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PREFACE

Agricultural Growth Program (AGP-II) is one and perhaps the biggest World Bank and other donor partners supported project with significant achievements in generating demand driven agricultural technologies, demonstrating proven technologies to farmers and other end users, producing ample early generation seeds and other source technologies, and enabling the implementation capacity of research institutions/centres through physical & human capacity building.

AGP-II beneficiary research centres found under Oromia Agricultural Research Institute (IQQO) conducted 642 different research activities during the last four years (2016/17 – 2019/20) with the financial support of AGP-II. Among those, 236 research activities were technology generation/adaptation. From the experiments conducted under technology generation and adaptation sub component, 152 deliverable technologies were generated (165% of the five years project plan), where 108 are demand driven and 44 are from end stage verifications. The technologies generated are categorized as gender sensitive (26), nutrition sensitive (43), Climate Smart Agriculture (41) and multipurpose (42). Those deliverable technologies were generated from multidisciplinary (93 from crops, 12 from livestock, 26 from natural resource, 20 from Agricultural Engineering & 1 from food science directorate). A total of 20 improved crops varieties were released with the support of this project (15 food & 5 feed crops).

In 2019/20, a total of 95 research activities were conducted under the technology generation and adaptation sub-component. About 62 research activities were completed and a total of 52 delivered agricultural technologies were generated in the year 2019/2020 (2012 EFY). These deliverable agricultural technologies were generated from crops 32 (61.15%), from livestock 3 (5.77%), natural resource management 12(23.08%), agricultural engineering 4 (7.69%) and 1 (1.92%) belongs to food and nutrition science.

Therefore, this workshop is organized with the purpose of critically reviewing research findings related to adaptation and generation agricultural technologies conducted during 2019/20 (2012 EFY). I am fully confident that the technical quality of the research conducted and proceeding paper will be enriched with this forum and the forthcoming peer reviewing program. The workshop participates includes researchers from different disciplines, research directorate directors, director general, deputy director generals, other relevant stakeholders from Oromia bureau of Agriculture and natural resource and the national AGP-II research coordination unit.

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CROP RESEARCH

Registration of "Moybon and Tosha", faba bean varieties for the highlands of Bale, South eastern Ethiopia

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ABSTRACT

At different breeding stages, a number of faba bean lines were evaluated in order to identify high yielding and stable faba bean genotypes. Accordingly, eighteen faba bean lines were evaluated in multi-location trial at three locations viz,Sinana, Agarfa and Sinja for three consecutive years (2016-2018) during main cropping season. Out of eighteen tested genotypes, genotypes such as EH00021-1/Tosha/ቶሻ/) and EH011088-3/Moybon/ሞይቦን/ were found to be superior in grain yield, stable in performance and tolerant to major faba bean diseases. The variety "Moybon" is characterised with large seed weight associated with high grain yield with a range of 3100 to4300 kg ha^{-1}) and showed a yield advantage of 35% and 22% over the local check standard check (Gebelcho) respectively. While,, variety "Tosha" had showed higher number of pods per plant and also gave grain yield of (3400-5200 kg ha^{-1}) with yield advantage of 51% and 38% over the local cultivar and the standard check, respectively. Besides, this variety had a stable performance over the tested locations, and also showed tolerance to major faba bean diseases prevailing in the areas such as chocolate spot (Botrytis fabae Sard.), Rust (Uromyces Vicia-fabae) and aschochyta blight (Aschocyta fabae Speg.). Keeping in view of all these merits varieties "Moybon, and Tosha" were approaved for release by the National Variety Releasing Commiittee (NVRC) in 2019 for production in the highlands of Bale and similar agro-ecologies.

Key Words: Moybon , NVRC, Stability, Tosha, , Variety Release

INTRODUCTION

Faba bean is an important source of protein supplement for the majority of the Ethiopian population and is used in various popular dishes and use as a source of foreign earning (Asfaw et al., 1993). It is known that variety is released whenever it has merits over the local cultivar and the previously released varieties both in terms of seed yield, other agronomic traits and their reaction to diseases. Variety releasing is an ongoing process since a given variety has performed well for specific period of time and reduces its production potential after a while due to segregation, becoming susceptible to diseases, and to some degree due to out crossing. Therefore, rather than trying to develop new variety after the given variety become out of production due to different factors, it is a must to have stable and widely adapted with different merits over the previously released variety before a given variety become out of production. Therefore, due to the importance of having released variety, the present study was undertaken, to evaluate and release faba bean genotypes that are stable,

wider adaptation and resistant/tolerant to major faba bean diseases in the highlands of Bale, South eastern Ethiopia.

MATERIALS AND METHODS

Testing sites

The experiment was carried out at three locations. One of the experimental sites was at research farm of SinanaAgricultural Research Center, Oromia Agriculture Research Institute, and the others were at Agarfa and Sinja on-farmer's field in the Southeastern Ethiopia. The multi-location regional variety trial was conducted at each location on vertisol clay loam soil under rain fed conditions for three years in the meher season (August-January) of 2016 to 2018 cropping season, and the verification trial was conducted in meher season (August-January) of 2019 cropping season.

Fifteen faba bean genotypes promoted from the yield trial, were used for this study (Table 1) and evaluated at three locations for three years, 2016-2018. Out of these eighteen genotypes, EH00021-1 "Tosha" and EH011088-3 "Moybon" were selected due to their superior performance over the previously released varieties used as a checks and the local cultivar, and verified in the 2019 cropping season for the regional release. The genotypes during the multi-location trails were arranged in randomized complete block design with four replications. None replicated 10mx 10m plot were used during the verification trial of these two candidate genotypes along with the checks. Seeding rate was applied at the rate of 200 kg/ha and fertilizers were applied at the rate of 100kg NPS/ha. Weeds were controlled by hand. Data are collected on both plot and plant basis.

Table 1. Lists of Faba bean genotypes tested in the multi-location for three years, 2016-2018

Genotype
EH 00126-1
EKLS/CSR02022-1-1
EH 01000117-2
EK01021-8-1
EH 00126-7
EH01008-3
EKLS/CSR02009-2-1
EKLS/CSR02013-2-1
EH01088-3 (Moybon)
EKLS/CSR02016-1-4
EKLSO1009-2
EKLS01009-2
EH00021-1 (Tosha)
EKLS/CSR02006-2-1
EH00049-4
Gebelcho
Mosisa
Local check

Agronomic and Morphological characteristics

Variety Tosha requires 64 and 138 days for flowering and maturity, respectively. Furthermore, Tosha is characterized by having more number of pods/plant i.e. 15 pods/plant compared to the variety used as standard check, Gebelcho, which had showed only 12 pods/plant. In addition, this variety had plant height of 121cm with an erect type of growth habit having thousand seed weight of 673.3gm with cotyledon color of yellow and seed color of light green. Whereas, the other variety, Moybon flowers in 61 days and reached stage of physiological maturity within 138 days. Thousand seed weight of this variety weights 774.5gm which is higher than the standard check, Gebelcho (766.4gm). Its plant height reaches as high as 119cm with an erect type of growth habit. Moybon has similar cotyledon and seed color with that of variety Tosha. Summary of the agronomic and morphological characteristics of the varieties are given in Appendices I and II.

Yield Performance

In the screening stage from 2014 to 2015, these two varieties were evaluated along with other lines at the main station, Sinana for yield and other agronomic traits, and showed better performance than the checks and based on these criteria, these varieties were promoted to the next breeding stages. In multi-location evaluation trial, variety Tosha gave mean grain yield of 44.3 Qt/ha whereas variety Moybon gave an average mean yield of 39.24 Qt/ha on the research field whereas on farmers' field, variety Tosha gave an average of 36.82Qt/ha while variety Moybon gave 33.01 Qt/ha. Overall, variety Tosha has showed a yield advantage of 37.63% whereas variety Moybon had showed a yield advantage of 21.78% as compared to the standard check used, Gebelcho which gave an average yield of 28.83 Qt/ha.

Stability Performance

Yield stability analysis was carried out to evaluate eighteen faba bean lines considered in multilocation trial using AMMI model with objective of identifying stable geotype. Different stability parameters were generated from stability analysis, such as liner regression coefficient, deviation from regression, AMMI Stability Value, (ASV), and Genotype Selection Index (GSI) (Farshadfar, 2008), and these parameters were considered to evaluate level of the stability of these varieties. Based on the results of stability analysis, the two faba bean varieties were relatively more stable as compared to the rest of the genotypes considered in this study across the tested locations.

Disease reaction

These two varieties had showed a tolerant type of reaction to chocolate spot, Achochyta bilght and rust diseases which are common to faba bean crop (Table 2).

CONCLUSION

The two faba bean varieties, Tosha and Moybon, are identified as high yielder, stable in performance across test locations and also showed tolerant types of reaction to major faba beab diseases as compared to the local and standard checks used in this studied. Variety Tosha has more number of pods/plant whereas variety moybon has large seed size which contributes to have more seed yield per unit area. Based on these merits, these two varieties were released for the highlands of Bale, South-eastern Ethiopia. Tosha has got its name from one of the locally named village in Goba district, which is suitable for faba bean production,

whereas Moybon which is litrarly mean in Afaan Oromo as ‘ a winner’ has got its name from its overall performance which showed superiori performance as compared to all the test entries and other previously released faba bean varieties. These varieties are currently under seed multiplication for scaling up for cultivation in Bale highlands and similar agro-ecologies.

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Table 2. Summary of the mean grain yield performance and other agronomic traits for the two faba bean varieties ‘Tosha and Moybon’ along with checks.

Variety	Days to		Plant ht. (cm)	Number of Pods/Plant	Seeds/ Pod	Stand %	1000 seed wt. (g)	Seed yield (kg/ha)	Disease score (1-9 scale)		
	Flower	Maturity							Cho.sp	Rust	ASBLT
Tosha	**64**	**138**	**121**	**15**	**3**	**73**	**673**	**3968**	**3**	**3**	**3**
Moybon	**61**	**138**	**119**	**12**	**2**	**72**	**775**	**3534**	**3**	**3**	**4**
Gebelcho	62	137	118	12	2	73	766	2883	4	4	5
Local cultivar	62	136	117	13	2	71	586	2622	6	5	4

Cho.sp= Chocolate spot, ASBLT= Aschochyta Blight

Appendix 1. Agronomic and morphological characteristics of faba bean variety 'Tosha/ቶሻ/ (EH00021-1)' and Moybon /ሞይቦን/ (EH011088-3)'

No	Agronomical Characteristics		*Tosha/ቶሻ/ **(EH00021-1)'***	*'Moybon /**ሞይቦን/** **(EH011088-3)'***
1	Adaptation areas		Sinana, Goba, Agarfa, Gassera, Goro (Meliyu), Adaba, Dodola and other similar agro-ecologies	
2	Altitude (m.a.s.l.)		2300 – 2600	2300 – 2600
3	Rainfall (mm)		750 – 1000	750 – 1000
4	Seed Rate (Kg/ha)		175-225	175-225
5	Planting date		End of July to Early August	End of July to Early August
6	Fertilizer Rate (NPS kg/ha)		100	100
7	Days to Flower		64	61
8	Days to Maturity		138	138
9	Plant Height (cm)		121	119
10	Growth habit		Erect	Erect
11	1000 Seed Weight (gm)		673.3	774.5
12	Seed Color		Light green	Light green
13	Cotyledon Color		Yellow	Yellow
14	Flower Color		White with black spot	White with black spot
15	Yield (Qt/ha)	On-station/ (Research Field)	44.43	39.24
		On-farm	36.82	33.01
16	Disease reaction		Tolerant to chocolate spot, Rust and Aschochyta blight	Tolerant to chocolate spot, Rust and Aschochyta blight
17	Yield advantage over Gebelcho (%)		37.63	21.78
18	Year of Release		2019 G.C	2019 G.C
19	Breeder and Maintainer		*SARC(OARI)	*SARC(OARI)

- *SARC (OARI)= Sinana Agricultural Research Center of Oromia Agricultural Research Institute*

Registration of "Adola-01" Bread Wheat (Triticum aestivum L.) Variety

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ABSTRACT

Improved varieties play an important role in enhancing production and productivity of crops and thereby contributing to the change in farmers' livelihood. The name Adola-01 *was given to the bread wheat (*Triticum aestivum L.) *variety with the pedigree of TILILA/MUBASHIIR-1, which was developed and release by Bore agricultural research center in 2019. The* Adola-1 *and the other pipeline bread wheat genotypes were evaluated against the standard checks across three locations (Dufa, Gobicha and Wadara) in 2016 and 2017 main cropping seasons. AMMI, GGE biplot analysis, and Eberhart and Russell model revealed that genotype ETBW8408 (*Adola-01*) is stable and high yielding (2733 kg ha^{-1}) with yield advantage of 10.27% over the best standard check Hidase (2478 kg ha^{-1}), and thus released in 2019.*

Key words: Adola-01, *Bread Wheat (*Triticum aestivum), *yield performance, stability, resistance*

INTRODUCTION

About six hundred million metric ton of wheat is produced each year and accounts about 30% of global cereal crops production (www.csiro.au). In Ethiopia, wheat is the most widely produced cereal crop and the most important staple food behind (GAIN, 2018). Wheat provides around 20% of human daily energy and also provides a significance healthy benefit for humankind (www.csiro.au). Development of improved bread wheat variety is one of the most important mechanisms for the increment of production and productivity thereby improving the livelihood of the farmers in our country. Even though many bread wheat varieties have been released for production in Ethiopia over the past years, most of them were pushed out of production few years after release. This is mainly due to the newly and existing rust disease virulent races. Additionally, climate fluctuation is also challenging and therefore, there is a need to develop climate resilient crop variety.

