following objectives:

- To assess the effect of NPS rates on yield components and yield of bread wheat
- To determine economically appropriate rate of NPS fertilizer for bread wheat production

Materials and Methods

Description of the Experimental Site

The experiment was conducted on a farmers' field in Lume district, East shewa Zone of Oromia Regional State in Central Ethiopia during 2018/2019 cropping season. is one of the woredas in the Oromia Region of Ethiopia. Part of the East Shewa Zone located in the Great Rift Valley, Lume is bordered on the south by the Koka Reservoir, on the west by Ada'a Chukala, on the northwest by Gimbichu, on the north by the Amhara Region, and on the east by Adama. Geographically Lume district is located at 8° 34' 59.99" N and 39° 09' 60.00" E Latitude and Longitude respectively.

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) was used

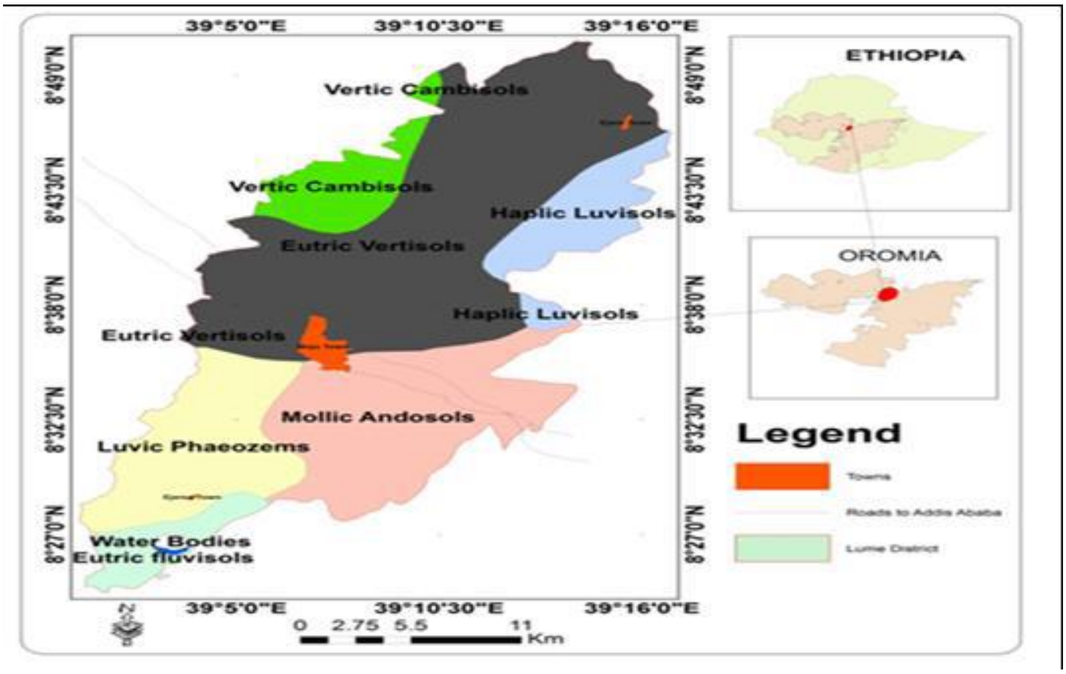


Figure 1. Location Map of Lume District

Treatments and Experimental Design

The treatments were arranged based on already determined Phosphorous critical and requirement factor and consisting of 100% Pc from TSP fertilizer, 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 = 4.92 ppm***. The experiment was laid out in randomized complete block design (RCBD) with three replications and the gross plot size was 4 m x 3 m (12 m^2) and harvested from 4m^2 areas. Nitrogen fertilizer in the form of Urea (46%N) was used according to the recommended optimum rate of 46 kg N ha^{-1} (Kefyalew *et al*., 2016). However the amount of nitrogen found in different levels of DAP and blended NPS was subtracted.

Management of the Experiment

The experimental fields were 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 mid-July of 2019 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 (Tilt) sprayed for yellow rust was 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

Yield Components and Yield

Number of kernels per spike: The mean number of kernels 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.

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.

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

Thousand kernels weight

The analysis of variance indicated that different rates of phosphorus, using phosphorus critical from NPS and TSP fertilizers did not significantly ($p < 0.05$) influence thousand kernels weight of bread wheat crop at study area (Table 2).

Plant Height

The analysis of variance indicated that different rates of phosphorus from NPS and TSP fertilizers have highly significantly ($p <0.01$) influenced plant height of bread wheat crop (Table 2). Decreasing the amount of phosphorus from hundred Pc to the lowest rates of Pc from NPS significantly decreased plant height. However the highest (100% Pc from NPS/TSP were no statistically significant difference between 75% Pc and 50% Pc of NPS application. The maximum application rate of 100% Pc (263 kg from NPS ha^{-1}) resulted in the highest (121 cm) plant height. While no fertilizer application has recorded the shortest plant height (93.1 cm) (Table 1). In agreement with this result Diriba *et al*., (2019) reported the highest (95.5 cm) plant height by application of 300 kg ha^{-1} blended NPSB and 100kg urea fertilization.

Table 1. Plant height, spike length, seed per spike, biomass yield, grain yield and Harvest index of bread wheat as influenced by variable rates Blended NPS and TSP fertilizers.

Treatments	PH (cm)	SPL (cm)	SPS	BM ton ha^{-1}	GY kg ha^{-1}	HI %	TKW (gm)
control	93.1^{c}	9.04^{b}	44.1^{b}	4.75^{c}	1594^{d}	33.63^{a}	50.83
25%PC NPS	107.1^{b}	10.03^{a}	51.28^{a}	8.62^{b}	2974^{c}	34.55^{cd}	52.67
50%PC NPS	112.6^{ab}	10.25^{a}	49.32^{ab}	10.69^{a}	3769^{bc}	35.28^{bcd}	51.69
75%PC NPS	120.4^{a}	10.31^{a}	50.47^{a}	11.00^{a}	4426^{ab}	40.24^{a}	50.42
100%PC NPS	121^{a}	10.30^{a}	54.04^{a}	11.03^{a}	4702^{a}	38.36^{abc}	50.63
100%PC TSP	117.7^{ab}	10.66^{a}	53.52^{a}	12.25^{a}	4305^{ab}	38.97^{ab}	51.76
LSD (0.5)	10.92	0.8648	5.811	1925.8	825.9	3.9	NS
CV (%)	3.80	3.30	4.50	7.70	8.9	4.10	4.15

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, PH= plant height, SPL= spike length, SPS= seed per spike, BM= biomass, GY= grain yield, HI= harvested index, CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant

Spike Length

The analysis of variance indicated that different rates of phosphorus from NPS and TSP fertilizers were significantly ($p < 0.05$) influenced spike length of Bread wheat crop (Table 2). The result showed that except the control plot, all applied fertilizers rates were not statistically significant different from each other. The maximum application rate of 100% Pc /217 kg from TSP ha^{-1} resulted in the highest (10.66 cm) spike length. While no fertilizer application has recorded the shortest spike length (9.04 cm) (Table 1). This result is consistent with (Abebaw and Hirpha, 2018) who reported the highest (8.55 cm) spike length by application of 150 kg ha^{-1} blended NPSZnB for bread wheat. This result is also in line 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 indicated that different rates of phosphorus critical (Pc) from blended NPS and TSP fertilizers have significantly ($p < 0.05$) influenced number of seed per spike of Bread wheat crop (Table 2). The result indicated that there was no constant rate of increments on the number of seed per spike, as the rate of phosphorus from NPS source increased from the lowest rate to the highest rate of fertilizer application. The maximum application rate of 100% Pc/263 kg from NPS ha^{-1}) resulted in the highest (54.04) number of seed per spike. While no fertilizer application was recorded the smallest (44.1) number of seed per spike (Table 1). This result is consistent with the finding of (Tilahun *et al*., 2021) who reported the highest (39.94) number of seed per spike by application of 200 kg NPS ha^{-1} for bread wheat. This result is also in parallel with the finding of Dinkinesh *et al*., (2020) who reported the highest (42.7) number of seed per spike by application of 183 kg ha^{-1} blended NPSB for durum wheat.

Biomass Yield

The analysis of variance indicated that different rates of phosphorus critical (Pc) from NPS and TSP fertilizers have highly significantly ($p < 0.01$) influenced plant biomass yield of bread wheat crop. Biomass Yield has been increasing as the rate of phosphorus increased from the lowest rate to the highest phosphorus application. However except control plot there were no statistically significant differences between the treatments. The maximum application rate of 100% Pc/217 kg from TSP ha^{-1}

has recorded the highest (12.25 tone ha^{-1}) biomass yield. However, except control and 25% Pc there were no statistically significant different among the treatments applied (Table 1). The result is in parallel with Dinkinesh *et al*., (2020) who reported the highest (11772 kg ha^{-1}) biomass yield by application of the highest (183 kg ha^{-1}) NPSB for durum wheat varieties. Similarly, (Eyasu *et al*., 2020) reported that application of 200 kg NPSZnB resulted the highest 16.9 tone ha-1 biomass yield of wheat.

Grain Yield

The analysis of variance indicated that different rates of phosphorus from NPS and TSP fertilizers have highly significantly ($p <0.01$) influenced grain yield of Bread wheat crop. Grain Yield has been increasing as the rate of phosphorus critical increased from the lowest rate to the highest phosphorus application (100% Pc) from NPS/TSP. The result indicated that the highest phosphorus application (100% Pc) from NPS/TSP were not statistically significant different from the preceding rate of 75% Pc from NPS/197 kg NPS ha-1 fertilizer application. The maximum application rate of 100% Pc from NPS fertilizer (263 kg NPS ha^{-1}) resulted in the highest (4702 Kg ha^{-1}) grain yield. While no fertilizer application has recorded the lowest grain yield of (1594 kg ha^{-1} (Table 1). In agreement with this result, (Tagesa *et al*., 2018) reported increased grain yield of bread wheat as NPS/N application increased from nil to the highest rate and obtained the highest grain yield of 6832 kg ha^{-1} at the highest 200/92 kg ha^{-1} rate of NPS and N supplemented. Similarly, (Tilahun and Tamado, 2018) reported the highest (5274 kg ha^{-1}) grain yield by application of the highest (200 kg ha^{-1}) NPS for durum wheat.

Harvest Index

The analysis of variance indicated that different rates of phosphorus) from blended NPS and TSP fertilizers have highly significantly ($p <0.01$) influenced harvest index of bread wheat crop. Harvest index was constantly increasing as the rate of phosphorus critical increased from the lowest rate up to 75% Pc/ 197 kg from NPS ha^{-1} of fertilizer application. This might be indicated that the plant achieved its optimum rate of fertilizer application at this level and translocate the nutrient from its vegetative part to the grain. The maximum application rate of 75% Pc from NPS fertilizer (197 kg NPS kg ha^{-1}) resulted in the highest (40.24%) harvest index. While no fertilizer application has recorded the lowest (33.63 %) harvest index (Table 1). This result is parallel with (Lemi and Negash, 2020) who reported the highest (53.64%) harvest index by application of 100/100 kg ha^{-1} blended NPSZnB/Urea fertilizers.

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 2, the partial budget and dominance analysis showed that the highest net benefit 35,610 Birr ha^{-1} was obtained in the treatment that was treated with 75%Pc/197 kg ha^{-1} from NPS and recommended 46 kg N ha^{-1} while the lowest net benefit 14,346 Birr ha^{-1} was obtained in the control treatment. In general, the economic analysis revealed that, a farmer's investment of one Birr in 197 kg NPS ha^{-1} and 46kg N ha^{-1} on bread wheat (variety Kekeba) production recoups the one Birr and gives an additional 5.26 Birr.

Table 2. Partial budget and marginal analysis for blended NPS, TSP and supplemented N rates of Teff crop.

Treatment	fertilizers (kg ha^{-1})	Urea (kg ha^{-1})	Adjusted grain yield down wards by 10% (kg ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net return (Birr ha^{-1})	MRR %
Control	0	0	1,435	14,346	-	14,346	0
25%Pc NPS	66	100	2,677	26,766	2,320	24,446	435
50%Pc NPS	132	100	3,392	33,921	3,279	30,642	646
75%Pc NPS	197	100	3,983	39,834	4,224	35,610	526
100%Pc NPS	263	100	3618	36,180	5,184	30,996	D
100%Pc TSP	217	100	3,875	38,745	6,677	32,069	72

Where, NPS cost = 14.54 Birr kg^{-1}, TSP cost = 24.50 birr kg $^{-1}$, UREA cost = 10.60 Birr $kg^{-1}$of N, Teff grain per ha = 20 Birr kg^{-1}, NPS and Urea application cost = 300 Birr ha^{-1}, MRR (%) = Marginal rate of return, D= Dominated treatment, Control = unfertilized, TSP= Triple supper phosphate, NPS= blended NPS fertilizer.

Conclusion and Recommendation

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).However, according to the report of (FAOSTAT, 2019) its productivity have been 19.38 % far below the world's average yield. This is might be due to blanket way of fertilizer application in type (only DAP and Urea) and amount without considering agro-ecology and crop types. Such practice leads to inefficient use of fertilizers by wheat since, the amount to be applied can be more or less than the crop requires. Therefore, soil test based crop response and site specific P fertilizer application with new introduced fertilizers such as NPS are very important for fertilizer recommendations to improve the trend and increase crop yield

The treatments was arranged based on already determined Phosphorous critical and requirement factor and consisting of 100% Pc from DAP fertilizer, 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application). Applied Phosphorus = (Critical P - Po)* Pf. Whereas Pc= 19 ppm and Pf = 4.72 ppm (Kefyalew et al., 2017). The experiment was laid out in randomized complete block design (RCBD) with three replications. The analysis of variance indicated that, except thousand kernels weight all tasted parameters of bread wheat were significantly ($p<0.05$) influenced by treatment applied. Plant height, and grain yield were highly significantly ($p <0.01$) influenced by 100 % Pc/263 kg ha^{-1} of NPS fertilizer but harvest index was significantly ($p < 0.05$) affected by 75% Pc/197 kg ha^{-1} of NPS fertilizer. However, spike length and biomass yield were significantly ($p <0.05$) and highly significantly ($p <0.01$) influenced by 100% Pc/217 kg ha^{-1} TSP, respectively. The highest (121 cm) plant height, the highest(54.04) seed per spike, and the highest (4702 kg ha^{-1}) grain yield were recorded by 100 % Pc/263 kg ha^{-1} of blended NPS. But the highest (10.66 cm) seed per spike and the highest (10.25 tone ha^{-1}) biomass yield were recorded by application of the highest 100% Pc/217 kg ha^{-1} TSP. However the highest (40.24%) harvest index was recorded by 75% Pc/197 kg ha^{-1} of NPS. Moreover, from all tasted parameters the lowest values were recorded by control plots. The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of 75% P from NPS (197 kg NPS ha^{-1}) is profitable which gave the highest (35610 Birr) net return with acceptable (526%) marginal rate of return and recommended for farmers in Lume district and other areas with similar Agro-ecological conditions

Acknowledgement

We kindly thank the Oromia Agricultural Research Institute (IQQO) for financial sponsorship and 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. At last but not at least, our special thank also forwarded to experts of Lume Agricultural office, DA's and participant farmers for their effective collaboration work voluntarily in this study

References

Abebaw Tadele Alem and Hirpa Legese. 2018. Effects of fertilizer rate (blended) and sowing methods on yield of bread wheat (*Triticum aestivum*) and its economic profitability in western Ethiopia. *International Journal of Comprehensive Research in Biological Sciences,* 5(7): 1-14.

Asfaw, N., B. Shiferaw, Jawoo Koo, K. Sonder, M. Smale, H.J. Braun, S. Gbegbelegbe, Zhe Guo, D. Hodson, S. Wood, T. Payne, and B. Abeyo. 2013. The Potential for Wheat Production in Africa: Analysis of Biophysical Suitability and Economic Profitability. Mexico, D.F.: CIMMYT.

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.

Assefa Workineh, Yemane Nega, and Dawit Habte. 2015. Planting Density, and Nitrogen and Phosphorus Fertilization Effect on Different Bread Wheat (*Triticum aestivum* L.) Genotypes in Southern Tigray, Ethiopia. *Journal of World Science Research*, 3(2): 20–28.

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

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)

Eyasu Elias, Bayena Teklu and Tewodros Tefera, 2020. Effect of blended fertiliser application on bread wheat yield, agronomic efficiency and profitability on Nitisols of Southern Ethiopia. South African Journal of Plant and Soil Volume 37, 2020 - Issue 4

Food and Agriculture Organization of the United Nations (2019).FAOSTAT (Online). Available at: http://www.fao.org/faostat/en/#data/QC.

GenStat. (2012). GenStat Executable Release 15.2. Lawes Agricultural 425 Trust, Rothamstead Experimental Station, Harpenden, Clarendon 426 Press, London

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.

James D. Mauseth (2014). Botany. Jones & Bartlett Publishers. p. 223. ISBN 978-1-4496-4884-8. Perhaps the simplest of fruits are those of grasses (all cereals such as corn and wheat)...These fruits are caryopses.

Kefyalew Assefa, Tilahun Firomsa and Tadesse Hunduma. 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.

Kefyalew Endale. 2010. Fertilizer Consumption and Agricultural Productivity in Ethiopia. Ethiopian Development Research Institute (EDRI), Addis Ababa, Ethiopia. Accessed on November, 13/ 2020.

Lemi Aga and Negash Geleta. 2020. Effects of Variety and Fertilizer Rate on Yield of Bread Wheat (Triticum aestivum, L) Varieties in East Wollega Zone, Western Ethiopia: Agricultural and Biological Sciences Journal. Vol. 6, No. 2, 2020, pp. 60-71

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

MoA (Ministry of Agriculture). 2016. Ministry of Agriculture, Animal and Plant Health Regulatory Directorate. Crop variety register, Issue No. 19. Addis Ababa, Ethiopia.

Shewry, P.R., 2009. Darwin Review. *Journal of Experimental Botany*, *60*(6), pp.1537-1553.

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 , Amante Lemma , Chali Hundesa , Abdurhman Husen and Tilahun Firomsa 2021. Response of Yield Components and Yield of Bread Wheat (Triticum aestivum L.) to Blended NPS and N fertilizers Levels at Liban Chukala District, East Shewa Zone, Oromia, Ethiopia. International Journal of Research and Innovations in Earth Science Volume 8, Issue 1, ISSN (Online): 2394-1375

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.

Determination of NPS Fertilizer Rates on Yield and Yield Components of Bread Wheat (Triticum aestivum L.,) in Negelle Arsi District, West Arsi Zone of Oromia, Ethiopia

Abdurahman Husien[1], Tilahun Abera[1], Tilahun Firomsa[1], and Amante Lema[1]
Batu Soil Research Center, P.O. Box 59, BatuOromia, 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 NagelleArsi District in 2018/19 to 2019/20 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. The experiment was laid out in randomized complete block design (RCBD) with two replications and a plot size 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).The test crop used was Bread Wheat Variety Ogolcho with seed rate 150 kg ha^{-1}. Weed and yellow rest were also managed by pallas and Rexcido, respectively. The main effects of NPS fertilizer rate under Eutricvertisolsoils on yield and yield components were highly significant with respect to phosphorus critical and requirement factors ($P < 0.01$) on spike length, seed per spike, aboveground dry biomass and grain yield. The plant height and thousand kernels weight were not significant.The partial budget analysis showed that the maximum net benefit with an acceptable MRR was obtained from 75% pc from NPS fertilizer source and supplemented with 69 kg N ha^{-1} application on EutricVertisols.Whereas, the main effects of NPS fertilizer rates on MollicAndosols soils were highly significant with respect to phosphorus critical and requirement factors ($P < 0.01$) on plant height, aboveground dry biomass and grain yield. The spike length, seed per spike and thousand kernels weight were not significant.The highest grain yield was obtained due to the application of 100 % Pc from TSP with recommended 46 kg N ha^{-1} and flowed by rate of 100% Pc from NPS fertilizer source with recommended 46 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 46 kg N ha-1 application on MollicAndosols and recommended for the study area.

Keywords: Bread wheat, NPS, EutricVertisols, MollicAndosols, Phosphorus critical and phosphorus requirement factor

Introduction

Bread wheat (*Triticumaestivum 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) (EthioSIS, 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 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

The experiment was conducted on a farmers' field in Nagelle Arsi District which is located in West Arsi Zone of Oromia Regional State in the central highlands of Ethiopia. Geographic location of the district is 7° 17' N to 7° 66' N latitude and 38° 43' E to 38° 81' E longitudes. The elevation is 2,043 m (6,703 ft) above sea level; the area is characterized by erratic type of bimodal rainfall pattern; and the soil type of NegelleArsi is mainly with pH 7.5 (OoARD, 2009). According to National Meteorological Services Agency (NMSA), NegelleArsi had mean annual minimum and maximum temperatures of 8.14 and 27.89°C, respectively, while rainfall varied between 20 - 180 mm per month during cropping season. In general, the average monthly maximum and minimum temperatures and rainfall distribution are suitable for wheat production. The environment is seasonally humid and major soil type of the trial sites are EutricVertisols and MollicAndosols

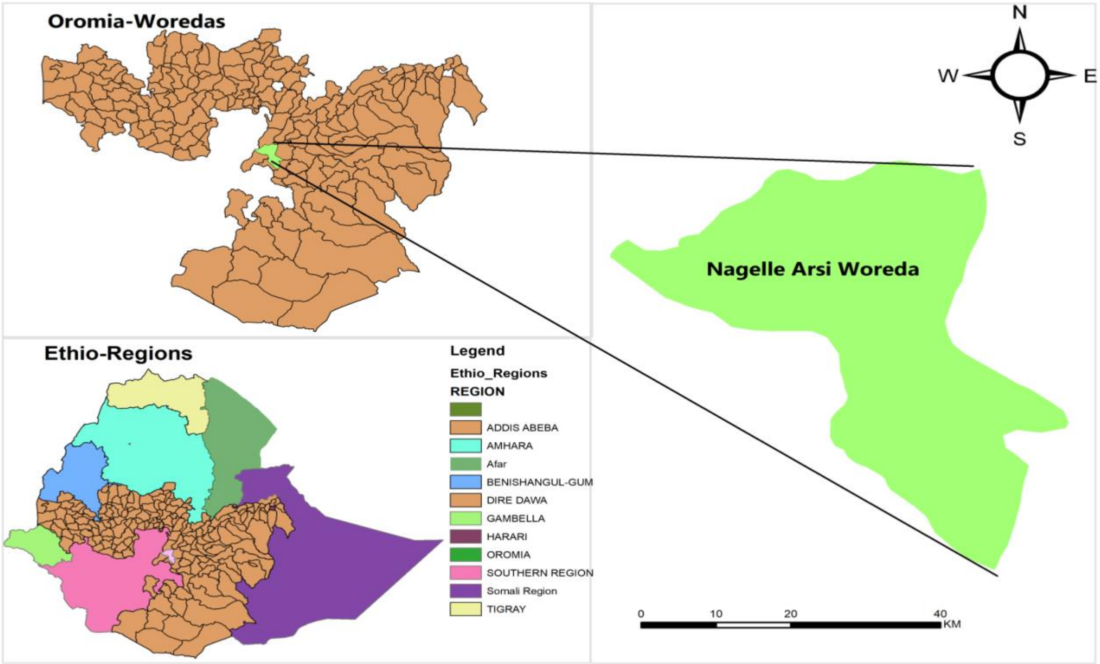


Fig.1. Map of the study area

Treatments and Experimental Design

The experiment was laid out in randomized complete block design (RCBD) with two replications. 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 Pc= 18 ppm Pf = 4.72 and 3.63 ppm on two major soil types MollicAndosols and EutricVertisols 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 soil types of MollicAndosols and EutricVertisols, respectively. Moreover the available phosphorus was determined by extraction with 0.5 M NaHCO3 according to the methods of Olsen et al. (1954).

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 2019 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 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 costwascost incurred due to application of NPS fertilizers rate with pc and Pf of both soils which was MollicAndosols and EutricVertisols 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 two major soil types (MollicAndosols and EutricVertisols) in Negelle Arsi for the determination of optimum nitrogen, P-critical (Pc) and phosphorus requirement factor (pf). Economically Optimum Nitrogen rate for MollicAndosols and EutricVertisols were 46 N kg ha^{-1} and 69 N kg ha^{-1}, respectively .While determined P critical (Pc) concentrations and P (Pf) requirement factors on MollicAndosols and EutricVertisols for bread wheat in ArsiNegelle District were 18 ppm and 3.63, and 18ppm and 4.72, respectively.

Yield and Yield Components of Bread Wheat on MollicAndosols

The main effects of NPS fertilizer rate MollicAndosols highly significant with phosphorus critical and requirement factors ($P < 0.01$) effect on plant height, aboveground dry biomass and grain yield .However, the spike length, seed per spike and thousand kernels weight were not significant. The highest grain yield was obtained due to the application of 100 % pc TSP with recommended 46 kg N ha^{-1} and flowed by rate of 100% pc NPS ha^{-1} with recommended 46 kg N ha^{-1}. The highest grain yield (4818 kg ha^{-1}) and (4530 kg ha^{-1}) was obtained in response to application of 100%pc TSP and 100% pc of NPS fertilizers, respectively. While the lowest grains yield (2468 kg ha^{-1}) was obtained in response to control. This study in line with Tagesse*et.al* (2018) that states use of higher NPS fertilizer with supplemental N rates is the realistic approach to address the problem of low productivity of bread wheat. Therefore, combined application of 200 kg NPS ha^{-1}supplemented with 46 kg N ha^{-1} are recommended to achieve sustainable bread wheat in the study area.

Table 3. Effect of NPS fertilizers rate on yield and yield components on MollicAndosols

Treatments	Plant height(cm)	Spike length(cm)	Seed Per Spike	Biomass ton ha^{-1}	Grain Yield (Qt ha^{-1})	TKW (gm)
No appl	85.05b	7.50	45.68	6.53c	24.68e	40.62
25 % pc	92.00ab	8.32	49.11	10.00b	38.01d	41.00
50 % pc	95.17a	8.06	46.81	10.37ab	41.10cd	38.73
75 % pc	95.58a	8.15	49.26	10.94ab	42.41bc	40.61
100 % pc NPS	97.05a	8.38	48.92	10.97ab	45.30ab	39.43
100 % pc TSP	97.85a	7.91	47.20	11.03a	48.18a	40.19
Lsd (0.05)	7.10	NS	NS	0.97	3.78	NS
CV (%)	7.51	9.27	9.38	9.69	9.39	18.48

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

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 spike length , seed per spike, aboveground dry biomass and grain yield .However, the plant height and thousand kernels weight were not significant. The highest grain yield was obtained due to 100 % Pc from TSP with recommended 69 kg N ha-1, and flowed by the rate of 75 % Pc from NPS ha^{-1} fertilizer with recommended 69 kg N ha^{-1}. The highest grain yield (4593 kg ha^{-1}) and (4295 kg ha^{-1}) was obtained in response to application of 100% Pc from TSP and 75% pc of blended NPS fertilizers, respectively. While the lowest grains yield (2508 kg ha^{-1}) was obtained in response to control. This study in line with Tilahun *et.al.* (2019) that show the main effect of NPS fertilizer was significantly ($P < 0.05$) influenced plant height and grain yield .Therefore, increasing the rate of NPS fertilizer from 100 to 200 kg ha^{-1} increased grain yield and the highest grain yield (5274 kg ha^{-1}) was obtained at the highest (200 kg ha^{-1}) of NPS fertilizer.

Table 4. Effect of NPS fertilizers rate on yield and yield components on EutricVertisols

Treatments	Plant height(cm)	Spike length(cm)	Seed Per Spike	Biomass ton ha^{-1}	Grain Yield (Qt ha^{-1})	TKW (gm)
No appl	79.33	6.57b	27.99b	6.30c	25.08d	38.48
25 % pc	87.43	7.61a	36.13a	8.58b	34.72c	37.39
50 % pc	89.82	7.87a	36.92a	9.92a	39.45bc	37.63
75 % pc	91.82	7.81a	35.28a	9.63ab	42.95ab	37.76
100 % pc NPS	91.17	7.76a	37.81a	9.33ab	41.72ab	37.46
100 % pc TSP	93.00	7.76a	40.60a	9.38ab	45.93a	37.99
Lsd (0.05)	NS	0.79	6.40	1.21	6.18	NS
CV (%)	8.95	8.81	15.19	11.60	13.68	15.24

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.

Economic Analysis for MollicAndosols

The partial budget analysis showed that the maximum net benefit with an acceptable MRR was obtained from 100% Pc from TSP and 100 % Pc from NPS fertilizer and supplemented with 46 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 75 % Pc from NPS and 50% Pc from NPS rates. Therefore, the net positive benefit obtained with application of 100% Pc from NPS ha^{-1} + 46kg N ha^{-1} to bread wheat are economically profitable application rates and can be recommended for farmers on MollicAndosols of the study area and other areas with similar agro-ecological conditions. This study in line with the study of Tagesseet.al (2018) use of 200 kgNPS ha^{-1} supplemented with 46 kg SN ha^{-1} produced highest grain yields, together with the best economic benefit or profitability with results of the economic analysis showed that the maximum net return was obtained due to the application of 200 kg NPS ha^{-1}+ 46 kg N ha^{-1}.

Table 5: Partial budget analysis for NPS fertilizers rate of bread wheat on MollicAndosols

Treatments	**Gy (Qt ha^{-1})**	**AGY (Qt ha^{-1})**	**GFB (ETB ha^{-1})**	**TVC (ETB ha^{-1})**	**NB (ETB ha^{-1})**	**MRR (%)**
No application	24.68	22.21	39426.30	0.00	39426.30	0
25 % pc	38.01	34.21	60720.98	2264.55	58456.43	840.35
50 % pc	41.10	36.99	65657.25	3066.21	62591.04	515.76
75 % pc	42.41	38.17	67749.98	3620.84	64129.14	277.32
100 % pc NPS	45.30	40.77	72366.75	4175.44	68191.31	732.45
100 % pc TSP	48.18	43.36	76967.55	4769.32	72198.23	674.70

ETB= Ethiopian birr; GFB = gross field benefit; TVC = total variable cost; NB = net benefit; MRR = marginal rate of return, PC = Phosphorus critical, FP = Farmer Practice, GY = grain yield, AGY= adjusted grain yield

Economic Analysis for EutricVertisols

The partial budget analysis showed that the maximum net benefit with an acceptable MRR was obtained from 100%Pc fromTSP and 75% Pc from NPS fertilizer and supplemented with 69 kg N ha^{-1} application. The net benefit obtained by the use of improved bread wheat with rates of 75% pc NPS ha^{-1} fertilizer were found to be greater than the benefit of applying 100 % Pc from NPS and 50%Pc from NPS rates. Therefore, the net positive benefit obtained with application of 75% Pc from NPS ha^{-1} + 69 kg N ha^{-1} to bread wheat are economically profitable application rates and can be recommended for farmers on EutricVertisols of the study area and other areas with similar agro-ecological conditions.This study in line with Tilahun*et.al* (2019), the economic analysis revealed that for a treatment to be considered worthwhile to farmers (100% marginal rate of return), application of 100 kg NPS ha^{-1} with 69 kg N ha^{-1} supplementation are profitable and recommended for farmers in Negelle Arsi district. This study in line with the study Adamu (2018),Application of 167/45 kg N/P ha^{-1} was more economical (79.7-134.1% marginal return) and is suggested to be promoted for bread wheat production following teff and lentil precursors on both types of Vertisols of the test locations and similar areas in the central highlands of Ethiopia.

Table 6: Partial Budget analysis for NPS fertilizers rate of bread wheat on EutricVertisols

Treatments	Gy (Qt ha^{-1})	AGY (Qt ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
No appl	25.08	22.57	40065.30	0.00	40065.30	0.00
25 % pc	34.72	31.25	55465.20	2360.11	53105.09	552.51
50 % pc	39.45	35.51	63021.38	2763.28	60258.10	1774.19
75 % pc	42.95	38.66	68612.63	3166.45	65446.18	1286.82
100 % pc NPS	41.72	37.55	66647.70	3567.85	63079.85	D
100 % pc TSP	45.93	41.34	73373.18	4113.46	69259.72	1132.65

ETB= Ethiopian birr; GFB = gross field benefit; TVC = total variable cost; NB = net benefit; MRR = marginal rate of return, PC = Phosphorus critical, FP = Farmer Practice, 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 was made for MollicAndosols and EutricVertisols for bread wheat in NagelleArsi District. Accordingly, the highest grain yield was obtained due to the application of 100 % Pc from TSP supplemented with 46 kg N ha^{-1} and flowed by rate of 100% Pc from NPS ha^{-1} with supplemented 46 kg N ha^{-1}. The highest grain yield (4818 kg ha^{-1}) and (4530 kg ha^{-1}) were obtained in response to application of 100%Pc from TSP and 100%Pc of NPS fertilizers, respectively. While the lowest grains yield (2468 kg ha^{-1}) was obtained in response to control on MollicAndosols. Similarly, the highest grain yield was obtained due to 100 % Pc from TSP with supplemented 69 kg N ha-1, and flowed by the rate of 75 % Pc from NPS ha^{-1} fertilizer supplemented 69 kg N ha^{-1}. The highest grain yield (4593 kg ha^{-1}) and (4295 kg ha^{-1}) was obtained in response to application of 100%Pc from TSP and 75% pc of NPS fertilizers, respectively. While the lowest grains yield (2508 kg ha^{-1}) was obtained in response to control on Eutric Vertisols. Generally the net positive benefit obtained with application of 100% Pc from NPS ha^{-1} + 46kg N ha^{-1} on MollicAndosols and 75% Pc from NPS ha^{-1} + 69 kg N ha^{-1} on EutricVertisols 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

First of all, we thank our God who enables us, in all circumstance, to perform our research activity properly. Secondly, the authors would like to thank Oromia agricultural research institute and Batu soil research center for funding the research and providing all the necessary facilities required for the research, respectively. At last but not at least, our special thank also forwarded to all staff members, especially to Laboratory analysis team for their support and unreserved effort to provide reliable samples analysis data on time.

Reference

Adamu Molla. (2018). Response of Wheat to NP Fertilizer Rates, Precursor Crops and Typesof Vertisols in Central Highlands of Ethiopia Journal of Agricultural Science; Vol. 10, No. 4;ISSN 1916-9752 E-ISSN 1916-9760.

Assefa Menna, Johnson M R Semoka, NyambililaAmuri, and TekalignMamo.(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.

CIMMYT(1988). From Agronomic Data to Farmer Recommendations: An Economics Training Manual. revised edition. Mexico, D.F. ISBN 968.

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 (*Triticumaestivum*) quality. *New Zealand JournalofCrop 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, TekalignMamo, RiikkaKeskinen, Erik Karltun, HelufGebrekidan, and TayeBekele. (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 (*Triticumaestivum*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.

Tagesse Abera, KetemaBelete and TamadoTana .(2018). Effect of Blended NPS Fertilizer Supplemented with Nitrogen on Yield Components and Yield of Bread Wheat (Triticumaestivum L.).Journal of Natural Sciences Research, ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)Vol.8, No.11.