Varietal origin and evaluation

The variety Adola-01 (ETBW 8408) was originally taken from Kulumsa agricultural research center. The ETBW 8408 was evaluated against 1 pipeline genotypes and five standard checks (Kubsa, Kakaba, Danda'a, Hidase and Ogolcho) across three locations (Dufa, Gobicha and Wadara) for two years (2015 and 2016).

Agronomic and morphological characteristics

The released variety, Adola-01 (ETBW8408) has amber seed color, average plant height of 75.18 cm and average thousand seed weight 50.45g. The detail agronomic characteristics of the newly released variety are given in table 1.

Yield performance

Adola-01 (ETBW8408) gave average grain yield of 2733 kg ha^{-1} (Table1 and Figure 2). As observed from multi-location and multi-year evaluation records, this newly released variety has a stable and high yield performance under rust disease (specially stem and yellow) and

moisture stressed areas. Additionally, Adola-01 gave an average grain yield ranging from 2600-3000 kg ha^{-1} on farmers field and 27-38 kg ha^{-1} in verification research plots (Appendix 1).

Stability and adaptability analysis

Eberhart and Russell (1966) model revealed that the best yielding variety, Adola-01 (ETBW8408), showed regression coefficient (bi) closer to unity (1.15) and thus stable and widely adaptable variety then the remaining genotypes (Table 1 and Figure 2). Both environment-focused biplot and genotype focused comparison of the tested genotypes revealed that Adola-01 (ETBW8408) closest to central circle, indicating its high yield potential and relative stability compared to the remaining genotypes (Figure 1). Generally, GGE biplot analysis AMMI and Eberhart an Russell model revealed that Adola-01 (ETBW8408) was stable and high yielding (2733 kg ha^{-1}) variety with yield advantage of 10.27% over the best standard check Hidase (2478 kg ha^{-1}) and therefore, officially released and recommended for production under targeted areas.

Reaction to Major Wheat Diseases

Adola-01 is moderately resistance to major wheat rust diseases such as yellow rust (puccinia stiiformi f. sp. Tritici), stem rust (puccinia graminis f. sp. Tritici) and leaf rust (puccinia triticina) (Table 1).

Quality Parameters

Quality parameters such as grain protein percentage, grain gluten percentage and zeleny index were measured to see the nutritional quality of Adola-01 variety in the laboratory test. Accordingly, this variety showed grain protein and grain gluten percent of 13.83 and 28.50, respectively. It has zeleny index (ml) of 67.05.

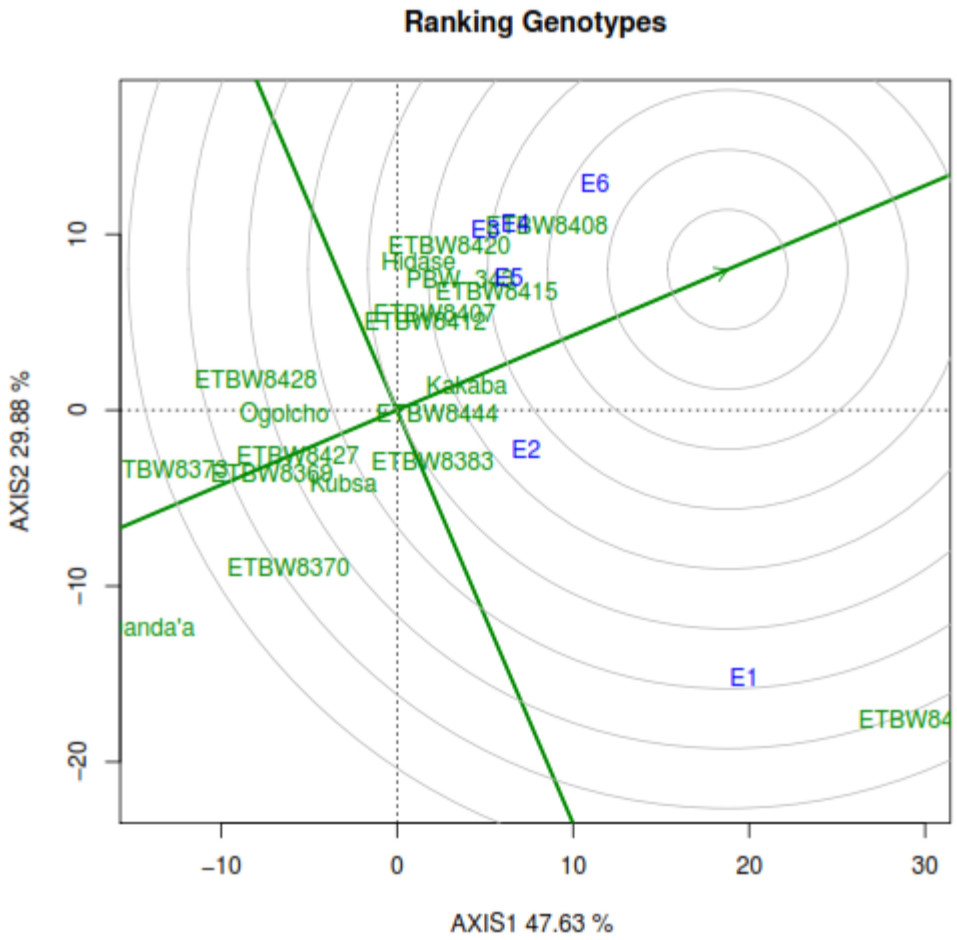
Conclusion

The newly released bread wheat variety, Adola-01 is hereby released for its high yield, stability, wider adaptability and tolerant/resistance to major wheat rust diseases. Therefore, smallholder farmers and other wheat producers inhabiting mid- to low-land of Guji Zone and areas with similar agro-ecologies can grow Adola-01 variety with its full agronomic and other management recommendations.

Table 1. Combined mean performance of grain yield performance and agronomic traits, yield stability parameters and major rust disease reactions

GEN	YLD	DTH	DTM	PH	SL	TKW	bi	Pi	Disease reactions		
									Yellow rust	Stem rust	Leaf rust
Danda'a	15.85	69.67	119.44	76.71	7.51	39.24	0.68	217.00	10s	15s	0
ETBW8369	20.58	67.78	120.94	74.59	7.81	38.40	1.08	167.59	10s	0	0
ETBW8370	19.48	74.50	116.17	74.60	7.20	40.18	0.86	154.91	0	0	10s
ETBW8373	16.72	67.33	117.00	74.77	7.81	36.41	0.84	222.29	40s	0	t
ETBW8383	22.87	69.06	111.56	75.76	7.16	39.74	1.41	113.48	30s	20ms	10ms
ETBW8407	24.69	66.50	101.50	76.66	8.31	37.20	1.15	116.77	30s	0	0
ETBW8408	**27.33**	**60.17**	**122.89**	**75.18**	**7.50**	**39.31**	**1.15**	**94.77**	**5ms**	**t**	**t**
ETBW8412	23.81	67.67	116.22	77.17	8.03	39.09	0.92	115.86	20ms	0	0
ETBW8413	30.60	66.83	163.94	76.74	7.08	37.38	0.15	14.72	30s	0	15s
ETBW8415	26.01	76.89	117.67	75.59	6.85	36.42	1.37	102.87	20s	0	t
ETBW8420	24.77	67.83	122.06	71.77	7.21	34.98	1.15	122.35	10s	0	t
ETBW8427	20.77	67.67	119.39	70.71	7.80	39.16	1.09	160.17	20s	0	t
ETBW8428	20.27	68.78	115.17	70.62	7.30	34.96	1.34	182.62	40s	0	0
ETBW8444	24.38	63.50	117.83	73.52	7.62	37.82	1.01	108.71	t	0	0
Hidase	24.78	67.17	116.50	75.62	11.46	38.18	1.12	127.02	10ms	15s	0
Kakaba	24.99	66.83	119.33	74.49	6.94	39.82	1.03	99.48	10ms	0	10s
Kubsa	21.26	70.83	116.33	71.05	7.14	35.01	1.01	134.45	60s	10s	0
Ogolcho	20.01	68.33	118.56	65.99	6.71	36.02	0.97	160.26	10s	10s	5ms
PBW-343	25.63	68.61	119.67	74.42	6.97	42.56	0.67	110.35	t	0	0
Mean	22.88	68.21	119.59	73.99	7.60	37.99					
LSD	5.02	2.58	6.05	6.85	0.57	6.48					
CV	18.13	0.60	1.72	6.27	6.50	16.91					

Key: GEN= genotypes, YLD = yield, DTH= days to heading, DTM= days to maturity, PH = plant height, SL= spike length, TKW = 1000 kernel weight



Key: E1 and E5 = Gobicha year one and two, E2 and E4 = Dufa year one and two, E3 and E6 = Wadara year one and two.

Figure 1. GGE biplot analysis showing stability of genotypes and test environments

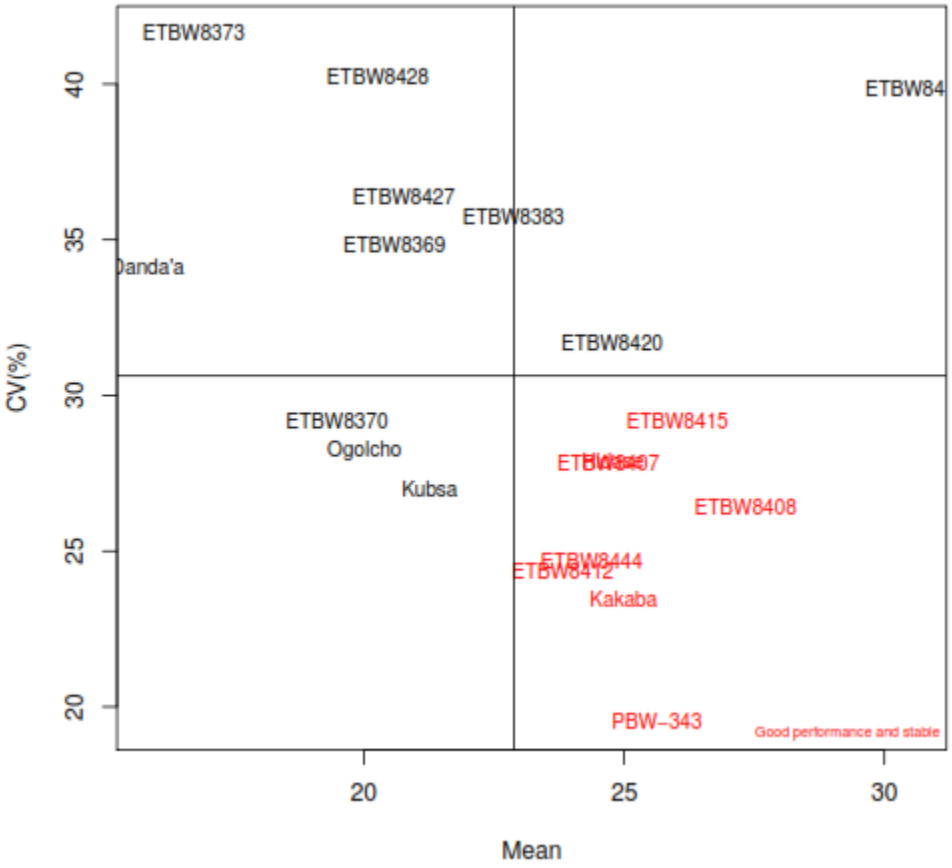


Figure 2. Matrix plot of genotypes mean grain yield (qt ha^{-1}) versus coefficient of variation (CV %) indicating stability and yield performance of the test genotypes.

Appendix 1: Agronomic and morphological descriptors of Adola-01 (TILILA/MUBASHIIR-1)

Agronomic character and description of Adola-01	
Variety Name	Adola-01 (ETBW 8408)
Adaptation area	Lowlands to Midland of Guji and similar agro ecology
Altitude (m.a.s.l)	1600-2100
Rainfall (ml)	792- 1126
Fertilizer (kg/ha)	
NPS	121
Urea	50
Seed rate (kg/ha)	150
Days to heading	62
Days to mature	103
1000 seed weight(g)	42.6
Hectoliter weight(kg/hl)	81.40
Plant height(cm):	75.18
Yield (kg ha^{-1})	
Research field	2700-3800
Farmers' field	2600-3000
Seed color	Amber
Growth habit	Erect
Grain Protein (%)	13.83
Grain Gluten (%)	28.50
Zeley index (ml)	67.05
Year of release	2019
Breeder/maintainer	BoARC/OARI

References

Eberhart, S.A. and Russell, W.A. (1966). Stability parameters for comparing varieties. Crop sci. 6: 36-40.

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Registrations of Billo-19 (Medium set) Soybean [Glycine max (L.) Merr.] Varieties

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ABSTRACT

Billo-19 potential candidate medium set soybeans [Glycine max (L.) Merr.] Varieties with pedigree of PM 12-37 was evaluated against standard checks & other genotypes for seed yield, agronomic characters and disease reaction at Bako, Billo Boshe and Gute experimental sites from 2016/2017 to 2017/2018. That variety was verified for possible release in 2019 at on farm and on station across all areas listed above. The pipeline variety PM 12-37 showed 24.7 % oil content and seed yield of 2480.6 kg ha^{-1} against commercial variety Korme. It was resistant to bacterial blight and bacterial pustule. The result of multi-environment yield trials showed that Billo-19 (PM 12-37) outperformed the standard check Korme (AGS-129-2) by 31.7 % in seed yield and 4.2 % oil content respectively. The stability analysis showed that both varieties are stable in grain yield performance than the commercial variety of Korme (AGS-129-2). The national variety release standing committee made their annual meeting and recommends genotype Billo-19 (PM-12-37) for possible release based on its field yield performance, farmers preferences, seed yield and oil content.