Tanner, D., AmanuelGorfu and AsefaTilahun. (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 TamadoTana. (2019).Growth, yield component and yield response of durum wheat (Triticumturgidum L. var. Durum) to blended NPS fertilizer supplemented with N rates at ArsiNegelle, Central Ethiopia.African Journal of Plant Science, DOI: 10.5897/AJPS2018.1697, Vol. 13(1), pp. 9-20.

Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Bread Wheat in Wachale District, North Shewa Zone, Oromia, Ethiopia

Dejene Getahun, Abera Donis, Tadele Geremu*, Dereje Girma, Abreham Feyisa, Lello Dejene, Meron Tolosa
Oromia Agricultural Research Institute, Fitche Agricultural Research Center, Soil Fertility Improvement and Problematic Soil Research Team
*Corresponding author:bekgeremu@gmail.com

Abstract

Farmers are using NPS fertilizer rates in the area without any recommendation of crop response to the respective fertilizers This experiment was conducted to evaluate the effect of NPS fertilizer rate for higher yield of bread wheat in Wachale district. The experiment consisted six rates of NPS fertilizer rate supplemented with 92 kg N ha^{-1} laid out in RCBD with three replications. Improved variety of bread wheat Danda'a was used. The analyzed result indicated that, plant height and wheat grain yield were significantly ($P<0.05$) influenced by NPS fertilizer rate. The highest (94.56 cm) plant height was recorded from the application of 100% P-critical in NPS fertilizer rate and the lowest (63.62 cm) plant height was recorded from unfertilized plot. The highest (2833 kg ha^{-1}) grain yield was obtained from the application of 100% P-critical in NPS fertilizer rate and the lowest (888 kg ha^{-1}) grain yield was obtained from unfertilized plot. Partial budget analysis showed that the highest net benefit (53401.51 ETB ha^{-1}) and marginal rate of return (MRR) (1093.80%) were obtained from the fertilizer application of 100% P critical in NPS fertilizer). Therefore, 100% equivalent rate of NPS fertilizer rate in relative to determined critical phosphorus supplemented with 92 kg N ha^{-1} for bread wheat could be recommended and thus soil test based crop response phosphorus fertilizer recommendation with 92 kg ha^{-1} of Nitrogen could be demonstrated and further scaled up for Bread Wheat in Wachale district.

Key Words: *Fertilizer, blanket recommendation, Soil test based, Net income*

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 cereals in Ethiopia and it is one of the largest producers of wheat in sub-Saharan Africa. 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). There are two types of wheat grown in Ethiopia: durum and bread wheat accounting 40 and 60% of production, respectively. Wheat production in Ethiopia are characterized by subsistence farming and mostly dominated by small holder farmers (CSA, 2019; Minot *et al.,*2015). The national average productivity of wheat (2.7 tone ha) (CSA, 2019) is still lower than world's average (3.4 tone ha) (FAOSTAT, 2014). 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.

In order to tackle this soil fertility problem, the Ministry of Agriculture was conducting soil and plant nutrient survey to determine the key soil nutrient limitations along with importation of different blended fertilizers and micro-nutrients from abroad and test these against Urea (50 kg ha^{-1}) and di-ammonium phosphate (DAP, 100 kg ha^{-1}) for their impact on crop yield in different areas and crops. The results from both of these initiatives showed deficiency of 3 to 6 nutrients N, P, S, Zn, Mo and B. In most parts of the country and crops responded to the application of additional nutrient. Moreover, the plant analysis data from the same sites indicated that wheat plants were deficient in N, P, Zn and K

(Hillette*et al.,* 2015). Due to this, Ethiopia is moving from blanket recommendations for fertilizer application rates to recommendations that are customized based on soil type and crop. This is a move towards diversification and away from DAP and Urea, which have long been the only type of fertilizer imported for grain crops. The farmers in most parts of the country in general and in the study area in particular have limited information on the impact of different types and rates of fertilizers except blanket recommendation. However, according to the soil fertility map covering over 150 districts, most of the Ethiopian soils lack about seven nutrients (N, P, K, S, Cu, Zn and B) (EthioSIS, 2013). Wheat crop responded to fertilizer rate in some areas of the country. Moreover, Assefa*et al.* (2015) reported that grain yield and yield components of wheat (100%) fully responded to applied nitrogen, 72.3% showed response to sulfur, 78% showed response to applied phosphorus on eighteen fields studied in central high lands of Ethiopia and strongly indicated sulfur deficiency along with its importance to include in balanced fertilizer formula. Apart from blanket recommendation of nitrogen and phosphorus, the effect of other fertilizers on yield components and yield of bread and durum wheat are unknown in Ethiopia, even though new blended fertilizers such as NPS (19% N, 38% P_2O5 and 7% S) are currently being used by the farmers with blanket recommendation of 100 kg NPS ha^{-1} in Ethiopia.

Since, Ethiopia is moving from blanket recommendations to soil test based fertilizer recommendations, Fitche Agricultural Research Center was conduct a research to determine critical phosphorus concentration and phosphorus requirement factors for bread wheat in Wachale district, North Shewa Zone. However, the effect of NPS fertilizer rate was not determined for bread wheat in the study area. Thus, based on the determined Pc (9.5 ppm) and Pf (14.23), optimum NPS fertilizer rate determination was carried out in the study area with the objectives; to determine an equivalent rate of NPS fertilizer in relative to determined P-critical for bread wheat and to estimate the economically feasible NPS fertilizer rate for higher yield of bread wheat in Wachale district.

Material and Methods

Description of the Study Area

The experiment was conducted in Wachale district of North Shewa Zone, Oromia, central high lands of Ethiopia. The district is located at 78 km of the capital Addis Ababa in the Northwest direction. The district is located between 9°25'2.13" to 9°48'44" North and 38°38'49.02 " to 39°08'41" East. The altitude of the study area ranges between 1200 and 2880 (m.a.s.l). That means the districts have the three major classification of landform such as highland, lowland and midland. The mean annual rainfall of the area is about 1000 mm that ranges from 1000 to 1800 mm. The maximum and minimum annual temperature is 3^0C and 25^0C, respectively.

The major farming systems of Wachale district were mixed farming; cereal crop cultivation and livestock rearing. Livestock production is the most important agricultural activity next to crop production in the district, which supports the traditional subsistence farming of cereal crops. The crops such as wheat, teff, beans, barley, chickpea, lentil, pea etc are the major crop in the study area.

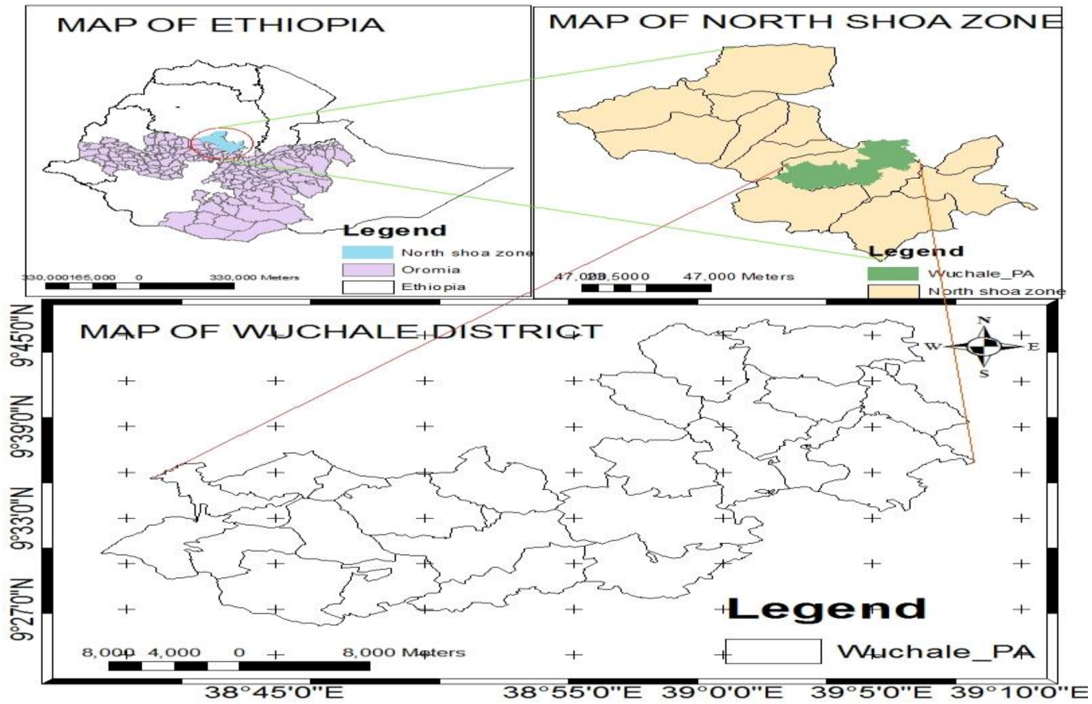


Figure 1: Location map of Wachale district.

Site Selection, Soil Sampling and Analysis Methods

Bread wheat production potential kebeles (small Administrative unit) were selected from the district. Accordingly, the 10 farmer's fields were selected based on their willingness to handle the experimental fields. Before planting, surface composite soil samples were collected from the field for analysis at a depth of 0-20 cm ina zigzag methods. 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) and Available P was determined by the 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 soil pH above 5.5 and available soil phosphorus below critical phosphorus (Pc) was selected for the experiments.

Experimental Design and Treatments

The experiment was carried out on 10 farmers' field for two consecutive years. The experimental field was arranged with a total of 6 treatments with 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 * 4m and the space between block and plot was 50cm. The net plot size was 2 * 2m. The required amount of seeds was weighed per plot by considering the recommended rate of wheat seed per hectare (150 kg ha^{-1}). Urea, NPS, and DAP (Di ammonium Phosphate) was used as source of nitrogen and phosphorus containing fertilizers. Uniform field management practices for all plots were conducted. A bread wheat variety (danda'a) was used.

The treatments were;
T1 = Control (No fertilizer).
T2 = 25% P-critical in NPS fertilizer +Recommended Nitrogen
T3 = 50% P-critical in NPS fertilizer + Recommended Nitrogen

T4 = 75% P-critical in NPS fertilizer + Recommended Nitrogen
T5 = 100% P-critical in NPS fertilizer + Recommended Nitrogen
T6 = 100% P-critical in DAP fertilizer + Recommended Nitrogen

The determined P-critical value (9.5 ppm) and phosphorous requirement factor (14.23) was used to calculate the rate of 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

Data Collection

Bread wheat grain yield was harvested at the ground level from the net plot area. Then, plant height was measured at harvest. After threshing, grain yield were cleaned and weighed. Economic data such as production cost (input cost), gross income and net income based on the current market price of the yield and input

Economic Analysis

Partial budget analysis was done to identify economical feasibility among. The average open market price (Birr kg^{-1}) of Bread Wheat, 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. Marginal rate of return (MRR) were calculated by using the formula given blow;

$$MRR = \frac{NetIncomeFromFertilizedField - NetIncomeFromUnfertilizedField}{TotalVariableCostFromFertilizerApplication}$$

Total variable cost is a cost incurred due to application of P fertilizer (Soil test based P calibration result) with the assumption that the rest of the costs incurred are 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 yield. **Net income** is calculated by subtracting the total variable cost from the gross income.

Data Analysis

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

Result and Discussions

Soil Reaction and Available Phosphorus

The soil pH (H_2O) of the study area was moderately to slightly acidic with the value ranged from 5.56 to 5.9 according to the ratings suggested by Tekalign, 1991 (Table 1). Thus, the pH of the experimental soil was within the range for productive soils. The available phosphorus content of soils was low to medium with the value ranged from 7.24 to 10.39 ppm according to the rating given by Cottenie, 1980. Therefore, the soil of the study areas needs application of phosphorus containing fertilizers for crop production.

Table 1. Soil pH and Available Phosphorus of experimental field

Site	Soil pH	Available P
1	5.59	7.87
2	5.57	10.39
3	5.90	8.18
4	5.56	10.07
5	5.66	7.24
Average	5.66	8.75

Plant Height

Mean plant height was significantly ($P<0.05$) affected by NPS fertilizer rate. The highest (94.56 cm) plant height was recorded from the application of 100% P-critical in NPS fertilizer rate supplemented with recommended Nitrogen. The lowest (63.62 cm) plant height was recorded from control (without fertilizer) (Table 2). The result showed that plant height increased with an increased of NPS fertilizer rate supplemented by Nitrogen fertilizer (Urea). The increment in plant height might be due to increase in cell elongation and more vegetative growth attributed to 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. The sulfur deficiency results in stunted growth and reduced plant height (Doberman and Fairhurst, 2000). This result is in line with results of Tilahun and Tamado, 2019, Abebaw and Hirpa, 2018 and Melesse, 2017, reported that increased application of blended fertilizer significantly increased plant height of bread wheat.

Grain Yield

Grain yield of bread wheat was significantly ($P<0.05$) influenced by NPS fertilizer rate. The highest (2833 kg ha^{-1}) grain yield was obtained from the application of 100% P-critical in NPS fertilizer rate supplemented with recommended Nitrogen and the lowest (888 kg ha^{-1}) grain yield was obtained from unfertilized plot (Table 2). The results of this study indicated that, the mean of grain yield were increased with the increment of blended fertilizer rate. The highest grain yield at the highest NPS rates might have resulted from improved root growth and increased uptake of nutrients and better growth which enhanced yield components and yield of crops. This result is in agreement with Tilahun and Tamado, 2019, Bizuwork, 2018, Diriba *et al., 2019* who reported that, the maximum grain yield of bread wheat was recorded at the highest application of blended fertilizer rate.

Table 2. Effects of NPS fertilizer rate and recommended nitrogen on plant height and grain yield of bread wheat

Treatment	PH (cm)	GY (kg ha^{-1})
Without fertilizer	63.62^{b}	888^{c}
25% P-critical in NPS fertilizer +Recommended Nitrogen	90.66^{a}	2018^{b}
50% P-critical in NPS fertilizer + Recommended Nitrogen	92.17^{a}	2238^{ab}
75% P-critical in NPS fertilizer + Recommended Nitrogen	92.25^{a}	2202^{ab}
100% P-critical in NPS fertilizer + Recommended Nitrogen	94.56^{a}	2833^{a}
100% P-critical in DAP fertilizer + Recommended Nitrogen	92.80^{a}	2431^{ab}
LSD $_{0.05}$	6.56	429.5
CV %	11.55	40

Means with the same letter in columns are not significantly different at 5% level of significance's, PH=plant height, GY= Grain yield, P = Phosphorus

Partial budget analysis

The partial budget analysis showed that the highest net benefit (53401.51 ETB ha^{-1}) and the highest marginal rate of return (MRR) (1093.80%) was obtained from the fertilizer application of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}). The lowest net benefit (17760ETB ha^{-1}) was obtained from unfertilized plots (Table 3). The MRR was indicated that bread wheat producers can get an extra of 10.94 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 bread wheat was more economically beneficial and recommended for Wachale district.

Table 3.Marginal analysis of bread wheat yield as influenced by NPS fertilizer supplemented by nitrogen rate

Trt	Variable Input (Kg/ha)		Unit price(ETB)		TVC	Output (Kg/ha)	Unit price (ETB)	Gross Income (ETB ha^{-1})	Net Income (ETB ha^{-1})	MRR (%)
	DAP/NPS	Urea	DAP	Urea						
1	0	0	0	0	0	888	20	17760	17760.00	
2	35.48	185.35	12.5	10.5	2389.68	2018	20	40360	37970.32	845.73
3	70.96	170.69	12.5	10.5	2679.25	2238	20	44760	42080.75	907.74
4	106.44	156.04	12.5	10.5	2968.92	2202	20	44040	41071.08	785.17
5	141.92	141.38	12.5	10.5	3258.49	2833	20	56660	53401.51	1093.80
6	117.24	154.12	12.5	10.5	3083.76	2431	20	48620	45536.24	900.73

Where: Trt = Treatment,TVC = Total Variable Cost, MRR = Marginal Rate of Return

Conclusion and Recommendation

The productivity of wheat is declining e due to many reasons and among the low soil fertility is the most one. With the objective of solving this soil fertility problem, soil test based crop response fertilizer rate recommendation has been conducted across the country. The grain yield of bread wheat was influenced by NPS fertilizer rate whereby the results of this study clearly indicated that, the mean of grain yield were increased with the increment of NPS fertilizer rate. In addition, partial budget analysis has also shown a variation among the treatments and 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 bread wheat was more economically beneficial and recommended for Wachale district.

Therefore, demonstration and further scale up of soil test based crop response phosphorus fertilizer recommendation with 92 kg ha^{-1} of Nitrogen demonstrated and further scaled up for Bread Wheat in Wachale district could be recommended and also the farmers could be used 100% equivalent rate of NPS fertilizer rate in relative to determined critical phosphorus for bread wheat in the district~~.~~

Acknowledgments

The authors would like to thank Oromia Agricultural Research Institute and Fitche Agricultural Research Center for funding the research and providing all the necessary facilities required for the research, respectively.

References

AbebawTadele and HirpaLegese, 2018.Effects of Fertilizer Rate (Blended) and Sowing Methods on Yield and Yield Components of Bread Wheat (*Triticumaestivum. L*) in Western Ethiopia. *International Journal of Compressive Research and Biological Science.DOI: http://dx.doi.org/10.22192/ijcrbs.2018.05.06.001*.

Assefa M., Johnson M. R. Semoka, N. A. and Tekalign M. 2015.Wheat Response to Applied Nitrogen, Sulfur and Phosphorous in three Representative Areas of the Central Highlands of Ethiopia.*International Journal of Plant & Soil Science,* 8 (5).pp: 1-11.

BizuworkTafes. 2018. Growth, Yield and Grain Quality of Durum Wheat (*Triticumturgidum*L.var. durum) as Influenced by Rates of Blended NPSB and N Fertilizers at DebreZeit, Central Ethiopia. MSc Thesis, Haramaya University.

CIMMYT (International Maize and Wheat Improvement Center). 1988. From agronomic data to farmer recommendation: An Economic work Book. Mexico, D.F.: CIMMYT.

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, Italy.

CSA (Central Statistical Agency). 2019. Agricultural sample survey. Report on area and production of major crops (private peasant holdings, meher season). Addis Ababa, Ethiopia.

DiribaShiferaw G, Rut-Duga D and Wogayehu W. 2019.Effects of Blended Fertilizer Rates on Bread Wheat (TriticumAestivum L.) Varieties on Growth and Yield Attributes. *Journal of Ecology & Natural Resource*, 3(3): 000170.

Doberman, A. and Fairhurst, T., 2000.Nutriments Disorders and Nutriments Management. International Plant Nutrition Institute

EthioSIS (Ethiopian Soil Information System). 2013. Soil analysis report. Agricultural Transformation Agency (Unpublished)

FAOSTAT.(2014). *Online [Internet]*.Retrieved August 6, 2020, from.http://faostat.fao.org/site/291/default. aspx. FAO, Rome.

HilletteHailu, TekalignMamo, R.Keskinen, E.Karltun, HelufGebrekidan and TayeBekele. 2015. Soil fertility status and wheat nutrient content in Vertisol cropping systems of central highlands of Ethiopia. *Agriculture and Food Secure*. 4, pp: 19-23.

Melesse H .2017. Response of bread wheat (Triticumaestivum L.) varieties to N and P fertilizer rates in Ofla district, Southern Tigray, Ethiopia. *African Journal of Agricultural Research* 12(19):1646-1660.

Minot, N., Warner, J., Lemma, S., Kasa, L., Gashaw, A., & Rashid, S. 2015. The wheat supply chain in Ethiopia:Patterns, trends, and policy options. *International Food Policy Research Institute (IFPRI).*

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA circular 939: pp 1-19.

TekalignTadese. 1991. Soil, Plant, Water, Fertilizer, Animal Manure and Compost Analysis. Working Document No. 13.International Livestock Research Center for Africa, Addis Ababa, Ethiopia.

Verification of Soil Test Crop Response Based Phosphorus Fertilizer Recommendations for Bread Wheat (TriticumAestivum L.) in Degem District, North Shewa Zone, Oromia Region, Ethiopia

Dejene Getahun, Abera Donis, Tadele Geremu*, Dereje Girma, Lello Dejene, Meron Tolosa
Oromia Agricultural Research Institute, Fitche Agricultural Research Center, Soil Fertility Improvement and Problematic Soil Research Team
*Corresponding author Email: *bekgeremu@gmail.com*

Abstract

On farm verification trial of soil test crop response based phosphorus calibration study on bread Wheat was conducted at Degem district of North Shewa zone during 2019 cropping season. The study was initiated to verify Phosphorus critical value and Phosphorus requirement factor for bread wheat production. The experiment consisted of three treatments; control (without fertilizer), blanket recommendation and soil test crop response based phosphorus recommendation laid out in Randomized Complete Block Design with seven replication. Soil data before planting, plant height and grain yield was collected and analyzed by using R software program. The analyzed soil samples indicated that, the soil pH (H_2O) of the study area was moderately to slightly acidic with the value ranged from 5.56 to 5.72 and the available phosphorus content of soils was low to high with the value ranged from 9.72 to 20.66 ppm. The statistical analysis indicated that, there was a significant difference ($p < 0.05$) among different fertilizer recommendation on plant height and grain yield. Accordingly, the maximum plant height (95.03 cm) and the highest grain yield (2996.43 kg ha^{-1}) were obtained from the application of site specific fertilizer recommendation. The economic analysis also showed that the highest net income (56202.01) and marginal rate of return (1090.27%) was obtained from soil test based fertilizer recommendation which was economically optimum and feasible for bread wheat production. Therefore, site specific soil test based crop response fertilizer recommendation could be recommended and thus the determined Pc and Pf for bread wheat production could be demonstrated and scaled up in Degem district, North Shewa Zone.

Key words: *Blanket recommendation, Soil test based fertilizer recommendation, Verification, Wheat, Degem district*

Introduction

Ethiopia is one of the largest wheat 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. Wheat is mainly grown in the highlands of Ethiopia (Engida, 2001; MoA, 2012). Mean wheat yield increased from 1.3 tons ha^{-1} to 2.74 tons ha^{-1} in 2017/18 (CSA, 2018), well below experimental yields of over 5 tons ha^{-1} (Gete Zelleke *et al.,* 2010; Mann and Warner, 2015). The average wheat productivity in SSA is 1.7 tons ha^{-1} (FAOSTAT, 2015), nearly 50% below the world average due to several factors such as low soil fertility, lack of improved wheat varieties and lack of other improved cultural management practices.

Among the above factors declining soil fertility is a major constraint on crop production in Ethiopian highland. Farmers are either entirely abandoning their traditional practices of using natural fallow to restore soil fertility, or are unable to leave land fallow for long enough time for it to be effective (Corbeels *et al*., 2000). Due to this, farmers are intending to find other options for managing continuous decline of soil fertility status for crop production.

Application of urea and DAP fertilizers has been adapted through extension program in Ethiopia. The blanket recommendations disregard considering the physical and chemical properties of the soil as well as does not take in to account climatic condition and available nutrient present in the soil (Taye Bekele *et al*., 2000). The popularization of urea and DAP (Diammonium Phosphate) fertilizers was increased from time to time through the extension programs until blended fertilizers introduced by EthioSIS. However, blanket recommendation of DAP and Urea exacerbate a major challenge facing the small holder farmers not only to find ways of making fertilizer available at affordable price but also recommendations on the amount and type of fertilizers to be applied for most crops and soil types. Farmers are using this blanket type fertilizer recommendations which is not recommended based on soil fertility status and crop nutrient requirements.

However, blanket fertilizer application may lead farmers to over-fertilize in some areas and under-fertilize in others, or apply an improper balance of nutrients for their soil or crop. This method of application might lead to economically wasteful and can also damage the environment (Meryl *et al.,* 2015). On the other hand, insufficient nutrient application can retard crop growth and results in lower yield.

An alternative to blanket guidance was 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 (Bruulselma *et al.,* 2012). Soil testing is the most reliable tool for making good economic and environmental decisions about applying fertilizers. Hence it is helpful for efficient and effective use of P fertilizer (Vitosh, 1998). Thus, Soil test based, site-specific nutrient management has become a major tool for increasing productivity of agricultural soils. Once 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 while managing for impacts.

In addition, soil testing is well recognized as sound scientific tools to assess inherent power of soil to supply plant nutrients and have been established through scientific research, extensive field demonstrations, and on the basis of actual fertilizer use by the farmers on soil test based fertilizer use recommendations (Corbeels *et al.,* 2000; India Soil Testing manual, 2011). Accordingly, Fitche Agricultural Research Center has developed soil test based phosphorus critical value (22 ppm) and p requirement factor (5.85 ppm) for wheat in Degem district (Dejene *et al.,* 2020a*).* Thus for further demonstration and scale up the achievement should be verified for the districts and develop phosphorus fertilizer recommendation guide line for all wheat growing areas in the district. Therefore, the study was initiated with the objectives to verify critical phosphorus and phosphorus requirement factor for bread wheat in Degem District, North Shewa Zone, Oromia.

Material and Methods

Description of the Study Area

The experiment was conducted in Degem district of North Shewa Zone, Oromia, central high lands of Ethiopia. The district is located at 124 km of the capital Addis Ababa in the Northwest direction. The district is located between 9°39'0" to 10°03'0" North and 38°15'0" to 38°55'0" East and at an average elevation of 2878 m.a.s.l. The mean annual rainfall of the area is about 1150 mm that ranges from 900 to 1400 mm. The maximum and minimum annual temperature is 15^0C and 22^0C, respectively.

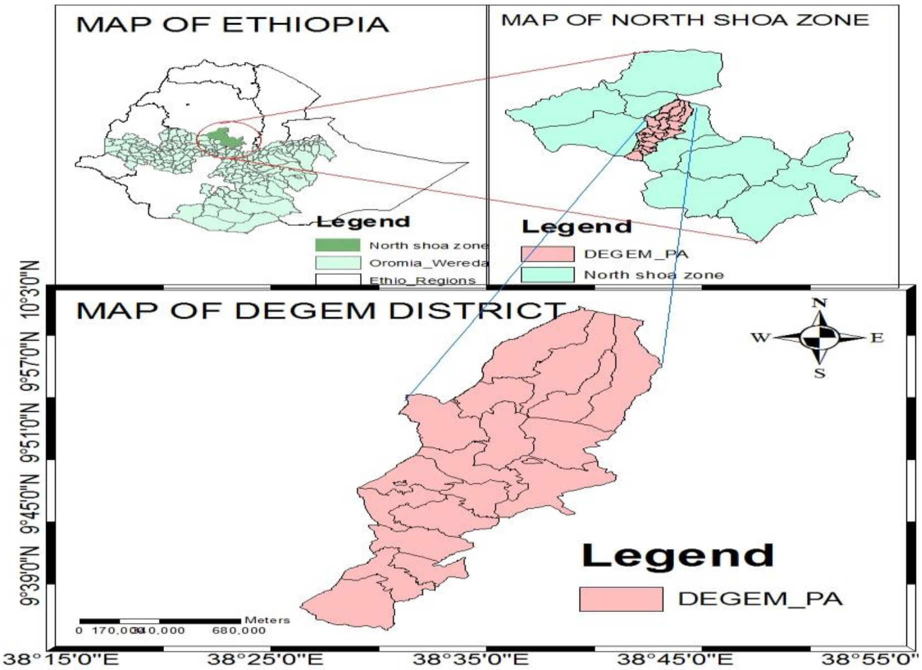


Figure 1. Location map of Degem district

Site Selection, Soil Sampling and Analysis Methods

Bread Wheat production potential kebeles (small Administrative unit) were selected from the district. Before planting 20 surface composite soil samples were collected from the field for analysis at a depth of 0-20 cm in a zigzag methods. 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) and Available P was determined by using the Olsen's method (Olsen *et al*., 1954) using a spectrophotometer. Then 7 farmer's field was selected based on the analyzed soil sample results (for which the soil pH above 5.5, available soil phosphorus below critical phosphorus (Pc)) and their willingness to permit their experimental field during the experimentation.

Experimental Procedures

The experiment was conducted on 7 farmers' field for one year. The experimental field was arranged with a total of 3 treatments with a randomized complete block design (RCBD) in seven replications. Farmers were used as replications. Control (without fertilizer), Blanket recommendation and soil test based P fertilizer recommendation with recommended Nitrogen rate of 92 kg ha^{-1} were used as a treatments. The gross plot area was 10 m * 10m and the space between plots was 1m. The required amount of seeds per plot was weighed from the conversion of the recommended wheat seed rate for a hectare (150 kg ha^{-1}). Urea and DAP (Diammonium Phosphate) was used as source of Nitrogen and Phosphorus containing fertilizers. Bread wheat variety ("*Danda'a*") was used. Uniform field management practices were employed for all plots during the experimental years.

The determined P-critical value (22 ppm) and phosphorous requirement factor (5.85 ppm) was used to calculate the rate of fertilizer to be applied.Thus,Phosphorus fertilizer rate was calculated by using the formula given below;

P-application Rate = (pc-pi)*pf

Where
Pc: Critical phosphorus concentration
Pi: Initial available P
Pf: Phosphorus requirement factor which was derived from the calibration study

Data Collection

Bread wheat grain yield was harvested at the ground level from the net plot area. Then, plant height was measured at harvest. After threshing, grain yield were cleaned and weighed. 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

The collected data was entered to the Microsoft excel and analyzed using R software program. Means separation was done using least significant difference (LSD) at 5%.

To evaluate the economic importance of fertilizer for wheat production, marginal rate of return (MRR) were calculated by using the formula given by;

$$MRR = \frac{Net\ Income\ From\ Fertilized\ Field - Net\ Income\ From\ Unfertilized\ Field}{Total\ Variable\ Cost\ From\ Fertilizer\ Application}$$

Result and Discussions

Soil Reaction (pH) and available phosphorus of experimental field

The analyzed soil samples indicated that the soil pH (H_2O) of the study area was moderately to slightly acidic with the value ranged from 5.56 to 5.72 according to the ratings suggested by Tekalign, (1991) (Table 1.). Thus, the pH of the experimental site soil was within the normal range for productive soils. The available phosphorus content of soils was varied from low to high value range (9.72 to 20.66 ppm) according to the rating given by Cottenie, 1980. Therefore, the soil of the study area needs application of phosphorus containing fertilizers for crop production.

Table 1. Soil pH and available phosphorus of experimental field

Site	Soil pH	Available Phosphorus
1	5.72	10.93
2	5.64	20.54
3	5.56	9.71
4	5.8	18.01
5	5.63	20.66
6	5.64	12
7	5.59	16.44
Mean	5.65	15.47
SD	0.08	4.58

Where: SD = Standard Deviation

Response of Bread Wheat to Blanket and Soil Test Based Fertilizer Recommendations

The statistical analysis indicated that, there was a significant difference ($p<0.05$) among different fertilizer recommendation on plant height and grain yield. Accordingly, the maximum plant height (95.03 cm) and the highest grain yield (2996.43 kg ha^{-1}) were obtained from the application of soil test based fertilizer recommendation. The results clearly showed that, wheat grain yield was significantly increased with the application of 92 kg N ha^{-1} and site specific fertilizer recommendation over the blanket type of fertilizer recommendation. The results of this study are agreement with the findings of Gidena*,* 2016; Dejene *et al.,* 2020; Temesgen and Chalsissa, 2020; who reported that the highest grain yield was recorded under the application of site specific fertilizer recommendation over blanket recommendation.

Table 2. Effects of blanket and soil test based Fertilizer recommendation on plant height and grain yield of bread wheat

Treatment	PH (cm)	GY (kg ha^{-1})
Without fertilizer	69.20^{c}	778.57^{c}
Blanket recommendation	88.89^{b}	1921.43b
Soil test based fertilizer recommendation	95.03^{a}	2996.43^{a}
LSD	5.55	288.96
CV (%)	5.86	13.55

Where: PH=plant height, GY=Grain Yield, LSD= Least Significant Difference, CV (%) = Coefficient of Variation

Partial budget analysis

So as to investigate the economic feasibility of fertilizers, partial budget analysis were employed to calculate the marginal rate of return (MRR). Based on actual unit prices during the year 2019/20 harvesting season farm gate price of 20 ETB (Ethiopian Birr) per kg of wheat, 12.78 and 10.4 Birr per kg of DAP and Urea, respectively were used to calculate variable cost. The economic analysis showed that the highest net income (56202.01 ETB) and marginal rate of return (MRR) (1090.27%) was obtained from soil test based fertilizer recommendation (Table 3). Thus, the MRR showed that it would yield 10.91 birr for every birr invested. Therefore, the soil test based fertilizer recommendation recorded the highest MRR in the acceptance range and so, farmers use this soil test crop response-based fertilizer application than blanket recommendation which is cost effective and economically feasible.

Table 3.Partial budget analysis for verification of bread wheat in Degum District

Treatment	Variable Input(Kg ha^{-1})		Unit price (ETB)		TVC	Output (Kg ha^{-1})	Unit price (ETB)	Gross Income	Net Income (ETB)	MRR (%)
	DAP	Urea	DAP	Urea						
Without Fertilizer	0	0	12.73	10.4	0	778.6	20	15,572	15572	-
Blanket Recommended	100	100	12.73	10.4	2313	1921.43	20	38428.6	36115.6	888.18
STBFR	190.13	125.6	12.73	10.4	3726.59	2996.43	20	59928.6	56202.01	1090..27

Where: ETB = Ethiopian Birr, TVC = Total Variable Cost, MRR = Marginal Rate of Return

Conclusion and Recommendation

A field experiment was designed and studied to verify the determined optimum amount of nitrogen (92 kg N ha^{-1}), P requirement factor (5.85) and the critical P concentration (22 ppm) in Degem districts. An optimum nitrogen (92 Kg N ha^{-1}) rate and soil test based phosphorus fertilizer recommendation significantly influenced plant height and grain yield of bread wheat. Accordingly, the highest plant height of 95.03 cm and the maximum grain yield of 2996.43 kg ha^{-1} 2996.43 kg ha^{-1} were recorded from soil test based fertilizer recommendation over the blanket fertilizer recommendation. The economic analysis also showed that the highest net benefit of 56202.01 ETB was obtained from site specific soil test based fertilizer recommendation with marginal rate of return 1090.27% which is greater than the acceptable minimum rate of return (100%). Therefore, site specific soil test based crop response fertilizer recommendation could be recommended and thus the determined Pc and Pf for bread wheat production could be demonstrated and scaled up in Degum district, North Shewa Zone.

Acknowledgments

The authors would like to thank Oromia Agricultural Research Institute and Fitche Agricultural Research Center for funding and facilitation of the research activities, during the experimental years.

References

Abebaw Tadele and Hirpa Legese. 2018. Effects of Fertilizer Rate (Blended) and Sowing Methods On Yield And Yield Components Of Bread Wheat (Triticum Aestivum) In Western Ethiopia ,Int. J. Compr. Res. Biol. Sci. (2018).5(6):1-16

Bruulselma TW, Fixen PE, and Sulewski G. (eds). 2012. 4R Plant Nutrition Manual: A Manual for Improving the Management of Plant Nutrition. International Plant Nutrition Institute (IPNI), Norcross, GA, USA.