Keywords: Commercial Variety; Pedigree, Stability, Soybean

INTRODUCTION

Billo-19, common name for soybean [Glycine max (L.) Merr.] Variety designated with pedigree name of PM-12-37. That variety was tested across multi environments (locations and years). Results from multi-location yield trials revealed that Billo-19 (PM-12-37) was found to be superior and stable in seed yield and quality traits than the commercial variety viz., Korme (AGS-129-2). In addition, Billo-19 variety is resistant to bacterial blight and bacterial pustule. Hence, that variety was released by the Bako Agricultural Research Center for Western parts of Oromia regional state and similar agro-ecological zones of western Ethiopia.

Origin and pedigree

Billo-19 soybean variety is with pedigree of PM 12-37 was brought from Jimma Agricultural Research Center.

Morphological description

Billo-19 (PM-12-37) is oval in seed shape (oval), seed coat color (yellowish) and seed coat luster (dull). Both are indeterminate and have erected growth habit, which enable them to prevent from pod rot during heavy rain fall. Billo-19 has medium seed size compared to the commercial variety, Korme (Table 1). Their leaf size is large and more uniform.

Phonological description

On three locations (Bako, Boshe and Gute) and two years (2016/2017 and 2017/2018) mean basis, Billo-19 flowered in 65 and matured in 131 day, respectively.

Agronomic description

Billo-19 (PM-12-37) was heavier than the standard check, Korme, in terms of seed yield oil content (Table 1). Billo-19 has comparable pod load than with commercial variety korme.

Hence, Billo-19 had heavier average pods per plant than korme and had similar seeds per pod (Table 1).

Yield performance

Billo-19 soybean variety was evaluated with standard check, in multi-locations yield trials. Billo-19 gave a seed yield of ranging from 1.8 to 2.4 t ha^{-1} on research stations and 1.5 to 1.9 t ha^{-1} on farmers' fields (Table 1). Similarly Korme gave a seed yield ranging from 1.4 to 2.0 t ha^{-1} on research station and 1.3 to 1.8 t ha^{-1} on farmers' fields (Table 1). Hence, Billo-19 has outperformed korme by 31.7 % yield advantage over the standard check korme in seed yield and 4.2 % in oil content respectively.

Table 1: Summary of Mean Grain Yield and other Data of Billo-19 Variety along With Commercial Variety Korme (AGS-129-2) Across Years and Location.

Characteristics	**Billo-19 (PM-12-12)**	**Korme (AGS-129-2)**
Adaptation area		
Altitude m (a.s.l)	1650-1900	1500-1900
Rainfall (mm)	1000-1200	1000-1200
Fertilizer rate (NPS) kg ha^{-2}	100	100
Fertilizer application time	At sowing	At sowing
Fertilizer application method	Side dressing & avoid seed contact	Side dressing & avoid seed contact
Planting and seeding		
Planting date	Mid-June	Mid-June
Seeding rate (kg ha^{-1})	60-70	60-70
Row spacing (cm)	60	60
Plant spacing (cm)	10	10
Weeding frequency	3-4	3-4
Days to flowering	65	72
Days to maturity	131	140
Number of pods $plant^{-1}$	80	56
Number of seeds pod^{-1}	3	3
Leaf size	Large	Large
Growth habit	Indeterminate	Indeterminate
Seed coat color	yellow	Dull
Seed coat luster	Dull	Dull
Helium color	White	White
Seed shape	Oval	Round
Seed size	Medium	Large
100 seeds weight	18	19
Oil content **(%)**	24.7	23.7
Crop pest reaction (1-9 scale)		
Bacterial blight	3.0	4.0
Bacterial pustule	2.5	3.0
Rust	3.0	3.5
Yield (ton $ha^{-1)}$		
Research filed	1.8-2.4	1.4- 2.0
Farmer field	1.5-1.9	1.3-1.8
Year of release	2020	2011

Oil and protein content

24.7 % of oil content recorded from Billo-19 while 23.7 % recorded from commercial variety Korme (AGS-129-2). The laboratory result revealed that Gute-19 had higher oil content than commercial variety Korme (AGS-129-2) by 4.2 %. However, the newly released Gute-19 soybean variety had comparable protein content with that of the commercial verity Korme (AGS-129-2).

Stability performance

Yield stability comparisons for seventeen soybean genotypes including Billo-19 and Korme (AGS-129-2) for two years and three locations were illustrated based on meta-analysis (GGE Biplot) method (Yan and Tinker, 2005). Genotype x environments interaction was partitioned into principal component axes and the first IPCA 42.34 %) and the second IPCA (18.98%) explained the largest proportion (61.33 %) of the interactions. The result of the study revealed that Billo-19 (PM-12-37) is ideal and stable varieties compared to the commercial variety, Korme (AGS-129-2) (Figure 1). Billo-19 was found to be a more stable soybean variety and higher in oil content compared to the commercial variety korme (Ags-129-2).

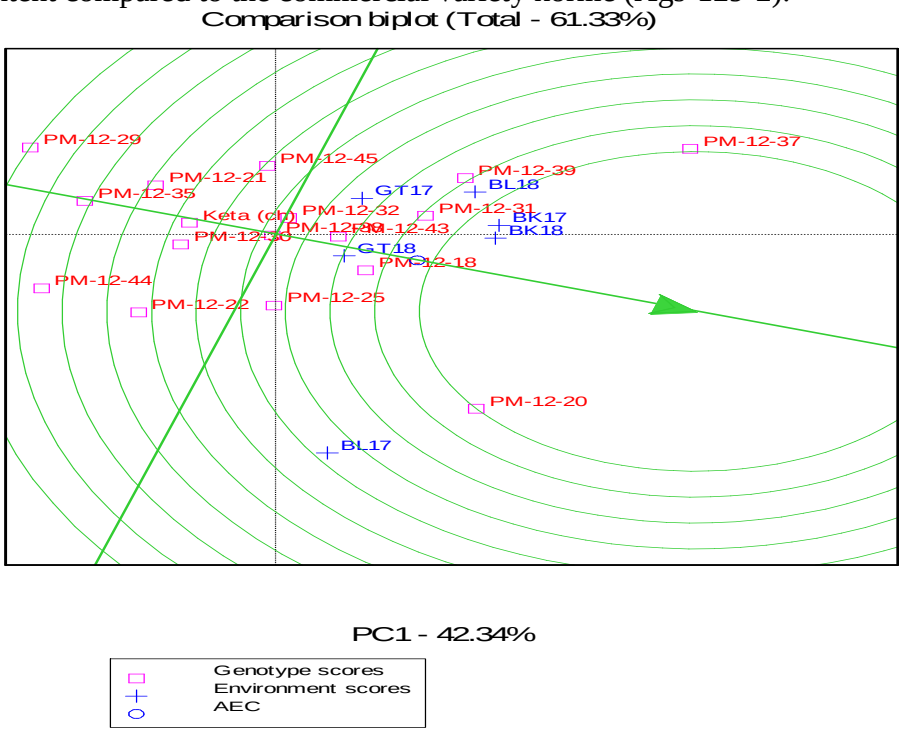

Figure 1: Ranking the genotypes relative to the ideal genotype for medium maturity class of soybean varieties.

Disease reaction

Billo-19 (PM-12-37) was resistant (n < 3 where n = 1-9 scores) to the common soybean diseases viz., bacterial blight, bacterial pustule and rust (Table 1).

CONCLUSION

The soybean variety Billo-19 had higher seed yields and better stability performances than the commercial variety Korme (AGS-129-2). The seed of Billo-19 has also higher oil contents compared to the seed of the commercial variety, Korme (AGS-129-2). Those variety was also resistant to common soybean diseases viz., bacterial blight, rust and bacterial pustule and hence, have been released for Western Oromia and similar agro ecologies of the Western Ethiopia.

REFERENCE

Yan, W. and Tinker, N.A. 2005. An integrated biplot analysis system for displaying, interpreting and exploring genotype x environment interaction. Crop Science 45: 1004-1016.

Registration of Gute-19 (Late Set) Soybean Varieties (Late Maturity Class)

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ABSTRACT

Gute-19 potential candidate soybean [Glycine max (L.) Merr.] Variety with pedigree of PM 12-3 was evaluated against the check and other genotypes for seed yield, agronomic characters and disease reaction at Bako, Billo Boshe and Gute experimental sites from 2016/2017 to 2017/2018. Gute-19 variety was verified for possible release in 2019 at on farm and on station across all areas listed above. The pipeline variety PM 12-3 showed 22.3% oil content, and seed yield of 2779.1 kg ha^{-1}, respectively. It was resistant to bacterial blight and bacterial pustule. The result of multi-environment yield trials showed that PM 12-3 outperformed the standard check (PRAC-3) by 20.1 % in seed yield and comparable in oil content. The variety was evaluated by the national variety releasing committee. It was resistant to bacterial blight and bacterial pustule. The stability analysis showed that the variety stable in grain yield performance than the check variety PARC-3. The national variety release standing committee made their annual meeting and recommends genotype PM-12-3 (Gute-19) for possible release based on its field yield performance and farmers preferences

Keywords: Commercial Variety; Pedigree, Stability, Soybean

INTRODUCTION

Gute -19 soybean [Glycine max (L.) Merr.] Variety designated by pedigree of PM 12-3. This variety was tested across multi-environments (locations and years). Results from multi-location yield trials revealed that PM 12-3 was found to be superior and stable in seed yield and quality traits than the commercial variety viz., PARC-3. In addition, PM-12-3 varieties are resistant to bacterial blight and bacterial pustule. Hence, PM 12-3 variety was released by Bako Agricultural Research Center for Western part of Oromia regional state and similar agro-ecological zones of western parts of Ethiopia.

Origin and pedigree

Gute-19 soybean variety is with pedigree of PM 12-3 was brought from Jimma Agricultural Research Center.

Morphological description

Gute-19 is similar in seed shape (round), seed coat color (gray) and seed coat luster (creamy). It is indeterminate and has erected growth habit, which enable them to prevent from pod rot during heavy rain fall. Gute-19 has large seed size compared to the commercial variety, PARC-3 (Table 1). Their leaf size is large and more uniform and is suitable for intercropping with erected leaf type maize verities.

Phenological description

On three locations (Bako, Billo-Boshe and Gute) and two years (2016/2017 and 2017/2018) mean basis, Gute-19 flowered in 74 days and matured in 141 days, respectively.

Agronomic description

Gute-19 with pedigree of PM-12-3 was heavier than the standard check, PARC-3 in terms of seed weight (Table 1). Gute-19 has better pod load than PARC-3 with comparable average seeds per plant (Table 1).

Yield performance

Gute-19 soybean variety was evaluated with standard check PARC-3, in multi-locations yield trials. Gute-19 gave a seed yield ranging from 1.8 to 2.7 ton ha^{-1} on research *stations* and 1.5 to 2.4 ton ha^{-1} on farmers' fields (Table 1). Gute-19 has outperformed than PARC-3 by 20 % and 14 % on station and on-farm in seed yield, respectively

Oil and protein content

About 22.3 % of oil content recorded from Gute-19 while 22.6 % recorded from commercial variety PARC-3. The laboratory result revealed that Gute-19 had higher seed yield and comparable oil content with commercial variety PARC-3. However, the newly released Gute-19 soybean variety had comparable protein content with that of the commercial verity PARC-3.

Stability performance

Yield stability comparisons for twelve soybean genotypes including Gute-19 and PARC-3 for two years and three locations were illustrated based on meta-analysis (GGE Biplot) method (Yan and Tinker, 2005). Genotype x environments interaction was partitioned into principal component axes and the first IPCA (69.28%) and the second IPCA (22.41%) explained the largest proportion (91.68 %) of the interactions. The result of the study revealed that Gute-19 (PM-12-3) is ideal and stable varieties compared to the commercial variety, PARC-3 (Figure 1). Gute-19 was found to be a more stable soybean variety and higher in oil content compared to the commercial variety PARC-3.

Disease reaction

Gute-19 (PM-12-3) was resistant ($n < 3$ where $n = 1$-9 scores) to the common soybean diseases viz., bacterial blight, bacterial pustule and rust (Table 1).

Breeder seed maintenance

Breeder and foundation seed of the variety is maintained by Bako Agricultural Research Center.

CONCLUSION

The soybean variety Gute-19 had higher seed yields and better stability performances than the commercial variety PARC-3. The seeds of the new varieties have also higher oil contents compared to the seed of the commercial variety, PARC-3. Those variety was also resistant to common soybean diseases viz., bacterial blight, rust and bacterial pustule and hence, have been released for Western Oromia and similar agro ecologies of the Western Ethiopia.

Table 2: Summary of Mean Grain Yield and other Data of Gute-19 Variety along With Commercial Variety (PARC-3) Across Years and Location.