Corbeels Marc, Abebe Shiferaw and Mitiku Haile. 2000. Farmers' knowledge of soil fertility and local management strategies in Tigray, Ethiopia; Managing Africa's Soils No. 10

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, Italy.

CSA (Central Statistical Agency). 2018. Agricultural Sample Survey: Report on Area and Production of Major Crops. Vol.I. Addis Ababa, Ethiopia.

Dejene Getahun, Abraham Feyisa, Lello Dejene, and Dereje Girma. 2020a. 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,* 5(1): 1-5.

Dejene Getahun, Dereje Girma, Abreham Feyisa, Ajema Lemma, Lello Dejene. 2020b. 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.

Diriba Shiferaw G, Rut-Duga D and Wogayehu W. 2019. Effects of Blended Fertilizer Rates on Bread Wheat (*Triticum aestivum* L.) Varieties on Growth and Yield Attributes. *Journal of Ecology & Natural Resource*, 3(3): 000170.

Doberman, A. and Fairhurst, T., 2000. Nutriments Disorders and Nutriments Management. International Plant Nutrition Institute

Engida Mersha. 2001. Application of Agro-climatic Analogue Technique to Characterize the Crop Growing Season in Ethiopia. *Ethiopian Journal of Natural Resources*, 3 (1):1-18.

FAOSTAT (Food and Agricultural Organization of the United Nations Statistics). 2015. Food Balance Sheets. FAOSTAT. Rome.

Gete Zeleke, Getachew Agegnehu, Dejene Abera, and Shahidur Rashid. 2010. Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system. IFPRI, Addis Ababa, Ethiopia.63 p.

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, 6(1).

India Soil Testing Manual. 2011. Department of Agriculture & Cooperation Ministry of Agriculture, Government of India New Delhi

Mann, M. and Warner, J. 2015. Ethiopian Wheat Yield and Yield Gap Estimation: A Small Area Integrated Data Approach. *International Food Policy Research Institute (IFPRI)*, Addis Ababa, Ethiopia.

Melesse H. 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 12(19):1646-1660. Mengistu B (2015). Growth, Yield, and Grain Quality of Durum Wheat

Mery B. Richards, Klaus Butterbach-Bah, ML Jat, Brian Lipinski, Ivan Ortiz-Monasterio, Tek ., Sapkota. 2015. Site-Specific Nutrient Management; Implementation guidance for policymakers and investors. Practice brief on CSA.

MoA (Ministry of Agriculture). 2012. Ministry of Agriculture: Animal and Plant Health Regulatory Directorate. *Crop variety register, Issue No.15*. Addis Ababa, Ethiopia.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA circular 939: pp 1-19

Taye Bekele, Verkuij, H., Mwangi, W. and Tanner, D. 2000. Adoption of Improved Wheat Technologies in Adaba and Dodola Wored as of the Bale Highlands, Ethiopia. Second National Maize and Wheat Workshop.12-16 November 2000; Addis Ababa. International Maize and Wheat Improvement Center) and Ethiopian Agricultural Research Organization (EARO) Addis Ababa, Ethiopia.

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.

Temesgen Chimdessa and 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). pp. 52-56.

Tilahun Abera and Tamado Tana. 2019. Growth, yield component and yield response of durumwheat (*Triticumturgidum*L. var. Durum) to blendedNPS fertilizer supplemented with N rates at Arsi Negelle, Central Ethiopia. Vol. 13(1), pp. 9-20, January 2019.

Vitosh M.L. 1998. Wheat fertility and fertilization, Department of crop and soil sciences, Michigan University state university.

Determination of NPS Fertilizer Rates Based on Calibrated Phosphorus for Maize Production in Bako Tibe and Gobu Sayo Districts of West Shewa and East Wellega Zones of Western Oromia

Shiferaw Tadesse, Mamo Mekonnen, Temesgen Tamene, Bayissa Baye and Lemi Gebrekidan
Bako Agricultural Research Center
Coresponding author: Shiferaw Tadesse

Abstract

Determination of NPS fertilizer rates based on calibrated phosphorus for maize production was a continuation of soil test based crop response P calibration and on farm verification of soil test based crop response recommended Pc and Pf. The NPS rate determination based on calibrated phosphorus which consisted of 6 treatments (100% Pc from NPS, 75% Pc from NPS, 50 Pc from NPS, 25% Pc from NPS, 100% Pc from DAP and control/without fertilizers) was executed in randomized complete block design with three replications. Hence pH of all the sites were less than 5.5, lime was applied based on exchangeable acidity. Maize variety BH 546 was planted on nine farmers' fields during 2019 main cropping season in Bako Tibe and Gobu Sayo districts. Significantly ($P < 0.05$), the highest grain yield 7021 kg ha^{-1}, the highest plant height (294 cm) and the lowest and preferable days to maturity (146 days) were obtained by application of 100% Pc from NPS. Similarly, highest net benefits of Birr 45,684 and high and reasonable marginal rate of return (7.11) were also obtained by 100% Pc from NPS. Considering overall advantages, 100% Pc from NPS is recommended for further use in Bako Tibe and Gobo Sayo districts of West Shewa and East Wellega zones, respectively. Awareness creation, demonstration, scaling up and engaging farmers to use NPS fertilizer rates based on calibrated phosphorus for maize production in the respective districts requires research and extension efforts.

Key Words: NPS, fertilizer, rate, maize production

Introduction

Declining of food crop production has been incompetent to feed the ever increasing population in most sub-Saharan Africa. Land degradation, soil fertility declining and plant nutrient depletion are major threats to land and crop productivity (Zeleke *et al.*, 2010). Major plant nutrients like N, P and K are among nutrients limiting plant growth but depleted in alarming rate. Ethiopia, being the sub-Saharan Africa shared these agricultural production and economic growth constraints due to severe loss of the major plant nutrients (Hailesilassie *et al.,* 2005). Continuous cropping or monocropping, high proportion of cereals in the cropping system, application of suboptimal level of inorganic fertilizers and inappropriate management of acid forming fertilizers have aggravated soil acidity, the decline in soil fertility and reduction of crop yields (Agegnehu *et al.*, 2006).

Fertilizer application on acid soils resulted in loss of major nutrients in particular in that particular source which leads to decrease of crop yield. Phosphorus and nitrogen source fertilizers are among plant nutrients exposed to unavailability and loss whereby phosphorus availability is highly affected by soil acidity. Lime application to the acid soils increases soil pH whereby soil test based P-calibration provides P fertilizer application maintaining P to extent level and considerable yield response to application of P fertilizer.

Extremely acidic or very strongly acidic records were obtained for soils of the central highlands of west Shewa (Tesfaye *et al.,* 2015). Soil pH of all 36 samples from Bako Tibe district of West Shewa by Tolera *et al.,* (2015), ranged between 4.63 and 5.92. This could be due to the depletion of basic cations in crop harvest and due to its highest microbial oxidation that produces organic acids providing H ion to the soil which lowers pH value. Lime application at the rate of 5.75 t ha^{-1} has increased soil pH from 4.86 to 5.67 and 6.12 during the second and third year of applications, respectively. Application of lime resulted in 90% yields advantages over non-limed but applied recommended NP fertilizers. Meanwhile, yield increase of 13% was reported during the second and the third years of lime application (BARC, 2013). In fact, soils with low pH (less than 5.5) would have been applied lime whether for production or for research purpose; because availability of P to crops decreases as soil acidity increases. However, due to lack of lime, it was not possible to reclaim soils of even very strongly acidic soils. Soil test crop response based P calibration and verification of Pc were undertaken during 2015 in Bako Tibe and Gobu Sayo districts. Soil analysis for all these activities at Bako Tibe and Gobu Sayo districts of West Shewa and East Wellega zones resulted in pH record of less than 5.5. Hence, Lime application has been critical to maintain P availability. Moreover, this experiment is targeting sites where Pc was identified as 14.5 (Shiferaw *et al.*, 2018).

Objective

- To determine NPS fertilizer rate based on calibrated P for maize production in Bako Tibe and Gobu Sayo districts

Materials and Methods

The study was conduct in Bako Tibe and Gobo Sayo districts of West Shewa and East Wellega zones, respectively. A total of thirteen sites were selected from these districts whereby nine of them with AVP less than 14.5 were selected. The NPS rate determination based on calibrated phosphorus consisted of 6 treatments (100% Pc from NPS, 75% Pc from NPS, 50 Pc from NPS, 25% Pc from NPS, 100% Pc from DAP and control without fertilizers).

The experiment with the objective to determine Pc based NPS fertilizer determination for maize production under limed condition was executed on 9 farmers' field in RCBD 3 replications in Bako Tibe and Gobo Sayo districts. Soil pH of each field analyzed using pH meter 1:2.5 soil: water ranged between 4.27 and 5.34 (extremely acidic to strongly acidic). Exchangeable acidity was also analyzed to determine the amount of lime applied to each experimental site. Available P was determined using Bray II method to identify the amount of P applied to each treatment. Total nitrogen and organic carbon were analyzed to see the fertility condition of each field. Total nitrogen was determined using Kjeldhai method while Walkley-Black method was used to obtain OC. Maize variety, BH 546 was planted on a plot area of 3 m x 4 rows x5 m (13.5m^2) at spacing of 30 cm x 75 cm. NPS and DAP fertilizers were applied during maize planting. Urea, N fertilizer source was applied as split application (50% at maize planting and the remaining 50% at 40 days after planting.

Data Collection and Measurements

Phenological: days to maturity was recorded when 95% of the population in the plot reached physiological maturity
Growth: Plant height was measured using graduated stick during crop maturity

Harvest: Biomass weight were measured after the plants were cut above the ground. Grain yield was weighed and adjusted to 12.5% moisture content standards.

Economic Evaluation

Economic evaluation was done using partial budget, marginal rate of return, and dominance analysis following from agronomic from agronomic data to farmer recommendation (CIMMYT, 1988). Mean grain yield yields from all sites for respective treatments were considered for economic evaluation whereby one year average cost of production and average farm gate prices were considered. Costs of fertilizer, harvesting and shelling were among variable costs considered in the partial budget. Yield was down adjusted by 12% considering minimum acceptable MRR as 100%.

Data Analysis

Data were analyzed using SAS version 9.0 (SAS, 2002) computer software and were subjected to ANOVA to determine significant differences among treatments. Means were separated using LSD test. For all analyzed parameters, $P< 0.05$ was interpreted as statistically significant.

Results and Discussion

Biomass Weight and Grain Yield

Overall maize biomass weight and grain yield were significantly affected by Pc based application of fertilizers. Significantly the highest biomass weight which was 36% over the 100% Pc from DAP was obtained by100% Pc from NPS. Significantly the highest grain yield 7021 kg ha^{-1} was obtained by application of 100% Pc from NPS and followed by 75% Pc from NPS (6302 kg ha^{-1}). Among the treatments received fertilizers, application of 25% Pc from NPS and application of 100% Pc from DAP produced significantly the lowest grain yields which were not significantly different from each other (Table 1). When grain yield of individual farmer’s field is concerned, 100% Pc from NPS and 75% Pc from NPS produced the highest grain yields which were not significantly different from each other in many of the fields (Table 2). This could be attributed due to efficient utilization of P applied. The result agree with the works of Tisdale *et al.*, (2002) which investigated photosynthesis, respiration, energy storage and transfer of plants were enhanced by availability of P to plants.

Plant Height

Plant height was influenced by Pc based application of fertilizers. Significantly highest plant height (294 cm) was obtained by 100% Pc from NPS. Plant heights recorded for 75% Pc from NPS and 50% Pc from NPS were not significantly different from each other. Similarly, plant height recorded for 25% Pc from NPS and 100% Pc from DAP were not significantly different from each other (Table 1). The results obtained agrees with performance evaluation of on farm verification of soil test based crop response of recommended Pc and Pf in Bako Tibe and Gobo Sayo districts which confirmed 85% of the respondents preferred 100% Pc for growth performances (Shiferaw and Mamo, 2019).

Days to Maturity

Days to maturity was influenced by Pc based application of P source fertilizers. Treatments without fertilizers (control) and 25% Pc from NPS took significantly the highest, 155 and 153 days to mature. On the other hand. 100% Pc from NPS took significantly the lowest, 146 days to mature (Table 1). This could be due to efficient utilization of P attributed to normal growth and enhancement of maturity which agrees with similar work by (Tisdale *et al.,* 2002a), who reported phosphorus enhanced early flowering and ripening. Early maturity was influenced by P availability and efficient utilization which primarily enhanced storage and transfer of energy produced by photosynthesis.

Economic evaluation

Net benefits of Birr 45,684, Birr 40, 956 and Birr 35, 954 were obtained by 100% Pc from NPS, 75% Pc from NPS and 50% Pc from NPS, respectively. Likewise, all Pc from NPS resulted in acceptable MRR ranging between 3.48 (25% Pc from NPS) and 7.57 (75% Pc from NPS) whereby 50% Pc from NPS and 100% Pc from NPS resulted in MRR of 7.43 and 7.11 respectively (Table 3). The recommendation is not necessarily based on the highest marginal rate of return (CIMMYT, 1988). In our case, producers who used 75% Pc from NPS obtained a very high marginal rate of return, but if producers stopped there, they would miss the opportunity for further earnings at an attractive marginal rate of return. Considering the highest net benefit and reasonably high and acceptable MRR, 100% Pc from NPS is economically established better rate followed by 75% Pc from NPS.

Table 1. Maize biomass weight, grain yield, plant height and days to maturity as affected by NPS and DAP

Treatments	Days to Maturity	Plant height (cm)	Biomass weight kg ha^{-1}	Grain yield kg ha^{-1}
100% Pc from NPS	146	294	17440	7021
75% Pc from NPS	148	278	15937	6302
50% Pc from NPS	150	274	14734	5547
25% Pc from NPS	153	268	13011	4832
100% Pc from DAP	148	262	12871	4996
Control	155	219	6023	2158
LSD (5%)	1.67	9.97	1367	541
CV (%)	6.98	10.86	19.07	19.56

Table 2 Maize grain obtained from 9 (nine) farmers' fields

Treatments	Grain yield kg ha^{-1}								
	FRM1	FRM2	FRM3	FRM4	FRM5	FRM6	FRM7	FRM8	FRM9
100% Pc, NPS	5720	7158	8405	7806	6594	7950	6265	6532	6761
75% Pc, NPS	5094	6250	8065	6613	5805	7132	5924	5653	6179
50% Pc, NPS	4731	5783	7080	5757	5290	6354	4720	4979	5231
25% Pc , NPS	4279	5161	6406	5083	4898	5498	3631	4513	4020
100% Pc,DAP	4651	6561	6126	5625	5664	4979	5279	4985	5272
Control	2182	1686	3475	1634	1574	2593	1453	1478	2749
LSD (5%)	581	1271	1321	603	1614	1676	1397	637	1248
CV (%)	7.39	13.46	11.19	6.26	19.55	16.38	17.27	7.63	13.94

Table3: Economic evaluation of P critical based NPS Fertilizer Rates

Treatments	Yield kg/ha	Adjusted 12%	Gross Benefit	Fertilizer	Harvest Shelling	TCV	Net Benefit	MRR
Control	2158	1899	16185	0	540	540	15646	
25% Pc from NPS	4832	4252	36240	3805	1208	5013	31227	3.48
50% Pc from NPS	5547	4881	41603	4262	1387	5649	35954	7.43
75% Pc from NPS	6302	5546	47265	4734	1576	6310	40956	7.57
100% Pc from DAP	4996	4397	37470	5429	1249	6678	30792	D
100% Pc from NPS	7021	6179	52658	5219	1755	6974	45684	7.11

Recommendation and Conclusions

Determination of NPS fertilizer rate based on calibrated phosphorus resulted in significant increase of biomass and grain yields and other important agronomic characters of maize for 100% Pc from NPS. Preferably, shorter days to maturity, high and reasonable marginal rate of return was also recorded for this treatment as well. Hence, 100% Pc from NPS is recommended for maize production in Bako Tibe and Gibu Sayo districts of West Shewa and East Wellega zones of western Oromia. Obviously the technology could be new for farmers used blanket fertilizer recommendations for long time. Indeed, it is important to deal with further awareness creation, demonstration, scaling up, technology transfer and engaging farmers to know nutrient requirement their specific soils. The transfer and scaling up of NPS fertilizer rates based on calibrated phosphorus for maize production in the respective districts require research and extension efforts.

References

Agegnehu Getachew, Amare Ghizaw, and Woldyesus Senebo, 2006. Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. *Europ. J. Agron. 25:202-207.*

Bako Agricultural Research Center (BARC), 2013. Natural Resources Research Directory.

Bray, R.H. and L.T. Kurtz 1945. Determination of total organic carbon and available phosphorus in soils. *Soil Sci.59:39-45.*

CIMMYT, 1988. From agronomic to farmers recommendations. An economic training manual. Completely revised edition. D.F. Mexico.

HailesilassieA., J. Priess, E. Veldkamp, D.Teketay and J.P.Lesschen, 2005. Assesement od soil nutrient depletion and its spatial variability on small holders' mixed farming systems in Ethiopia using partial versus full nutrient balance. *Agric. Ecosyst Env. 108:1-16.*

SAS, 2002. Statistical Analysis System (SAS), users guide, statistics SASA, nc. Cary, Northern Carolina, USA.

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.

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 Gobo Sayo districts of West Shewa and East Wellega zones. 61-66 pp. *In:* Kefyalew Assefa, Tilahun Chibsa, Bikila Mengistu and Tilahun Geleto (eds.) Proceedings of review workshop on completed research activities of natural resource directorate held at Adami Tulu, Oromia, Ethiopia, 07-12 October 2019.

Tesfaye Balemi, Ibrahim Hamza and Abate Bayeh, 2015. Reaction classes and phosphorus and potassium contents of soils in major potato growing areas of West Shewa Zone as determined through different methods. *Int. J. Plant and Soil Sci. 4(6): 521-534.*

Tolera Abera Goshu, Ernest Semu, Tolessa Debele, Dagne Wegary and Haekoo Kim, 2015. Nutrient status of soils from farmers' maize fields in mid altitude areas of western Ethiopia. *Merit Res. J. Agri. Sc. and soil Sc. 3(8): 113-121.*

Tisdale, S.T., W.L.Nelson, J.D.Beaton. 2002, Soil fertility and fertilizers 4th edition, Macmillan publishing company, New York.

Zeleke Gete, Agegnehu Getachew, Dejene Abera and Shahidur Rashid, 2010. Fertilizer and and soil fertility potential in Ethiopia: constraints and opportunities sor enhancing the system. Food Polixy research Institute. Washiington DC, USA. 66p.

Effects of Lime Application Rate on Acidity of Soil on Maize at Nedjo District, West Wollega Zone, Oromia, Ethiopia

Wegene Negese, Tamasgen Mosisa and Gelana Mulugeta Sima
Haro Sebu Agricultural Research Center, Soil Fertility Improvement Team
P.O .Box 10, Haro Sebu, Kellem Wollega, Oromia, Ethiopia.
Corresponding author: Wegene Negese

Abstract

Soil acidity and soil fertility decline are forms of soil degradation adversely affecting sustainable crop production in Ethiopia in general and in Western Oromia in particular. It is one of the major soil chemical constraints which limit agricultural productivity in the mid and highlands of Ethiopia. The productivity of acid soils is limited by the presence of toxic levels of Al and Mn and deficiency of nutrients such as P, Ca, Mg and Mo. Some of the causes of soil acidity could be type of parent material, continuous application of acid forming fertilizers and leaching of base forming materials from soils in high rainfall areas. In the western part of the country such as Assosa and Wollega, soil acidity is a well-known problem that limiting crop productivity. This suggests for requirements of additional amendments to improve soil fertility and productivity. Therefore this study was conducted to evaluate the effects of lime on soil chemical properties and yield and yield attributes of maize in acid soil at Nedjo district, West Wollega, Oromia, Ethiopia during 2016 to 2019 cropping seasons. The experimental treatments consisted of six rates of lime ($CaCO_3$) (0, 1, 1.5, 2, 2.5 and 3 t $ha^{-1}$of lime and arranged in randomized complete block design with three replications. A total of six composited soil samples were also collected from each plot and then composited by replication to obtain one representative sample per treatments for determination of selected soil chemical properties. Maize yield and yield components were measured following standard procedures. The soil analysis results revealed that soil pH increased from 5.41 to 5.85 while exchangeable acidity decreased from 0.128 to 0.026 $cmol_c$ kg^{-1}, which resulted in improvement of others selected soil chemical properties. Likewise, Maximum grain yield was obtained at third year of lime application.

Key words: Soil acidity, Lime application, Maize yield

Introduction

Land degradation and low soil fertility are very common features of large parts of Sub-Saharan Africa (Vesterager *et al*., 2008). Soil degradation is caused by unsustainable land uses and management practices, and climate extremes (FAO, 2015). Approximately 50% of potentially arable land in Africa is currently under cultivation, of which 2000 million ha (23% of agricultural land) are already of low soil fertility, and the soil fertility of the remaining arable lands continues to decline due to mismanagement (FAO, 2003; UNEP, 2004). According to FAO (2015) estimation, about 83% of rural people in Sub-Saharan Africa depend on the land for their livelihoods, but 40% of Africa's land resources are currently degraded. Furthermore, about 33% of soils are moderately to highly degrade due to erosion, nutrient depletion, acidification, salinisation, compaction and chemical pollution (FAO, 2015). The decline in soil fertility is especially severe in tropical soils. Monocropping, nutrient mining, unbalanced nutrient application, removal of crop residues from the fields and inadequate re-supplies of nutrients have contributed to decline in crop yields (Nyamangara, 2001).

Soil degradation is also process that describes human-induced phenomena,which lowers the current and/or future capacity of the soil to support human life'(ISRIC, 1990). The ever-increasing human population is most challenging in developing countries because of soil degradation. For instance, in Sub-Saharan African countries, soil fertility depletion is the fundamental biophysical cause for declining per capital food production (Sanchez *et al.,* 1997). The population of Ethiopia is currently growing at a faster rate and demands an increasing proportion of agricultural products. On the other hand, growth in food production is not in equal footings with population pressure. This challenge will continue as population pressure increases and degradation of soil resources is aggravated. The rate of soil quality degradation depends on land use systems, soil types, topography, and climatic conditions. Several works showed that inappropriate land use aggravates the degradation of soil physicochemical and biological properties (Saikhe *et al*., 1998; He *et al.,* 1999). Maddonni *et al*.(1999) also reported that land use affects basic processes such as erosion, nutrient cycling, leaching and other similar physical and biochemical processes.

Soil acidity is one of the main factors that limit and prevent profitable and sustained agricultural productivity in many parts of the world (Sumner and Noble, 2003). It is estimated that approximately 50% of the worlds' arable soils are acidic and may be subjected to the effect of aluminum (Al) toxicity of which the tropics and subtropics account for 60% of the acid soils in the world (Sumner and Noble, 2003). The extent of soil acidity in Africa is difficult to quantify. Eswaran *et al*.(1997) estimated that 28.8% of the African continent has acid surface soils and 19.6% has sub soil acidity problems. In the tropics the soil acidity is aggravated by leaching or/and continuous removal of basic cations through crop harvest. About 40.9% of the Ethiopian total land is affected by soil acidity. Of this area, about 27.7% are dominated by moderate to weak acid soils (pH in KCl of 4.5-5.5), and around 13.2% are strong acid soils (pH in KCl <4.5 and nearly one-third have aluminum toxicity problem (Mesfin, 2007). In humid and sub-humid area of Ethiopia, vast areas of land in the western, south-western, north-western and even the central highlands of the country which receive high rainfall are thought to be affected by soil acidity (Mesfin, 2007) attributed to various factors including continuous cropping (in many areas mono-cropping) without the use of the required inputs, the problem of soil acidity in the country is apparently increasing recently both in area coverage and severity of the problem. The major soil forming factors and management practices giving rise to the increase in soil acidity in the country involve climatic factors such as RF/temp, topographic factors, soil parent materials, intensive mono-cropping and lack of technological inputs in the peasant sector to mitigate the problem (Mesfin, 1998).

Soil acidity affects the growth of crops because acidic soil contain toxic levels of aluminum and manganese and characterized by deficiency of essential plant nutrients such as P,N, K, Ca, Mg, and Mo (Wang *et al.,* 2006). At pH below five (5), aluminum is soluble in water and becomes the domination in the soil solution. In acid soils, excess aluminum primarily injures the root apex and inhibits root elongation (Sivaguru and Horst, 1998). The poor root growth leads to reduced water and nutrient uptake, and consequently crops grown on acid soils are confronted with poor nutrients and water availability. The negative effect of high levels of soluble aluminum on plants growth has been widely reported (Matsumoto, 2002; Langer *et al*., 2009). The net effect of which is reduced growth and yield of crops (Wang *et al*., 2006).

According to Angaw and Desta (1988), soil acidity severely affects the yields of many crops in the western, south-western and southern parts of high rainfall areas of Ethiopia. In these areas, the annual rainfall exceeds the potential evaporation. Leaching of cations in soils is most responsible for increased soil acidity (Schlede, 1989). The infertility of soils in these areas is attributed to excessive concentration of aluminum (Al), iron (Fe) or manganese (Mn) on one hand; and to deficiencies of calcium (Ca), magnesium (Mg), phosphorus (P) and molybdenum (Mo) on the other (Mesfin, 1996). Soil fertility and its potential productivity are closely related to soil physicochemical properties, among which soil reaction (soil pH) has the greatest share. As to the nature and deleterious effects of soil acidity, Al, Fe, and Mn become more soluble and hence their concentration on the exchange complex increases (Mesfin, 1996). The chemistry of these toxic elements in the soil is complex and affects the nutrient balance in soil solution. Among the soil chemical properties, available soil phosphorus, cation exchange capacity (CEC), exchangeable bases and available micronutrients are the most affected by soil acidity. To increase crop yields and reduce crop production risks associated with soil acidity, there is need to focus on soil amendment practices that target efficiency of nutrients use in soils especially phosphorus that is made unavailable chemically for plant uptake.

The The agronomic and management options to correct acid soils, improve nutrient use efficiency, and increase crop production on acidic soils include liming, application of organic materials, appropriate crop rotations and use of plant species and varieties tolerant to Al and Mn toxicity (Sanchez and Salinas, 1981). Liming acid soils is a general practice to reduce aluminum toxicity and is considered to many scientists as the first step towards providing a balanced nutrition for cultivated plants (Brown and Stecker, 2003; Essington, 2004). Liming is an important and commonly used acid soil management practices these days. Because, many small scale farmers of the country depend on this soil for their day today livelihoods its management has been given due attention. However, lime is obtained not for free as well as large quantity may be needed for highly affected areas and its transportation is difficult. The required amount of lime and frequency of lime application may be a solution.

Objectives:

- To evaluate the optimum application rate of lime and lime effect on soil and maize yield and
- To give proper frequency of lime application time in the study area.

Materials and Methods

Description of Study Area

The study was conducted on maize for four consecutive cropping seasons from 2016-2019 on acid soils of Gidda Kumbi FTC, Nedjo District, West Wollega Zone, Oromia Regional State, Ethiopia. It is found at about 516 km away from Addis Ababa and 70 km from Gimbi town. The district is geographically lies at an latitude of 9.5^o N and longitude 35.5^o E and an altitude that ranges from 1600 to 2200 meters above sea level (masl). The district is generally characterized by flat to undulated land with hills and valleys. The major rainy seasons in the district are from April-November. The average annual temperature range is 23^0c, the maximum and minimum temperature are 28 and 18 ^{0}c,, respectively. The annual rainfall is from 1350- 1600 mm, and also bimodal rainfall distribution. The predominant soil type in southwest and western Ethiopia in general and the study area in particular is Nitisols according to (FAO, 2001) soil classification system. Nitisols are highly weathered soils in the warm and humid areas of the west and southwestern Ethiopia (Mesfin, 1998).

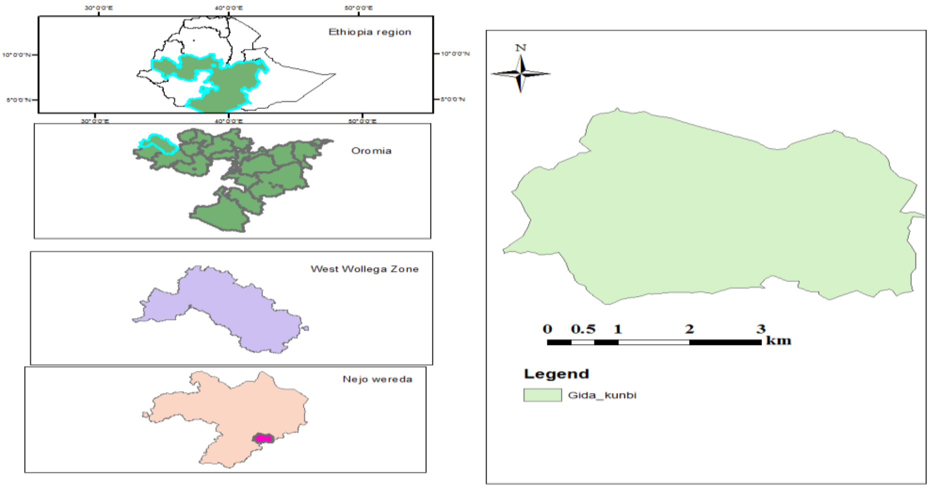


Figure 1: Map of Study Area

Treatment and Experimental Design

Following experimental site selection, initial soil sample was taken and analyzed at initial year of the experiment. Based on soil laboratory analyzed results, the lime rates were arranged as 0,1, 1.5, 2, 2.5, 3 t/ha. The treatments were handled by randomized complete block design (RCBD) with three replications. During year one (2016), lime rates were measured based on plot size & applied to each plot as per treatment arrangement before time of planting except for control plots. The field area and treatment plots within the area was marked during on and off season by making bund between them to avoid soil movement from block to block leave a minimum of 0.5 m gap between plots plot disturbance. During off-season, maize straw was maintained over the all plot to minimize the effect of mono cropping uniformly. During second, third and fourth years, maize was planted on previous plots without lime applications to observe the effects of the lime rates applied once in the first year (2016). The plots were stayed permanent for the duration of the experiments to observe effects of the lime over years. After harvest soil samples was collected from a depth of (0-20cm) and analyzed for the following parameters such as exchangeable acidity (H^+ and Al^{3+}), soil pH, avail. P, CEC, Exchangeable bases (Ca, and Mg,) following standard procedures. Maize (variety, BH -661) which is the main staple crop in the area were used as the test crop. The agronomic recommendation of inorganic fertilizer rate for maize in the area was used. Major agronomic data was collected and analyzed. The agronomic data obtained in this study were entered into excel spread sheet and then subjected to analysis of variance (ANOVA) using SAS software version 9.2 (SAS Institute, 2002). The Duncan's multiple range test (DMRT) at P≤ 0.05 were employed to separate treatment means where significant treatment differences existed.

Table 1: Selected soil chemical properties before planting

pH (H_2O 1:2.5)	Exch. Acidity (Al^{3+} +H^+) Meq/100 gm soil)	LR(t/ha)	Av. P(ppm)
5.29	1.28	2	4.65

pH = Soil reaction; LR = Lime requirement; Av. P = Available phosphorous

Result and discussion

Effects of lime application on selected soil chemical properties

Application of lime influenced some soil chemical properties. Lime applied at different rate increased pH. However, exchangeable acidity was decreased with lime application. This indicates that application of lime at different rates increased the soil nutrient availability such as soil pH, available phosphorous and maize yield (Table 2).

Table 2: Effect of lime application on some soil chemical properties at year one

ime ates(t/ha)	H $H_2O)$	vail. P ppm)	x.Acidity meq/100g oil)	x.Ca meq/100g oil)	x.Mg meq/100g oil)	EC meq/100g oil
ontrol	.41	.862	.128	3.338	.470	1.286
t/ha	.34	.011	.026	4.005	.536	.617
.5 t/ha	.50	.931	.026	4.019	.009	.962
t/ha	.66	.937	.026	4.686	.944	.448
.5 t/ha	.80	.458	.128	5.220	.278	1.502
t/ha	.85	.920	.026	5.836	0.023	1.822

pH = Soil reaction; Ex.Acidity = Exhangeable acidity; Av. P = Available phosphorous; Ca= Calcium; Mg = Magnesium; CEC = Cation exchange capacity

Effects of lime application on maize yield and yield components

Maize grain yield was affected by lime rates and year (Table 3). The highest grain yield recorded on third year (2018) of lime effects (Figure 1). Grain yield increments showed direct relationship with the soil pH values and inverse relationship with exchangeable acidity. Application of lime might contributed in releasing some amount of fixed P to be available for the crop. The results are in agreement with Achalu *et al.* (2012a) who reported increased crop yield in response to the application of lime, which might be attributed to the neutralization of Al^{3+}, supply of Ca^{2+} and increasing availability of some plant nutrients like P. This also indicates that deficiency of nutrient cannot be replaced by lime. As a result in acidic soils which are deficient in nutrient, it is important to apply fertilizer together with lime to increase production

Table 3. Effect of lime application on some maize yield and yield components

Lime rates(t/ha)	Year											
	2016			2017			2018			2019		
	PH(cm)	TSW(g)	GY(kg/ha	PH(cm)	TSW(g)	GY(kg/ha)	PH(cm)	TSW(g)	GY(kg/ha)	PH(cm)	TSW(g)	GY(kg/ha)
0	197.27b	401.67bc	4568.5c	272.1b	416.23	3900b	247.26	388	4098.2b	239.44b	334	2716.7b
1	213.07ba	447ba	5907.4ba	288.26b	422.37	5944ba	279.13a	379.33	6657.4a	278.07a	427.3	4566.7ba
1.5	212.33ba	443.33ba	5446.3bc	303.03a	443.67	7867a	289.73a	389.33	8248.2a	276.67a	418.3	5243.3a
2	237.2a	461.67a	6079.6ba	305.93a	429.27	7548a	296.13a	402	8106.3a	272.09a	484	5760a
2.5	190.33b	388.33c	6564.8a	293a	429.27	6889a	280.0a	403.33	7677.8a	290.73a	448	6306.7a
3	211.87ba	416.67ba	5971.7ba	294.2a	443.20	6096ba	288.53a	265.33	7350a	281.73a	40.67	5373.3a
CV(%)	7.32	6.46	8.49	3.41	7.41	20.87	4.12	12.89	16.17	5.729	18.29	22.76
LSD (0.05%)	28.04	50.19	889.54	18.19	58.14	2420.3	21.04	90.97	2067.2	28.465	141.5	2066.6

PH= Plant height; TSW = Thousand seed weight; GY = Grain yield

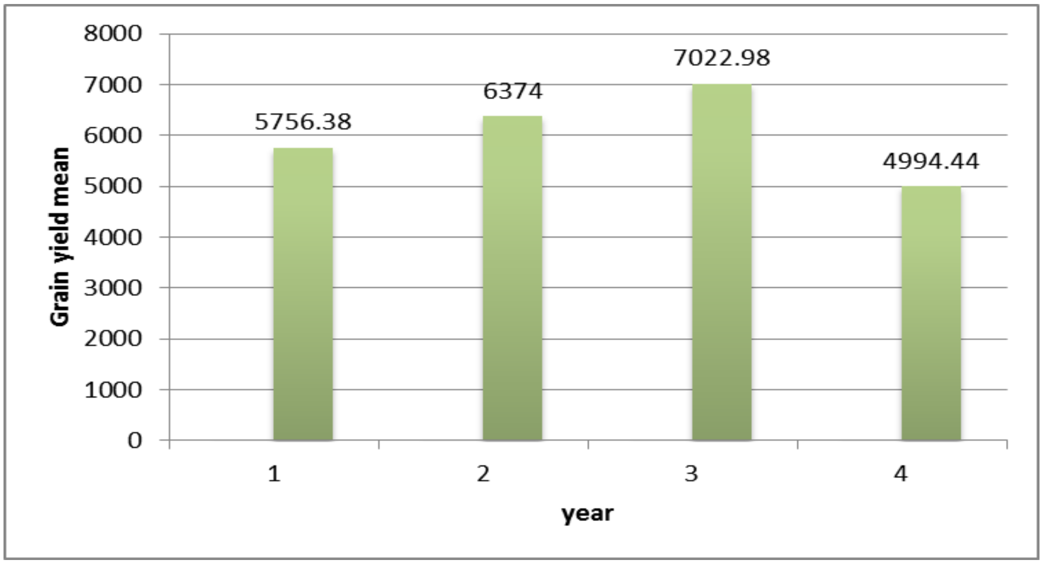


Figure 1. Effects of lime application over years

Conclusion and Recommendation

Soil acidity is a one of the major yield-limiting factor for crop production worldwide in general and Ethiopia in particular. Therefore this experiment was conducted to evaluate the optimum application rate of lime and lime effect on soil and maize yield and to give proper frequency of lime application time in the study area. The experimental treatments consisted of six rates of lime ($CaCO_3$) (0, 1, 1.5, 2, 2.5 and 3 t $ha^{-1}$of lime and arranged in randomized complete block design with three replications.