Characteristics	Gute-19 (PM-12-3)	PARC-3
Adaptation area		
Altitude m (a.s.l)	1650-1900	1500-1900
Rainfall (mm)	1000-1200	1000-1200
Fertilizer rate (NPS) kg ha^{-2}	100	100
Fertilizer application time	At sowing	At sowing
Fertilizer application method	Side dressing & avoid seed contact	Side dressing & avoid seed contact
Planting and seeding		
Planting date	Mid-June	Mid-June
Seeding rate (kg ha^{-1})	60-70	60-70
Row spacing (cm)	60	60
Plant spacing (cm)	10	10
Weeding frequency	3-4	3-4
Days to flowering	74	72
Days to maturity	141	140
Number of pods $plant^{-1}$	81	53
Number of seeds pod^{-1}	3	2.8
Leaf size	Large	Large
Growth habit	Indeterminate	Indeterminate
Seed coat color	Light yellow	Light yellow
Seed coat luster	Dull	Dull
Helium color	White	White
Seed shape	Round	Round
Seed size	Medium	Large
100 seeds weight	20	19
Oil content **(%)**	24.35	22.6
Crop pest reaction (1-9 scale)		
Bacterial blight	2.75	3.0
Bacterial pustule	2.75	3.0
Rust	2.5	2.5
Yield (ton $ha^{-1)}$		
Research filed	1.8-2.7	1.4- 2.1
Farmer field	1.5-2.4	1.3-2.2
Year of release	2020	2015

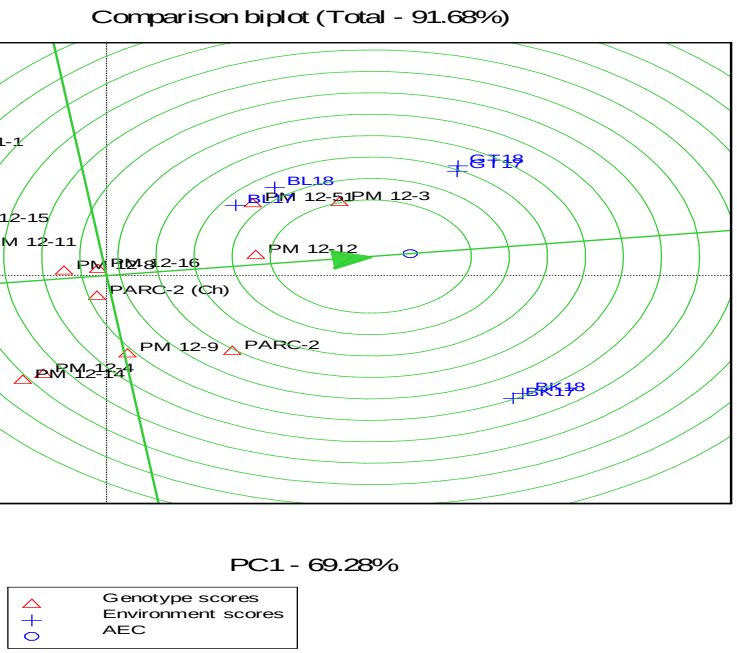

Figure 2: Ranking the genotypes relative to the ideal genotype.

REFERENCE

Yan, W. and Tinker, N.A. 2005. An integrated biplot analysis system for displaying, interpreting and exploring genotype x environment interaction. Crop Science 45: 1004-1016.

Genotype by Environment Interaction and Grain Yield Stability Analysis for Ethiopian Sorghum [Sorghum bicolor (L.) Moench] Genotypes

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ABSTRACT

Sorghum is an important cereal crop serving as main staple food crop on which the lives of millions Ethiopians depends on. Genotype performance depends on genetic makeup of the genotype and environment where it is grown. The effect of GxE can be reduced by identifying stable genotypes across environments. In this experiment, twenty best advanced genotypes and one standard check (Bonsa) were evaluated at Bako, Gute and Bilo during 2017-2019 cropping seasons with the objectives to identify stable and high yielding genotypes for grain yield and other agronomic traits among sorghum genotypes of Ethiopia. The experiment was arranged in randomized complete block design replicated three times within an experiment. Analysis of Variance (ANOVA), Additive Main effect and Multiplicative Interaction (AMMI), Genotype and Genotype-Environment interaction (GGE), and stability analyses were computed. Combined analysis of variance showed highly significant ($P<0.01$) differences among tested genotypes for grain yield. Additive main effect and multiplicative interaction (AMMI) model analysis revealed highly significant ($P<0.01$) variations among environments, genotypes, GxE interaction and interaction principal component analysis (IPCA); indicating the variation among testing sites that genotypes differently responded over environments. Only the first interaction principal component analysis (IPCA-I) showed high significant and contributed 46.02% of the total genotype by environment interaction (GxE). Genotypes ETSL 101259, 8 line 2A, ETSL 100618 and ETSL 101691 which had high grain yield, but with IPCA value close to zero, indicated the wide adaptability over locations. Analysis of Eberhart and Russell model also revealed that these genotypes showed acceptable range of regression coefficients (bi), approaching to one, and deviation from regression closer to zero (s2di). Genotype and genotype by environment (GGE bi-plot) analysis also revealed that these candidate genotypes were stable and high yielder. In addition, these genotypes showed resistant reaction to anthracnose and grain mold; a major diseases of sorghum in western parts of Ethiopia, hence selected as potential candidates for possible release in the study areas.

Key words: AMMI, GGE, Sorghum bicolor, Stability

INTRODUCTION

Sorghum [Sorghum bicolor (L.) Moench] belongs to the grass family Poaceae and it is diploid with 2n=2x=20 chromosome number (De Wet et al., 1976). Sorghum is the fifth most important cereal crop following wheat, rice, maize, and barley in both total production and acreage in the world (FAOSTAT, 2019). It is an important cereal crop serving as main staple food crop for millions peoples in the world and the second among the staple food grains in semi-arid tropics (Anagholi et al., 2000) and supports the lives of millions of people across the globe (Sleper and Poehlmen, 2006). Sorghum is an important food grain crop of Ethiopia which contributes about 19.3% of the total cereal production (CSA, 2018). High genetic diversity is vital for the development of stress resistant and climate resilient crop varieties to mitigate the impact of climate change. Ethiopia has a wealth of genetic resources for sorghum (Birhane, 1973) and has contributed for the global germplasm pools and sources of genes for important traits Doggett, 1988). As a major center of origin and diversity for sorghum (EBI, 2007; Dillon et al., 2007), extensive genetic variation of Ethiopian sorghum were reported. Genotypes by environment (G x E) interactions are considered to be one of the key factors limiting response to selection and the efficiency of breeding programs. Environment change can affect the performance of a genotypes, and breeders should give due attention to the impact of GXE in genetic exploitation to be efficient in selection. Ghaderi et al. (1980) observed that analysis of variance procedure helps to estimate the magnitude of GXE interaction; but is unable to provide information on the contribution of each genotypes and environment to GXE interactions. On the other hand, analyses models like additive main effects and multiplicative interaction (AMMI) can treat both the additive main effect and multiplicative interaction components employing the analysis of variance (ANOVA) and Interaction Principal Components (IPCA) (Gauch and Zobel, 1996). Besides, AMMI and GGE bi-plot analysis are considered to be effective graphical tools to estimate genotype by environment interaction patterns (Gauch and Zobel, 1996; Yuksel et al., 2002). Therefore, the experiment was conducted with the objective to identify stable and adaptable high yielding genotype(s) for possible release.

MATERIALS AND METHODS

Twenty Sorghum [*Sorghum bicolor* (L.) Moench] genotypes originally selected from Sorghum and Millets Innovate Lab (SMIL) core collections and the standard check (Bonsa) were used for this study (Table 1). The study was conducted for three years (2017-2019) main cropping season at Billo Boshe; and for two seasons (2018-2019) at Bako and Gute research stations. Bako Agricultural Research Center (BARC) is located at 9º6'N latitude and 37º09'E longitude with altitude of 1650 m.a.s.l. Mean and maximum temperature of the last 5 years is 13.1 and 28.4 0 C, respectively. Average 5 years relative humidity of the Bako station is 53.2% (Kebede et al., 2019) and the soil is deeply weathered and slightly acidic in reaction. Gute sub-station is also found at west and lies at 09001.06'N and 036038.196'E with altitude of 1915 m.a l. The average rain fall of 1431mm per annum and clay loom soil with slightly acidic property. The min and maximum temperature is 12.32 and 32^0C, respectively (Kebede et al., 2019). Bilo boshe subsite coordinated 8^o54'0"N Aand 37° 0'0''E with altitude 1762 masl.The three research stations have unimodal pattern of rain distribution, with the rainy period running from April to October.

The experiment was laid out in randomized complete block design with three replications and each plot comprised three rows of 5m long and 75 cm spacing between rows and 15 cm intra rows spacing. Seed rate of 12 kg $ha^{-1}$and fertilizer rate of 100 kg ha^{-1} NPS and 100 kg ha^{-1} Urea

were used. Urea was applied in split form; half at planting and the rest half at 35 days after emergence.

Data analysis

Grain yield data were subjected to analysis of variance (ANOVA) using SAS computer software (9.3 SAS version). Grain yield stability analysis was carried out using regression (Eberhart and Russell, 1966) and AMMI models and genotype and genotype by environment (GGE) Biplot using GenStat 18th edition software.

Additive main effect and multiplicative interaction (AMMI) model. The AMMI model equation was used:

$Yij=\mu + gi + ej + \Sigma\lambda k + \alpha ikyjk + Rij$

Where, Y_{ij} is the yield of ith -genotypes in jth environment; μ is the overall mean; g_i is the effect of the ith genotype; e_j is the effect of the jth environment; λk is the Eigen value of the PCA for axis k. Then α_{ik} and y_{jk} are the genotype and environment principal component scores for axis k, respectively, and R_{ij} is the residual term. Environment and genotype PCA scores are expressed as unit vector times the square root of λk.

Eberhart and Russell Regression Model.

The Eberhat and Russel model was used and is represented by: Yij = μi +biIj +S2dij; Where:

Yij is the mean performance of the ith variety (I = 1, 2, 3…, n) in the ith environment; μi is the mean of the ith variety over all the environments; bi is the regression coefficient which measures the response of ith variety to varying environments; S2dij is the deviation from regression of ith variety in the ith environment; and Ij is the environmental index of the ith environment.

Genotype and genotype by environment interaction (GGE) biplot.

To determine genotype by environment interaction and stability analysis, different methods were used. The genotypes and genotype by environment (GGE) biplot analysis is the most common currently utilized (Yan and Tinker 2005; Yan et al., 2007). GGE biplot analysis was carried out using the method proposed by Yan (2001) for multi environment data.

RESULT AND DISCUSSION

Analysis of variance

The results of the combined analysis of variance across locations revealed there was a significant (P<0.01) differences among sorghum genotypes for grain yield across all testing environments (Table 4). This result indicated there was wide range of genetic variability among sorghum genotypes across testing environments. The combined mean grain yield of the twenty sorghum genotypes were presented in table 4 which ranged 1.9 ton ha^{-1} to 3.9 ton ha^{-1}.

Additive Main Effects and Multiplicative Interaction (AMMI) Model

The combined analysis of variance indicated highly significant (P<0.01) variations among genotypes (G), environments (E), genotype by environment interactions (GEI), principal component analysis IPCA-I, IPCA-II, and IPCA-III and; significant difference (P<0.05) for

IPCA-IV (Table 3). The result revealed there were the variation among testing environments that genotypes are respond differently over environments, or the existence of GEI that affects the performance grain yield of the genotypes across locations.

Table 1: Genotypes and the test environments with their sorghum codes used in a study in Ethiopia

No.	Genotype	Genotype code	No.	Environment	Environmental code
1	10 line 2A	a	1	Bako 18	A
2	16 line 1A	b	2	Bako 19	B
3	8 line 2A	c	3	Bilo 17	C
4	8 line 2C	d	4	Bilo 18	D
5	Bonsa	e	5	Bilo 19	E
6	ETSL 100124	f	6	Gute 18	F
7	ETSL 100406	g	7	Gute 19	G
8	ETSL 100548	h			
9	ETSL 100587	i			
10	ETSL 100618	j			
11	ETSL 100621	k			
12	ETSL 100657	l			
13	ETSL 101066	m			
14	ETSL 101168	n			
15	ETSL 101259	o			
16	ETSL 101327	p			
17	ETSL 101343	q			
18	ETSL 101581	r			
19	ETSL 101691	s			
20	ETSL 101757	t			

The mean grain yield of genotypes across seven environments ranged from 0.9 ton ha^{-1} at Bilo boshe in 2018 to 6.7 ton ha^{-1} at Bako in 2018 (Table 4) which indicates the differences in genotypes, environments and testing years. This result implies genotypes were affected by environmental conditions during crop growing seasons, indicating the environmental and genotypes variation in the experiment. This finding is clearly implies contribution of environmental variation in which the experiment was undertaken is significantly different, and the variation observed among genotypes for grain yield is largely due to environmental effects.

Table 2. Grain yield (GY) (t ha^{-1}) and IPCA1 scores of sorghum genotypes assessed for stability in Ethiopia

Description of genotypes	Genotype name	IPCA1 score	Mean GY (t ha-1)
a	10 line 2A	-0.910	2.4
b	16 line 1A	-0.291	2.4
c	8 line 2A	-0.432	3.8
d	8 line 2C	0.473	1.9
e	Bonsa	0.859	2.7
f	ETSL 100124	0.653	3.4
g	ETSL 100406	0.432	2.9
h	ETSL 100548	-0.170	2.5
I	ETSL 100587	1.144	2.7
J	ETSL 100618	-0.804	3.7
k	ETSL 100621	0.078	3.0
L	ETSL 100657	-0.107	3.5
m	ETSL 101066	0.061	3.2
n	ETSL 101168	0.026	3.5
o	ETSL 101259	0.007	3.9
p	ETSL 101327	-0.170	2.9
q	ETSL 101343	-0.138	3.0
r	ETSL 101581	-0.375	2.9
s	ETSL 101691	-0.161	3.7
T	ETSL 101757	-0.178	2.7
Environments			
Bako 18	A	0.389	4.778
Bako 19	B	0.550	2.310
Bilo 17	C	0.207	2.637
Bilo 18	D	-0.004	2.457
Bilo 19	E	0.655	1.802
Gute 18	F	-1.991	4.460
Gute 19	G	0.195	2.834

a=10 line 2A, b=16 line 1A, c=8 line 2A, d=8 line 2C, e= Bonsa, f= ETSL 100124, g= ETSL 100406, h= ETSL 100548, i= ETSL 100587, j= ETSL 100618, k= ETSL 100621, l= ETSL 100657, m= ETSL 101066, n= ETSL 101168, o= ETSL 101259, p= ETSL 101327, q= ETSL 101343, r= ETSL 101581, s= ETSL 101691, t= ETSL 101757, A= Bako 18, B= Bako 19, C= Bilo 17, D= Bilo 18, E= Bilo 19, F= Gute 18, G= Gute 19

Various authors also reported similar results for sorghum genotypes evaluated across locations and years (Admas & Tesfaye, 2018; Worede et al., 2020; Al-Naggar et al., 2018). The AMMI analysis identified four principal component axes, and all contributed to 87.80% of the total variation observed among sorghum genotypes for grain yield due to GEI (Table 3). Of four principal component axes, except IPCA-IV all of the IPCA's were significant ($P<0.01$).