Results showed that lime applied at different rate based on the rate of exchangeable acidity combined with mineral fertilizer mostly improved selected soil properties and maize yields. lime applied once in the first year (2016) could be used for three consecutive years. Therefore, resource poor farmers could use and cultivate maize at study area as well as similar areas. These preliminary results recommend the use of lime frequency alongside with mineral fertilizers to increase maize yields. More research needs to be carried out for more locations to assess the consistence of these findings in areas where soil acidity is critical bottleneck to crop production.

References

Eswaran, H, Reich, P and Beinroth, F. 1997. Global distribution of soil with acidity. P159-164. In: Moriz, A.C., Furlani, A.M.C, Schaffert, R.E., Fageria, N.K., Rosalem, C.A., Contarella, H. (Eds). Plant-soil interactions at low ph Brazilian soil sci. society. Campinas/ Vicosa, Brazil

Fox, R.H. and Kamprath, E.J. 1970. Phosphate sorption isotherms for evaluating the phosphate requirements of soil. soil sci. soc. Am. Proc.34:902-907

Hue, N,V. 1992. Correcting soil acidity of a highly weathered ultisol with chicken manure and sewage sludge. comm. soil. sci. plant anal.23:241-264

Kamprath, E.J.1984. Crop response to lime on soils in the tropics p 341-348. In Adams F. (ed). Soil acidity and liming. ASA, Madison, Wisconsis.

Mesfin Abebe. 1998. Nature and management of Ethiopian soils. A.U.A. Ethiopia

Pearson, R.W. 1975. Soil acidity and liming in the humid tropics. Int. Agri. Bull. 30. Cornell Univ. New York

Schlede, H. 1989. Distribution of acid soils and liming materials in Ethiopia. Ethiopian Institute of Geological Survey. Report Note 326

Takow, J., Chase, R.G. and Hossner, L.R. 1991. Acid soil profiles of the semi arid and sub humid tropics in central and West Africa. P. 313-330. In: Plant- soil interactions at low pH. Kluwer Academic publishers

Preparation and Characterization of Vermi Compost Made from different Sources of Material at Fadis Agricultural Research center

Robe Elema wako
Oromia Agricultural Research Institute, Fedis Agricultural Research Centre,
P.O. Box 904, Harar, Ethiopia
**Corresponding Authors E-mail:robeelma663 @gmail.com*

Abstract

The study was conducted during 2020, in Fedis district of East Hararghe Zone, Oromia National Regional State; Ethiopia.. The objectives of the experiments were to prepare and characterize nutrient composition of different vermi –compost and to identify vermi- compost of different sources that contains high composition of essential nutrients. Different source of materials like Wheat, Sorghum, Soybean residues, Haricot bean, Maize stock, chick pea, Finger millet, Groundnut residues, Rhodes grass and Bracharia were used to prepare vermi compost. Substrates of 1:2 ratio were filled based on the volume of worm bin/plastic bag. Pit method was used for vermicomposting preparation. It was identified that the Ec of vermicomposting under this study was falls in the ranges of 3.22 dS m^{-}*-6.7 dS* m^{-1}*this alkalinity range is suitable for growth of most crops. Out of all analyzed vermicomposting, the highest TN (3.21%) was recorded from vermicomposting made from ground nut, soybean (2.93%) and haricot bean (2.73%) substrates/residues respectively. And the lowest total nitrogen was obtained from vermi compost made from maize stock (1.15%). The analyzed result revealed that, the highest available phosphorus (787.75 P mg/kg vermicomposting) was obtained from vermicomposting made from groundnut and haricot bean and followed by wheat (715.93P mg/kg) respectively. And the lowest value was recorded from the vermi compost made from groundnut substrate/residues (406.88P mg/kg. Vermicomposting made from chick pea, haricot bean and soya bean was rich in all essential nutrients and quality compost in other chemical parameters followed by finger millet and groundnut compost. Farmers should use vermi compost made from chick pea to reverse nutrient deficiency problem of soil.*

Key words: Vermicomposting, materials, characterization

Introduction

Environmental degradation is a major threat challenging the worldwide, and the extensive use of chemical fertilizers contributes largely to the deterioration of the environment, loss of soil fertility, less agricultural productivity, soil degradation and Climate change due to a number of reasons. For instance production of degradable organic waste and its safe disposal influence on soil fertility (Inbar, *et al.*, 1993). Meanwhile the transformation of degraded soils by protecting topsoil and sustainability of productive soils is a major concern at the international level. Ecological Agriculture", which is by definition different from "Organic Farming" that was focused mainly on production of chemical free foods. Ecological agriculture emphasizes on total protection of food, farm & human ecosystems while improving soil fertility & development of secondary source of income for the farmers (Devi 1998). Heavy use of agrochemicals since the "green revolution" of the 1960s boosted food productivity at the cost of environment & society. It killed the beneficial soil organisms & destroyed their natural fertility, impaired the power of 'biological resistance' in crops making them more susceptible to pests & diseases. Chemically grown foods have adversely affected human health. The scientific community all over the world is desperately looking for an economically viable, socially safe & environmentally sustainable alternative to the agrochemicals is vermicompost (US Board of Agriculture, 1980).

Vermicomposting is defined as a bio-oxidative process in which detritions earthworms interact with microorganisms and other fauna within the decomposer community, thus accelerating the stabilization of organic matter (OM) and greatly modifying its physical and biochemical properties of soil (Domínguez, 2004). Epigeic earthworms are natural colonizers of organic waste and the following properties make them suitable for vermicomposting: high rates of consumption, digestion and assimilation of OM; tolerance to a wide range of environmental factors; short life cycle, high reproductive rates, and endurance and resistance to handling (Domínguez and Edwards, 2010). Few epigeic earthworms display all these characteristics, and only four species have been extensively used in vermicomposting facilities. *Eisenia andrei*, Redworms *[Eisenia fetida]*, *Perionyx excavatus* and *Eudrilus eugeniae* (Domínguez and Edwards, 2010). Red worms are local endemic species therefore appears to be appropriate for vermicomposting; as such species are well adapted to different environmental conditions.

Vermicomposting differs from composting in several ways (Gandhi 1997). A mesophilic process utilizes microorganisms and earthworms that are active at 10°C to 32°C (not ambient temperature but temperature within the pile of moist organic material). The process is faster than composting; because the material passes through the earthworm gut that diverse biological processes involved in the recycling and recovery of waste components is of increasing importance for more sustainable production and consumption systems. In short, earthworms through a type of biological alchemy are capable of transforming garbage into “gold” (Vermi Co, 2001 and Tara Crescent, 2003).

According to Ruz-Jerez and Tillman, R (1992) literature description, Vermicompost is an excellent soil additive made up of digested compost and Worm castings are much higher in nutrients and microbial life; therefore, considered as a higher value product and Worm castings product contain up to 5 times the plant available nutrients found in average potting soil mixes. Chemical analysis of the castings was conducted and found that it contains 5 times the available nitrogen, 7 times the available potash and 1.5 times more calcium than that found in 15 cm of good top soil. In addition, the nutrient life is up to 6 times more in comparison to the other types of compost.

The combination of nutrients and microbial organisms are essential for growing healthy and productive plants. Vermicompost not only adds microbial organisms and nutrients that have long lasting residual effects, it also modulates structure to the existing soil, increases water retention capacity. Vermicompost may also have significant effects on the soil physical properties. According to Ferreras, *et al.*, (2006) and Marinari, *et al.*, (2000). Similarly, in description of Gopinath,et al., (2008) a significant decrease in soil bulk density and a significant increase in soil pH and total organic carbon after application of vermicomposting.

The earthworm population is about 8-10 times higher in uncultivated area so most of North-East and central part of Ethiopia suffer under soil degradation and loss of nutrients due to various reasons (Cultural beliefs and remains of early extension, Land tenure systems, Scarcity of organic materials, Fuel needs, High population densities and deforestation, Climate change, Inadequate use of synthetic fertilizers, Low availability of organic soil amendments and fertilizers etc). Thus Eastern Hararghe zone fail under low productivity situation. So in order to reverse such problem, organic amendments are necessary in which economic and ecological productive while also maintaining soil health and fertility by application of nature with nature for sustainable production system. Therefore, the study was proposed with the objectives of evaluating the quality and nutrient content of vermicompost made from different substrate and to identify and recommend the quality compost.

Objectives

- To prepare and characterize nutrient composition of vermi -compost made from different materials

Materal and Methods

Description of the Study Area

The study was conducted at Fedis district of East Hararghe Zone, Oromia Regional State; Ethiopia. It is located in the eastern part of the country at 550 km from Addis Ababa the capital city of Ethiopia and 24 km from Harar town in the southern direction(Figure 1).The geographical location of the district is 8^0 22' 0" and 9^0 14' 0" N and 42^0 62' 0" and 42^0 19' 0" E. The altitude of the area ranges from 500-2100 meter above sea level (FWANRDO, 2017/18).

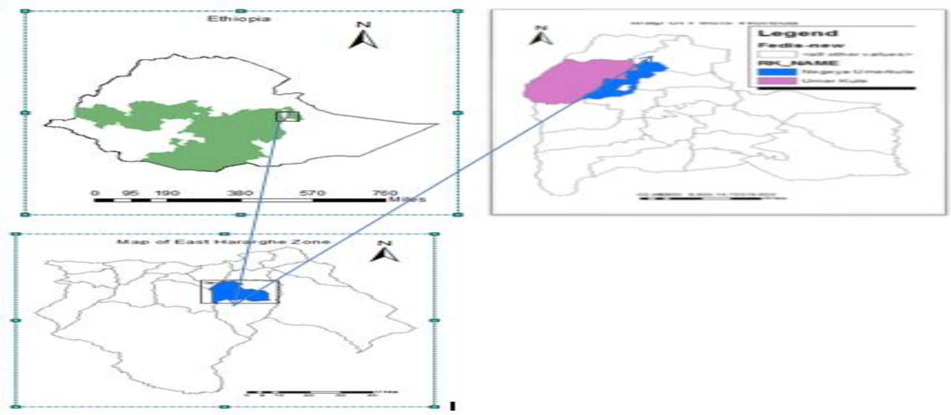


Figure 3**:** Location map of the study area

Topography and Land Use

Topographic feature of the study area is 70% plain area, 28% plateau and 2% mountain or hill. Cultivable land/cropland (21.02%), pasture (2.80%), forest (11.2%) ,grass land(38.01%) ,communal land (10.5%) and remaining (14.04%) is considered as mountainous, valley and otherwise unusable (FWANRDO,2017/18).

Climate and Rainfall

According to FWANRDO (2017/18) report, the district has two basic agro-climatic conditions, namely Midland (39%), and lowland (61%). The district experience mean annual maximum and minimum rainfall, mean annual maximum and minimum temperature in the area were 850 to 650mm, 30.4°C, and 10.0°C, respectively (fig.2). Accordingly, the district has a bimodal rainfall distribution pattern with heavy rains from April to June and long and erratic rains from August to October.

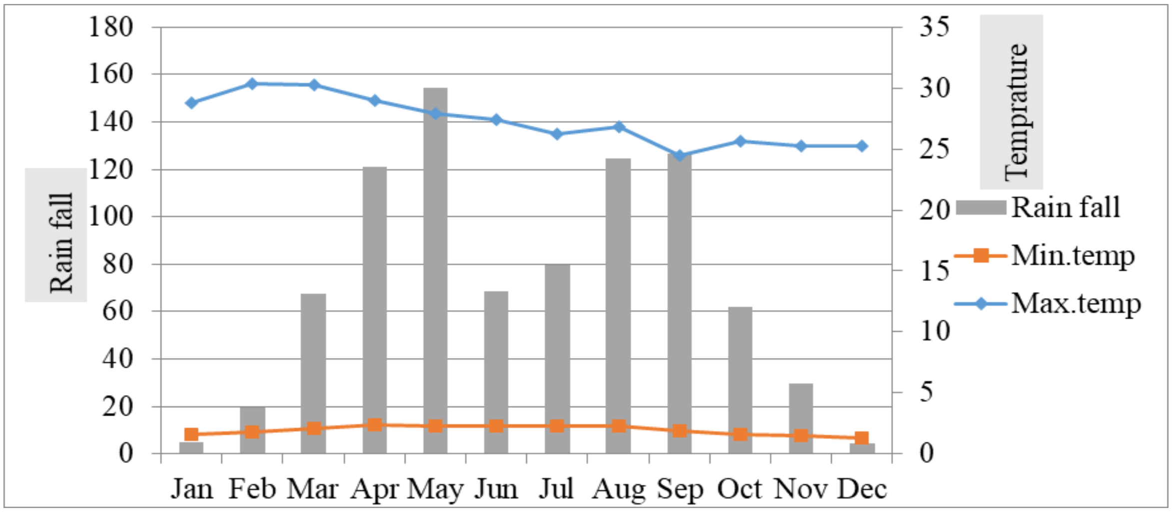


Figure 4: Rain fall and Temperature data of Fadis District, 2018 GC.

Design of Vermiculture

The worm bin where the worms live and produce compost, shallow boxes were constructed in the house with the dimension of 0.5m of height, 0.6m of width and 1m of length from concrete cement.

Experimental Materials and vermicompost preparation

The treatments consist of eleven types of feed materials were used as a treatment which undergone partial fermentation for 20 days with the combination ratio of crop residue to animal manure 1: 2 on weight basis. Vermicompost was prepared from different substrate materials which was locally available such as wheat straw, maize stock, sorghum, haricot bean, soya bean, finger millet, chick pea, ground nut, and grasses like, elephant grass, Rhodes grass and Brach aria. A red worm (*Eisenia fetida*) was used as a decomposer. The collected substrates were chopped and added to the worm bin. Animal manure was added to all substrates in equal amount. However, plastic bag were used to apply the treatments/substrates. After all substrates chopped, they added to plastic bags and mixed with animal manure as a starter and sprayed with water to maintain optimum moisture for worms. The mixture of substrates was prepared from equal amount (3kg) and finally mixed with animal manures. Substrates of 3kg kg mixed with 2kg of animal manure were filled based on the volume of worm bin/plastic bag. After moisture optimized 180 earthworms was counted and added to every treatment. Bottom face of plastic bag was drilled to avoid water logging. Water was sprayed, as it needed to keep the optimum moisture status of the worm feed.

Parameters and Test Methods

1. The pH and electrical conductivity (EC) was analyzed with the - potentiometry (1:2.5) methods. And organic carbon was analyzed by - Walkley and Black
2. Total nitrogen - Kjeldahal method
3. Available phosphorus by - Olsen method.
4. Cation exchange capacity (CEC) and Exchangeable cations K was analyzed by - neutral 1M ammonium acetate, neutral 1M ammonium acetate (by flame photometer) respectively. And
5. Available K by - Morgan methods.

Treatment arrangements are as follows:

1. Wheat straw
2. Sorghum residue
3. Soybean residue
4. Haricot bean residue
5. Maize stock
6. Chick pea residue
7. Finger millet residue
8. Groundnut residues.
9. Rhodes grass
10. Brach aria
11. Elephant grass

Vermicompost Analysis Result and discussion

The collected vermicompost samples were analyzed for soil reaction (pH (H_2O), Electrical conductivity, Available phosphorus and potassium, total nitrogen, exchangeable bases, CEC.

Electrical Conductivity (EC) in ds/m, Total nitrogen % and soil pH

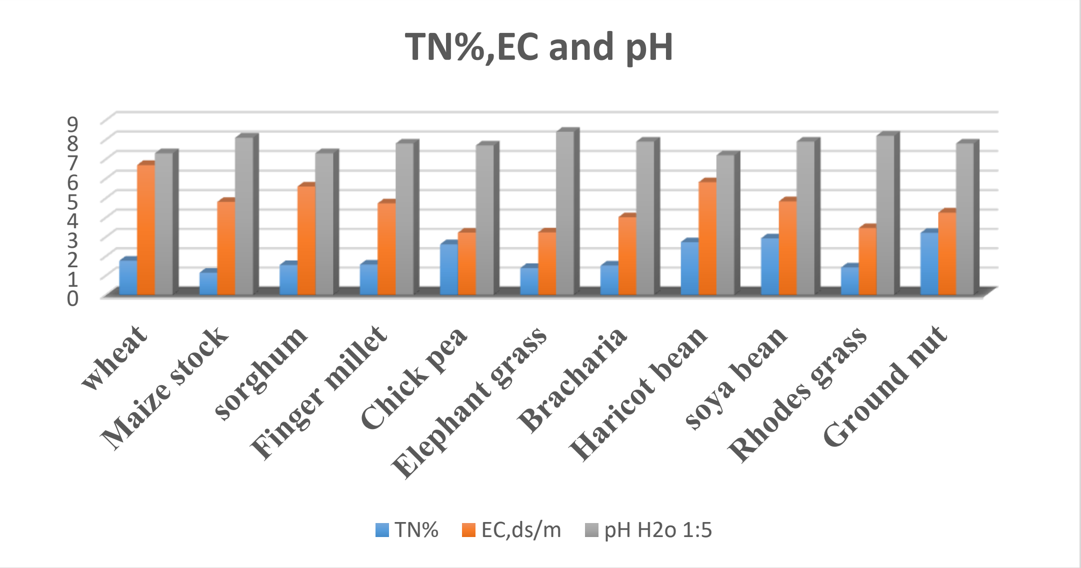


Fig1. Electrical Conductivity (EC) in ds/m, Total nitrogen and soil pH

To identify the salinity hazard of a vermicompost, electrical conductivity (EC) measurements was conducted. The salt content can thus be estimated from the electrical conductivity of a vermicompost suspension in distilled water. The highest (6.7ds/m) and lowest (3.22ds/m) EC was obtained from wheat and chick pea straw respectively. According to Soil salinity status in terms of ECe (Richards, 1954), vermicompost made from Sorghum and mixed straw showed slightly saline while from haricot bean, grasses, teff and maize straw showed moderately saline. The increased EC during the period of the vermicomposting processes is in consistence with that of earlier workers (Kaviraj and S. Sharma, 2003; C. D. Jadia and M. H. Fulekar, 2008), which was probably due to the degradation of organic matter releasing minerals such as exchangeable Ca, Mg, K, and P in the available forms, that is, in the form of cations in the vermicompost (L. Guoxue *et al.,* 2001; C. Tognetti et al., 2005).

Soil Reaction of Vermicompost (pH)

The highest pH value was obtained from vermi compost of elephant grass followed by Rhodes grass, and soybean maize stock pH (8.4, 8.2, 8.1) respectively (table 1). On the other hand, the lowest pH value was measured from vermi compost made from Haricot bean substrates followed by wheat and sorghum substrate/residues pH value (7.2, 7.3 and 7.3) respectively. This finding is in line with, the study of Tekalign (1991), pH ranged from moderately to strongly alkaline. Similarly Rogelio *et al.*, 2007; George W. Dickerson, 1994; EP. Jouquet *et al.,* 2013 obtained similar results in which the pH status of vermicompost was ranged from 6.8-8.41. Also Padmavathiamma, *et al*., 2008 reported that the pH of vermicompost ranged from neutral to alkaline. A pH greater than 8.5 and electrical conductivity of 8 dS m^{-1} were found to harm earthworms. Alkalinity and salinity are harmful to both earthworms and microorganism (Santamaria, Romero *et al*., 2001).

Total Nitrogen of vermi compost

The highest (3.21%) total nitrogen was recorded from vermicompost made from ground nut soybean (2.93%) and haricot bean (2.62%) substrates/residues respectively. And the lowest total nitrogen was obtained from vermi compost made from maize stock (1.15%) Elephant grass (1.39%) and Rhodes grass (1.42%) respectively.

The variation of TN among the vermicompost attributed to the substrates digested by worms. Because different types of straw were contains different nitrogen contents. Similarly S.Kalantari *et al.* (2009) was reported that, 3.50% of the total nitrogen was recorded from vermicomost. George W. Dickerson (1994) also obtain the total nitrogen recorded in vermicompost was 1.94%. The current result also in line with the finding of Tekalign (1991) rating of total nitrogen in a soil, the TN in a vermicompost made from all substrates was high (>0.25%) and significantly greater than in a soil. Therefore vermicompost application to soil could increase total nitrogen. Other studies (Tigist *et al.,* 2017) revealed application of vermicompost could increase total nitrogen in a soil. Vermi compost made from groundnut, soybean and haricot bean was rich in TN% than the rest compost made from other materials.

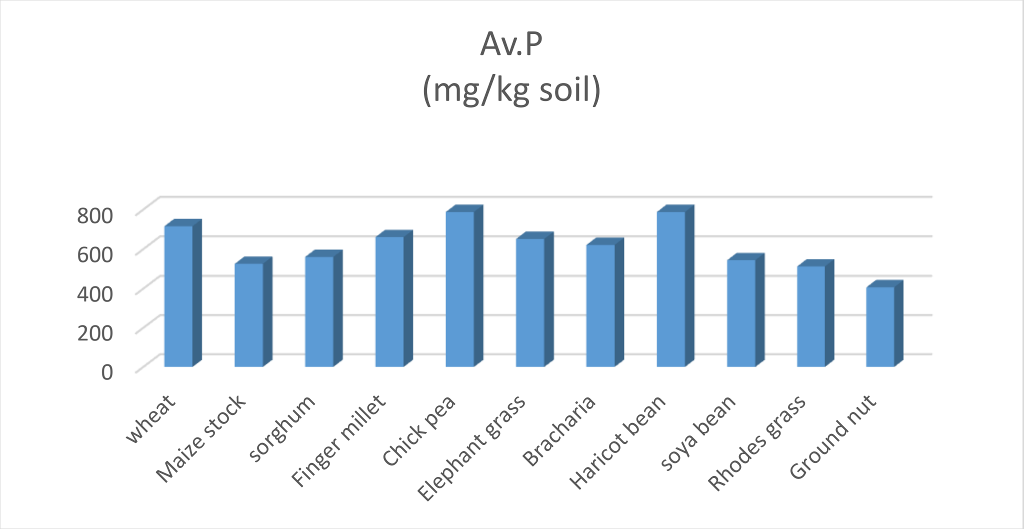


Figure 2. Available phosphorus

The analyzed result revealed that, the highest available phosphorus (787.75 mg/kgV. Compost) and 787.75mg/kg Vermicompost) was measured/obtained from vermicompost made groundnut and haricot bean and followed by wheat (715.93) respectively. And the lowest value was recorded from the vermi compost made from groundnut substrate/residues (406.88 mg/kgV. Compost) followed by Rhodes grass (512.44 mg/kg vermi Compost) and maize stock (525.5 mg/ of kg vermi compost) respectively. Their variation might be attributed to source substrates. The enhanced P level in vermicompost suggests phosphorous mineralization during the process. The worms during vermicomposting converted the insoluble P into soluble forms with the help of P-solubilizing microorganisms through phosphatases present in the gut, making it more available to plants (Padmavathiamma *et al*., 2008, Ghosh et al., 1999). When the values compared to soil, available phosphorous from vermicompost made from all substrates was very high. The current study was in agreement with the findings of Nagavallemma KP *et al.* (2004) reported that the available phosphorous in vermicompost was which was thus, application of vermicompost could increase P content of the soil if the soil is deficient with phosphorus.

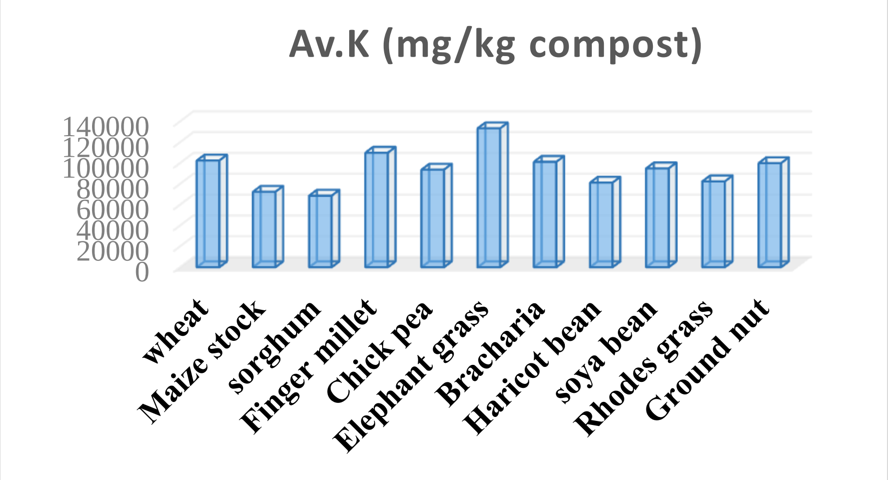


Figure 3. Available potassium (K)

The highest available potassium was measured from vermi compost made from Elephant grass (**133500** K2Omg/kg Vermi.Compost) substrates followed by finger millet (110000 K2Omg/kg Vermicompost), wheat and groundnut respectively. And the lowest available potassium was obtained from sorghum treatments/residues followed by maize stock treatments. According to previously, conducted study the available potassium in vermicompost was stated by S.Kalantari *et al.* (2009) that was 950.5K2Omg/kg and C. Tognettia *et al* 2013 backyard vermicompost total potassium content was 8.2g/kg means 8200mg/kg that contradict with S. Kalantari. The study conducted by C. Tognettia *et al.* (2013) and George W. Dickerson (1994) has close relation to this study which was 0.7% and 8.3g/kg when converted to similar unit. In addition to this the result obtained in this study is available in range stated by Nagavallemma KP *et al.* (2004) which was 1500-7300mg/kg of vermicompost.

Cation exchange capacity (CEC) of vermi compost

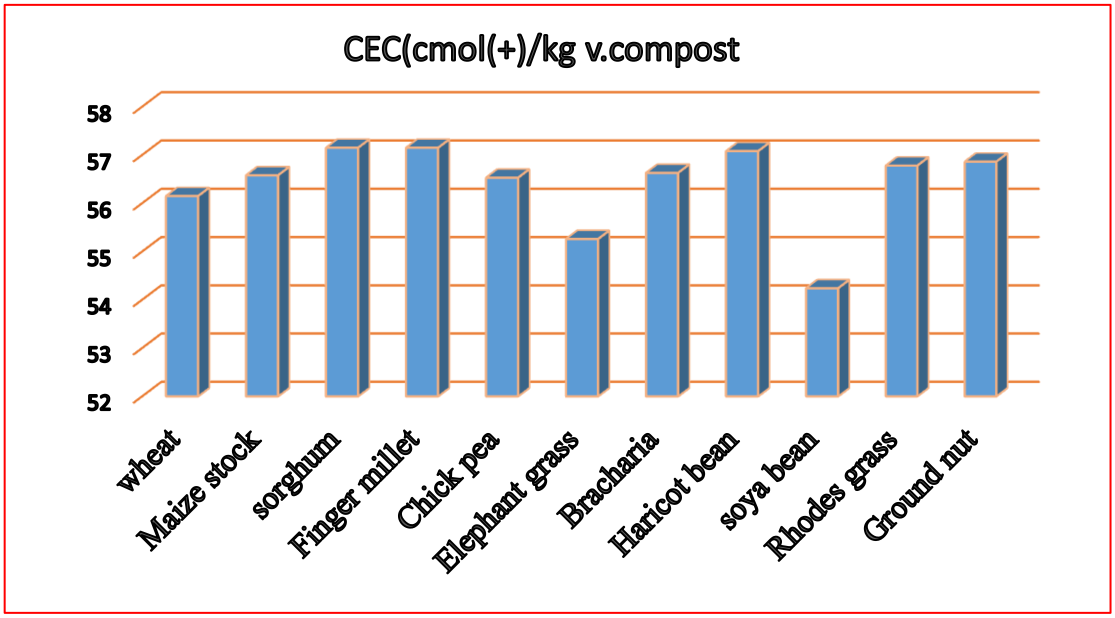


Fig 4. The CEC of different vermi compost

Among the treatments, vermi compost of sorghum and finger millet contain the highest CEC (57.15 cmol+ kg/vermi compost compost) and followed by haricot bean CEC 57.08(cmol(+)/kg compost. But, the lowest CEC (54.24 cmol+kg-1) obtained from Elephant grass followed by Elephant grass (55.26 cmol+kg/ vermicomposting). However, as per CEC rating indicated by Hazelton and Murphy (2007), the CEC of vermicomposting made from all substrates was rated to very high status. This result concedes with the study conducted by EP. Jouquet *et al.* (2013) which was 57.8 cmol+ kg^{-1} of CEC. Cation exchange capacity is the capacity of the soil to hold and exchange cations. If the CEC of a soil is low, the soil is infertile soil. Therefore application of vermicompost made from all substrates could increase CEC content of the soil in areas where soil with low CEC.

Conclusion and recommendation

Vermicompost made from different source of material have different nutrient contents based on source of feed for vermi worm. Highest and lowest pH value was obtained from vermi compost of elephant grass and Haricot bean substrates 8.4, 7.2 respectively. The pH value of this study was in range of 7.2-8.4 which falls under slight alkalinity range and suitable for any plant growth. This study revealed that, electrical conductivity of vermi compost made from different source of materials was in a ranges of 3.22 ds/m-6.7ds/m (fig1).The salt content can thus be estimated from the electrical conductivity of a vermicompost suspension in distilled water. The highest (6.7ds/m) and lowest (3.22ds/m) EC was obtained from wheat and chick pea straw respectively. Vermi compost made from groundnut, soybean and haricot bean was rich in TN% than the rest compost made from other materials respectively. The highest (3.21%) total nitrogen was recorded from vermicompost made from ground nut, followed by soybean (2.93%) haricot bean (2.73%) and chick pea (2.62%) substrates/residues respectively. And the lowest total nitrogen was obtained from maize stock (1.15%) Elephant grass (1.39%) and Rhodes grass (1.42%) respectively. TN% of current study was in the ranges of 1.15%-3.21%. Available phosphorus of vermi compost from different source of material was falls in the range of 406.88p mg/kgV. Compost-787.75 P mg/kg Compost. The highest available potassium was measured from vermi compost made from Elephant grass (**133500** Kmg/kg Compost) substrates followed by finger millet (110000 K2Omg/kg Compost), wheat and groundnut respectively. And the lowest available potassium was obtained from sorghum treatments/residues followed by maize stock treatments. The CEC of all vermicompost under this study was in a ranges of (54.24 cmol+kg-vermi compost of sorghum (57.15cmol+ kg/Vermicompost) -finger millet CEC (57.15 cmol+ kg/Compost). Out of all, vermi compost made from chick pea and haricot bean was rich in essential nutrients and parameters followed by finger millet and Brach aria compost.Accrding to this study, vermi compost made from chick pea was the most quality than the rest in terms of all quality parameters followed vermi compost of Haricot bean. Since, vermicompost prepared from Chick pea substrates showed highest nutrient contents for all parameters, farmers and any dwellers of organic farming can use it followed by , vermicompost made from haricot bean and soybean. Around 1.2t/ha of vermicompost can replaces the commercial fertilizer (blanket recomendetion.)Therefore, vermicompost could be used as source of macro nutrient organic fertilizers for soils deficient with macro nutrients.

Therefore, farmers should use vermi compost instead of heavy commercial fertilizers. Research center, NGO's and office of agriculture should create awareness on preparation and utilization of vermi compost. Vermicompost made from chick pea substrates showed highest nutrient contents as compared with the rest vermicompost and with top soil, so farmers should use vermi compost made from chick pea, haricot bean and soya bean based on the availability of composting materials. Besides, for further confidence verification of this result, should made under field condition.

Reference.

Domínguez, J., Edwards, C.A. and S. Subler. 1997. A comparison of vermicomposting and composting. *BioCycle*, 4: 57-59.

Eastman, B.R., Kane, P.N., Edwards, C.A., Trytek, L., Guandi, B., Stermenr, A.L. and Mobley, J.R. 2001. The effectiveness of vermiculture in human pathogen reduction for USEPA biosolids Stabilization. *Compost Sci. Util.*, 1:38-49.

Edwards, C.A. 1995. Historical overview of vermicomposting. *BioCycle*, 6:56-58.

FAO (Food and Agriculture Organization), 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16, Rome, Italy.

Ferreras, L., Gomez, E., Toresani, S., Firpo, I. and Ro- tondo, R. 2006. Effect of organic amendments on some physical, chemical and biological properties in a horti- cultural soil. *Bioresource Technology*, **97**, 635-640. doi:10.1016/j.biortech.2005.03.018].

Gopinath, K.A., Supradip, S., Mina, B.L., Pande, H., Kundu, S. and Gupta, H.S. 2008. Influence of organic amendments on growth, yield and quality of wheat and on soil properties during transition to organic production. *Nutrient Cycling in Agroecosystems*, 82, 51-60. doi:10.1007/s10705-008-9168-0.

Gandhi, M., Sanghwan, V., Kapoor, K.K. and Dilbaghi, N. 1997. *Journal of Environment and Ecology*. . 15(2): 432-434.