The IPCA scores, which indicates the adaptability over environments and association between genotypes and environments of the present study showed that a significant proportion of main

GEI (46.02%) was explained by IPCA-I; followed by 20.42 %, 11.76 % and 9.60% for IPCA-II, IPCA-III and IPCA-IV, respectively (Table 3). The GEI components' values in this experiment using AMMI model are comparable with the reports from Mohammed (2020) in maize and Admas and Tesfaye (2017) in sorghum from their Genotype-by-environment interaction and yield stability analysis.

Table 3. Analysis of variance for Additive Main Effects and Multiple Interaction (AMMI) for yield stability of sorghum genotypes in Ethiopia

Source	Df	SS	MS	% GXE	% cumulative interaction explained
Genotypes	19	124.9	6.574**		
Environments	6	459	76.503**		
ENV*GEN	114	158.2	1.388**		
IPCA I	24	72.8	3.033**	46.02	46.02
IPCA II	22	32.3	1.468**	20.42	66.43
IPCA III	20	18.6	0.928*	11.76	78.19
PCA IV	18	15.20	0.844^{ns}	9.60	87.80
Residuals	266	140	0.526		

Grand mean = 3.0; R2 = 0.8574; Coefficient of variation (CV, %) = 15.2%; *, ** = Significant at P < 0.05 and P < 0.01 levels, respectively, ns=non-significant

In this study, we chose the first and second IPCAs to describe genotype by environment interaction and placement on the bi-plots. The AMMI analysis result revealed that ETSL 101259, 8 line 2A, ETSL 100618 and ETSL 101691 attained IPCA values (0.007, -0.432, -0.804 and -0.161, respectively) which is relatively close to zero, and gave relatively high yield. These genotypes are better stable and widely adaptable genotypes across location, than the standard check and other tested genotypes (Table 2). On other hand, genotypes ETSL 100548, ETSL 101757, 16 line 1A and ETSL 101581 scored IPCA values closer to zero (-0.170, -0.178, -0.291, -0.375), but gave lower mean grain yield than the above genotypes. Hence, genotypes ETSL 101259, 8 line 2A, ETSL 100618 and ETSL 101691 are selected relatively as stable and high yielder candidates to be released as new variety in Ethiopia.

Genotypes such as ETSL 100587, Bonsa, ETSL 100124 and ETSL 100406 scored IPCA values deviating from zero (1.144, 0.859, 0.653, 0.432) and average mean grain yield; indicated unstable genotypes and their response were varied across locations. Among tested genotypes, 8 line 2C showed IPCA score deviating from zero and lower mean grain yield than other genotypes indicating environmental sensitivity of the genotype. The report of research result by Kebede et al. (2019) from finger millet and Worede eta al.(2020) from sorghum field experiments corroborated the present finding that genotypes with low grain yield and IPCA value deviated from zero are not stable and are highly environmental sensitive.

Regression analysis based on Eberhart and Russell Model

According to Eberhart and Russell Model, genotype with high yield and regression coefficient (bi) equal to unity (1), and deviation from regression (s2di) approach to zero, would be selected as stable genotypes Ebrehart and Russell (1966). Genotypes that fitted to Eberhart and Russell Model can be proposed for possible release in breeding program. In this study, pipeline genotypes, ETSL 101259, 8 line 2A, ETSL 101691 and ETSL 100618 were the most promising candidates and gave grain yield of 3.9, 3.8, 3.7, 3.7 ton ha^{-1}, respectively.

Table 4. Grain yield (t ha^{-1}) for the tested genotypes over location and years in Ethiopia

	Bako		Bilo Boshe			Gute				Disease reaction
Genotype	2018	2019	2017	2018	2019	2018	2019	Mean	ANTH (1-5 scale)[a]	GM (1-5 scale)[b]
ETSL 101168	5.9	3.4	1.4	3.4	2.6	5.0	2.7	3.5	3.7	1.0
ETSL 101757	4.6	1.6	1.7	2.0	1.7	4.5	2.7	2.7	3.2	1.0
10 line 2A	3.8	1.0	1.5	2.0	0.2	5.5	3.1	2.4	3.3	1.8
ETSL 101343	5.0	2.0	3.1	2.2	1.5	4.7	2.4	3.0	3.2	1.0
8 line 2C	4.2	1.3	1.8	0.9	0.4	2.3	2.6	1.9	3.3	1.8
ETSL 101066	4.0	2.6	2.9	2.4	2.5	4.5	3.4	3.2	2.8	1.0
ETSL 101327	3.9	2.4	2.4	2.7	1.9	4.7	2.1	2.9	3.0	1.0
ETSL 101691	5.1	3.1	2.9	3.8	2.5	5.4	3.0	3.7	2.4	1.2
ETSL 100548	4.9	1.1	2.2	2.1	1.1	4.2	1.6	2.5	3.3	1.2
ETSL 100618	4.8	2.6	3.7	2.6	2.6	5.7	4.0	3.7	2.4	1.5
ETSL 100657	4.9	2.3	3.2	3.4	2.2	5.0	3.4	3.5	3.0	1.3
ETSL 100621	4.7	2.7	2.6	2.2	1.3	4.2	3.1	3.0	3.7	1.3
ETSL 100406	4.7	2.9	1.7	2.2	1.9	3.5	3.1	2.9	3.3	1.2
ETSL 101581	4.4	2.7	3.4	1.5	1.2	5.2	2.1	2.9	2.7	1.0
ETSL 100124	4.7	3.1	4.3	2.6	2.8	3.6	3.0	3.4	3.0	1.0
16 line 1A	4.0	1.2	2.7	2.2	0.4	4.2	1.9	2.4	2.0	2.7
8 line 2A	5.8	2.9	2.8	3.9	1.9	6.0	3.4	3.8	2.3	1.0
ETSL 101259	6.7	3.0	3.3	2.4	2.9	5.6	3.6	3.9	2.2	1.0
ETSL 100587	5.4	2.7	2.4	2.5	1.8	1.8	2.2	2.7	3.7	1.0
Bonsa	4.2	1.7	2.7	2.0	2.6	2.4	3.6	2.7	3.5	1.8
Mean	4.8	2.3	2.6	2.5	1.8	4.4	2.8	3.0	3.0	1.3
LSD	1.3	0.6	0.6	0.5	0.4	0.9	0.8	0.3	0.8	0.8
CV	16.1	15.0	14.5	12.8	14.1	11.7	16.4	14.4	15.2	23.4
F-test at 5%	**	**	**	**	**	**	**	**	**	**

[a]=anthracnose severity score (1=highly resistant, 2=resistant, 3=moderately resistant, 4=susceptible and 5=highly susceptible), [b]= grain mold severity score (1=highly resistant, 2=resistant, 3=moderately resistant, 4=susceptible and 5=highly susceptible), ANTH=anthracnose, GM= grain mold, CV = coefficient of variation, LSD = Least Significant Difference, ** =highly significant at P<0.01 level

These genotypes showed regression coefficients (bi) approaching to one (1.34, 1.30, 0.93, 1.21) and acceptable deviation from regression approaching to zero (0.09, 0.08, 0.06, 0.69), respectively; indicating they are stable, widely adaptable and high yielding than other genotypes (Table 6). Supportive findings were reported by Kebede et al.(2019) in their genotype by environment interaction and grain yield stability on twelve finger millet genotypes.

Table 5. Analysis of variance for grain yield for sorghum genotypes using the Eberhart and Russell Regression Model

Source	Df	SS	MS
Total	139	247.39	1.78
Genotypes	19	41.638	2.191**
Env + (Gen x Env)	120	205.752	1.715
Env (linear)	1	153.007	153.007
Gen x Env (linear)	19	11.885	0.626^{ns}
Pooled deviations	100	40.86	0.409

Grand mean = 3.0; R2 = 0.8574; Coefficient of variation (CV) = 15.2 %,*, ** = Significant at P < 0.05 and P < 0.01 levels, respectively.

Sorghum genotype, Bonsa showed a highly significant regression coefficients (bi) different from unity and square deviation from regression (s2di) value also deviated from zero (Table 6); and square deviation from regression (s2di) is highly deviate from zero was obtained from ETSL 100587 genotype (Table 6).

Table 6. Regression coefficient (bi) and squared deviation from linearity of regression (s2di) by the test sorghum genotypes using Eberhart and Russell model

Genotypes	**Regression coefficient (bi)**	**squared (S2di)**	**Grain yield (ton ha^{-1})**
10 line 2A	1.46	0.50	2.38
16 line 1A	1.15	0.13	2.38
8 line 2A	1.30	0.08	3.81
8 line 2C	0.95	0.30	1.93
Bonsa	0.44	0.48	2.74
ETSL 100124	0.48	0.22	3.44
ETSL 100406	0.78	0.16	2.87
ETSL 100548	1.27	-0.01	2.46
ETSL 100587	0.62	1.07	2.68
ETSL 100618	1.21	0.69	3.70
ETSL 100621	1.01	-0.07	2.98
ETSL 100657	0.94	-0.07	3.46
ETSL 101066	0.69	-0.07	3.18
ETSL 101168	1.14	0.74	3.48
ETSL 101259	1.34	0.09	3.92
ETSL 101327	0.83	0.03	2.90
ETSL 101343	1.16	-0.06	2.98
ETSL 101581	1.17	0.43	2.94
ETSL 101691	0.93	0.06	3.70
ETSL 101757	1.13	-0.04	2.68

This result indicates that genotypes are less stable and not adaptable over testing environments. Genotypes, 8 line 2C and 10 line 2A showed better stability and, also were widely adaptable over the environment; but recorded lower grain yield. In the present study, the result obtained using Eberhart and Russell (1966) model is in agreement with that of the AMMI model. Similar result

was reported by Kebede et al. (2019) that significant differences between genotypes for grain yield of eight finger millet genotypes across six environments.

Stability analysis

Stability analysis using biplot for grain yield explained 69.68 % of total variation (46.52, 23.16 % by PC1 and PC2, respectively) (Figure 1). The biplot showed that genotype ETSL 101259 was in the first concentric circle, closer to IPCA stability horizontal line; followed by ETSL10691, ETSL 100618, ETSL 101168 and 8 line 2A and away from the mean vertical line which indicates these genotypes were stable and high yielders among tested genotypes.

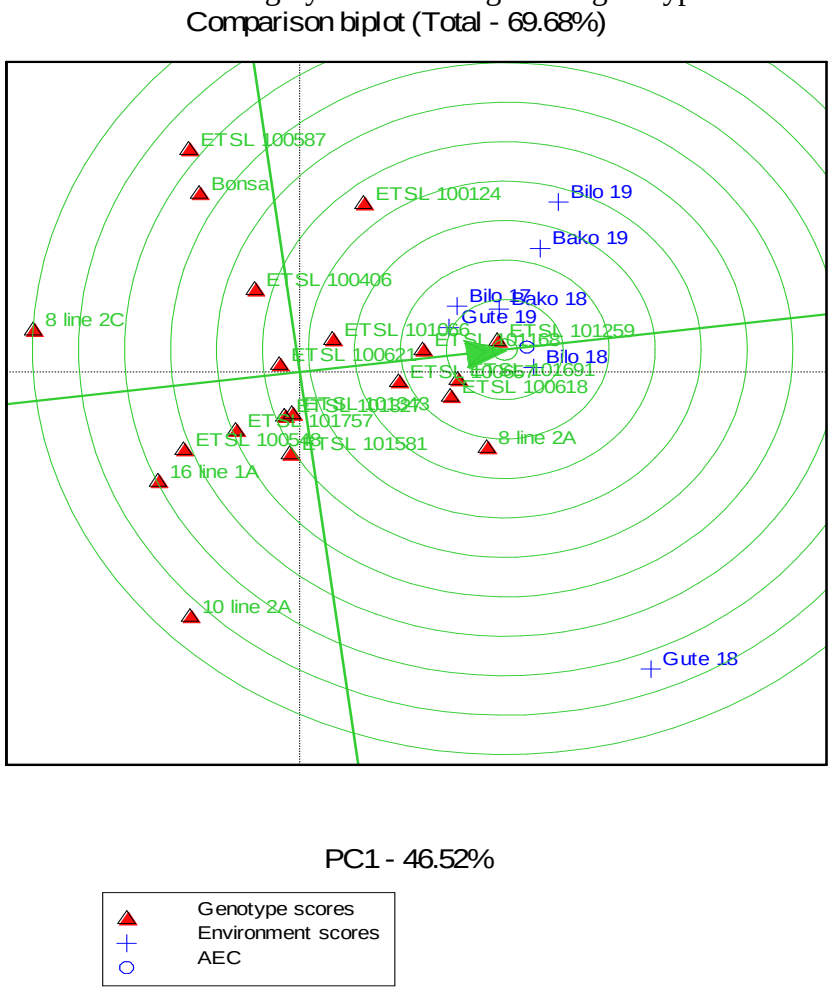

Figure 1. GGE Biplot analysis showing grain yield stability of sorghum genotypes and environments in Ethiopia.