Gandhi, M., Sangwan, V., Kapoor, K.K. and Dilbaghi, N. 1997. Composting of household wastes with and without earthworms. *Environment and Ecology*. 15, 432-434.

Golueke, C.G. 1991. Understanding the process. *In*: Staff of BioCycle (Eds.). *The BioCycle Guide to the Art and Science of Composting*. The JG Press, Inc., Emmaus, Pennsylvania, USA. pp. 14-27.

Inbar, Y., Chen, Y., Hadar, Y. 1993**.** *Journal of Environmental Quality*. 22: 875-863.

Li, K. and Li, P.Z. 2010. Earthworms helping economy, improving ecology and protecting health. In: Sinha, R.K. *et. al.*, Eds. Special Issue on 'Vermiculture Technology', *International Journal of Environmental Engineering*, In-derscience Pub.

Marinari, S., Masciandaro, G., Ceccanti, B. and Grego, S. 2000. Influence of organic and mineral fertilizers on soil biological and physical properties. *Bioresource Tech- nology*, **72**, 9-17. doi:10.1016/S0960-8524(99)00094-2].

Munroe, G. 2007. Manual of On-farm Vermicomposting and Vermiculture. Publication of Organic Agriculture Centre of Canada, Nova Scotia.

Pajon, S. 2007. The Worms Turn-Argentina. Intermediate Technology Development Group. Case Study Series 4; Quoted in Munroe. http://www.tve.org./ho/doc.cfm?aid. Accessed on Feb. 20, 2014.

Padmavathiamma, P. K., Li, L. Y., & Kumari, U. R. (2008). An experimental study of vermi-biowaste composting for agricultural soil improvement. [10.1016/j.biortech.2007.04.028]. *Bioresource Technology, 99*, 1672-1681.

Parkin, T.B. and Berry, E.C. 1994 Nitrogen transformations associated with earth worm casts. *Soil Biology and Biochemistry*, **26**, 1233-1238. doi:10.1016/0038-0717(94)90148-1

Patil, B.B. 1993. Soil and Organic Farming. *Proceeding of the Training Program on* '*Organic Agriculture*, Insti-tute of Natural and Organic Agriculture, Pune.

Reinecke, A., Viljoen, S.V. and Saayman, R. 1992. The suitability of *Eudrilus eugenie*, *Perionyx excavatus* and *Eisenia fetida* (Oligochaeta) for vermicomposting in southern Africa in terms of their temperature require- ments. *Soil Biology and Biochemistry*, **24**, 1295-1307 doi:10.1016/0038-0717(92)90109-B].

Ruz-Jerez, B.E., Ball, P.R. and Tillman, R.W. 1992 Laboratory assessment of nutrient release from a pasture soil receiving grass or clover residues, in the presence or absence of *Lumbricus rubellus* or *Eisenia fetida*. *Soil Bi- ology and Biochemistry*, 24, 1529-1534. doi:10.1016/0038-0717(92)90145-N).

Santamaria-Romero-S; Ferrera-Cerrato-R; Almaraz-Suarez-JJ; Galvis-Spinola-A; Barois-Boullard-I. 2001. Dynamics and relationships among microorganisms, C-organicand N-total during composting and vermicomposting. Agrociencia-Montecillo,
35 (4), 377-384.

Satchel, J.E. and Martin, K. 1984. Phosphatase activity in earthworm feces. *Journal of Soil Biology and Bio-chemistry*, 16(2), 191-194.

Subler, S., Edwards, C. and Metzger, J. 1998. Comparing vermicomposts and composts. *BioCycle*, 7: 63-66.

Suhane, R. K. 2007. Vermicompost. Publication of Ra-jendra Agriculture University, Pusa, Bihar, India, 88. info@kvksmp.org Accessed on Feb. 20, 2014.

Suhane, R. K. 2007. Vermicompost. Publication of Ra-jendra Agriculture University, Pusa, Bihar, India, 88. info@kvksmp.org Accessed on Feb. 20, 2014.

Tara, C. 2003. Vermicomposting. Development Alternatives (DA) sustainable livelihoods. http://www.dainet.org/livelihoods/default.htm. Accessed on Feb. 12, 2014.

Tiwari, S.C., Tiwari, B.K. and Mishra, R.R. 1989. Mi-crobial populations, enzyme activities and nitrogen, phosphorus, potassium enrichment in earthworm casts and in surrounding soil of a pineapple plantation. *Journal of Biological Fertility of Soils*, 8(1): 178-182.

Tognetti, C., Laos, F., Mazzarino, M.J. & Hernández, M.T. 2005. Composting vs. Vermicomposting: A vermicomposting, In: C.A. Edwards, N.Q. Arancon, R.L. Sherman (Eds.), *Vermiculture.*

Tomati, V., Grappelli, A. and Galli, E. 1985. Fertility factors in earthworm humus. *Proceedings of Interna-tional Symposium on ‘Agriculture and Environment*: *Prospects in Earthworm Farming*, Rome, 49-56.

Tomati, V., Grappelli, A. and Galli, E. 1995. The Hor-mone like Effect of Earthworm Casts on Plant Growth. *Biology and Fertility of Soils*, 5(4): 288-294.

US Board of Agriculture. 1980. Report and recommendations on organic farming—Case studies of 69 organic farmers in USA. Publication of US Board of Agriculture.

USEPA. 1993. Standards for the use or disposal of sewage sludge. Federal Register 58: 9248 - 9415. Washington, D.C.

Vermi Co. 2001 Vermicomposting technology for waste management and agriculture: An executive summary. Vermi Co., Grants Pass. http://www.vermico.com/summary.htm. Accessed on Feb. 15, 2014.

Webster, K. 2007. Compost as part of a vineyard salinity remediation strategy. 3rd National Compost Research and Development Forum Organized by COMPOST Aus-tralia, Murdoch University, Perth. www.compostforsoils. com.au Accessed on Feb. 20, 2014.

Whalen, J.K., Parmelee, W.R., McCartnney, A.D. and Vanarsdale, J.L. 1999. Movement of nitrogen (n) from decomposing earthworm tissue to soil microbial and ni-trogen pools. *Soil Biology and Biochemistry*, 31(4): 487-492. www.tandfonline.com/page/terms-and-conditions. Accessed on April 15, 2014. Domínguez, 2004.

Atiyeh, R.M., Subler, S., Edwards, C.A., Bachman, G., Metzger, J.D. and Shuster, W. 2000. Effectsof Vermi-composts and Composts on Plant Growth in Horticultural Container Media and Soil. *Pedobiologia*, 44(5): 579-590.

Berhanu Debele. 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Canellas. L.P., Olivares, F.L., Okorokova, A.L. and Fa-canha, R.A. 2002. Humic Acids Isolated from Earth-worm Compost Enhance Root Elongation, Lateral Root Emergence, and Plasma Membrane H+ - ATPase Activity in Maize Roots. *Journal of Plant Physiology*, 130(4), 1951-1957.

Chaoui, H.I., Zibilske, L.M. and Ohno, T. 2003. Effects of earth worms casts and compost on soil microbial activ-ity and plant nutrient availability. *Soil Biology and Bio-chemistry*, 35(2): 295-302.

Devi, D., Agarwal, S.K. and Dayal, D. *Indian Journal of Agronomy*. 1998. 43(3): 469-473.

Domínguez, J., Edwards, C.A. 2010. Biology and ecology of earthworm species used for vermicomposting, In: C.A. Edwards, N.Q. Arancon, R.L. Sherman (Eds.), *Vermiculture Technology: Earthworms, Organic Waste and Environmental Management*, CRC Press, Boca Raton, Florida, pp. 25-37.

Evaluation of Multipurpose Tree Species Integrated with Moisture Conservation Structures on Degraded Area Closure at Babille District, East Hararghe, Ethiopia

Musa Abdella, Bira Cheneke and Robe Elema
Oromia Agricultural Research Institute, Fedis Agricultural Research Center, P.O.Box 904, Harar, Ethiopia.
Corresponding author: musaabdellah345@gmail.com

Abstract

*Tree planting on degraded lands plays a key role in rehabilitation processes through afforestation and/or reforestation. Moisture conservation structures have significant impact on seedling survivals at degraded lands. The objectives of this study were to evaluate the effect of moisture conservation structures on seedling survival and growth performance of trees. Field experiments were conducted for four rainy seasons (2016-2020) years in the degraded area at Babile District East Hararghe Zone, Ethiopia. The experimental design followed was the split plot design. The moisture conservation structures as main plot used were Soil level bund, Trenches and as control normal pit. The tree species grown as subplots were Moringa oleifera, Milia azedarach, Grevillea robusta, Luceana leucocephala and Sesbanea sesban. The five tree species were planted by using seedlings. The tree survival rate, plant height, diameter at barest height and root collar diameter of the five tree species were measured every three months in year after transplanting. The analysis of variance revealed that moisture conservation structures were significant ($P \leq 0.05$) in survival rate, plant height, a*nd root collar diameter but not in tree diameter at barest height. Plant height and root collar diameter grown in the soil level bund were significantly higher than those grown in moisture conservation structures, trench and normal pit. Survival rate and diameter at barest height grown in the trenches were significantly higher than those grown in moisture conservation structures, soil bund and normal pit. The survival rate of tree seedling was higher when grown in trenches than normal pit (control). The mean survival of seedlings planted in trench (65%) is higher than in normal pit (57%) and soil bund (56%) four years after establishment. Similarly, species planted in soil bund recorded relatively higher in diameter and height size followed by trench structure. Based on the experiments, it is concluded that moisture conservation structures particularly the trenches was considered as the most appropriate planting pit. Therefore, further demonstration of trenches tree planting should be carried out.*

Keywords: Land degradation, moisture conservation, multipurpose trees, survival rate

Introduction

Land degradation is the major problem due to a number of factors in Ethiopia. One of the importance causes is the removal of forest and vegetation cover as result of increased population leading to high demand for forest products land for expanding agricultural activities (Demel *et al*.,2001).In Ethiopia, rapid deforestation caused by an escalating demand for fuel wood and expansion of land for agriculture has brought an ever increasing pressure on native woodland species(Mebrate *et al*.,2004).Consequently these areas are now characterized by loss of soil fertility and soil erosion problem. If no remedial action is taken, this will cause severe impact on agricultural productivity leading to energy poverty and environmental degradation. Eastern Ethiopia particularly, highland areas of East Hararghe are well known by vegetation cover and most of the surrounding area is covered by forests comprising a rich mixture of woody species (Abebe *et al*., 2000). In spite of the importance of forest ecosystem to the livelihoods of the people in the area, the forest is dwindling from time to time due to high exploitation of woody and non-woody products.

Forest plantation on degraded rangelands can play a key role in harmonizing long-term forest ecosystem rehabilitation process (Sharma and Sunderraj,2005).The process of forest ecosystem rehabilitation can be accelerated through human intervention like afforestation or/and reforestation with moisture stress tolerant tree seedling transplanting from nursery sites in dry land areas. Afforestation is the common approach of restoration on degraded land and biodiversity conservation, and eco-environmental improvement (Cao, 2011). However, the vegetation establishment on degraded land is constrained by many factors in which the insufficient moisture availability listed as the top constraint (Li *et al*., 2008).The conserved and stored rainwater supports flourishing plant growth and tree seedling survivals in dry areas (Suleman *et al.*, 1995). These could be possible through in-situ rainwater harvesting devices which have hydrological functions as it modifies water flows and facilitating plant growth and improve vegetation cover (Singh *et al*., 2010). This was enhanced by reducing velocity of runoff and the water is collected behind the structures. However, it only could be realized through well designed and improved soil and water conservation and harvesting devices (Gowing *et al.*, 1999).

Trees are known to bring about changes in edaphic, micro-climatic, floral, faunal and other components of the eco-system through bio-recycling of mineral elements, environmental modifications (including thermal and moisture regime) and changes in floral and faunal composition (Shukla, 2009). Multipurpose tree species play a considerable role in addressing such multi-faceted demands in mixed crop-livestock production systems (Betre *et al*., 2000). They have the ability to fit into farming systems to use as a source of manure, soil conservation, fuel wood, farm implements and others like shade and shelter (Kahsay *et al*., 2001). Before introducing any species to a given agro ecology, there is always a need for a well conducted field trial for matching of the species to a particular site (Mebrate *et al*., 2004). The most reliable information is based on trial planting in the proposed plantation area. The first trial should be species screening trial that will test the survival and early growth performance of the species in one to three years (Eldridge *et al*., 1994).

In the Babille District, particularly, moisture stress of the study area, farmers and government have been planting many tree seedlings species year after year but the survival of those seedlings are poor and variable as the area is mainly affected by moisture stress and soil fertility problems. The moisture conservation integrated with planted seedling survival has so far scarcely been investigated. Therefore, the objectives of this study were to select the best performing multipurpose tree species integrated with suitable planting methods of moisture conservation structures in moisture stress area of Babille District and for the same agro ecologies.

Materials and methods

Description of the study site

The study was conducted in Babille District Eastern Oromia, Ethiopia (Fig. 2). It is located in eastern part of Ethiopia, about 593 km east of Addis Ababa, and 37 km east of Harar town. The altitude of the study area ranges from 950 to 2000 meters above sea level and latitude 9°21'-9.35° North and longitude 42°48'-42.8° east. The climate of the district is predominantly agro-pastoral type (low land) which is characterized by high temperature and the mean annual rainfall in the area ranges from 600 to 700 mm (Fig. 1). The area characterized by very short rainy season of 3 to 4 months (single quarter of the year), with all its intermittent condition and erratic distribution. The mean annual temperature was 24^{o}C. The soil experimental site is clay loam in texture and medium in organic matter content and high in exchangeable potassium. The pH of the soil (7.94) is in the optimum range for growth of most plants.

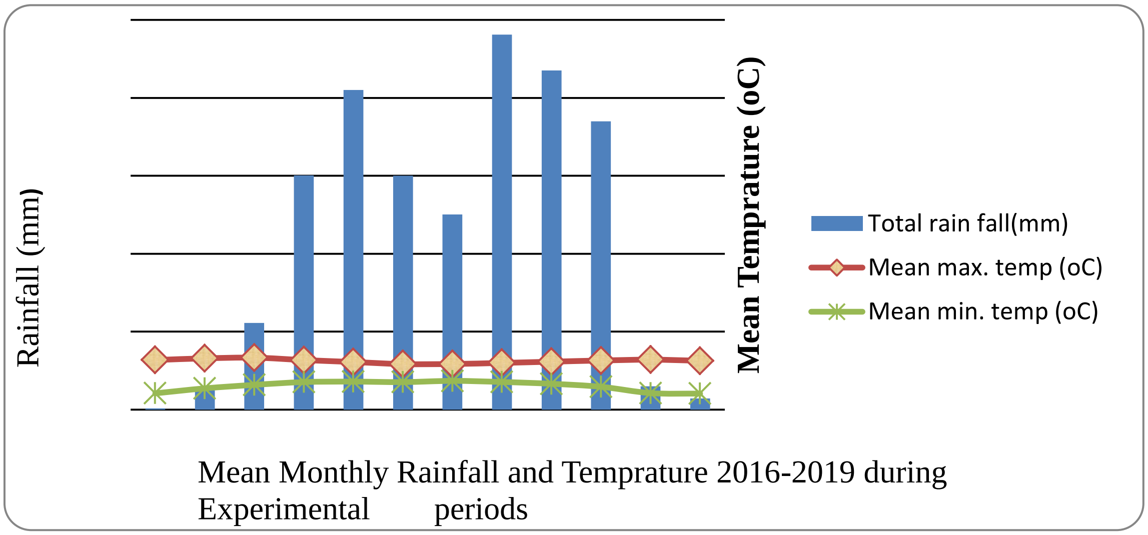


Figure 1: Mean monthly rainfall and temperature during experimental period based on meteorological data nearest to the study area.

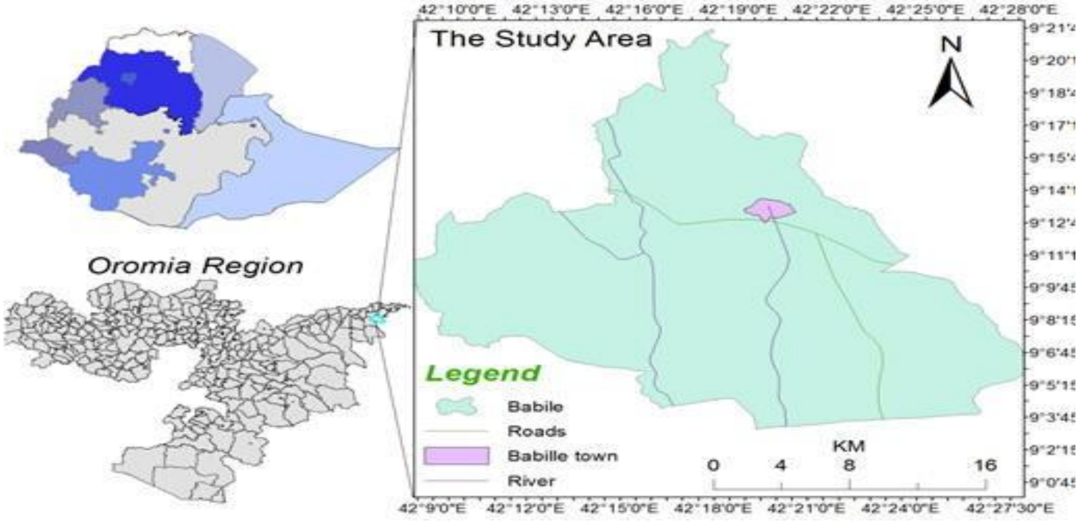


Figure 2: Map representing the study area (Babille district)

Nursery and field management

Seeds of the five tree species were obtained from Central Ethiopian Environment and Forestry Research Center. Seedlings were raised in polythene tubes of size 10cm diameter and 15cm length at kile nursery site. The out planting site was cleared of bushes and the selected moisture conservation structures (planting methods) were prepared before planting the selected tree seedlings.

Species Selection

Five tree species were carefully selected for experimentation based on the preference of the community's multi-criteria decision approach taking into account indicators of ecological suitability, socio-economical functions, protection functions and root characteristics. Accordingly, *Grevillea robusta, Moringa oleifera, Melia azedarach, Sesbania sesban nd Leucaena leucocephala trees were selected for this study.*

Moisture conserving structures Selection (planting methods)

Three moisture conservation structures were selected for this study based on familiar in the rehabilitation of degraded land were adopted in Ethiopia. Accordingly, Trenches, Soil level bund and Normal Pit were selected with the specification and design of the structures.

Treatments and Experimental Design

The experiment was laid out in factorial in a split-plot design with three replications. The experiment had two factors; moisture conservation (planting methods) and tree species were involved. The moisture conservation structures factor had three levels; trenches (size: 1.5 length x 0.4 m x width x 0.5 m depth), soil level bund (size: 3 m length x 1.1 width x 0.5 m depth) and normal pit (size: 40 cm depth x 40 cm width). The normal pit was used as control. The tree species factors involved five tree species; *Grevillea robusta, Moringa oleifera, Melia azedarach, Sesbania sesban and Leucaena leucocephala trees* were involved. Design: 3*5 factorial arrangements of treatments(three planting methods * five tree species =15 treatments) in a split-plot design replicated three times, 3*5*3 =45 total treatment combinations (plots) were used in this study. Moisture conservation structures were the main plot factor in this experimental design, and tree species were randomly assigned (subplot) to one of three conservation structures (planting methods). The tree species were planted by using seedlings.

Data Collection

Data for survival rate count, plant height, diameter at breast height (DBH) and Root collar diameter were collected as growth variables of tree species.

Statistical Analysis

Data were analyzed using Gens tat software. Analysis of variance (ANOVA) was made to determine the significance of variation between the tree species and moisture conservation structures. Least Significant Difference (LSD) Test was used to compare mean values of various growth variables in each treatment at 5% level of significance.

Results and Discussion

Survival rate of tree species

The Analysis of variance revealed that the main effect of moisture conservation structures was not significant ($P>0.05$) at 3 and 4 years of age (Table 1). But highly significant variations among species in survival rate, the interaction of tree species survival with planting methods was found to be significant ($P<0.05$), in all, trench, level soil bund and normal pit at all four years of experimental period at the study area. But survival rate ($P<0.05$) variations among the tree species was recorded highly significant during the experimental year. *Moringa oliefera, Melia azedarach* and *Sesbania sesban* showed good performance among tested tree species while; *Leucaena leucocephala* and *Grevillea robusta* performs least among those tested species. The survival trend for five tree species showed declining trend for the assessment year .Although there was no significant difference in survival rate (%) of trees with respect to different planting methods during the assessment year, the mean survival of seedlings planted in trench (65%) is higher than in normal pit (55%) and soil bund (54%) after four years of establishment. This finding supports Abraham (2014) who reported that the effects of moisture stress account for more than 87.9% in the death of tree seedlings. In similar ways, the moisture stress commonly limits growth, survival and distribution of tree seedlings (Warren *et al.*,2005).These reduced soil moisture conditions may be viewed as a significant barrier to artificial reforestation (Padilla and Pugnaire, 2007).

Plant height

The Analysis of variance revealed that the main effect of moisture conservation structures was not significant ($P>0.05$) at all years of age (Table 2). The significant variations among structures with tree species in plant height was significant ($P<0.05$), at all four years of experiment at the study area. *Moringa oliefera, Melia azedarach, Sesbania sesban* and *Leucaena leucocephala* showed good performance in height tested tree species while; *Grevillea robusta* performs least among those tested species. The plant height trend for tree species showed increment trend for the assessment year. Plant height is increased due to moisture conservation measures at different intervals of growth within years. Soil level bund, recorded significantly highest plant height (1.22 m) followed Trench (1.20 m) and the lowest is recorded in control (NP) with (1.18 m). Trees species at *Moringa oleifera* had a significant effect on plant height (1.5 m) over the other treatments. The interaction effect was not significant ($P>0.05$) at first year among combinations of soil moisture conservation measures and tree species interactions. The interaction of soil level bund with *Moringa oleifera*, trench with *Moringa oleifera* and normal pit with *Moringa oleifera* had exhibited significant effects on plant height at all the intervals. The finding is in line with the previously stated that the major limitations of plant height are soil nutrients and moisture availability within the rooting zone and a planted seedling's ability to access it (Grossnickle, 2005).

Table 1. Effect of moisture structures on survival rate of tree species within different years intervals

Treatments	**Mean survival rate of trees (%) at different year**			
Min plots(Structures)	Year 1	Year 2	Year 3	Year 4
Trench (TR)	63.13^{a}	58.48^{a}	57.13	56.73
Normal Pit (NP)	57.93^{b}	53.00^{b}	58.28	56.40
Soil level bund (SLB)	57.13^{b}	52.40^{b}	57.93	56.00
LSD(0.05)	2.312	2.286	NS	NS
CV	4.48	2.42	4.88	4.42
Sub plots(Trees)				
Moringa oleifera	67.89^{a}	64.11^{a}	63.56^{a}	60.12^{a}
Melia azedarach	64.78^{ab}	60.11^{a}	58.56^{b}	57.07^{ab}
Sesbania sesban	62.89^{bc}	62.67^{a}	61.78^{a}	53.44^{c}
Leuceana leucocephala	59.87^{c}	59.89^{b}	54.33^{b}	56.56^{bc}
Grevillea robusta	42.11^{d}	42.11^{c}	42.00^{c}	37.11^{d}
LSD(0.05)	3.49	3.83	4.06	3.40
CV	7.89	7.44	7.06	5.97
Interactions (Structures x Trees species)				
TR with *M.olefera*	75.00^{a}	58.33^{abc}	65.03^{a}	57.01^{a}
TR with *M.azadarach*	75.01^{a}	55.33^{bcd}	60.33^{ab}	55.00^{bc}
NP with *M. oliefera*	64.67^{b}	62.33^{ab}	58.33^{bc}	55.67^{a}
TR with *L.leucocephala*	64.67^{b}	63.67^{a}	58.33^{bc}	57.00 ^{a}
SLB with *M.oliefera*	64.33^{b}	63.00^{a}	57.00^{bcd}	55.67^{a}
NP with *L.leucocephala*	62.67b^{c}	61.67^{ab}	56.33^{bcd}	55.67^{bc}
TR with *S.sesban*	62.33^{bcd}	61.33^{abc}	55.33^{bcd}	48.67^{c}
SLB with *M.azadarach*	62.00^{bcd}	61.33^{abc}	56.33^{cd}	54.67^{b}
NP with *S.sesban*	60.67^{bcd}	55.67^{cd}	53.67^{cd}	49.33^{bc}
SLB with *L.leucocephala*	60.67^{bcd}	60.00^{abcd}	55.33^{bcd}	54.33^{bc}
NP with *M.azadarach*	57.00^{cd}	55.33^{d}	54.67^{cd}	51.03^{bc}
SLB with *S.sesban*	56.67^{d}	55.33^{cd}	51.33^{d}	48.67^{bc}
NP with *G.robusta*	44.33^{e}	47.00^{ef}	37.33e	35.33^{c}
SLB with *G.robusta*	42.33^{e}	40.33^{fg}	35.67e	32.67^{c}
TR with *G.robusta*	39.67^{e}	38.67^{g}	32.33e	35.67^{c}
LSD(0.05)	6.04	7.66	5.89	6.22
CV	9.58	7.67	5.61	12.87

NB: TRs, trench (TRs), Soil level bund (SLB) and normal pit (NPs) as control. Similar letter in the row shows not significant difference and different letters indicate significance differences, NS: not significant difference between moisture structures at P≤0.05

Table 2 .Effect of moisture structures on height of tree species within different year intervals

Treatments	**Mean Plant height (m) at different year**			
Min plots(Structures)	Year 1	Year 2	Year 3	Year 4
Soil level bund (SLB)	0.72	1.02	1.48	1.62
Trenches (TR)	0.70	1.01	1.53	1.59
Normal Pit (NP)	0.70	0.99	1.47	1.57
LSD(0.05)	NS	NS	NS	NS
CV	9.37	7.49	13.64	7.01
Sub plots(Trees)				
Moringa oleifera	0.91^{a}	1.32^{a}	1.80^{a}	1.89^{a}
Melia azedarach	0.75^{b}	1.02^{b}	1.48^{b}	1.58^{b}
Sesbania sesban	0.67^{bc}	0.98^{b}	1.43^{b}	1.53^{bc}
Leuceana leucocephala	0.64^{c}	0.92^{bc}	1.41^{b}	1.51^{bc}
Grevillea robusta	0.55^{d}	0.82^{c}	1.33^{b}	1.43^{c}
LSD(0.05)	0.08	0.12	0.1	0.14
CV	10.91	10.73	8.28	7.86
Interactions (Structures x Trees species)				
SLB with *M.oliefera*	0.9	1.37^{a}	1.85^{a}	1.63^{b}
TR with *M.oliefera*	0.96	1.36^{a}	1.79^{a}	1.88^{a}
NP with *M.oliefera*	0.88	1.23^{a}	1.77^{ab}	1.52^{bcd}
NP with *M.azedarach*	0.77	1.03^{b}	1.51^{bc}	1.92^{a}
SLB with *M.azedarach*	0.75	1.02^{b}	1.49^{cd}	1.91^{a}
TR with *S.sesban*	0.71	1.00^{bc}	1.48^{cd}	1.48^{bcd}
NP with *S.sesban*	0.67	0.96^{bc}	1.45^{cd}	1.53^{bcd}
SLB with *S.sesban*	0.67	0.96^{bc}	1.44^{cd}	1.54^{bcd}
TR with *M.azedarach*	0.77	0.95^{bc}	1.44^{cd}	1.52^{bcd}
TR with *L.leucocephala*	0.63	0.94^{bc}	1.43^{cd}	1.54^{bcd}
SLB with *L.leucocephala*	0.66	0.92^{bc}	1.43^{cd}	1.51^{bcd}
NP with *L.leucocephala*	0.62	0.91^{bc}	1.41^{cd}	1.61^{bc}
NP with *G.robusta*	0.57	0.85^{bc}	1.39^{cd}	1.34^{d}
SLB with *G.robusta*	0.55	0.83^{c}	1.28^{cd}	1.59^{bcd}
TR with *G.robusta*	0.52	0.81^{c}	1.24^{d}	1.37^{cd}
LSD(0.05)	NS	0.23	0.24	0.10
CV	12.87	12.87	10.22	9.30

Note*: TRs: trench (TRs), Soil level bund (SLB) and normal pit (NPs) as control. Similar letter in the row shows not significant difference and different letters indicate significance differences, NS: not significant difference between moisture structures at P≤0.05*

Root Collar Diameter

The Analysis of variance revealed that the main effect was not significant (P>0.05) in RCD (cm) with respect to moisture conservation structures during the first and second years (Table 3). But it was significant (P<0.05) variations among structures in RCD at third and fourth years of experiment at the study area. *Moringa oliefera and Melia azedarach* showed good performance in RCD tested tree species while; *Sesbania sesban*, *Leucaena leucocephala* and *Grevillea robusta* performs least among those tested species. Collar diameter increased significantly with moisture conservation measures at different intervals of growth. The RCD is increased due to moisture conservation measures at different intervals of growth within years. Normal pit, recorded significantly highest RCD (3.04cm) followed soil level bund (2.92cm), and the lowest is recorded in trench (2.76 cm). Trees species at *Moringa oleifera* had a significant effect on RCD (3.75 cm) over the other tree species. The interaction effect was not significant (P>0.05) at fourth year among combinations of soil moisture conservation measures and tree species interactions. The interaction of soil level bund with *Moringa oleifera*, trench with *Moringa oleifera* and normal pit with *Moringa oleifera* had exhibited significant effects on RCD at all the years of study. The finding is in line with the previously stated that the planted seedling's ability to access it (Grossnickle et al, 2005).

Diameter at Breast Height (DBH)

The Analysis of variance revealed that the main effect was not significant (P>0.05) in DBH (cm) with respect to moisture conservation structures during the second and third years (Table 4). But it was significant (P<0.05) variations among structures in DBH at fourth year of experiment. *Moringa oliefera and Melia azedarach* showed good performance in DBH tested tree species while; *Sesbania sesban*, *Leucaena leucocephala* and *Grevillea robusta* performs least among those tested species at all years of experiment. DBH increased significantly with moisture conservation measures at different intervals of growth within years. Trench struvture, recorded significantly highest DBH (2.20cm) followed soil level bund (1.95cm), and the lowest is recorded in normal pit (1.86 cm). Trees species at *Moringa oleifera* had a significant effect on DBH (2.46 cm) followed by *Melia azedarach* (1.95cm) over the other tree species. The interaction effect was not significant (P>0.05) at all assessment year among combinations of soil moisture conservation measures and tree species interactions. The interaction of soil level bund with *Moringa oleifera* and normal pit with *Moringa oleifera* had exhibited significant effects on DBH at three years of study.

Table 3 .Effect of moisture structures on RCD (cm) of tree species within different year intervals

Treatments	**Mean of RCD(cm) at different year interval**			
Min plots(Structures)	Year 1	Year 2	Year 3	Year 4
Soil level bund (SLB)	1.82	1.92	2.09^{a}	5.83^{a}
Trenches (TR)	1.72	2.08	1.95^{ab}	5.28^{a}
Normal Pit (NP)	1.68	1.93	1.94^{b}	6.59^{b}
LSD(0.05)	NS	NS	0.145	3.067
CV	8.92	8.26	22.68	51.71
Sub plots(Trees)				
Moringa oleifera	2.34^{a}	2.57^{a}	2.57^{a}	7.52^{a}
Melia azedarach	1.73^{b}	1.97^{b}	1.97^{b}	5.61^{b}
Sesbania sesban	1.63^{bc}	1.79^{bc}	1.80^{bc}	5.82^{b}
Leuceana leucocephala	1.53^{c}	1.80^{bc}	1.88^{bc}	4.64^{b}
Grevillea robusta	1.47^{c}	1.72^{c}	1.75^{c}	5.91^{b}
LSD(0.05)	0.188	0.216	0.187	1.84
CV	10.56	10.95	15.73	20.94
Interactions (Structures x Trees species)				
SLB with *M.oliefera*	2.37^{a}	2.60^{ab}	2.60^{a}	4.82
TR with *M.oliefera*	2.45^{a}	2.69^{a}	2.42^{a}	6.91
NP with *M oliefera*	2.20^{a}	2.42^{ab}	2.68^{a}	6.5
NP with *M.azadarach*	1.55^{c}	1.84^{c}	1.84^{c}	6.73
SLB with *M.azadarach*	1.55^{c}	1.78^{c}	1.67^{c}	8.93
TR with *S.sesban*	1.65^{b}	1.85^{c}	2.28^{b}	4.6
NP with *S.sesban*	1.56^{c}	1.82^{c}	1.79^{c}	6.21
SLB with *S.sesban*	1.67^{b}	1.71^{c}	1.82^{c}	4.79
TR with *M.azadarach*	2.07^{b}	2.29^{b}	1.94^{c}	5.01
TR with *L.leucocephala*	1.51^{c}	1.84^{c}	1.84^{c}	4.73
SLB with *L.leucocephala*	1.53^{c}	1.82^{c}	1.75^{c}	4.6
NP with *L.leucocephala*	1.55^{c}	1.75^{c}	1.88^{c}	7.13
NP with *G.robusta*	1.52^{c}	1.79^{c}	1.82^{c}	6.20
SLB with G.robusta	1.46^{c}	1.67^{c}	1.71^{c}	5.41
TR with G.robusta	1.43^{c}	1.71^{c}	1.89^{c}	6.14
LSD(0.05)	0.366	0.364	0.369	NS
CV	12.87	10.96	10.36	32.72

Note: TRs: trench (TRs), Soil level bund (SLB) and normal pit(NPs) as control. Similar letter in the row shows not significant difference and different letters indicate significance differences, NS: not significant difference between moisture structures at P≤0.05

Table 4 .Effect of moisture structures on tree DBH within different year intervals

Treatments	**Mean of DBH(cm) at different years** of **a**ge		
Min plots(Structures)	Year 2	Year 3	Year 4
Trenches (TR)	0.18	1.24	5.19^{a}
Soil level bund (SLB)	0.26	1.27	4.33^{b}
Normal Pit (NP)	0.24	1.24	4.11^{b}
LSD(0.05)	NS	NS	1.12
CV	5.2	5.69	42.64
Sub plots(Trees)			
Moringa oleifera	1.24^{a}	1.31^{a}	4.83^{a}
Melia azedarach	1.13^{b}	1.23^{b}	3.47^{b}
Sesbania sesban	1.13^{b}	1.23^{b}	3.22^{b}
Leuceana leucocephala	1.13^{b}	1.23^{b}	3.93^{ab}
Grevillea robusta	1.13^{b}	1.23^{b}	4.05^{ab}
LSD(0.05)	0.19	0.06	1.09
CV	5.5	4.96	26.05
Interactions (Structures x Trees species)			
SLB *M.azedarach*	1.130^{b}	1.230^{b}	5.48^{a}
NP with *M.oliefera*	1.120^{ab}	1.213^{b}	5.48^{a}
SLB with *M.oliefera*	1.301^{a}	1.413^{a}	4.74^{ab}
NP with *M.azadarach*	1.130^{b}	1.230^{b}	4.74^{ab}
NP with *L.leucocephala*	1.130^{b}	1.230^{b}	4.38^{ab}
TR with *G.robusta*	1.130^{b}	1.230^{b}	4.28^{ab}
TR with *M.oliefera*	1.230^{ab}	1.303^{ab}	4.25^{ab}
NP with *G.robusta*	1.130^{b}	1.230^{b}	4.24^{ab}
SLB with *L.leucocephala*	1.130^{b}	1.230^{b}	3.75^{ab}
SLB with *G.robusta*	1.130^{b}	1.230^{b}	3.61^{ab}
TR with *L.leucocephala*	1.130^{b}	1.230^{b}	3.60^{ab}
NP with *S.sesban*	1.130^{b}	1.230^{b}	3.05^{b}
SLB with *S.sesban*	1.130^{b}	1.230^{b}	2.85^{b}
TR with *S.sesban*	1.130^{b}	1.230^{b}	2.84^{b}
TR with *M.azadarach*	1.130^{b}	1.230^{b}	2.60^{b}
LSD(0.05)	0.103	0.104	1.712
CV	89.14	87.14	29.204

Note: TRs: trench (TRs), Soil level bund (SLB) and normal pit (NPs) as control. Similar letter in the row shows not significant difference and different letters indicate significance differences, NS: not significant difference between moisture structures at P≤0.05

Conclusion and recommendation

Moisture conservation structure devices are an important way in facilitating favorable conditions for plant growth as well as tree seedling survival in moisture stress areas. Four years after establishment, the study results revealed that survival rate of trees for the interaction was not significant; strongly indicating it was not influenced by the combined treatments (tree species and moisture conservation structures). With their good survival rate and outstanding height and diameter growth; *Moringa oliefera, Melia azedarach* and *Sesbania sesban* planted in soil level bund are the most promising among the species tested at Babile district. The growth parameters of the tree species planted in the soil level bund is better than trenches in color diameter. Tree species planted in trenches were also appropriate planting pit in surviving plant than normal pit. The moisture conservation (soil level bund) structures shows great potential in increasing tree survival and growth performance due to helping to harvest rainwater and protecting them in moisture stress areas. Therefore, *Moringa oliefera, Melia azedarach* and *Sesbania sesban* has shown potential to be used as fuel wood, soil conservation, farm implements and others like shade and shelter and medicinal plantation species in Babile district and in other areas with similar agro ecology. More studies are needed on slope, type and runoff storage capacity before transplanting the trees with more representative locations and in different soil and agro ecology

.Acknowledgment

The authors are thankful to Oromia Agricultural Research Institute for financial support and Fadis Agricultural Research center for provision of facility for research work. The authors also thankful to all agroforetry teams for their participation in concerning of the trail's management

References

Abebe Yadessa, Diriba Bekere and Taye Bekele.2000.Growth performance of different multipurpose trees and shrub species at Bako,Western Oromia. pp 177-186. In: Proceeding of the Fifth Conference of the Ethiopian Society of Soil Science. Addis Ababa, Ethiopia, 30-31 March 2000, Ethiopian Society of Soil Science, Addis Ababa, Ethiopia.