On other hand, genotypes 8 line 2C, 10 line 2A and 16 line 2A were stable genotypes, but showed inferior in grain yield which gave less than average (1.9, 2.4, and 2.4, respectively). Genotype ETSL 100124 gave high grain yield (3.4 ton ha^{-1}), however; it deviate from the mean horizontal line, which implies the genotype is not stable (Figure 1).

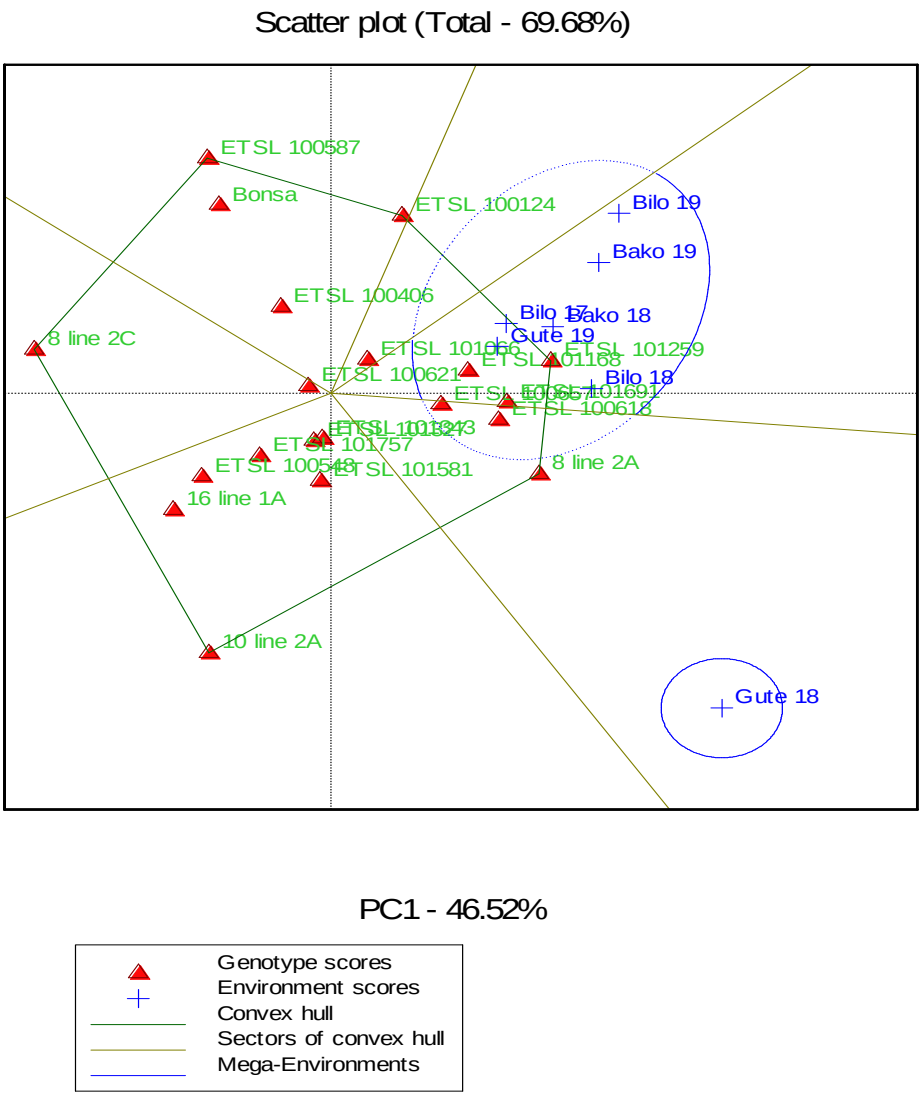

Figure 2. Polygon view of the GGE biplot based on grain yield for the environments

This result is in agreement with the AMMI and Eberhart and Russell models discussed above. Kebede et al.(2019); Kebede et al. (2018) for finger millet and, Worede et al. (2020); Hamidou et al. (2019) for sorghum also identified stable genotypes in their earlier research findings. The GGE biplot analysis (Fig.2 and 3) indicates the best performing genotype(s) for specific environment and the group of environments. Biplot divided the plot into seven sections and the environments categorized in two mega environments.

In biplot analysis, graphical analysis of multi environment trial reveled when different environments fall into different sectors shows different high yielding cultivars for those sectors and also the presence of a cross over interaction (Yan et al., 2007).

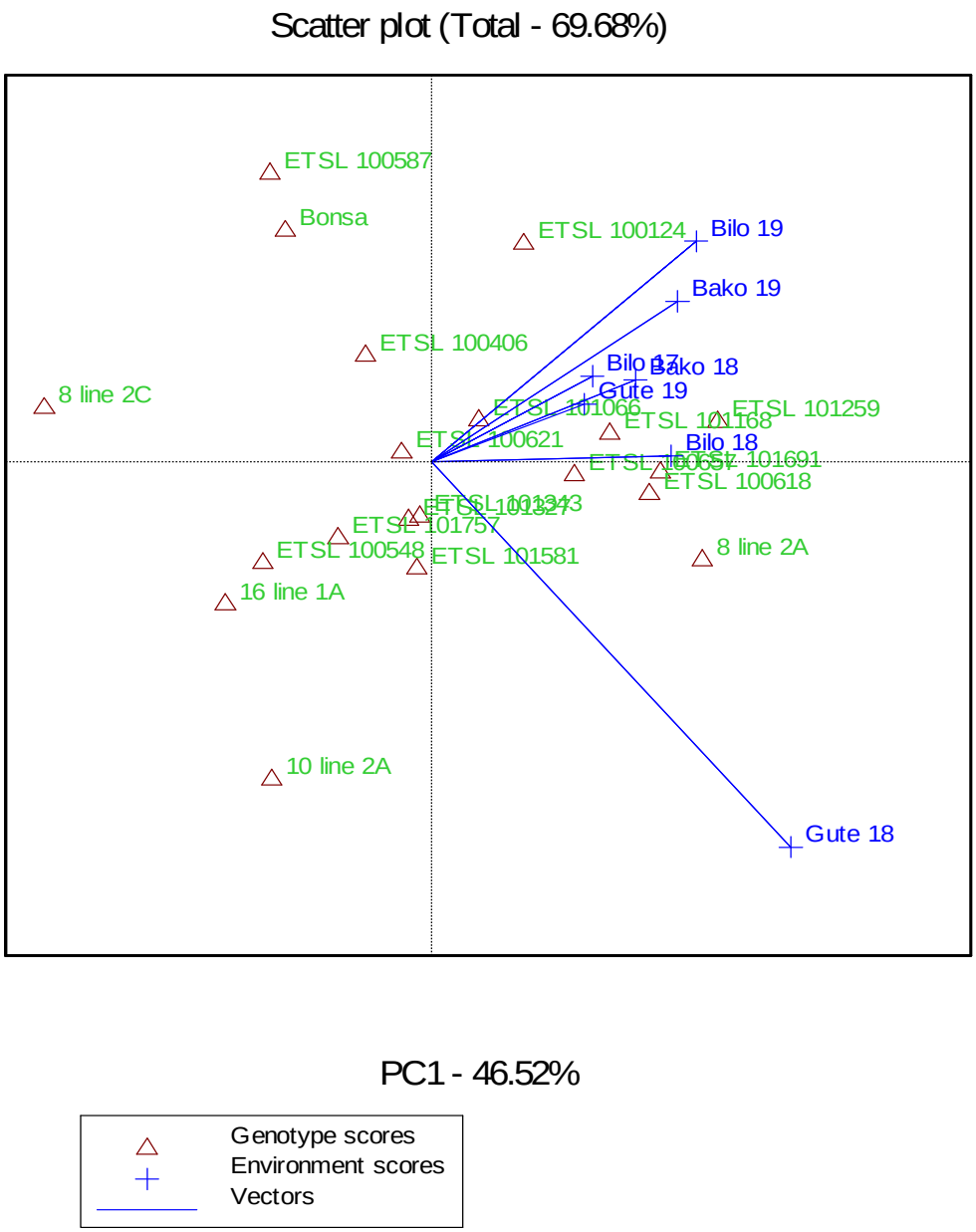

Figure 3. GGE biplot based on grain yield for the 20 genotypes showing the relationship among environments.

Moreover, according to Yan (2002) and Yan and Tinker (2006), genotype at the vertex of the polygon performs best in the environment falling within the sectors. In the present study, ETSL 101259, ETSL10691 and ETSL 101168 performs best at Gute 2019, Bako 2018, Bilo 2018 and Bilo 2017.

On other hand, presence of wide obtuse angles between environment vectors (Fig. 3) indicates strong negative correlations among the test environments, suggesting existence of strong crossover GE across some locations for grain yield. Moreover, this result indicates genotypes responded differently over environments that genotypes performing better in one environment might be poorly performed in another environment. Oppositely, the closer relationship among

other locations is an indication of there is no cross over GxE which implies ranking of genotype does not change from location to location.

In the present study, AMMI, GGE biplot and Eberhart and Russell model analysis results confirmed that ETSL 101259, 8 line 2A, ETSL 100618 and ETSL 101691 were stable and high yielding genotypes; selected for variety verification trial in test environments and other similar agro ecologies of the country.

CONCLUSION

GEI study is a very important for plant breeding programmes especially where a diverse environmental, climatic and soil variability is existed like in Ethiopia. Studying GEI is a key vital in developing a stable variety that fits wider adaptation areas which could make breeders work easy. In the present finding, the combined analysis of variance indicated highly significant ($P<0.01$) variations among genotypes (G), environments (E), genotype by environment interactions (GEI), principal component analysis IPCA-I, IPCA-II, and IPCA-III and; significant difference ($P<0.05$) for IPCA-IV. This result indicates there is variation among testing environments that genotypes are respond differently over environments, or the existence of GEI that affects the performance grain yield of the genotypes across locations. The AMMI analysis identified four principal component axes, and all contributed to 87.80% (46.02, 20.42, 11.76, and 9.60, respectively) of the total variation observed among sorghum genotypes for grain yield due to GEI. According AMMI model, genotypes such as ETSL 101259, 8 line 2A, ETSL 100618 and ETSL 101691 attained IPCA values (0.007, -0.432, -0.804 and -0.161, respectively) which is relatively close to zero, and gave relatively high yield which implies these genotypes are better stable and widely adaptable genotypes across locations whereas ETSL 100587, Bonsa, ETSL 100124 and ETSL 100406 scored IPCA values deviating from zero (1.144, 0.859, 0.653, 0.432) indicated unstable genotypes and their response were varied across locations. Eberhart and Russell Model, which indicates genotypes that fitted to Eberhart and Russell Model can be proposed for possible release in breeding program. Accordingly, pipeline genotypes, ETSL 101259, 8 line 2A, ETSL 101691 and ETSL 100618 were showed regression coefficients (bi) approaching to one (1.34, 1.30, 0.93, 1.21) and acceptable deviation from regression approaching to zero (0.09, 0.08, 0.06, 0.69), respectively. Stability analysis using GGE biplot also revealed, grain yield explained 69.68 % of total variation and genotype ETSL 101259 was in the concentric circle, closer to IPCA stability horizontal line; followed by ETSL10691, ETSL 100618, ETSL 101168 and 8 line 2A and away from the mean vertical line which indicates these genotypes were stable and high yielders among tested genotypes. In general, based on the regression, AMMI and GGE Biplot analyses, therefore, ETSL 101259, 8 line 2A, ETSL 100618 and ETSL 101691 are the most stable and high yielding genotypes and as a result, they are proposed for variety verification for Bako, Gute, Bilo boshe and similar agroecologies of the western Oromia, Ethiopia. Hence, they are recommended for possible release for wider adaptability around Bako, Gute and Bilo boshe including areas with similar agro-ecology in the country.

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Adaptation of improved tef (Eragrostis tef varieties in West and Kellem Wollega zones of Western Oromia

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ABSTRACT

Tef (Eragrostis tef (Zucc.) Trotter) is an annual grass crop and important indigenous cereal crop harvested for grain in Ethiopia. Twenty-six improved tef varieties were tested across three environments against one local check in western Oromia, Ethiopia during 2018/19 and 2019/20 main cropping seasons to evaluate, and recommend adaptable and high yielding improved tef varieties for West and Kellem Wollega Zones of Western Oromia. The varieties were arranged in a randomized complete block design (RCBD) with three replications. Pooled analysis of variance (ANOVA) indicated significant differences among tested varieties. The combined mean of tested varieties indicates that Kuncho and Dukem were highest yielding varieties as compared to local check and other varieties evaluated. Therefore, the two varieties need to be demonstrated at the farmers' level for larger scale production till other recommendation provided for the area.

Key words: Adaptation, Yield, Tef, Recommendation.

INTRODUCTION

Population growth which was 6 billion in 1999 is expected to beat 9.7 billion in 2050 (UNDESA, 2015) whereas grain crops projected to increase by nearly 48% from 2000 – 2025 and by 70% up to 2050. The concerning issue for scientific community is nearly all of this growth conjecture is to take place in the developing countries of which sub-Saharan Africa's population would grow the fastest. In addition, our growing population is becoming increasingly urban. The World Health Organization (WHO) estimates that 7 out of 10 people will live in a city by 2050. With the rapid increase in the global population and the impact of climate change on agriculture, there is a need for crops with higher yields and greater tolerance to abiotic stress. Keeping all this concern in mind giving emphasis to vulnerable crops become an essential effort the way forward.

Tef (Eragrostis tef (Zucc.) Trotter) is domesticated in Ethiopia around 4000- 1000 BC and Ethiopia is considered as center of origin of tef (Kebede et al., 1989). The great diversity within the species is evident in seed color (Ebba, 1975). There are reports of purple, white, brown and red seeded types (Mengesha 1966; Costanza, 1979). The reputation of tef is based primarily on consumer preference for Injera (Ethiopian bread). Other utilizations of tef include local alcoholic beverages called tela and katikala, and porridge. Additionally, tef plant residues could be used as fodder for livestock, and often incorporated as construction materials.

Tef's agronomic versatility and reliability even under adverse conditions suit it well to a country of contrasting and unpredictable environments where water logging, drought, pest and disease

are common, makes this crop very important. It is grown in different climatic and edaphic zones at elevation ranging between 1000-2500m above sea level (Westphal, 1975). Owing to it is hardy nature, this species has a considerable potential for agriculture in areas unsuitable for other cereals. However, a lot of manual labor is needed to grow the crop because there's not enough mechanization for planting or sowing, weeding and harvesting.

Additionally, tef has also a good balance of essential amino acids, except lysine (Ebba,1969). Among the cereals, tef straw is the best and comparable to a good natural pasture (Stallknech, 1997). Even though tef is one of the dominant cereal crops in Ethiopia in terms of area coverage and yet the yield per hectare nationally was hampered at 15.60 quintal (CSA, 2015/16). Besides, nationally there are very low levels of tef yields compared to other major cereals mainly due to the limited use of improved seeds, inefficient farming practices and fragmented farm plots. The yields of tef in Wollega areas are low due to different production problems of which lack of improved varieties that resist disease and pests are some of the most serious production constraints of tef production in the area. In contrast, tef production was expanding at the expense of other, higher-yield crops such as maize, wheat, barley and sorghum mainly due to food preference and this could stance a significant challenge to achieving food security. Thus, to maintain the balance of farmers preference of this particular commodity and yield, increasing tef yield may seem like the most viable solution to pull Ethiopian farmers out of poverty and ensure food security nonetheless comprehend overcoming a number of obstacles. The increase in production of tef depends on the optimization of crop management and genetic improvement. Unlike other crops of international importance such as rice and wheat, where basic and applied research contributed significantly to their improvement, tef has received little attention. The lack of improved tef technology was evident in Western part of the country, especially in West and Kellem Wollega Zones. Therefore, the project was initiated with the following objectives to solve the existing problems.

MATERIALS AND METHODS

Description of locations and Experimental materials

The experiment was conducted at three different rain fed locations of Kellem and West Wollega zones viz, Bellam research site (altitude 1759 masl, 09° 02' N, 035° 104'E), Mata Farmers Training Center (FTC) (altitude 2016 masl, 08° 34' N, 034° 44'E) and Aroji FTC (altitude 2054 masl, 08° 40' N, 034°47'E) in Western Oromia, Ethiopia, during 2018-2019 main cropping seasons. Twenty-six improved tef varieties were evaluated with local check (Table 1).

Experimental design and management

Randomized completed block design (RCBD) with three replications were used in all locations. Each experimental plot consisted six rows of 2.5 m long spaced and 20 cm apart with a plot area of 1.2 m x 2.5 m. Drill planting by hand was used with 10 kg ha^{-1} seed rate for all locations. Fertilizer was applied at a rate of 41 and 46 kg ha^{-1} of N and P_2O_5, respectively, in the form of Urea and NPS. All NPS and half of N were applied during planting, while the half splits were applied at tillering stages. First weeding was carried out 35 days after emergence and the second one at 30 days after the first weeding for all locations.

Table 3. List of varieties evaluated during 2018-2019 main cropping seasons

No	Varieties	Hosting Center/Source	Year of Release	No	Varieties	Hosting Center/Source	Year of Release
1	Simada	Debrezeit	2009	15	Flagot	Debrezeit	
2	Boset	Debrezeit	2012	16	Enatit	Debrezeit	1970
3	Megna	Debrezeit	1978	17	Dagem	Debrezeit	2016
4	Tseday	Debrezeit	1984	18	Gibe	Debrezeit	1993
5	Amarech	Debrezeit	2006	19	Kenna	Bako	2008
6	Quncho	Debrezeit	2006	20	Nigus	Debrezeit	
7	Geredo	Debrezeit	2002	21	Asgori	Debrezeit	
8	Keytana	Debrezeit	2002	22	Melko	Debrezeit	
9	Menagesha	Debrezeit		23	Kora	Debrezeit	2014
10	Welenkomi	Debrezeit		24	Tesfa	Debrezeit	
11	Dukem	Debrezeit	1995	25	Dega teff	Debrezeit	2005
12	Ziquala	Debrezeit	1995	26	Guduru	Bako	2006
13	Gimbichu	Debrezeit	2005	27	Local check	Local farmer	-
14	Koye	Debrezeit	2002				

Data collection and statistical analysis

Days to heading, days to maturity, grain filling duration, plant height, head height, lodging percentage, and grain yield data were collected based on multi-crop descriptors (FAO/IPGRI, 2001) and were subjected to analysis using statistical analysis software (SAS Inc., 2003). The data considered for analysis was from four central harvestable rows. The harvested varieties were sun dried before being tested for moisture content where 12% was the preferred average moisture content. Grain yield data was then obtained by weighing the dried grain and adjusted to 12% moisture content.

RESULTS AND DISCUSSION

Analysis of variance

Pooled analysis of variance indicated highly significant differences for genotypes, environments and genotype by environment interaction (G×E). This indicated that environmental factors played a leading role for the variability observed among tef varieties tested in western Ethiopia. In addition to the environmental factors, the contribution of G×E was also appreciable. The significant G×E suggests that grain yield of tef varieties varied across environmental conditions.

Table 4 Analysis of variance of major agronomic and yield components of teff tested at western Oromia

Source of variation	DF	Mean Squares								
		DH	DM	GFP	PT	PH	HH	LDG	BM(Qt/ha)	GY(Qt/ha)
Trt	26	1287.03***	3602.22***	755.2***	30.42***	1491.7***	488.96***	3.41**	2235.27***	70.78***
Rep	2	54.59***	309.59***	624.04***	0.78	386.47***	67.08**	0.96	172.1**	3.12
Env	3	1360.63***	2206.8***	5223.9***	145.93***	1712.6***	1165.80***	3.08	60432.6***	2487.53***
Trt*env	26	1287.03***	61.29***	86.70***	2.42	24.85	19.99*	2.07	373.1***	8.83***

Yield performance

The mean grain yield (Qt ha^{-1}) of the twenty-seven tested tef varieties at Western Oromia indicated statistically significant difference among tef varieties. The combined mean of tested varieties indicated Kuncho and Dukem as better performers followed by Wolenkomi, Boset and Tseday while Dega tef was the poor performer in a level that it cannot bear any yield. This result in line with Asaye et al. (2020) who reported that 30.7 quintal per hectare for Dukem variety in Dembia. In line with the current finding, Daniel et al. (2016) reported Dukem and Boset as highest yielder among tested varieties in Gondar. Besides, Ziquala, Menagasha, Gimbichu and Geredo were also the poorest in terms of yield they bear (Table 3). In contrast to this finding, Gimbichu variety is found to be a highest yielder among tested varieties in Western Hararge (Gebayo et al., 2018).

Agronomic performance

Differences among the genotypes were significant for a number of characters (Table 3). The tested varieties shows statistically significant variation that ranged from 44.9 (Simada) to 56.1 (Geredo) for days to heading and 82.1 (Geredo) to 96.7 (Menagasha) for days to maturity. In concurrent with this finding Simada and Geredo varieties were found to be the earliest to days to heading and days to maturity in Dembia and Borana, respectively (Asaye et al., 2020; Natol et al., 2020). A local variety included in this investigation was the intermediate in days to heading (52.6 days). However, this local landrace was earliest for maturity relative to other varieties. This indicates that local landraces had relatively a shorter grain filling period. Geredo were the earliest to maturity whereas Menagasha and Melko were the late maturing varieties. Though Geredo was late to flower (56.15); it pays its late to heading by filling the grain as short as possible (26). In contrast to this, Flagot, Melko, Simada and Menagasha acquired a long grain filling time.

On the other hand, in terms of plant height Asgori, Enatit, and Gimbichu were the shorter whereas Kora and Geredo were comparatively the taller varieties. In line with this study, tef varieties that were tested at Dembia signifies similar trends in favor to plant height (Asaye et al., 2020).

There is a small difference display among tested varieties for lodging; except Simada which is susceptible to lodging. Besides, Boset, Tseday and Kuncho contributed high biomass yield which were possibly accounted from their corresponding higher productive tiller. In contrast with this study, Tseday offered low biomass per hectare in Dembia, Gondor (Asaye et al., 2020).

Table 5. Combined Mean performance of Tef Adaptation Trial at Mata, Bellam and ArojiAgamsa, 2019-2020

Varieties	DH	DM	GFP	PT	PH (cm)	HH (cm)	LDG	BM(Qt/ha)	GY(Qt/ha)	HI (%)
Simada	44.94o	89.08e-h	44.14a	7.96ab	49.72i-k	28.97d-h	3.565a	60.63jk	10.37h-l	18.46b-j
Boset	49.94lm	89.25e-g	39.30b-f	7.11b-d	54.60d-g	31.10b-d	1.261b	79.27a	12.23a-d	16.55jk
Megna	52.60g	88.16f-i	35.55i-l	6.55c-e	52.88gh	29.24d-g	1.36b	68.72c	10.35h-l	16.18k
Tseday	47.94n	87.66hi	39.72b-e	7.30a-c	53.08f-h	27.77f-h	1.24b	74.05b	12.13a-e	18.23d-k
Amarech	54.85c	90.08c-e	35.22j-l	4.92h-j	58.19bc	24.25j	1.14b	63.50g-j	10.01j-m	17.71e-k
Kuncho	55.10bc	89.5d-f	34.39kl	8.17a	58.15bc	29.92c-f	1.24b	73.90b	13.35a	17.35f-k
Geredo	56.15a	82.16j	26.00n	3.92j	60.10ab	24.91ij	1.14b	54.22l	9.97k-m	19.43b-f
Keytana	51.27jk	91.08bc	39.83b-d	6.53c-e	49.14jk	28.43e-h	1.16b	64.41f-i	10.35h-l	18.40c-j
Menagesha	55.82ab	96.75a	40.92b	4.25ij	57.77bc	24.75ij	1.14b	61.44i-k	8.29n	17.88e-k
Welenkomi	53.44ef	90.41c-e	36.97g-j	6.11d-f	50.70h-j	27.36gh	1.16b	68.30c-e	12.28a-d	16.58i-k
Dukem	54.52cd	89.83c-e	35.30j-l	4.54ij	55.97c-f	31.19b-d	1.16b	67.98c-f	13.11ab	18.68b-i
Ziquala	55.82ab	87.5i	31.67m	3.92j	53.77e-g	21.75k	1.14b	53.78l	8.99mn	19.51b-e
Local	52.60g	87.75g-i	35.14kl	5.67e-h	55.61c-g	31.92bc	1.37b	66.00c-g	12.41abc	18.19d-k
Gimbichu	52.69fg	89.91c-e	37.22g-i	6.59c-e	46.86h-j	28.64e-h	1.20b	64.77d-i	9.56mn	17.27g-k
Koye	51.44ij	90.58c-e	39.14b-f	6.34c-e	50.65h-j	31.95bc	1.20b	65.69c-h	10.66g-l	17.07h-k
Flagot	47.44n	88.08f-i	40.64bc	7.30a-c	54.04e-g	32.31b	1.45b	62.07h-k	11.54c-f	22.30a
Enatit	52.35gh	88.08f-i	35.72i-l	5.01g-i	47.80jk	28.38e-h	1.06b	61.18i-k	10.87e-l	19.63b-e
Dagem	53.85de	87.91g-i	34.05l	5.07f-i	57.43b-d	32.63b	1bc	62.95g-j	11.96b-f	19.31b-g
Gibe	49.44m	88.08f-i	38.64d-j	5.98e-g	49.01jk	29.73c-f	1.08b	64.58f-i	10.17i-m	16.60i-k
Kenna	52.02g-j	88.08f-i	36.05h-k	6.01e-g	56.60c-e	28.32e-h	1bc	58.69k	11.09d-k	20.38a-c
Nigus	50.02lm	87.83g-i	37.80f-h	6.51c-e	55.40c-g	31.07b-d	1bc	67.57c-f	11.83d-g	20.22ab
Asgori	50.60kl	89.91c-e	39.30b-f	6.63c-e	47.83jk	27.94f-h	1bc	60.32jk	10.81g-l	20.53ab
Melko	52.10g-i	92.16b	40.05b-d	5.73e-h	52.70g-i	26.65hi	1.18b	58.40k	10.39h-l	19.03b-g
Kora	51.77h-j	90.83b-d	39.05c-f	6.38c-e	61.50a	31.72bc	1.18b	64.93d-i	11.33d-i	19.83b-e
Tesfa	51.77h-j	87.91g-i	36.14h-l	5.07f-i	57.22b-d	30.36b-e	1.18b	60.60jk	11.28d-j	19.75b-e
Degateff	0	0	0	0.1567k	0l	0l	0c	0m	0	0l
Guduru	52.025g-j	90c-e	37.97e-g	6.34c-e	58.365bc	36.374a	1.3658b	68.382cd	11.425d-k	17.344f-k
Mean	50.10	85.88	35.78	5.78	52.04	28.06	1.22	62.09	10.61	17.87
CV	2.06	2.23	6.33	22.60	7.32	10.39	10.85	7.51	15.23	14.72
LSD	0.83	1.55	1.82	1.05	3.07	2.35	1.04	3.76	1.30	2.12
Ftest	**	**	**	**	**	**	**	**	**	**

Key: DH=Days to heading, DM= Days to maturity, GFP=Grain filling period, PT= Productive tiller, PH= Plant height in cm, HH= Head height in gm, LDG= Lodging in percentage, BM= Biomass yield, GY= Grain yield in qt, HI= Harvest index.