Abraham M (2014). Factors Affecting Survival of Tree Seedlings in the Dry lands of Northern Ethiopia. 4(16):2224-3186.

Betre Alemu,Tekeligm Mamo, Alemayehu Zewdie and Ebrahim Ahmed. 2000. Promising multipurpose tree species and their response to land form on highland Vertisols at Chefe Donsa, central highlands of Ethiopia. pp. 145-155. In: Proceeding of the Fifth Conference of the Ethiopian Society of Soil Science. Addis Ababa, Ethiopia, 30-31 March 2000, Ethiopian Society of Soil Science, Addis Ababa, Ethiopia.

Boers TM, Ben-Asher J (1982). A review of rain water harvesting. Agric. Water Manage. 5(2):145-158.

Cao S (2011).Impact of China's large-scale ecological restoration program on the environment and society in arid and semiarid areas of China: achievements, problems, synthesis, and applications. Crit. Rev. Environ. Sci. Technol. 41(4):317-335

Daws MI, Mullins CE, Burslem DF, Paton SR, Dalling JW (2002). Topographic position affects the water regime in a semideciduous tropical forest in Panama. Plant soil 238(1):79-89.

Demel Teketel, 2001. Deforestation, wood famine, and environmental degradation in Ethiopia's highland Ecosystems: urgent need for action. Northeast African Studies, 8(1):53-76.

Demisachew Tadele, Awdenegest Moges and Mihret Dananto(2018)**.** Impact evaluation on survival of tree seedling using selected in situ rainwater harvesting methods in Gerduba Watershed, Borana Zone, Ethiopia. Journal of Horticulture and Forestry 10(4):43-51.

Desalegn Mamo, Eshetu Ararso , Alemayhu Diriba, Shimelis Dekeba, Dulo Hussen (2016). Early Survival Evaluation of Trees and Shrubs for Their Adaptability Planted Under Moisture Conservation Structures at Hawi Gudina District, West Hararghe Zone, Ethiopia. American Journal of Agriculture and Forestry 4(6): 152-155.

Eldridge, K., Davidson, J., Harwood, C. and G. van Wyk. 1994. Eucalyptus Domestication andBreeding. Clarendon Press, Oxford. 288p.

Evans, J. 1996; plantation forestry in the tropics (2nd ed.). Oxford science publications. Clarendan press, Oxford.

Gowing JW, Mahoo HF, Mzirai OB, Hatibu N (1999). Review of rainwater harvesting techniques and evidence for their use in semiarid Tanzania. Tanzania J. Agric. Sci. 2(2).

Grossnickle SC (2005). Importance of root growth in overcoming planting stress. New Forests 30(2-3):273-294.

Gupta GN (1995). Rain-water management for tree planting in the Indian Desert. J. Arid Environ. 31(2):219-235.

Hatibu N, Mahoo HF, Gowing JW, Kajiru GJ, Lazaro EA, Mzirai OB, Senkondo EM (2001).Rainwater harvesting for natural resources management: a planning guide for Tanzania. Regional Land Management Unit.

Jha AK, Singh JS (1992). Restoration of degraded land: concepts and strategies. Rastogi Publication Meerut pp. 212-254.

Kahsay Berhe, Giulia Conchedda and Mohammad A. Jabbar.2001. Areas suitable for five leguminous trees and shrubs in Ethiopia: A digital data based analysis. Ethiopian Journal of Natural Resources (EJNR) 3 (1):77-97.

Li WQ, Liu XJ, Khan MA, Gul B (2008). Relationship between soil characteristics and halophytic vegetation in coastal region of North China. Pak. J. Bot. 40(3):1081-1090

Malik ZA, Bhatt AB (2016). Regeneration status of tree species and survival of their seedlings in Kedarnath Wildlife Sanctuary and its adjoining areas in Western Himalaya, India. Trop. Ecol. 57(4):677-690

Mebrate Mihretu, Alemu Gezahegn and Belachew Gizachew. 2004. Early survival and height performance of some Australian species in field trials at Didessa, Western Ethiopia. Ethiopian Journal of Natural resources (EJNR) 6(2):253-263.

Musa Abdella and Bira Cheneke (2019). Adaptation and Growth Performance Evaluation of Agroforestry Tree Species Under Dire Dawa condition, Eastern Ethiopia Octa Journal of Environmental research 7(4): 138-143

Padilla FM, Pugnaire FI (2007). Rooting depth and soil moisture control Mediterranean woody seedling survival during drought. Functional Ecol. 21(3):489-495.

Saville, P., Julian, E., Daniel, A. and F. Jan. 1996. Plantation Silviculture in Europe. Oxford University Press, Oxford.

Sharma D, Sunderraj SW (2005). Species selection for improving disturbed habitats in Western India. Curr. Sci. pp. 462-467

Shukla PK (2009). Nutrient dynamics of tea plantations and their impact on soil productivity -A case study from India. *Proceedings of the 8th World Forestry Congress*, Oct. 18-23, Buenos Aires, Argentina, p. 1-11.

Singh G, Rani A, Bala N, Shukla S, Baloch S, Limba NK (2010). Resource availability through rain water harvesting influenced vegetation diversity and herbage yield in hill slope of Aravalli in India. Front. Agric. China 4(2):145-158.

Suleman S, Wood MK, Shah BH, Murray L (1995). Rainwater harvesting for increasing livestock forage on arid rangelands of Pakistan. J. Range Manag. pp. 523-527.

Warren JM, Meinzer FC, Brooks JR, Domec JC (2005). Vertical stratification of soil water storage and release dynamics in Pacific Northwest coniferous forests. Agric. For. Meteorol. 130(1):39-58.

Evaluation of Lowland Bamboo Propagation techniques in West Hararghe zone, Oromia region, Ethiopia

Alemayehu Diriba*, Shimelis Dekeba and Wasihun Gizaw
Mechara Agricultural Research Center, Mechara, Ethiopia
Corresponding Author's Email**:** alemayhudiriba@gmail.com

Abstract

Bamboo has diverse utility ranging from construction to delicacy in Asia and Africa, and also several desirable qualities that make it a useful resource compared to many other plants. For example; it uses as food and feed preservative, construction, medicine purpose, natural conservation, charcoal and energy, arts and culture, aesthetic value, financial return and environment protection. Bamboo has additional unique characteristic that a fast growing plant than any other tree species and starts to give utility within three or four years of planting time in the exception of bearing fruits. To give fruit full seeds takes a long time that after 50 years old. Even though Ethiopia is one of the most endowed countries in having huge coverage of bamboo resource in Africa, the country has narrow genetic diversity only has two species those are Yushania alpine (highland bamboo) and Oxytenanthera abyssinica (lowland bamboo). Indigenous and introduced species of bamboo do not readily produce seeds within a short period of time. So to get its utilities has to be raised through various propagation methods. In this trial; propagations with culm cut, offsets cut and branch cut on Dendrocalmus membracius, Dendrocalmus hamlitonii and Oxytenanthera abyssinica bamboo species had been executed in RCBD design with three replications, respectively. So that in this experiment, among the methods of bamboo propagation technique; offset cutting (bamboo rhizome) followed by branch cut had been recommended based on consideration of giving adequate planting materials. The outcomes showed highly significant difference at ($p<0.001$) level between and within treatments as well as interaction effect based on the given parameters. Regardless of this fact; the highest mean value discovered under Dendrocalmus hamlitonii bamboo species with culm cut planting followed by Dendrocalmus memebranceous with branch cut planting, while the least mean value was recorded under Oxytenanthera abyssinica with culm cut planting based on number of new emerging bamboo shoot parameter. Based on root collar diameter, Length of shoot and number of node parameters, the highest mean value recorded under Dendrocalmus hamlitonii and Dendrocalmus memebranceous with offset cut planting, while the least mean value was recorded under Dendrocalmus hamlitonii with branch cut planting, respectively (Table 2). Despite this fact, we recommend that with ***offset cut plating*** *for Dendrocalmus hamlitonii and Dendrocalmus memebranceous of bamboo species followed by Oxytenanthera abyssinica. The Culm cut planting parts designated higher mean value for Dendrocalmus hamlitonii bamboo species only, while branch cut planting designated higher mean value for Dendrocalmus memebranceous bamboo species only (Table 2). Generally, the study was propagations of lowland bamboo species (Dendrocalmus membracius, Dendrocalmus hamlitonii and Oxytenanthera abyssinica) with culm cut, offsets cut and branch cut techniques under Mechara and for related agro ecology zones is trustworthy so, we advocate these technologies with further economic and livelihood benefits for different stakeholders through expanding the plantation materials with full package.*

Keywords*: Exotic and Indigenous; Propagation Techniques of Lowland Bamboo Species; Unique Characteristics of Bamboo.*

Introduction

Bamboo belongs to the grass family and is mostly found in tropical, sub-tropical and in rare cases temperate zones. In terms of ecological habitat, it is classified into lowland and highland bamboo. Lowland bamboo grows naturally in tropical areas where temperature ranges from 20 to 35^{o}c and rainfall is over 1500 mm per year. In Africa, indigenous bamboo grows mainly in the highlands, medium and lowland altitudes of Eastern and Central Africa. In nature, bamboo grows as pure stands or is mixed with other trees. Bamboo growing in forested catchments plays a vital role in the protection of soils and water sources (Okamura, 1986).

Bamboo forms the bulk of elephant and wildlife feed and has diverse utility ranging from construction to delicacy in Asia and Africa, and it has also several desirable qualities that make it a useful resource compared to many other plants. It is tremendously valuable plant which has been used for hundreds of years with society. Long lasting accountability of bamboo with society is for its ability to restore degraded sites, short growing cycle, and ability to regenerate vegetativelly, tolerance to repeated harvesting, strong and lightweight material, and compatibility with other tree species (Ong, 2004).

Bamboo can be raised through various methods such as with seeds, wildings, culm cut, offsets cut, branch cut and tissue culture. However, culm cutting propagation technique is not suitable for solid or no hollow in the middle of the stem (Ray and Ali, 2017). Indigenous and introduced species of bamboo do not readily produce seeds within a short period of time. This is taken a long time that after 50 years old to give fruit full seeds. Globally at present, the local demand for bamboo propaguller is greatest for ornamental purpose but that for its multipurpose utilities, bamboo is expected to get closer soon with put up their own plantations in very near future by many private landowners, and due these, its demined become double folded. So that in order to compensate such imperative spots; its propagation methods had been identified with such kind of experiment (John, C.K. and R.S. Nadgauda. 2002).

In Ethiopia, there are a number of limitations at bamboo production and promotion thought out the regions those are agricultural expansion, lack of scientific knowledge on its management, propagation methods and utilization potential are the major bottlenecks for bamboo resources. But in this experiment, among the methods of bamboo propagation technique, offset cutting (bamboo rhizome) followed by branch cut had been recommended based on consideration of agro ecology zone that is as a faster providing of adequate planting material and higher regeneration percentage from each species (Mekonen *et al.* 2014).

Commonly in Ethiopia and particularly in Hararghe; as population size is increased, deforestation and land degradation problems have been gradually aggravating. So searching of alternative technology is mandatory. Therefore; important of the study is, to evaluate and document propagation methods of low land bamboos species with full package of economic and environmental values for all end users.

Material and Methods

Description of the study areas

The trial had been conducted at Mechara Agricultural Research Center (on station). The center is located at 431 Km west of Addis Ababa. The altitude is 1650 m.a.s.l. The area experiences bimodal rainy season extending from March to October, but the effective rain is from May to September (IAR, 1991). The mean annual rainfall is about 1280 mm with a peak in July. Mean annual temperature is 20^{oc}, with mean minimum temperature of 13°c and maximum of 27°c; and the soil of the area is dominantly reddish brown that is Nitosols (Mechara agricultural research center, meteorological station).

They are generally clay dominated and are characterized by low available phosphorous with a pH ranging from 5.3 to 6 in surface soils (Dawit and Legesse, 1993). The vegetation cover of the area is of woodland and open wooded grassland types.

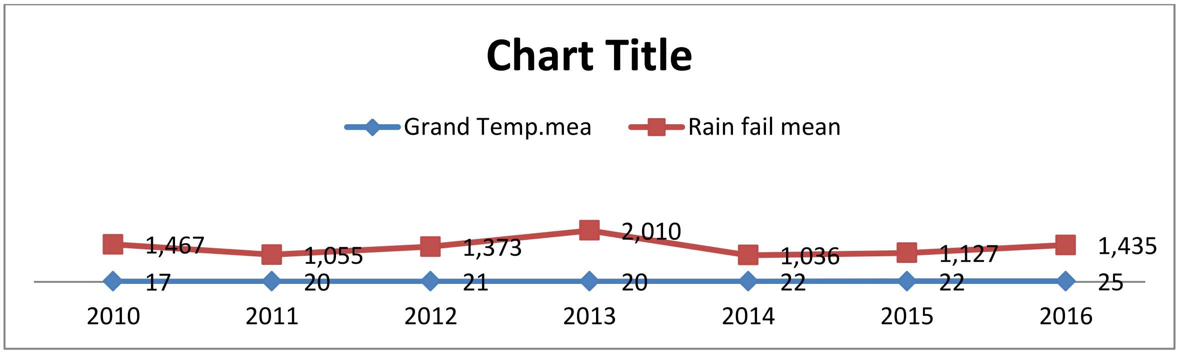


Fig.1 (2009-2016 G.C) Rainfall and temperature of Darolabu District 2016/2017

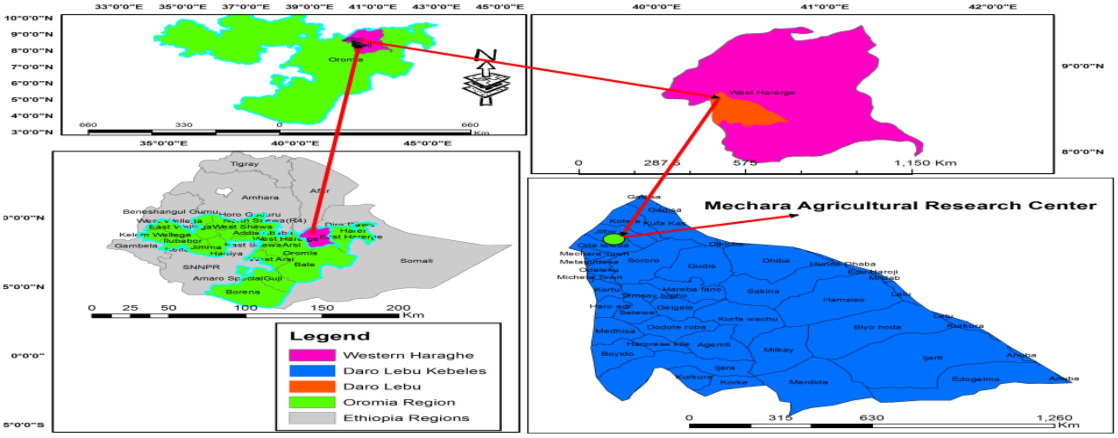


Fig.2. Description of Daro labu Woreda

Planting materials and tending operation

The planting materials were taken from 2-3 years old of low land bamboos species namely (*Dendrocalamus hamlitonii, Dendrocalamus memebranceous* and *Oxytenanthera abyssinica*) and prepared based on manuals for tropical bamboos (Njuguna and Kigomo, 2008). In this experiment, the propagating materials (treatments) were prepared by serving offset planting, culm cut planting and branch cut planting. The offset planting consists of a rhizome and a portion of the culm cut just including the 4th or 5th node from the base. Culm Cutting was planted from the near base of selected culm that had the branches of 2 or 3 internodes lengths with the cut positioned 2 to 3 cm below the basal node and water was poured into the cuttings through the holes. Branch cut planting method was performed with branches that have adventitious roots below the branch bases, “swollen” bases and 2 to 3 internodes length. The space between and within each planting materials were 2m apart. On per plot, 3 propagation materials were taken from one bamboo species and similarly for others. A total of 27 planting materials from three bamboo species at total areas of 5.5m*20.5m (m112.75m^2) were planted in experimental site. The planting technique of all parts was inclined horizontally with 45^0 in the prepared pit. The pit was prepared with 50cm deep and 50cm wide. The tools using were a sharp axe, saw, sickle, meter and dagger to separate from parent rhizome and culms as well as to dig and measure.

Treatments, experimental design, data collection and data analysis

Each bamboo species (*Dendrocalamus hamlitonii*, *Dendrocalamus memebranceous* and *Oxytenanthera abyssinica*) with its offset planting, culm cut planting and branch cut planting parts were used as treatments. The experimental designed had been implemented by Randomized Complete Block Design (RCBD) factorial with three replications. The collected data were emerging time taken of planting materials, regeneration percentage, number of new emerging bamboo shoots, root collar diameter, length of shoots and number of nodes. The collected data was examined with SAS, version 9.0 and interpreted significance difference between treatments' mean value based on a given parameters.

Table 1: Treatments of a given experiment

No.	Treatments	
	Bamboo species	**Grafting parts of Bamboos**
1	*Dendrocalamus hamlitonii*	offset planting/secure
		culm cut planting
		branch cut planting parts
2	*Dendrocalamus memebranceous*	offset planting/secure
		culm cut planting
		branch cut planting parts
3	*Oxytenanthera abyssinica*	offset planting/secure
		culm cut planting
		branch cut planting parts

Result and Discussions

Emerging time Taken of Planting Materials

The present study indicated that the interaction effect and the mean value of the given parameters that emerging time taken of planting materials were revealed highly significant difference at (p<0.001) level within the planted parts and species of bamboo. The shortest value of emerging time taken of planting materials were seen from *Dendrocalamus hamlitonii offset planting/secure* and *Oxytenanthera abyssinica culm cut planting*, while the highest value were seen from *Oxytenanthera abyssinica Offset cut* and *Dendrocalamus hamlitonii culm cut* planting (Table 2). In this parameter, from the selected cutting part of bamboo species, the shortest time taken of emerging has to be taken as the best one is due to its shortest time taken to be emerged within a shortest duration than the others of a given treatments' materials (Table 2).

Regeneration Percentage of Bamboo Materials

The mean value and interaction effect of the given parameters that on regeneration percentage of bamboo materials showed highly significant difference at the level of (p<0.001) point within the planted parts and species of bamboo (Table 2). The highest mean value of a given results were recorded from *Dendrocalamus hamlitonii species and offset planting* parts followed by *Dendrocalamus hamlitonii species* with culm *planting* and *Oxytenanthera abyssinica* species with *offset planting*, while the lowest mean values were recorded from *Dendrocalamus hamlitonii species* with *branch cut planting* and *Oxytenanthera abyssinica* species with culm cut planting respectively (Table 2).

The highest mean value of *a* given treatments' parameter was greater than that of the lowest mean value is 66.7 percent (Table 2). This is difference might be due to environmental factors as well as bamboo species and part of cutting performances.

Number of New Emerging Shoots

The mean value of the given treatments' parameters showed highly significant difference at the level of (p<0.001) point within the planted parts and species of bamboo. The capacity of lateral buds forming new rhizome and shoot is might be closely related to rhizome species, age, vigor, and nutrient storage. Based on the analysis results of the given data of *Dendrocalamus hamlitonii species* with *culm cut planting* revealed a highest mean value on the number of new emerging shoots followed by *Dendrocalamus Membracius species* with brunch cut planting*, while* the lowest mean value was showed from *Oxytenanthera abyssinica* species with *culm cut planting* part (Table 2).

The mean value of *Dendrocalamus hamlitonii* species with *culm cut planting* part on the given parameter was greater than that of *Oxytenanthera abyssinica* species with *culm cut planting* part *by* 84.3% *(*Table 2). This is might be due to high capability of producing new emerging shoots of the species when compare to the other planting part and specie of bamboo. This result is similar with the report from Bako Agricultural Research Center, 2016; which shows higher shoot emerging for *Dendrocalamus hamlitonii species.* Whereas, *Oxytenanthera abyssinica* species revealed a low performance in emerging a new number of shoots during the pursue periods (Table 1). On the opposite side of this result is revealed that the sprout of new shoots between the propagation part was similar except dry and wet season, reported by (Senyanzobe, 2013),

Root Collar Diameters

The mean value and interaction effect of the given parameter that on *root collar diameter* showed highly significant difference at the level of (p<0.001) point within planted parts and species of bamboo. The highest mean was observed from *Dendrocalamus memebranceous* species with *offset cut planting* followed by *Dendrocalamus membracius* species with *branch cut planting*, while the least mean was recorded from *Oxytenanthera abyssinica* with *culm cut planting*, respectively (Table 2). *The highest* mean value of *Dendrocalamus memebranceous* species with *offset cut planting* is greater than that of the least mean value of *Oxytenanthera abyssinica* with *culm cut planting by 81.3%.* This might be based on the growth performance and adaptability of the species (Table 2). This result is in line with the report of *World Scientific journals* that is the mean value of root collar diameter (RCD) a highly significant difference on the number highland bamboos species*'* shoots at the beginning of the first six months *(World Scientific News, 2017).*

Length of Emerging Shoot

The mean value and interaction effect of the given parameters that on length of emerging shoot showed highly significant difference at the level of (p<0.001) point within planted parts and species of bamboo. The highest mean value s of a given treatments' parameter observed from *Dendrocalamus hamlitonii species* and *Dendrocalamus memebranceous* species both with *offset cut planting*, while the least mean values were recorded from *Dendrocalamus hamlitonii species* with *branch cut planting* followed by *Oxytenanthera abyssinica* species with *culm cut planting, respectively.*

The highest mean value of a given treatments' parameter greater than that of the least mean value is observed by *40%* (Table 2). The result agreed with the report from Pawe by Yared k, 2013 (unpublished) which shows higher Culm height for *Dendrocalamus hamlitonii species.* On the other hands, these result disagreed with the report from Bako Agricultural Research Center, 2016; on *Oxytenanthera abyssinica value.* . The full length of emerging shoot is varied among the species and part of cuttings; this disparity might be due species vary on its adaptability and performance conditions.

Number of Nodes

The mean value of the given parameter that on *number of node* showed highly significant difference at the level of (p<0.001) point within planted parts and species of bamboo. The highest mean value was observed from *Dendrocalamus memebranceous* species with *offset cut planting* that followed by *Dendrocalamus hamlitonii species* with *offset cut planting*, while the least mean values were recorded from *Dendrocalamus hamlitonii* and *Oxytenanthera abyssinica* species with *branch cut* and *culm cut planting, respectively* (Table 2). Based on the given parameter, *Dendrocalamus memebranceous species* with *offset cut planting* mean greater than that of *Dendrocalamus hamlitonii* and *Oxytenanthera abyssinica* species with *branch cut* and *culm cut planting* is by 86.5%, respectively (Table 1).

Generally, *Dendrocalamus hamlitonii* and *Dendrocalamus memebranceous* show higher number of internodes as compare to others which is similar with the report of Yared K, 2013 (unpublished) which show higher number of internodes for *Dendrocalamus hamlitonii*. On the other hands, these results showed disagree with the report from Regassa Terefe *et al.,* 2016 at the numbed of internodes *Oxytenanthera abyssinica species*.

Table 2- ANOV table of treatments' value based on the given parameters

Lakk	Treatments		Parameters					
	Bamboo species	Part of species	Emerging time (days)	Regeneration %	No. new emerging bamboo shoot	Root collar diameter (cm)	Length of shoot (m)	No. of node
1	D. hamilton	Offset cut	29.5d	100a	8.2bc	7.3a	2.5a	12.2b
2	D. Hamilton	Culm cut	41ab	66.7b	10.8a	5.3b	2.2ab	8.8c
3	D. Hamilton	Branch cut	35.3c	33.3cd	4de	2.5de	0.5e	2e
4	D. membracius	Offset cut	35c	100a	6.8c	8a	2.5a	14.8a
5	D. membracius	Culm cut	38bc	29.6d	2.7ef	3cd	1cde	3de
6	D. membracius	Branch cut	30d	44.4c	9.4ab	7.5a	1.6bcd	10.3bc
7	O. abyssinica	Offset cut	42a	66.7b	4.8d	3cd	1.8abc	3.2cd
8	O. abyssinica	Culm cut	29.5d	33.3cd	1.7f	1.5e	0.7de	2e
9	O. abyssinica	Branch cut	37.5bc	44.4c	4.7d	4bc	1.5bcd	5d
Interaction effect between treatments			***	***	***	***	***	***
Lsd			3.8	8.1	1.6	1.5	0.9	2.6
Cv			6.2	8.6	15.7	19.3	34.2	21.9

(Vertically mean values with the same letter are not significantly different; No–Number, cm= centimeter, m= meter, D=Dendrocalamus and O= Oxytenanthera)

Conclusion and Recommendations

Adaptation trial of lowland bamboo species had been took placed under Mechara condition and likewise for similar agro ecology zones as to be more affordable, available and acceptable for farmers rather than some miner variation on growth performances. Therefore, Mechara Agricultural Research Center believed that to disseminate the more adaptable bamboo species with recommended propagation techniques for all an end users with full packages. Because, bamboo species naturally long last to give seeds. So identifying of the best propagation parts of the more adaptable bamboo species already had been done based on the previous research gap to be as a mandatory.

Therefore, as a conclusion that with regardless of this fact, the highest mean value of *Oxytenanthera abyssinica* specie was showed with offset cut plating, while the least mean value was recorded from *Dendrocalmus hamlitonii* and *Oxytenanthera abyssinica* with offset cut plating and *culm cut planting* based on emerging *time taken* parameter (Table 2) .

Based on *regeneration percentage* parameter the highest mean value found under *Dendrocalmus hamlitonii* and *Oxytenanthera abyssinica* with offset cut plating, while the least mean value was recorded from *Dendrocalmus memebranceous* with *culm cut planting*, respectively (Table 2).

On the other necessary parameter, the highest mean value discovered under *Dendrocalmus hamlitonii* bamboo species with culm cut planting followed by *Dendrocalmus memebranceous* with *branch cut planting*, while the least mean value was recorded under *Oxytenanthera abyssinica* with *culm cut planting* based on *number of new emerging bamboo shoot* parameter. Based on *root collar diameter*, *Length of shoot* and number *of node* parameters, the highest mean value recorded under *Dendrocalmus hamlitonii* and *Dendrocalmus memebranceous* with *offset cut planting*, while the least mean value was recorded under *Dendrocalmus hamlitonii* with *branch cut planting*, respectively (Table 2).

Generally, the best recommendation had been given based on a given parameters' mean value. So that the highest mean value indicated with ***offset cut plating*** for *Dendrocalmus hamlitonii* and *Dendrocalmus memebranceous* of bamboo species followed by *Oxytenanthera abyssinica*. The ***Culm cut planting*** parts designated higher mean value for *Dendrocalmus hamlitonii* bamboo species only, while ***branch cut planting*** designated higher mean value for *Dendrocalmus memebranceous* bamboo species only (Table 2).

Finally these trails indicate that the further research study needs with these operation on other bamboo species. The other point has to be considered is promotion and dissemination of the selected bamboo species with the recommended propagation methods. The future research track must be intended on provenance study and adaptation of highland bamboo, and its propagation techniques.

Acknowledgements

The authors express their gratitude to the staff of Agroforestry Research Team of Mechara Agriculture Research Center for their follow- up and data collection, and Oromia Agricultural Research Institution for its financial support.

Referances

Dwivedi, A.P. 1993. Forests: The non-wood resources. International Book distributors, Dehra Dun, India.352pp. forest management..

Fu Maoyi., 2005. Bamboo resources and utilization in China.

John, C.K. and R.S. Nadgauda. 2002. Bamboo flowering and Famine. Current Science, 82(3): 261-262.

Kigomo, B. N. (1995). Guidelines for Establishment and Managing Plantations of Bamboo in Kenya. Occasional Management Paper No.1. Kenya Forestry Research Institute, Muguga, Kenya.

Kigomo, B. N. (2007). Guidelines for Growing Bamboo. Kenya Forestry Research Institute. Guidelines Series No. 4. 58pp.

Mekonnen, Z., Worku, A., Yohannes, T., Alebachew, M., and Kassa, H. (2014) Bamboo
Njuguna and Kigomo, 2008. Tropical bamboos history.

Okamura, H. (1986). The Horticultural Bamboo Species in Japan.

Ong, C. (2004). Giant Bamboo: A Grass Becomes a Multipurpose Tree.

Ray, S. S., and Ali, M. N. (2017). Factors affecting macro propagation of bamboo with Research and Applications, 12, 511-524. dx.doi.org/10.1016/j. Resources in Ethiopia: Their value chain and contribution to livelihoods. Ethnobotany: Science, 47(1), 17: DOI 10.1186/s40490-017-0097.

Sesyanobe, Journal, 2013). Response of vegetative propagation of Bambusa spps under special reference to culm cuttings: a review update. New Zealand Journal of Forestry.

World Scientific News, 2017. Highland bamboos species' characteristics

Ethnobotanical Study of Medicinal Plants in West Hararghe Zone, East Oromia

Shimelis Dekeba*, Alemayehu Diriba and Wasihun Gizaw
Mechara Agricultural Research Center, Oromia, PO box 19
Corresponding Author's Email: shimedekeba@gmail.com

Abstract

Traditional medicinal plant species documentation is very crucial in Ethiopia for biodiversity conservation, bioactive chemical extractions and indigenous knowledge retention. The present study is initiated with an objective to assess and document medicinal plants, the knowledge and practices on use of medicinal plant species used by the by people of Western Hararghe to treat different human and livestock ailments. The study was conducted in 2020 and used descriptive field survey design. Multi stages sampling techniques were applied to collect the data. First stage, the districts in Western Harerghe zone were stratified into three (highland, midland and lowland) based on their agro-ecologies. In the second stage, 3 districts (Gemechis from highland, Habro from midland and Hawi Gudina from lowland) were selected randomly. In the third stage, from each selected districts three kebeles were selected purposively based on extensive use of medicinal plants. Finally 141 informants were selected from the nine kebels. Both quantitative and qualitative data were collected through semi-structured interviews, guided field walks, demonstrations, and focus group discussions with the help of guided questions. Data were organized and analyzed by descriptive statistics with SPSS version 20 and Microsoft Office Excel 2013. Most of the respondents get indigenous knowledge of medicinal plants from their father (43.57%). A total of 162 medicinal plant species within 70 families were documented to treat various livestock and human ailments. The study indicated that many of the medicinal plants are harvested from the forest (53.2%) followed by homegarden (38.8%) and the other accounts for (7.9%). Ocimum lamifolium scored the highest use frequency and highest Familiarity index, followed by Cissampeclos pareira. Sorenson and Jaccard's similarity index among the three districts were above 61.79 % which showed significant similarity/even distribution of species among the three districts. According to Jaccard's similarity indices Hawi Gudina and Gemachis were the most similar pairs. Herbs constitute the highest species representative followed by trees and 59.03% of medicinal plants were collected from wild whereas 35.68% from cultivation 5.29% both wild and cultivation. The most frequently utilized plant part was leaf (35.47%) followed by root (21.80%), Seed (12.50%). A total of 115 ailments were identified as being treated by traditional medicinal plants, among which sudden sickness was frequently reported. Allium sativum was reported for the treatment of many of the reported diseases. The processed remedies were mostly administered through oral (62.09%) and dermal (20.26%) routes. Traditional medicinal plants and associated indigenous knowledge are the main systems to maintain human and livestock health in West Hararghe Zone. But minimal conservation measures were recorded in the community. Thus, in-situ and ex-situ conservation practices and sustainable utilization are required in the Zone

Keywords: Ethnobotany, Medicinal plants, Indigenous knowledge, West Hararghe

Introduction

Since time immemorial, humans have looked to nature for ways to improve their living conditions and increase their chances of survival. One example is the way in which humans have interacted with plants, developing various uses for them. The close relationship between humans and plants has promoted the accumulation of botanical knowledge that is transmitted through the sharing of family narratives and community experiences, that has resulted in a valuable genetic heritage, each society maintaining a knowledge base of edible and therapeutic plants (Palheta, *et al.*, 2017).

Ethnobotany is the study of the interaction between plants and people, with a particular emphasis on traditional tribal cultures. According to the World Health Organization (WHO) about 65-80% of the world's population in developing countries depends essentially on plants for their primary healthcare due to poverty and lack of access to modern medicine (Kalayu *et al.*, 2013). In Ethiopia, about 80% of the human population and 90% of livestock is said to be dependent on traditional medicine for primary healthcare services and most of this comes from plants (Belayneh *et al.*, 2012).

Ethiopia is endowed with a huge potential of medicinal plants(estimated to be over 700 species (Mengistu, 2004) and their uses that provide a wide contribution to the treatment of human and livestock aliments (Giday, *et al.*, 2013). These wide and vital uses of traditional medicine in the country could be attributed to cultural diversity and acceptability, psychological comfort, perceived efficacy against certain type of diseases and economic affordability as compared to modern medicines (Tolossa, *et al., 2013*). Medicinal plants are viewed as the first-line treatment for most diseases, because they represent a low-cost alternative to pharmaceutical drugs (Palheta, *et al.*, 2017).

Traditional knowledge of medicinal plants and their use by indigenous healers and drug development in the present are not only useful for conservation of cultural tradition and biodiversity but also for community health care and drug development in the local people (Kalayu *et al.*, 2013). The loss of valuable medicinal plants due to population pressure, agricultural expansion, deforestation and environmental degradation is widely reported by different researchers in Ethiopia for example, (Abebe, 2001 and Birhanu *et al.*, 2015).

Even though it is known the Zone has relatively better plant resource and associated traditional knowledge resource is expected to be significant; the continuity of practices related to the use of medicinal plants is threatened by loss of interest on traditional gardening, loss of traditional knowledge, the urbanization and destruction of green spaces which may be due to lack of conservation actions (Palheta, *et al.*, 2017). Their traditional knowledge is not widely used as it could be because the skills are fragile and there is not written document (easily forgettable) that include medicinal plants and indigenous knowledge of the community as most of the medicinal plants are in the hands of a handful and kept as a secret (Fisseha, 2007). Although there are various Ethnobotanical researches has been carried out in Ethiopia, there is no study conducted on medicinal plants in Western Harerghe Zone. Consequently, the need to perform ethno-botanical researches and to document the medicinal plants and the associated indigenous knowledge must be an urgent task. The present study is initiated with an objective to assess and document medicinal plants, the knowledge and practices on use of medicinal plant species used by the by people of Western Hararghe to treat different human and livestock ailments.

Materials and Methods

Description of the Study Area

The study was conducted in the West Harerghe Zone of Oromia, Eastern Ethiopia in 2020 at selected three Woreda, which were Habro, Gemechis and Hawi Gudina (Figure 1). Habro district is located about 410 Km southeast of Addis Ababa, the capital city of Ethiopia and 78 Km from Chiro town, the capital of West Hararghe Zone. Geographically, Habro district is located at 8.57° N to 8.91° N latitude and 40.34° E to 40.69° E longitude. Gelemso town is the administrative capital of the district. The elevation of the district ranges from 1400 to 2400 m.a.s.l. (HDANRO, 2014).Thirty years (1988-20017) data of Gelemso meteorological station indicates that the study area receives a mean annual rainfall of 966.7mm. The rainfall pattern in the area is bi-modal with high amount of rainfall occurring during the main rainy season between June to September (*kiremt*) and the short rainy season stretching from March to May (*belg*). The highest rainfall is received in August and fallowed by April. The mean annual temperature was 19.97°C with the hottest months being May and June and coldest month being November and December (Wasihun *et al., 2019).* Gemechis district elevation ranges from 1300 to 3400m above sea level (m.a.s.l). The minimum and maximum annual rainfall is 800mm and 1200mm with the average of 850mm (Sudi *et al.,* 2018). Hawi Gudina is located at a distance of 519 km from Addis Ababa. The total area of the district is estimated to be 3,041.19 km2. The district is situated between 7˚52`15`` and 9˚25`43``N and 40˚34`13`` and 41˚9'14" E. with altitudes ranging from 976 to 2077 m.a.s.l.

Selection of Study Districts, Kebele and Informants'

Multi stages sampling techniques were applied to collect the data. First stage, the districts in Western Harerghe zone were stratified into three (highland, midland and lowland) based on their agro-ecologies. In the second stage, 3 districts (Gemechis from highland, Habro from midland and Hawi Gudina from lowland) were selected randomly. In the third stage, from each selected districts three *kebeles* were selected purposively based on extensive use of medicinal plants in the area. Sample respondents were randomly drawn from sampling frame using simple random sampling based on probability proportional to size. For the drawn sample respondents, the simplified formula provided by Yamane, (1967) were employed to determine the required sample size at 95% confidence level with degree of variability = 0.5 and level of precision (e) = 7.5%.

$$n= \frac{N}{1+N(e^2)}$$

Where n is the sample size, N is the population size (total household size), and e-is the level of precision. Finally 141 knowledgeable informants were selected from the three districts.

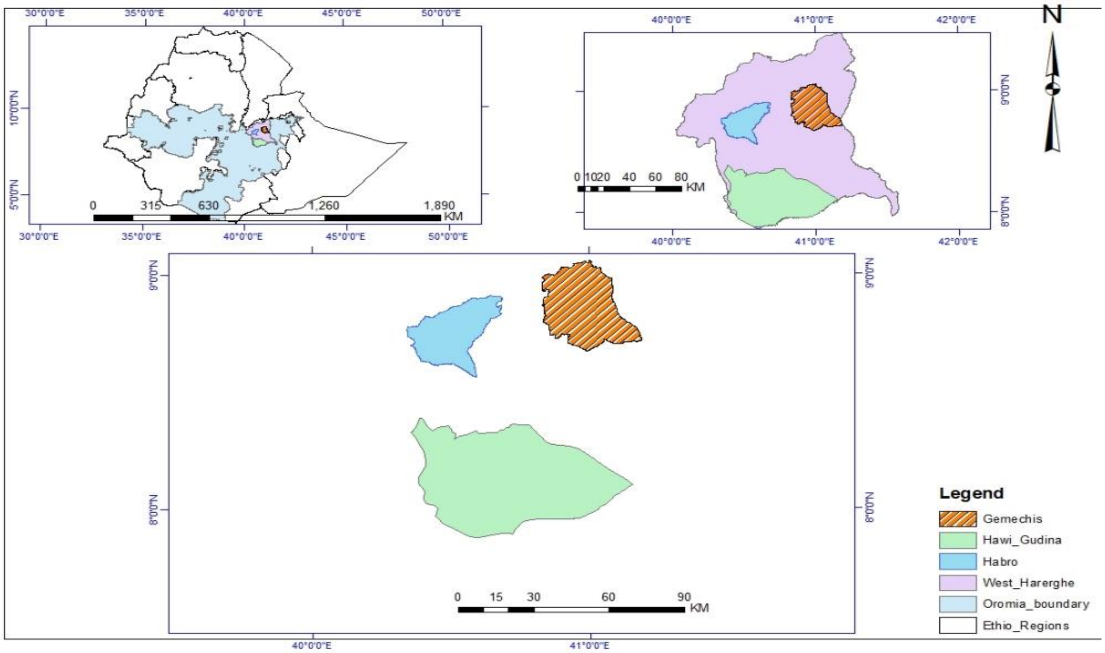


Figure 1. Study area map

Ethnobotanical Data Collection and Specimen Identification

Ethnobotanical data were collected using semi-structured interview, group discussion and field observation. Interviews were conducted using pre-prepared questions with 141 informants after receiving their full consent. The informants who cannot read and write will be considered as illiterate while; those respondents attended formal education will be considered educated. Interviews were based on a checklist of questions prepared beforehand in English and translated to the local language. The collected information include local name of the medicinal plant, growth form, source of medicinal plants (wild/cultivated), diseases treated, parts used, method of preparations, routes of administration, ingredients added, indigenous knowledge transfer (oral /written) and existing threats to medicinal plants. Moreover, tours with key informants were employed to collect specimens of medicinal plant species. The collected specimens were dried and then identification of common and well known species were made using the published volumes of the Flora of Ethiopia and Eritrea, useful trees and shrubs for Ethiopia while for unknown plant specimens identification were made by the help of experts.

Data Analyses

The collected Ethnobotanical data were entered into SPSS 20 software package and Excel spreadsheet 2013 and summarized using descriptive statistical methods such as frequency, percentage, tables, and graphs.

Jaccard's similarity coefficient was estimated for comparing a similarity of medicinal plant species composition among the three selected districts as they represent different ecology (lowland high land and midland). The formula J =c/(c+a +b), where J=Jaccards similarity index, c = number of species shared by the study sites, a = number of species in study site A only and b =number of species in study site B only. The J values range between 0 and 1, whereby a value of 1 indicates complete similarity.

The **Sørensen similarity index (Ss)** is applied to qualitative data and is widely used because it gives more weight to the species that are common to the samples rather than to those that only occur in either sample (Kent and Coker, 1992). The similarity of species composition between the study districts was calculated with the Sørensen similarity index with the formula:

$\mathrm{Ss} = \frac{2\mathrm{A}}{\mathrm{B+C}} * 100\%$ Where; A = number of species common to two village (X and Y); B = total number of species in village X; C = total number of species in village Y. The coefficient values range from 0 (complete dissimilarity) to 1 (total similarity). Familiarity index (FI) is used as an indicator of the popularity of a species (Tabuti et al., 2004). FI is defined as the number of respondents that mentioned a species for a specific use, divided by the total number of respondents. The value of FI varies between 0 and 1, whereby a value of 1 represents the highest familiarity of a medicinal plant in the study site.

$$\mathrm{FI} = \frac{Frequency of a\ given\ species\ mentioned\ as\ a\ medicine}{Total\ number\ of respondents}$$

Result and Discusion

Socio demographic and knowledge characteristics of respondents

One hundred forty one informants were take part in this study. Of which one hundred twenty one (85.8%) were male and twenty (14.2%) were female (Table 1), which indicated that most people continue to use traditional systems of health care including medicinal plants alone or in combination with modern pharmaceuticals. This continued reliance of many African people on traditional medicines is partly due to economic circumstances, which place modern health facilities, services and pharmaceuticals out of the reach of the majority of the population. However, in many cases, it is also attributable to the widespread belief in the effectiveness of many traditional therapies. Even where western biomedical care is available, many people still prefer traditional treatments for treating many aliments (Asfaw et al. 1999, Addis., 2001).

Most of the informant were found between age of 20-65 (88.7%) followed by ages of 65(9.2%) and bellow the age of (2.1%). From the total respondents, 94.3% were farmers, (5.7%) other. Regarding educational status, the majority of respondents (58.7%) were illiterate while (38.4%) and (2.9%) respondents attended primary and secondary school, respectively (Table 1).

Table 1. Socio demographic and knowledge characteristics of respondents

Characteristic	Number of respondents	Percent
Districts		
Habro	54	38.30
Gemachis	47	33.33
Hawi Gudina	40	28.37
Sex of respondents		
Male	121	85.8
Female	20	14.2
Age of respondents		
<20	3	2.1
20-65	125	88.7
>65	13	9.2
Occupation of respondents		
Farmer	132	94.3
Other	8	5.7
Education of respondents		
Illiterate	81	58.7
Primary school	53	38.4
Secondary school	4	2.9

Indigenous knowledge of Medicinal plants

Mainly the respondents get indigenous knowledge of medicinal plants from their father (43.57%) (Table 2). Most informants' transfer their Indigenous knowledge for their son (41.4%) and the transfer way of this knowledge is through oral and showing that accounts (92.4%) (Table 2). This agrees with the previous reports of Ethnobotanical studies in northern and southern Ethiopia (Asfaw *et al.* 1999, Addis., 2001, Teklehaymanot, 2007). This is because the traditional knowledge in the family or community is passed from male parent to his first-born son (Bishaw, 1990, Tesfu, 1995, Teklehaymanot, 2007).

Table 2. Indigenous knowledge source, transfer and transfer way

Characteristic	Number of respondents	Percent
Source of IK of Medicinal plants		
Father	61	43.57
Other	40	28.57
Grandfather	20	14.29
Uncle	10	7.14
Mother	5	3.57
Relative	4	2.86
IK medicinal plants transfer		
Yes	134	95.04
No	7	4.96
IK transfer to		
Son	55	41.4
All person	51	38.3
Relative	12	9
Daughter	10	7.5
Wife	4	3
Friends	1	0.8
IK transfer way		
Oral and showing	121	92.4
Written	6	4.6
Oral	2	1.5
Oral and Written	2	1.5

Conservation and Threats of Medicinal Plants

The study indicated that most of the informants who have had knowledge on traditional medicine utilization give priority to the immediate use of the medicinal plants than to its sustainable future uses, as a result of that their harvesting style is destructive. However, some plants have been protected for their spiritual and cultural purposes. Thus, these places are good sites for the protection of the medicinal plants since cutting and harvesting are not allowed in such particular areas. This was indicated that a good practice for the conservation of medicinal plants through cultivation. The study revealed that there were a number of threats that affect the medicinal plants in the study area. The threats include agricultural expansion (47.7%) followed by deforestation (32.7%) and overgrazing (12.1%) (Table 3).The study indicated that many of the medicinal plants are harvested from the forest **(**53.2%) followed by home-garden (38.8%) and the other accounts for (7.9%). This indicated the effort to conserve medicinal plants in the district was observed to be poor. Some traditional practitioners have started to conserve medicinal plants by cultivating at home gardens, though the effort was minimal. Traditional beliefs in the area also have their own unintentional role in conservation and sustainable utilization of medicinal plants. Giving conservation priority for identified threatened medicinal plants, promoting in-situ and ex-situ conservation of medicinal plants in West Hararghe Zone helps to conserve the fast eroding medicinal plants of the study area.

Most of the informants (81.02%) say there is medicinal plants' conservation in their area where homegarden is the most conservation niche (48.7%) of the medicinal plants followed by forest (39.3%).

Table 3. Conservation and Threats of Medicinal Plants

Variables	Number of respondents	Percent
Sources of Plants		
Forest	74	53.2
Home garden	54	38.8
Intercropping	10	7.2
Monocroping	1	0.7
Medicinal plants conservation niche		
Home garden	57	48.7
Forest	46	39.3
Intercropping	13	11.1
Monocroping	1	0.9
Trends Medicinal plants in the Forest		
Decrease	96	70.1
No change	25	18.2
Increase	16	11.7
Trends Medicinal plants in the farm		
Decrease	89	65.9
No change	24	17.8
Increase	22	16.3
Presence of Deforestation in the area		
Yes present	96	68.6
No deforestation	44	31.4
Treats to medicinal plants		
Human being	69	67.65
Natural disaster	22	21.57
Animals	11	10.78
Training		
Have not gain training on medicinal plants	138	97.87
Gain training	3	2.13

In West Harerghe Zone various factors that were considered as main threats for medicinal plants were recorded by interviewing the informants. The major factors claimed were human being (67.65%), natural disaster (21.57%) and animals (10.78%) (Table 3). Other research on threats to medicinal plants used by Kereyu pastoralists in Ethiopia (Balemie *et al.*, 2004) indicates similar investigation.

Diversity of Medicinal Plant Species and Healers' Indigenous Knowledge

A total of 162 medicinal plant species were used by local people of the West Hararghe Zone to treat various livestock and human ailments (Table 4). *Ocimum lamifolium* 95 (5.89%) was the frequently used plant species having highest Familarity index (FI=0.67), followed by *Cissampeclos pareira* 88 (5.45%)

(FI=0.62), *Otostegia integrifolia* 64 (3.97%) (FI=0.45), *Lepidium sativum* 56(3.47%) (FI=0.40), and *Withania somnifera* 49(3.04%) (FI=0.35) (Table 4). The total number of plant treatments cited in this study could indicate that the general culture of ethnomedicinal knowledge secrecy was slightly lower with few exceptions (Lulekal *et al.*, 2008) compared to some ethnobotanical studies in other parts of the country (Giday *et al.*, 2003; Fassil, 2003; Giday et al., 2007; Teklehaymanot et al., 2007; Teklehaymanot and Giday, 2007; Yineger *et al*. 2008). On average a female respondents reported 3.55 medicinal plant species while a male reported 1.33 medicinal plant species.

Table 4. Species diversity of medicinal plants in West Hararghe zone

Scientific Name	Frequency of report	Percent	Familiarity index
Ocimum lamifolium Hoschst. ex. Benth.	95	5.89	0.67
Cissampeclos pareira L.	88	5.45	0.62
Otostegia integrifolia Benth	64	3.97	0.45
Lepidium sativum L.	56	3.47	0.40
Withania somnifera (L.)	49	3.04	0.35
Foeniculum vulgare Mill.	47	2.91	0.33
Solanecio gigas (Vatke) C. Jeffrey	47	2.91	0.33
Croton macrostachyus Del.	42	2.60	0.30
Ruta chalepensis L.	41	2.54	0.29
Citrus aurantiifolia (Christm.) Swingle	38	2.35	0.27
Allium sativum	36	2.23	0.26
Vernonia anygdalina	36	2.23	0.26
Cucumis pustulatus Naud. ex Hook.f.	35	2.17	0.25
Moringa oleifera Lam.	30	1.86	0.21
Rhynchosia malacotricha Harms	30	1.86	0.21
Other 147 plant species	882	54.58	6.26
Total	1616	100	11.46

Medicinal plants were distributed across 70 families (Table 5). The family and Fabaceae was represented by 15 species (9.26%), Asteraceae 14 species (8.64%) Lamiaceae 10 species (6.17%), Cucurbitaceae 6 species(3.70%), Euphorbiaceae, Myrtaceae, Rosaceae, Rutaceae and Solanaceae represented by 5 species (3.70%) each and the other 61 families consist of 1-4 representative species 92 species (56.79%). (Table 5)

Table 5. Family of medicinal plants in West Hararghe Zone

Family Name	No of species	Percent
Fabaceae	15	9.26
Asteraceae	14	8.64
Lamiaceae	10	6.17
Cucurbitaceae	6	3.70
Euphorbiaceae	5	3.09
Myrtaceae	5	3.09
Rosaceae	5	3.09
Rutaceae	5	3.09
Solanaceae	5	3.09
Other 61 families	92	56.79
Total	162	100

From 162 collected medicinal plants 16(9.88) were found only in Hawi Gudina, 26(16.05) only in Habro, 21(12.96) only in Gemechis, 60 (37.04) were commonly found in 3 districts, 13(8.02) in only Hawi Gudina and Habro, 10(6.17) in only Hawi Gudina, and 16(9.88) only in Habro and Gemachis. In other words 99 MPS were found in Gawigudina, 115 found in Habro and 107 from Gemechis district (Table 6).

Table 6. Number of Medicinal plants in the districts

Districts	OnlyHG	OnlyHa	OnlyGe	3Distirícts		OnlyHG&Ha	OnlyHG&Ge	OnlyHa&Ge	Total
	16(9.9)	26(16.1)	21(13)	60(37)		13(8)	10(6.2)	16(9.9)	162
HG	16			60		13	10		99
Ha		26		60		13		16	115
Ge			21	60			10	16	107
*HG= Hawi Gudina, Ha=Habro, Ge= Gemechis Districts, The Number in brackets were percent									

Table 7. Jaccards and Sørensen similarity index of plant species between the three Districts

Districts	Habro	Gemachis
Hawi Gudina	63.48% (68.22%)	65.42% (67.96%)
Habro		61.79% (68.47%)
*Index outside brackets was calculated using Jaccards index (J) while the index inside brackets was calculated using Sørensen similarity index (S).		

Species Similarity between Survey Sites

Sorenson and Jaccard’s similarity index among the three districts were calculated and the results ranged from 67.96% to 68.47% for Sorenson and 61.79 % to 65.42 % for Jaccard’s it was higher than 0.5 which showed significant similarity/even distribution of species among the sampling areas (Table 7). Sørensen similarity index it gives more weight to the species that are common to the samples rather than to those that only occur in either sample (Kent and Coker, 1992). The most similar pair was Habro and Gemachis districts according to Sørensen similarity index. Higher values of Jaccard`s similarity coefficient indicates a higher similarity in medicinal plant species composition between the paired study areas. These results agree with the case reported by (Shimelis et al., 2019) from home-gardens of Habro district where

Sorenson and Jaccard's ranged from 69.03% to 81.82% and 52.70% to 69.23% respectively. The similarity is higher than 0.5 shows even distribution of species among the sampling areas.

Life forms (habit) of medicinal plants

Herbs constitute the highest species representative by 76 species (46.91%), trees 39(24.07%), shrubs 38(23.46%) and Tree/Shrub 9 (5.56%), species (Figure 2). The plant life form use pattern by traditional healers for remedy preparation in this study was consistent with the use patterns noted by other studies in Ethiopia (Teklehaymanot et al., 2007; Yineger et al., 2007, Yineger *et al.*, 2008) where herbs and shrubs were consistently preferred life forms.

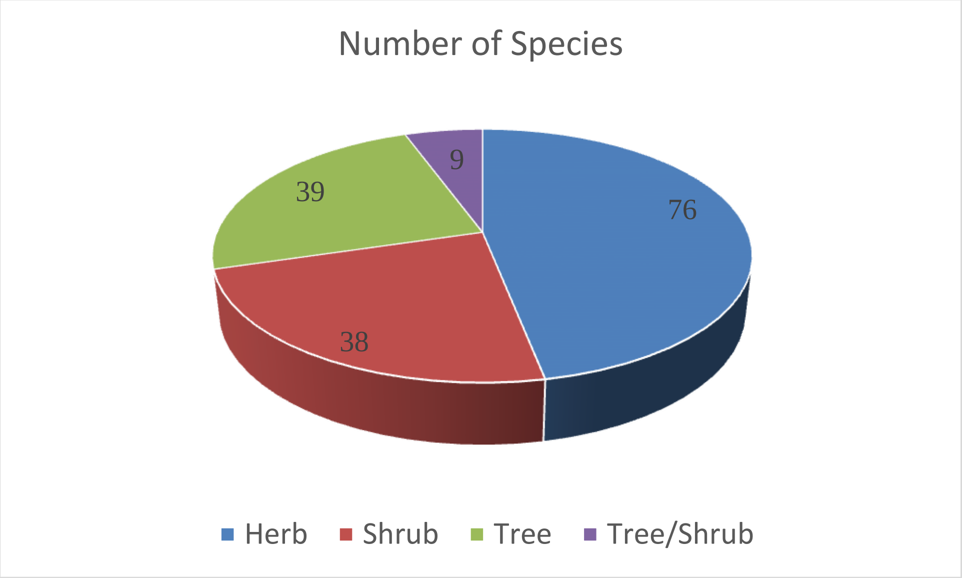


Figure 2 Life forms (habit) of medicinal plants

Table 8. Habit of medicinal plants in the study area

Habit	Number of Species	Species Percent	Use Frequency	Use Percent
Herb	76	46.91	864	53.47
Shrub	38	23.46	455	28.16
Tree	39	24.07	269	16.65
Tree/Shrub	9	5.56	28	1.73
Total	162	100.0	1616	100

Source of medicinal plants

The majority of the reported species (59.03%) were wild whereas some (35.68%) were reported as cultivated and others (5.29%) both wild and cultivated (Figure 3). This indicates that the practitioners depend on the wild source or the natural environment rather than home gardens to obtain the medicinal plants, and the activity of cultivating medicinal plants is very poor in the study area. It also indicates that the natural forest of West Hararghe Zone is being over exploited by traditional practitioners for its medicinal plants composition.

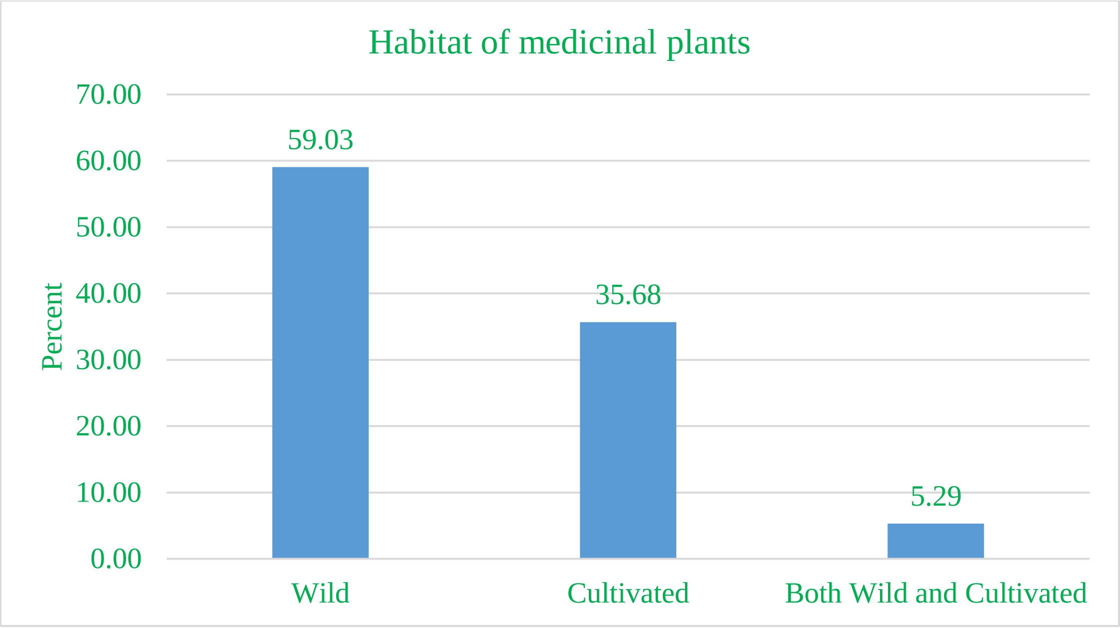


Figure 3. Source (habitat) of medicinal plants

Plant parts used to treat human and livestock ailments

People of the study area harvest different plant parts for preparation of traditional drugs (e.g. leaves, roots, seeds, barks and fruit). In the study area, the most frequently utilized plant part was leaf (35.47%) followed by root (21.80%), Seed (12.50%) (Table 8).

The diversity of plant parts found by this study agrees with the results obtained from other Ethnomedicinal studies; (Lulekal *et al.*, 2008, Yineger *et al.*, 2008, Mesfin *et al.*, 2009 and Mesfin *et al.*, 2014) and all reported that leaves were the plant parts most used in medicine preparations. Another similar result was shown in the work of Huai and Pei (2005) where the frequencies of harvest for leaves and roots were reported to be 35.47and 21.80%, respectively. The preference of leaves to other plant parts could be due to (1) ease of collection and preparation, (2) preparation of medicinal teas (Gazzaneo *et al*. 2005), and/or (3) the presence of more bioactive ingredients in leaves developed in response to phytophagous organ- isms since leaves are the most vulnerable parts of a plant (Bhattarai *et al*. 2006).

Such wide harvesting of leaf and the most harvested habit is herbs, which are important for survival of plants has a negative influence on the survival and continuity of useful medicinal plants and hence affects sustainable utilization of the plants (Lulekal et al., 2008).

Table 8. Plant parts used to treat human and livestock ailments

Parts used	Frequency of respondents	Percent
Leaf	122	35.47
Root	75	21.80
Seed	43	12.50
Stem	24	6.98
Leaf and Root	20	5.81
Fruit	11	3.20
Latex	8	2.33
Bark	7	2.03
Leaf and Seed	7	2.03
Leaf and Stem	7	2.03
Rhizome	7	2.03
Bulb	3	0.87
Root and Stem	3	0.87
Bark and Stem	2	0.58
Seed and Root	2	0.58
Husk	1	0.29
Leaf, fruit and Root	1	0.29
Oil	1	0.29
Total	344	100.00

Disease types, treatment methods and herbal preparations used to treat human health problems. Though 115 different disease types were recorded as human and livestock health problems in the districts, the major and most widespread diseases according to the informants include Sudden sickness, Skin disease/Tufaa/, Febrile illness, Evel eye and Stomachache (Table 9). In addition to these the practitioners were also visited for diseases like Dysentery, Toothache, Blotting, Gonorrhea, rheumatoid arthritis and hemorrhoids.

Table 9: Common diseases affecting human and livestock health in West Hararghe Zone

Disease type	No. plant used to treat	Percent
Sudden sickness	45	5.94
Skin disease/*Tufaa*	32	4.22
Febrile illness	31	4.09
Evel eye	26	3.43
Stomachache	26	3.43
Dysentery	25	3.30
Toothache	23	3.03
Blotting	22	2.90
Swelling	22	2.90
Gonorrhea	20	2.64

Onnee	20	2.64
Kidney problem	19	2.51
For blocked urination	18	2.37
Rheumatoid arthritis	18	2.37
Swollen body part (GOFLA)	18	2.37
Total	758	100.0

Internal ailments were commonly treated by making the patient drink herbal preparations; skin infections such as ringworm were treated by rubbing and painting herbal preparations on an infected skin; sores by chewing and spitting remedial plant part on the sore; headaches and fever by steam bath and vapor inhalation. Similar results were reported elsewhere in Ethiopia by (Balemie *et al.*, 2004 and Lulekal *et al.*, 2008).

Though special care was taken, some herbal preparations had side effects and resulted in diarrhoea and vomiting. When such conditions happened, antidotes like milk, honey and powder of roasted barley were used or ordered by most of the practitioners to reverse the condition. Most of the medicinal plant preparations given did not have standardized doses. In most cases dosages were determined according to the age, sex and physical appearance of the patient. Some of the medicinal plant preparations were measured in a small cup, a jug, while others as handful, or spoonful. Proper care is needed for sanitation of herbal preparations and their containers. Some preparations were placed in unclean containers and areas which may result contamination and seriously affect users when drunk. Patients suffered from overdose and contaminations were believed to recover by application of antidotes.

Substances like cold water, tea, honey, coffee, butter, olive oil, salt, sugar, meat, ash and milk were reported to be mixed with the plant materials during the preparation of remedies. The processed remedies were mostly administered through oral (62.09%) and dermal (20.26%) routes (Figure 4). These were followed by nasal (6.71%), the rest in total (10.96%) administrations. These results are consistent with the findings of various Ethnobotanical researches elsewhere in Ethiopia, such as that of (Giday *et al.*, 2003, Hunde *et al.*, 2004 and Lulekal *et al.*, 2008).

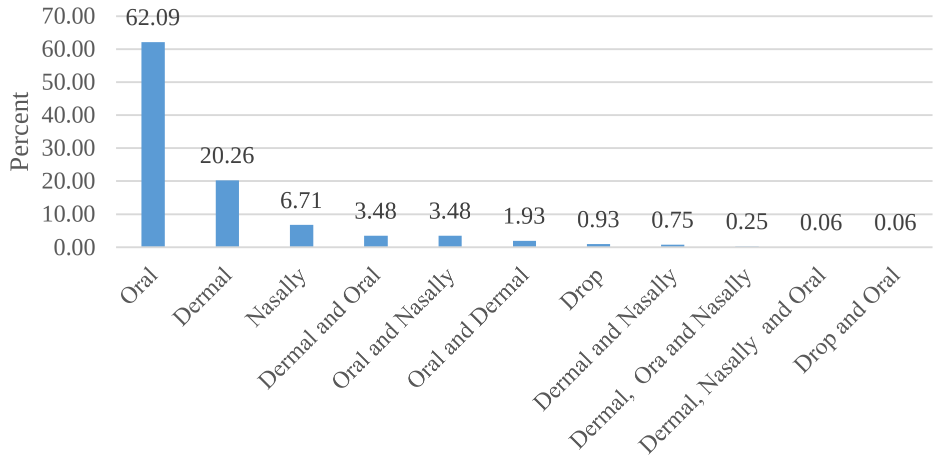


Figure 4. Route of Admistration

Medicinal Plants Used to Treat Human, Livestock and Both Human and Livestock Ailments

Among the collected medicinal plants, 86(53.09%) used to treat Human disease, 69 (42.59%) used to treat livestock ailments and 7 (4.32%) used to treat both human and livestock ailments (Table 10).

Table 10. Number of medicinal plants treat human, livestock and both human and livestock disease

Category	Number of plant	Percentage
Human	86	53.09
Livestock	69	42.59
Both Human and Livestock	7	4.32
Total	162	100

Conclusions and Recommendation

Traditional healers of West Hararghe Zone were found to be rich in their indigenous knowledge on the use of Ethnomedicinal plant species to manage various human and livestock ailments within the study area. This was evidenced with the result that a total of 114 human and livestock ailments were reported to be treated using 162 Ethnomedicinal plant species. The total number of plant treatments cited in this study could however indicate that the general culture of Ethnomedicinal knowledge secrecy was slightly lower with few exceptions.

Traditional healers dwelling in the three districts varied significantly in their indigenous knowledge on management of human and livestock ailments. This could on the one hand be attributed to the individual knowledge differences as a result of their background or indeed the depth of indigenous knowledge inherited. On the other hand it could be because of the ecological and environmental variations of the three districts, in other words there may be variations in species richness of the three districts. According to our result male uses few plants for different human and livestock diseases where females uses many plant for few human and livestock disease.

Most of the Ethnomedicinal species were reported to be collected from wild sources. The majority of Ethnomedicinal plant species reported in this study were repeatedly harvested for their leaves and roots. Similar result was shown in the work of Huai and Pei (2005) where the frequencies of harvest for leaves and roots were reported to be 35.47and 21.80%, respectively. The plant life form use pattern by traditional healers for remedy preparation in this study was consistent with the use patterns noted by other studies in Ethiopia (Fassil, 2003; Teklehaymanot *et al*., 2007; Yineger *et al*., 2007, Yineger *et al.*, 2008) where herbs and shrubs were consistently preferred life forms.

Most medicinal plant species were reported to be threatened by several factors such as human being, natural disaster and animals. In addition, traditional healers significantly cited the absence of efforts to conserve the reported Ethnomedicinal plant species. Urgent measures should therefore be taken so as to involve the traditional healers residing in West Harerghe Zone in the conservation and sustainable use of Ethnomedicinal plant resources as these were found to have significant contribution to meet the primary health cares of the local people in in the zone. Any benefits arising from use or application of the indigenous knowledge reported in this study accrues equitably to traditional healers residing in the zone. Traditional medicinal plants and associated indigenous knowledge are the main systems to maintain human and livestock health in West Harerghe Zone. But minimal conservation measures were recorded in the community. Thus, in-situ and ex-situ conservation practices and sustainable utilization are required in the Zone.

Acknowledgements

The authors express their gratitude to the staff of Agroforestry Research Team of Mechara Agriculture Research Center for their follow- up and data collection, and Oromia Agricultural Research Institution for its financial support.

Reference

Abebe D, Zewdu M, Demissei A: The role of medicinal plants in health care coverage of Ethiopia, the possible integration. Conservation and sustainable use of medicinal plants in Ethiopia, proceeding of the national work shop, 28 april-01 May. 2001, Addis Ababa: Institute of Biodiversity Conservation and Research, 6-21.

Addis G, Abebe D, Urga K: A survey of traditional medicine in Shirka District, Arsi Zone, Ethiopia. Ethiop pharm j 2001, 19:30-47.

Asfaw D, Abebe D, Urga K: Traditional medicine in Ethiopia: perspectives and developmental efforts. J Ethiop Med Pract 1999, 1(2):114-17.

Balemie K, Kelbessa E, Asfaw Z: Indigenous medicinal plant uti- lization, management and threats in Fentalle area, Eastern Shewa, Ethiopia. Ethiopian Journal of Biological Sciences 2004, 3:37-58.

Bhattarai, S., R.P. Chaudhary & R.S.L. Taylor. 2006. Eth- nomedicinal plants used by the people of Manang district, central Nepal. Journal of Ethnobiology and Ethnomedicine

Bishaw B: Attitudes of modern and traditional medical practi- tioners toward cooperation. Ethiop Med J 1990, 28:63-72.

Belayneh, Anteneh Asfaw, Zemede Demissew, Sebsebe Bussa, Negussie F. 2012. Medicinal plants potential and use by pastoral and agro-pastoral communities in Erer Valley of BabileWereda, eastern Ethiopia. Journal of Ethnobiology and Ethnomedicine.; 8:42.

Birhanu T, Abera D, Ejeta E. Ethnobotanical study of Medicinal Plants in Selected HorroGudurruWoredas, Western Ethiopia. Journal of Biology Agriculture and Healthcare.2015; 5:1.

Fisseha M. 2007. An ethnobotanical study of medicinal plants in Wonagooreda, SNNPR, ETHIOPIA.M.Sc. Thesis, Addis Ababa University, Ethiopia.

Gazzaneo, L.R.S., R.F.P. Lucena & U.P. Albuquerque. 2005. Knowledge and use of medicinal plants by local specialists in an region of Atlantic Forest in the state of Pernambuco (Northeastern Brazil). Journal of Ethnobi- ology and Ethnomedicine

Giday M, Asfaw Z, Elmqvist T, Woldu Z: An ethnobotanical study of medicinal plants used by the Zay people in Ethiopia. J Eth- nopharmacol 2003, 85(1):43-52.

Giday M, Teklehaymanot T, Animut A, Mekonnen Y: Medicinal plants of the Shinasha, Agew-awi and Amhara peoples in Northwest Ethiopia. Journal of Ethnopharmacology 2007, 110:516-525

Giday M, Teklehaymanot T. Ethnobotanical study of plants used in management of livestock health problems by Afar people of Ada’ar district, afar regional state, Ethiopia. J EthnobiolEthnomed.2013; 9:8.

HDANRO. (2014). Habro District’s of Agricultural and Natural Resource Office, the Annual Report. Gelamso, Ethiopia.

Huai HY, Pei SJ (2005). Plants Used Medicinally by Folk Healers of the Lahu People from the Autonomous County of Jinping Miao, Yao, and Dai in Southwest China. Economic Botany 58:265-273.

Hunde D, Asfaw Z, Kelbessa E: Use and management of ethnoveterinary medicinal plants by indigenous people in 'Boosat', Welenchiti area. Ethiopian Journal of Biological Sciences 2004, 3:113-132.

Ivanete Cardoso Palheta1, Ana CláudiaCaldeira Tavares-Martins1, Flávia Cristina Araújo Lucas1 and

Mário Augusto GonçalvesJardim. 2017. Ethnobotanical study of medicinal plants in urban home gardens in the city of Ethnobotanical study of medicinal plants in urban home gardens in the city of Abaetetuba ,Pará state , Brazil.

Kalayu Mesfin ,GebruTekle , TeklemichaelTesfay . (2013). Journal of Medicinal Plants Studies Ethnobotanical Study of Traditional Medicinal Plants Used by Indigenous People of Gemad District , Northern Ethiopia, 1(4), 32–37.

Kebede, A., Ayalew, S., Mesfin, A., &Mulualem, G. (2016). Ethnobotanical investigation of traditional medicinal plants commercialized in the markets of Dire Dawacity , eastern Ethiopia, 4(3), 170–178.

Kent, M. and Coker, P. 1992. Vegetation description and analysis: A practical approach, Belhaven Press, London, UK.

Lulekal, E., E. Kelbessa, T. Bekele & H. Yineger. 2008. An ethnobotanical study of medicinal plants in Mana Angetu District, southeastern Ethiopia. Journal of Ethnobiology and Ethnomedicine 4:10. dx.doi.org/10.1186/1746-4269- 4-10

Mengistu A.K., 2004. The Effect of Herbal Preparations on Staphylococcus aureus and Streptococcus agalactiae isolated from clinical bovine mastitis (Un published MSC thesis Faculty of veterinary medicine, AAU).

Mesfin, F., S. Demissew & T. Teklehaymanot. 2009. An ethnobotanical study of medicinal plants in Wonago Wore- da, SNNPR, Ethiopia. Journal of Ethnobiology and Ethno- medicine 5:28 1–18. dx.doi.org/10.1186/1746-4269-5-28

Mesfin, F., Seta, T., & Assefa, A. (2014). An ethnobotanical study of medicinal plants in Amaro Woreda, Ethiopia. Ethnobotany Research and Applications, 12(September), 341–354.

Shimelis Dekeba, Lisanework Nigatu., & Muktar Mohammed (2019). Floristic composition of homegarden agroforestry system in habro district, oromia regional state, ethiopia. 7(3), 074–086.

Sudi Dawud, M. C. and J. M. S. (2018). Floristic Composition , Structural Analysis and Regeneration Status of Woody Floristic Composition , Structural Analysis and Regeneration Status of Woody Species of Gemechis Natural Forest , West Hararghe Zone , Oromia , Ethiopia.

Tabuti JRS, Dhillion SS, Lye KA. The status of wild food plants in Bulamogi County, Uganda. Int J Food SciNutr.2004;55(6):485–498.

Tolossa K, Debela E, Athanasiadou S, Tolera A, Ganga G, Jos H. Ethno-medicinal study of plants used for treatment of human and livestock ailments by traditional healers in South Omo, Southern Ethiopia. J Ethnobiology Ethnomed. 2013; 9:32

Teklehaymanot T, Giday M. Ethnobotanical study of medicinal plants used by people in Zegie Peninsula, northwestern Ethiopia. J Ethnobiol Ethnomed. 2007;3:12.

Tesfu CB, Mengistu B, Wolde Aregay G: Women Lead in Protecting Food Germplasm and Herbs for Health in Ethiopia Report submitted to EarthCare Africa, Nairobi, Kenya (unpublished); 1995

Wasihun et al., 2019; Characterization of Past and Future Climate Variability of Habro District, West Harerghe Zone, Oromia, Ethiopia

Yineger, H., Kelbessa, E., & Bekele, T. (2008). Plants used in traditional management of human ailments at Bale Mountains National Park, Southeastern Ethiopia. J. Med. Plant. Res, 2(6), 132–153.

Appendix

Table 1: Individual medicinal plant species used to treat ailments human and livestock health in West Hararghe Zone

S.N	Names of medicinal plant species	No. of ailments treated
1	*Allium sativum*	19
2	*Aloe spp*	18
3	*Croton macrostachyus* Del.	18
4	*Withania somnifera* (L.)	18
5	*Cissampeclos pareira L.*	17
6	*Citrus aurantiifolia* (Christm.) Swingle	17
7	*Solanecio gigas* (Vatke) C. Jeffrey	17
8	*Vernonia anygdalina*	17
9	*Carissa spinarum* L.	16
10	*Lepidium sativum* L.	16
11	*Ruta chalepensis* L.	16
12	*Artemisia abyssinica* Sch. Bip. ex A. Rich.	15
13	*Cucumis pustulatus* Naud. ex Hook.f.	15
14	*Moringa oleifera* Lam.	15
15	*Nigella sativa* L.	15
16	*Tragia cinerea* (Pax) Gilbert & Radcl.-Smith	13
17	*Datura stramonium* Mill.	12
18	*Rhynchosia malacotricha* Harms	12
19	*Calpurnia aurea* (Ait.)Benth.	11
20	*Echinops kebericho* Mesfin	11
21	*Hydnora johannis* Becc.	11
22	*Viscum triflorum* DC.	11
23	*Clerodendrum myricoides* (Hochst.)	10
24	*Ocimum lamifolium* Hoschst. ex. Benth.	10
25	*Plectranthus barbatus* Andrews	10
26	*Brassica carinata* A. Br.	9
27	*Euclea racemosa subsp. schimperi (A. DC.) White*	9
28	*Mirabilis jalapa* L.	9
29	*Pycnostachys abyssinica* Fresen.	9
30	*Solanum incanum* L.	9
31	*Verbascum sinaiticum* Benth	9
32	*Hagenia abyssinica* (Bruce) Gmelin.	8
33	*Zingiber officinale* Roscoe*	8
34	*Gomphocarpus fruticosus* (L.) R..Brown	7
35	*Thymus schimperi+ Ronniger*	7
36	*Dodonaea angustifolia* L. f.	6
37	*Jasminum abyssinicum* Hochst ex Dc.	6

38	*Melia azedarach* L.	6
39	*Myrsine africana* L.	6
40	*Bidens pilosa* L.	5
41	*Carica papaya* L.	5
42	*Cordia africana* Lam.	5
43	*Ehretia cymosa* Thonn.a	5
44	*Eucalyptus globulus* Labill.	5
45	*Foeniculum vulgare* Mill.	5
46	*Olea europaea* L.	5
47	*Otostegia integrifolia* Benth	5
48	*Parthenium hysterophorus* L.	5
49	*Premna schiniperi* Engler	5
50	*Ricinus communis* L.	5
51	*Rumex nepalensis* Spreng.	5
52	*Zanthoxylum chalybeum* Engl.	5
53	*Chlorophytum somaliense* Bak.	4
54	*Erythrina burana* Chiovenda.	4
55	*Gossypium barbadense* L.	4
56	*Justicia schimperiana* (Hochst. ex Nees) T. Anders	4
57	*Kalanchoe marmorata* Bak.	4
58	*Kirkia burgeri Stannard* (Simaroubaceae).	4
59	*Lawsonia inermis* L.	4
60	*Linum usitatissimum* L	4
61	*Lippia adoensis* Hochst. Ex Walp.	4
62	*Ocimum americanum* L.	4
63	*Plantago lanceolata* L.	4
64	*Rhamnus prinoides* L Herit.	4
65	*Rumex abyssinicus* Jacq	4
66	*Silene macrosolen*	4
67	*Xanthium spinosum* L.	4
68	*Acokanthera schimperi* (A.D.C.)	3
69	*Asparagus africanus* Lam	3
70	*Capsicum annuum* L.	3
71	*Catha edulis* Forsk.	3
72	*Commelina benghalensis* L.	3
73	*Coriandrum sativum* L.	3
74	*Cucumis ficifolus* A.Rich	3
75	*Cymbopogon martini* (Roxb.)	3
76	*Digitaria velutina* (Forsk.) Beauv.	3
77	*Eleusine floccifolia* (Forssk.)Spreng.	3
78	*Flacourtia indica* (Burm.f.) Merr.	3

79	*Kalanchoe lanceolata* Forssk.	3
80	*Leonotis ocymifolia* (Burml. f.)	3
81	*Nicotiana tabacum* L.	3
82	*Quercus brantii* Lindl	3
83	*Rhus natalensis* Krauss.	3
84	*Rhus ruspolii* Engl.	3
85	*Sphaeranthus suaveolens* (Forssk.) DC.	3
86	*Ziziphus mauritiana* Lam.	3
87	*Ziziphus spina-christi* L.	3
88	*Acacia brevispica*	2
89	*Allium cepa* L	2
90	*Aloysia triphylla* Britt.	2
91	*Alysicarpus rugosus* (Willd.) DC.	2
92	*Caesalpinia decapetala* (Roth) Alston	2
93	*Capparis tomentosa*	2
94	*Coffea arabica* L.	2
95	*Cucurbita pepo* L	2
96	*Cyphostemma adenocaule* (Steud. ex A. Rich.)	2
97	*Dichrostachys cinerea* (L.)Wight and Arn.	2
98	*Ekebergia capensis*	2
99	*Grewia bicolor* Juss.	2
100	*Guizotia scabra* (Vis.) Chiov.	2
101	*Hypoestes triflora* (Forssk.)	2
102	*Kleinia longiflora* DC.	2
103	*Lagenaria siceraria* (Molina) Standley.	2
104	*Lycopersicn esculentum* Milerl	2
105	*Malus domestica* Borkh.	2
106	*Malvaverticillata* L.	2
107	*Maytenus arbutifolia* (A.Rich.) Wilczek	2
108	*Momordica spp.*	2
109	*Myrtus communis* L.	2
110	*Plumbago zeylanica* L.	2
111	*Prunus persica* (L.) Stockes.	2
112	*Psidium guajava* L.	2
113	*Raphanus sativus* L.	2
114	*Rubus apetalus* Poir	2
115	*Schefflera abyssinica* (Hochst. ex A. Rich.)	2
116	*Senna didymobotra*	2
117	*Setaria pumila* (Poir.) Roem. & Schult.	2
118	*Suregada procera* (Prain) Croizat.	2
119	*Syzygium guineensevar*. (Wild.) DC.	2

120	*Acacia etbaica* Schweinf.	1
121	*Acacia tortilis*	1
122	*Anethum foeniculum* L.	1
123	*Arachis hypogaea*	1
124	*Balanites aegyptiaca* (L.) Del.c	1
125	*Buddleja polytachya*	1
126	*Casimiroa edulis* La Llave	1
127	*Celtis africana* Burm.	1
128	*Cicer arietinum* L.	1
129	*Citrus sinensis* (L.) Osb.	1
130	*Commicarpus pedunculosus* (Rich.) Cuf.	1
131	*Corchorus olitorius* L.	1
132	*Daucus carota* L.	1
133	*Dipcadi lanceolatum* Baker	1
134	*Dovayalis abyssinica*	1
135	*Dracaena afromontana* Mildbr.	1
136	*Euphorbia tirucalli* L.	1
137	*Ficus sycomorus* L.	1
138	*Guizotia abyssinica* (L.f.)	1
139	*Helianthus annuus* L.	1
140	*Ipomoea batatas* (L.) Lam.	1
141	*Lantana camara* L.	1
142	*Lens culinaris* Medikus	1
143	*Leucas stachydiformis* Hochst ex. Benth.	1
144	*Mangifera indica* L.	1
145	*Mimusops kummel* Bruce ex DC.	1
146	*Musa paradisiaca* L.	1
147	*Osyris quadripartite* Decn.	1
148	*Phaseolus vulgaris* L.	1
149	*Phytolacca dodecandra* L'Her.	1
150	*Podocarpus gracilior* Pilger.	1
151	*Prunus africana* (Hook.f.) Kalkm.	1
152	*Punica granatum* L.	1
153	*Rumex bequartii* De Wild.	1
154	*Sarcostemma viminale* (L.) R. Br.	1
155	*Senna occidentalis*	1
156	*Stephania abyssinica* (Qu. Dillon. & A. Rich.) Walpers.	1
157	*Syzygium aromaticum* (L.) Merr. & Perry	1
158	*Tagetes minuta* L.	1
159	*Tamarindus indica* L.	1
160	*Trigonella foenum-graecum* L.	1

161	*Urtica urens* L.	1
162	*Vernonia stipulacea* Klutt.	1

Table 2: Human and livestock ailments treated in West Hararghe Zone

Disease type	No. of plant used to treat ailments
Sudden sickness	45
Skin disease/Tufaa	32
Febrile illness	31
Evil eye	26
Stomachache	26
Dysentery	25
Toothache	23
Blotting	22
Swelling	22
Gonorrhea	20
Onnee	20
Kidney problem	19
For blocked urination	18
Rheumatoid arthritis	18
Swollen body part (*GOFLA*)	18
Cough	16
Stop bleeding	15
Headache	14
Vomiting	14
Earache	12
Snake poison	12
Gowwajes	11
Jaundice	10
Tonsils	10
Asthma	9
Gastritis	9
Homeoroide	9
Internal parasites	9
Willistii	9
Animal Sickness	8
Koleeraa	8
Lack of milk	8
Stomach dryness	8
Wound	8
Eye infection	7
Worm	7
Evil sprit	6

Delivery problem	5
Herpes zoster	5
Pharingitis	5
Blood pressure	4
Ajii	4
Baaraga	4
Babies' sickness	4
Closed breast	4
Cow Refused milking	4
Hepatitis	4
Impotence	4
Malaria	4
Ring worm	4
All disease	3
Anthrax	3
Dandruff	3
Falfala	3
Gaagura uluf	3
Garaa looni	3
Germs	3
Hollachisa horii	3
Hurgufannaa	3
Kalaada	3
Lung Infection	3
Mental disorder	3
New castle	3
Retained feces	3
Scabies	3
Stomach bleeding	3
Tinea corporis	3
Abortion	2
Anemia	2
Back pain	2
Blindness	2
Booftaa	2
Breast ulcerate	2
Cabisa	2
Diabetes	2
Eczema	2
Epilepsy	2
Fincile	2

Hidda mormaa	2
Insect	2
Intestinal infection	2
Liver disease	2
Parasite	2
Poison	2
Rabies	2
Sickness	2
Tick	2
Abacoqqarree	1
Baloqa jiaa	1
Bira'uu	1
Body dryness	1
Body pain	1
Breast pain	1
Bullet resistance	1
Cancer	1
Cirkirii(rifensa)	1
Dwarfism	1
Dysentery With blood	1
Erythroblasts	1
Furrunqoo	1
Gororsaa	1
Hafuura horii	1
Hemorrhoids	1
Laydaa	1
Leeches	1
Lung disease	1
Machii	1
Menstrual disorders	1
Malnutrition	1
Nasal bleeding	1
Retained placenta	1
Skin infection	1
Skin rash	1
Stress	1
Tape worm	1

Adaptation and Growth Performance of Nitrogen Fixing Tree/Shrub Species in Dello-menna District of Bale zone, Southeast Ethiopia

Wondmagegn Bekele[1*], Bikila Mengistu[2], Hirpha Aregay[1], Zerihun Dibaba[1] and Fikru Ameyu[1]

[1]Oromia Agricultural Research Institute, Sinana Agricultural Research Center, Bale-Robe, Ethiopia
[2] Oromia Agricultural Research Institute, Fitche Agricultural Research Center, North-Shewa, Ethiopia
*Corresponding author email: wondmagegnb2004@gmail.com

Abstract

Prior integration of any tree/shrub species in a given land use system there is always the need of undertaking a field trials for their adaptability and growth performance under a particular environment. Study was planned and conducted to evaluate the adaptability potential and growth performance of six nitrogen fixing tree/shrub species in Dello-menna district of Bale zone, southeast Ethiopia. The considered species in the study are Cajanus cajan, Flemingya macrophylla, Gliricidia sepium, Sesbania sesban, Calliandra calothyrsus and Leucaena leucocephela. Seedlings were produced in a nursery site and transplanted to the experimental site. The experiment was laid out in RCBD design with three replications, and the management practices employed uniformly for each species throughout the stud period. In the study the necessary growth performance data parameters; plant height, root collar diameter and survival rate were measured and recorded. Thereafter, the data was analyzed by GenStat (15th ed) and Excel computerized programs. Results obtained showed that, these growth performance data parameters were significantly ($p < 0.05$) varied among the tested species. In this respect, Flemingya macrophylla, Sesbania sesban, Gliricidia sepium and Cajanus cajan attain the higher mean values in survival rate, plant height and root collar diameter. While Leucaena leucocephela and Calliandra calothyrsus attain the lowest mean values for the entire growth performance parameters. Hence, it can be inferred that the study site matched well with the environmental requirement of F. macrophylla, S. sesban, G. sepium and C. cajan. The species therefore offers much promise for future use in any of agroforestry practices in the area. However, evaluation of their contribution to soil fertility improvement and crop yield needs to be further investigated as this may insights to know their nutrient provision potential while integrated together with annual and/or perennial plants in agroforestry land use system.

Keywords; Agroforestry, plant height, root collar diameter, survival rate

Background and Justification

In Ethiopia, Bale zone is well known by vegetation cover and most of the surrounding area is covered by forests comprised of a rich mixture of woody species. In spite of the importance of forest ecosystem to the livelihoods of the people in the area, the forest is dwindling from time to time due to over exploitation of woody and non-woody products. Consequently, the area is now characterized by loss of soil fertility and soil erosion problems (Wondmagegn and Lisanework, 2019). The integration of woody species in agricultural landscape could reduce the pressure on the surrounding natural forest. For instance, agroforestry, which combine forestry and agriculture, have the capacity to sustain the productivity of farmlands (Nair, 1993). Moreover, the system could also serve as buffer zone for forest degradation and deforestation.

The most decisive factor for the successive Agroforestry is the choice of suitable useable tree/shrub species. Nitrogen fixing (legume) tree/shrub species are found to get popularity because of their fast growth, reducing fertilizer needs and coppicing behavior (Sarmin *et al*., 2014). However, this will be effective if the right species planted in the right place as their adaptability potential strongly dependent up on the local climatic conditions and soil characteristics (Tilahun *et al.*, 2006; Getahun *et al.*, 2017). This has pointed that, prior planting of any tree/shrub species in a given agro-ecology there is always the need of conducting a field trials on the suitability of the species for a particular site focusing on their adaptability and growth performance.

In many parts of Ethiopia, studies on adaptability and growth performance of tree/shrub species have been conducted (Getahun *et al.*, 2017; Musa and Bira, 2020). However, in Dello-menna district of Bale zone, southeast Ethiopia, such experiments have not been yet conducted. This has been resulting that, plantation effort which has been undertaken by different stakeholder in the area to be restricted on a narrow range of tree/shrub species. Hence, this calls the introduction and evaluation of more alternative tree/shrub species via test of trial is the need so as to diversify the options available and reduce the risks of over dependency on fewer species. The species may also offer an opportunity to develop better productive agroforestry land use system, importantly to solve the continuum soil degradation problem of the area. In realizing this, study was planned and undertaken with an objective of evaluating the adaptability potential of nitrogen fixing tree/shrub species in the study area.

Materials and Method

Description of the study area

The experiment was conducted at Sinana Agricultural Research sub sites of Cirri found in Dello-menna district of Bale zone, southeast Ethiopia. Geographically, Cirri research subsite located at 6. 405 N and 39.782 E. The altitude of the district ranges within 1000 - 2500 meters above sea level (Abiyot and Gonfa, 2015). The rainfall pattern in the area is the bimodal type, that is, middle of March to end of May (short rain season) and September to October (the main rainy season). Annual rainfall ranges within 700 - 1200 mm. The average temperature for Dello-menna is 18°C whereas the soil type is dominantly clay Niti-sol.

Treatments and Experimental Procedure

Six nitrogen fixing tree/shrub species namely; *Cajanus cajan, Gliricidia sepium, Calliandra calothyrsus, Flemingya macrophylla, Sesbania sesban* and *Lucaena leucocephela* are used. The seeds of the species were obtained from International livestock Research Institute (ILRI) of Ethiopia, which is located in Addis Ababa. In doing so the seeds were sown at chiri nursery site there by using a polythene tube size of 10 cm and potting mixture of 3:2:1 (forest, local and sandy soil). Initially the seedlings were raised under 60% of shade netting. However, in the meantime shading and watering frequency reduced as the seedlings grew. Even, the shade was completely removed a few days prior to planting in the field trial, in order to harden off. Finally, seedlings were transplanted and installed to the field trial by using RCBD design with three replications with a plot size of 8 m x 6 m for each species. The spacing between plants was 2 m x 2 m consisting of 12 plants over a single plot.

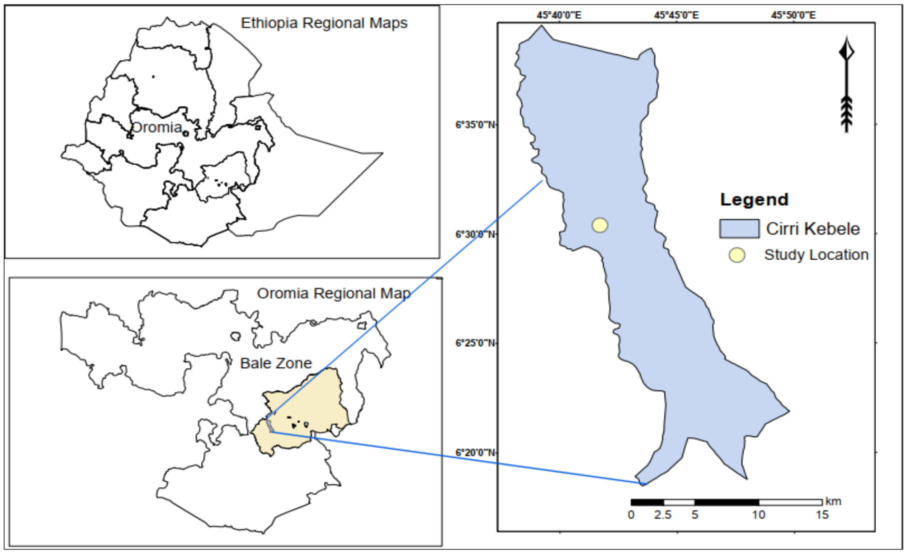


Figure 1. Location of the study area

Data collection and statistical analysis

The necessary growth-performance evaluating data parameters were collected. Survival rate, height and root collar diameter were the three parameters, which are considered for each species. Survival count was made for the whole tree/shrub species found in a plot (12plants/plot), whereas for the remaining parameters about 6 trees are used as data source. Heights were measured using meter tape and/or graduated stick depending on the height of the trees. Likely, diameter (RCD) is measured by meter tape and caliper. Finally, the collected data were summarized and analyzed by using GenStat (15th ed.) and Microsoft Excel computerized programs.

Results and Discussion

Survival Rate

Results obtained from the study show that, except the first year a significant difference ($p<0.05$) was reported for the survival rate of the species (table 1). During the 2nd and 3rd years of study period, *Flemingya macrophylla*, *Sesbania sesban*, and *Cajanus cajan* and *Gliricidia sepium* attain the highest mean values ranging from 83.33 to 100. This infers the condition of the study area matched well with the environmental requirement of these species.

Against to this *Calliandra calothyrsus and Lucaena leucocephela* had the lowest survival rates over the entire experimental period. The lower survival rates of *Lucaena leucocephela and C. calothyrsus* attribute to their suitability for fodder production. As a result of this finding the seedlings of these two species were adversely attacked by wild animals, namely: by antelope and buck at the night time of experimental period.

Table 1: The mean of survival rate of the species over the years of experimental period

Species	Year I	Year II	Year III	Total mean
Cajanus cajan	97.22 ^{a}	97.22 c	94.63 ^{c}	96.36 ^{b}
Flemingya macrophylla	100.00 ^{a}	100 ^{c}	100 ^{c}	100 ^{b}
Calliandra calothyrsus	83.89 ^{a}	52.78 ^{b}	11.11 ^{a}	49.26 ^{a}
Lucaena leucocephela	*83.33* ^{a}	16.66 ^{a}	13.89 ^{a}	37.96 ^{a}
Glericidia sepium	97.22 ^{a}	91.66 ^{c}	83.33 ^{b}	90.74 ^{b}
Sesbania sesban	100·00 ^{a}	97.22 ^{c}	96.14 ^{c}	97.89 ^{b}
LSD ($p < 0.05$)	25.46	26.06	9.52	21.10

N/B: Means in columns with the same letters are not significantly different, LSD= Least significant difference

Height Growth

Analysis of variance revealed that variations in height among the species was considerably ($P<0.05$) variable over the years of study period (table 2). As results reported, plant height of *Sesbania sesban* was the tallest closely followed by *Flemingya macrophylla and Cajanus cajan.* This is in line with the findings of Betre *et al.* (2000), who found superior performance of *Sesbania sesban* as compared to other species. Yamoah (1989) also reported better growth performance of *Sesbania* as compared to *Lucaena*, *Calliandra* and *Chamaecystisus* in Rwanda. This might be attributed to environmental requirement of the species and/or their genetic superiority.

Table 2: Mean of plant height (cm) as influenced by species over the years of study period

Species	Year I	Year II	Year III	Total mean
Cajanus cajan	218.10 ^{b}	227.30 ^{c}	242.20 ^{c}	229.20 ^{bc}
Flemingya macrophylla	150.0 ^{ab}	244.00 ^{c}	222.00 ^{c}	199.80 ^{ab}
Calliandra calothyrsus	62.50 ^{a}	70.00 ^{a}	37.10 ^{a}	186.90 ^{ab}
Lucaena leucocephela	*72.30* ^{a}	107.70 ^{ab}	38.20 ^{a}	111.10 ^{a}
Glericidia sepium	50.50 ^{a}	133.00 ^{b}	115.40 ^{b}	99.60 ^{a}
Sesbania sesban	485.90 ^{c}	423.30 ^{d}	596.00 ^{d}	396.60 ^{c}
LSD ($p < 0.05$)	108.6	51.69	46.22	168.70

N/B: Means in columns with the same letters are not significantly different, LSD= Least significant difference

Root collar diameter

Significant variation ($p < 0.05$) in root collar diameter growth is also reported among the studied species (table 3). Consistent to the observation made for plant height, the maximum root collar diameter was measured for *S. sesban* followed by *F. macrophylla* and *C. cajan*, the former being significantly higher than the latter two over the entire experimental period.

Table 3: Mean of root collar diameter (cm) as influenced by species type over the years of study period

Species	Year I	Year II	Year III	Total mean
Cajanus cajan	2.96 ^{b}	5.32 ^{bcd}	6.36 c	4.88 ^{b}
Flemingya macrophylla	5.06 ^{c}	6.13 ^{d}	6.14 ^{c}	5.77 ^{c}
Calliandra calothyrsus	1.60 ^{a}	2.20 ^{a}	2.96 ^{a}	2.25 a
Lucaena leucocephela	2.12 ^{ab}	3.47 ^{a}	3.47 ^{a}	3.09 ^{a}
Glericidia sepium	3.65 b	4.01 ^{bc}	5.08 ^{b}	4.25 ^{b}
Sesbania sesban	7.78 ^{d}	8.17 ^{e}	8.40 ^{d}	8.17 ^{d}
LSD ($p < 0.05$)	1.270	1.67	0.97	0.91

N/B: Means in columns with the same letters are not significantly different, LSD= Least significant difference

Results indicated that tree species having greatest root collar diameter were those, which grew tallest. Highly significant correlation (r =0.95, p = 0.001) was observed between height growth and root collar diameter development. Most of the tree and/or shrub species (about 83.3%) having more height growth exhibited higher root collar diameter growth. Similarly, species with lower height growth had lower root collar diameter growth. Abebe *et al.* (2000) also reported similar highest correlation between height growth and root collar diameter growth of tree/shrub species.

Summary and Conclusion

The most decisive factor for the successive Agroforestry is the choice of suitable useable tree/shrub species. Nitrogen fixing (legume) tree and shrub species are found to get popularity because of their fast growth, reducing fertilizer needs and coppicing behavior. However, this will be effective if the right species planted in the right place as their adaptability potential strongly dependent up on the local climatic conditions and soil characteristics. With this general understanding, study was planned and conducted to evaluate the adaptability potential of six nitrogen fixing tree/shrub species in Dello-menna district of Bale zone, southeast Ethiopia. The species were; *Cajanus cajan, Flemingya macrophylla, Gliricidia sepium, Sesbania sesban, Calliandra calothyrsus* and *Leucaena leucocephela*.

The result revealed that the survival rate of *Flemingya macrophylla* was found to be the highest followed by *Sesbania sesban* and *Cajanus cajan* respectively. While *Lucaena leucocephela* and *Calliandra calothyrsus* showed poor survival rate. The lower survival rates of *Lucaena leucocephela* and *Calliandra calothyrsus* were attributed to their suitability for fodder production as both were adversely attacked by wild animals during the study period. *Flemingya macrophylla, Sesbania sesban, Gliricidia sepium* and *Cajanus cajan* attain the highest mean values in height and root collar diameter while *Calliandra calothyrsus* and *Lucaena leucocephela* had the lowest values. Overall, *Flemingya macrophylla, Cajanus cajan, Gliricidia sepium* and *Sesbania sesban* species have shown the better vigorous growth performance in the study area. Hence, the integration of these tree/shrub species into any of tree-based land use system will be beneficial either to get their environmental or economic function. However, evaluation of their contribution to soil fertility improvement and crop yield needs to be further investigated as this may insights to know their nutrient provision potential while integrated together with annual and/or perennial plants in agroforestry land use systems.

References

Abebe Yadessa, Diriba Bekere and Taye Bekele, 2000. Growth performance of different multipurpose tree and shrub species at Bako, Wester Oromia. Pp. 177 – 186. In: Proceedings of the fifth conference of the Ethiopian society of soil science. March 30 – 31, 2000, Addis Ababa, Ethiopia.

Abiyot Molla and Gonfa Kewessa, 2015. Woody Species Diversity in Traditional Agroforestry Practices of Dellomenna District, Southeastern Ethiopia: Implication for Maintaining Native Woody Species. International Journal of Biodiversity; Article ID 643031.

Betre Alemu, Tekalign Mamo, Alemayehu Zemedie and Ebrahim Ahmed, 2000. Promising Multipurpose tree species and their response to landform on highland vertisols at Chefe Donsa, central highlands of Ethiopia. Pp. 145 – 155. In: Proceedings of the fifth conference of the Ethiopian society of soil science. March 30 – 31, 2000, Addis Ababa.

Getahun Yakob, Kebede Gizachew, Anteneh Fekadu, Kefyalew Kassa, 2017. Growth performance of some multipurpose tree species around the homesteads in Gimbo District, Southwestern Ethiopia. *Journal of Agriculture, Forestry and Fisheries. Vol. 6, No. 1,* pp. 1-5. Doi: 10.11648/j.aff.20170601.11.

Musa Abdella and Bira Cheneke, 2020. Adaptation and Growth Performance of Multipurpose Tree Species under Erer Dodota condition, Harari Region, Ethiopia. International Journal of Environmental Sciences & Natural Resources; vol. 24(1): 556130. Doi: 10.19080/IJESNR.2020.23.556130

Nair, 1993. An introduction to agroforestry. Kluwer Academic Publisher, Dordrecht, Netherland. pp. 499.

Sarmin, Miah and Mohd Hasmadi, 2014. Comparative growth performance of four multipurpose tree species in different containers under nursery condition at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh. *Journal of agroforestry and Environment, 8(2): 43 - 48.*

Tilahun Chibsa, Motuma Didita, Yifru Abera and Mengistu Yadessa, 2006. Screening of Multipurpose tree and shrub species for adaptability and growth performance at Sinana, Southeastern Ethiopia. Ethiopian Journal of Natural Resource, vol. 8 (2): pp. 271 – 279.

Wondmagegn Bekele and Lisanework Nigatu, 2019. Chemical composition of green foliage biomass of three agroforestry shrub species grown in Dello-menna district of Bale Zone, southeast Ethiopia. International Journal of Agroforestry and Silviculture: vol. 7(1), pp. 1 - 4

Yamoah, C., Grosz, R. and Nizeyimana, E., 1989. Early growth of alley shrub species in the highland regions of Rwanda. Journal of Agroforestry systems, vol 9(2): pp. 171 – 184.