CONCLUSION AND RECOMMENDATIONS

The study revealed that tef varieties differ in adaptation potential when subjected to different growing environments. From the current study some varieties exhibited an outstanding performance in terms of grain yield and yield related traits. The combined mean of tested varieties indicates that Kuncho and Dukem were top yielders compared with local check and other varieties evaluated. Therefore, the two varieties need to be demonstrated at the farmers level for larger scale production till other recommendation provided for the area.

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Performance Evaluation of Groundnut Varieties in Eastern Parts of Ethiopia

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ABSTRACT

Groundnut plays an important role as a food as well as cash crop in Ethiopia. Its production in Ethiopia is found to be constrained by several biotic and abiotic factors. Meanwhile, this study was done with the objective of identifying the high yielding, biotic and abiotic resistance or tolerance varieties in 2019. A total of six groundnut varieties were evaluated in RCBD. AMMI showed that environments, varieties and their interaction effects were significantly different. The stability and high yielding ability of the varieties has been graphically depicted by the AMMI bi-plot. The stability and high yielding ability of the varieties has been graphically depicted by the AMMI bi-plot. Environments E3 (Fadis 2018) and E1 (Fadis 2017) relatively showed high IPCA scores, contributed largely to GEI. These environments were favorable for high yielding varieties based on mean yield as they had more than the grand mean. The variation for seed yield among the varieties for each variety was significant at different environments. Varieties G1 (Bulki), G6 (Babile2) and G4 (Werer962) were specifically adapted to high yielding environments. G2 (Shulamiz) was the most unstable variety. G1 (Bulki) was more stable in comparison to other varieties. In GGE bi-plot; $IPCA_1$ and $IPCA_2$ explained 48.07% and 25.93%, respectively, of groundnut variety by environment interaction and made a total of 74.00% of variation. Therefore, Bulki (1075kg ha^{-1}) and Babile2 (1030kg ha^{-1}) were most stable recommended for the study area and similar agro-ecologies and Fedis was the ideal environment for groundnut production.

Key word: AMMI, G x E interaction, Groundnut

INTRODUCTION

Groundnut (Arachis hypogaea L.) plays an important role as a food as well as a cash crop in Ethiopia (Dereje A. et al., 2012). Currently the crop is becoming one of the high value crops that are growing in the lowlands areas of the eastern Oromia. Groundnut, or peanut, is commonly called the poor man's nut. Today it is an important oilseed and food crop (FAO, 2002). Groundnuts are produced in the tropical and subtropical regions of the world, on sandy soils.

In Ethiopia, groundnut is cultivated predominantly by the traditional and undeveloped farming community under rain-fed conditions. It occupies about 79,947 hectares of land with a corresponding gross annual production of about 1128,887 qt. (CSA, 2013). The yields of groundnut in Ethiopia compared to other countries are very low i.e. below 1.1 ton ha^{-1} as compared to average yields on a global scale i.e. 1.52 ton ha^{-1} but with good management practices, yields can be increased to 3.0 ton ha-1 (CSA, 2008). Groundnut production in Ethiopia is found to be constrained by several biotic and abiotic factors i.e. critical moisture stress especially during flowering and then after, lack of improved varieties and appropriate production and post-harvest practices, and diseases affecting both above- and underground parts of the plant (Alemeyehu et al., 2014).

MATERIALS AND METHODS

This activity has been conducted at Fedis on station. A total of seven recently released varieties (Bulki, Shumaliz, Werer961, Werer962, Roba, Babile2 and Baha Jiddu of groundnut were collected from BARC and one local check was used as planting materials. The experiment was arranged in RCBD with 3 replications. The varieties were grown under uniform rain fed conditions. The experimental plots consisted of six rows of 3 m length, 3.6 m width and 0.6 m row space. The central four rows were harvested to estimate grain yield. The spacing between adjacent replications and plots were used to be 1 m.

Important data like: - Days to flowering, Days to maturity, Pods per plant, Seeds per pod and Grain yield per hectare were collected.

RESULT AND DISCUSSION

Combined Analysis of Variance

Analysis of variance was carried out to determine the effects of varieties, location and their interaction on seed yield of groundnut varieties. Accordingly, Environment and Genotype for seed yield showed statistically highly significant differences ($P<0.01$) indicating the presence of genetic variation and possible selection of high yielding and stable varieties (Table 1). This indicates the big influence of environment and varieties on yield performance of groundnut varieties. The significant effect of environments indicated that the testing environments were significantly different from each other for expressing their yield potential. Similarly, Sunday C. et al., (2013) reported the different performance of genotypes across environments could also be indicative of wide variation in climatic conditions and soil types in the different growing environments. The mean yield potential of the varieties varying across environments and among varieties indicating the varieties were expressing their potentials even though they were affected by environments and genetic variations.

Table 1. Analysis of variance for seed yield of Groundnut varieties evaluated across two years for different locations.

Source of variation	d.f.	mean square
Block	2	3.75
Genotypes	7	11.667*
Environment	5	154.47**
Interaction	35	7.083
Error	94	5.081
Total	143	

Mean Seed Yield of Groundnut Varieties Evaluated at Six Environments

The average environmental seed yield across varieties ranged from the lowest of 6.44 $Qtha^{-1}$ at E2 (Erer 2017) to the highest of 12.85 $Qtha^{-1}$ at E1 (Fadis 2017), with a grand mean of 9.59 $Qtha^{-1}$(Table 2). The varieties average seed yield across environments ranged from the lowest of 8.06 $Qtha^{-1}$ for Shumaliz to the highest of 10.75 $Qtha^{-1}$ for Bulki (Table 2). This difference could be due to their genetic potential of the varieties, and also environment explained large variation indicated the existence of diverse mega environments.

Table 2: Mean seed yield (Qt/ha) of groundnut varieties evaluated at six environments

Varieties	Mean of seed yield across environment

	E1(Fadis 2017)	E2(Erer 2017)	E3(Fadis 2018)	E4(Dire 2018)	E5(Qile 2018)	E6(Qile 2019)	mean
Bulki	10.99	7.23	11.73	9.50	16.20	8.88	10.75a
Shumaliz	12.46	6.61	9.04	4.27	8.60	7.38	8.06c
Werer961	14.17	5.32	14.06	5.75	9.05	7.05	9.23bc
Werer962	13.56	6.37	13.03	9.05	9.25	7.69	9.83ab
Roba	14.22	7.16	10.94	7.36	9.81	8.78	9.71ab
Babile2	12.68	6.72	12.96	11.18	9.46	8.79	10.30ab
Baha Jiddu	13.33	6.57	12.73	7.86	9.08	8.04	9.60ab
Local Variety	11.42	5.56	12.30	8.62	9.57	7.84	9.22bc
Mean	12.85	6.44	12.10	7.95	10.13	8.06	9.59

Additive Main Effects and Multiple Interaction (AMMI) model

AMMI analysis of variance for Seed yield of eight groundnut varieties tested in six environments showed that environments, varieties and their interaction effects were significantly different (P<0.01) (Table 3) demonstrating the importance of applying AMMI analysis to investigate the main effects of varieties and environment and the complex patterns of their interaction. The environment modeled significant effect on the seed yield of groundnut, which explained 48.67% of the total variation indicating the existence of a considerable amount of deferential response among the varieties to changes in growing environments and the differential discriminating ability of the test environments. GEI contribute 15.62% of total variation while the varieties contribute only 5.15% of the total variation. Similarly, Amare K and Adisu G (2017) reported the analysis of variance showed genotype (8.8%), environment (69.8%), and GEI (21.4%) effects were significant (P < 0.01).

Table 3. Partitioning of the Explained Sum of square (Ex.SS) and Mean of square (MS) from AMMI analysis for seed yield of eight groundnut varieties evaluated at six environments

Source of variation	d.f.	Sum square	Ex Sum square%	Mean square
Total	143	1587.1	100	11.1
Treatments	47	1101.9	69.43	23.45**
Genotypes	7	81.7	5.15	11.67**
Environments	5	772.4	48.67	154.47**
Block	12	174.3	10.98	14.53**
Interactions	35	247.9	15.62	7.08**
IPCA 1	11	136.1	8.58	12.37**
IPCA 2	9	74.3	4.68	8.25*
Error	15	37.5	2.36	2.5
Pooled Error	84	310.8	19.58	3.7

As reported by Purchase et al., 2000, genotype with least ASV score is the most stable varieties. Accordingly, Bulki and Babile2 were most stable and Werer961 and Baha Jiddu were the most unstable. This measure is essential in order to quantify and rank varieties according to their seed yield stability. The least Genotype Selection Index (GSI) is considered to identify the most stable with high grain yield (Hagos et al., 2011). Based on the GSI, the most desirable variety for selection of both stability and high seed yield was Bulki followed by Babile2.

Table 4. $IPCA_1$, $IPCA_2$ scores, AMMI stability value and Genotype Selection Index of eight groundnut varieties

Variety	Meanyield	RYi	IPCA1	IPCA2	ASVi	RASVi
Bulki	10.754	1	-2.28129	0.2415	0.933	7
Shumaliz	8.06	8	0.23873	1.42978	1.80	3
Werer961	9.233	6	0.95733	0.24238	3.533	8
Werer962	9.826	3	0.43839	-0.56141	2.067	5
Roba	9.713	4	0.29972	0.69252	2.867	6
Babile2	10.301	2	0.04194	-1.23832	1.733	2
Baha Jiddu	9.601	5	0.48956	-0.11966	3.40	1
Local Variety	9.217	7	-0.18438	-0.68679	1.933	4

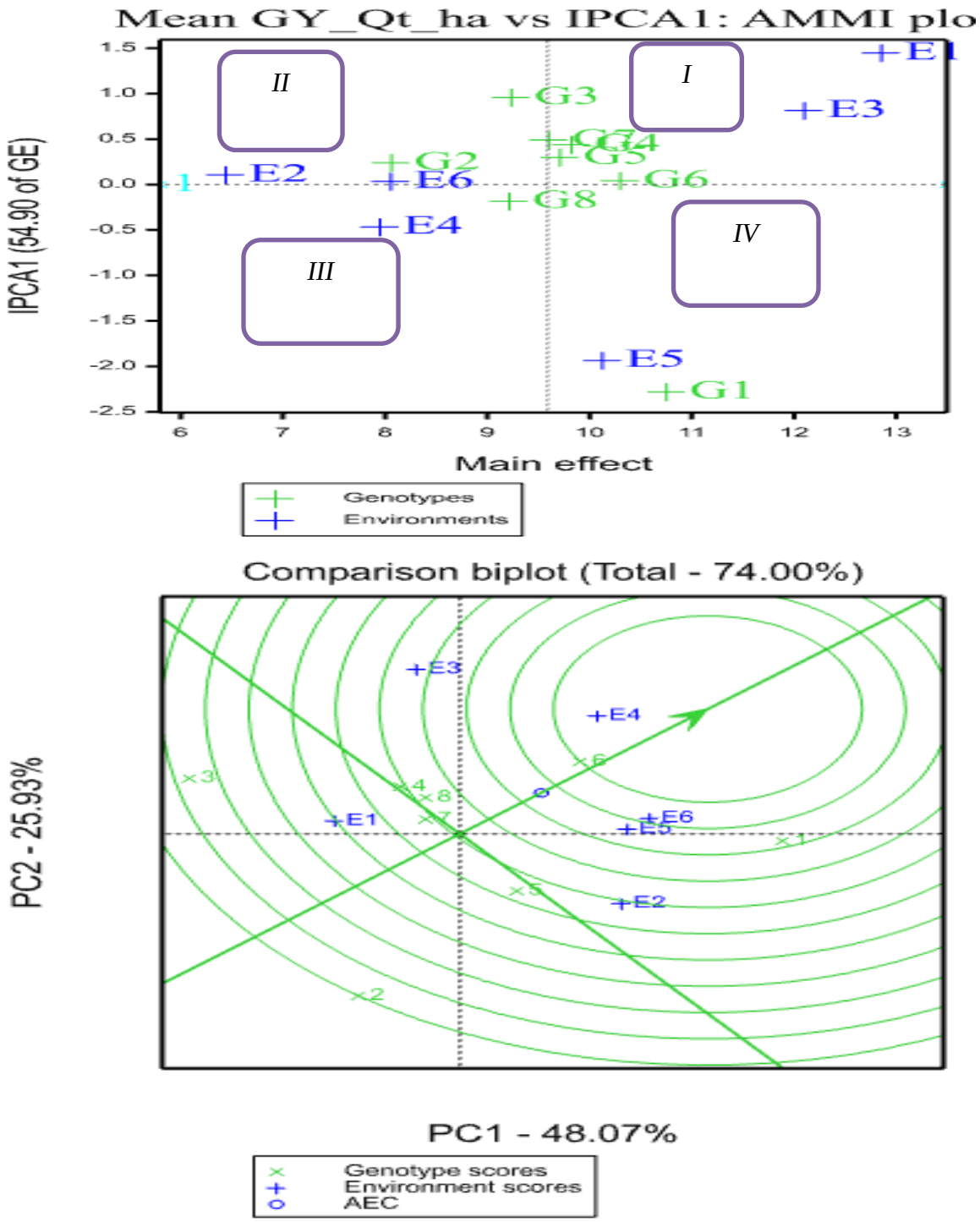
The stability and high yielding ability of the varieties has been graphically depicted by the AMMI bi-plot. Environments E3 (Fadis 2018) and E1 (Fadis 2017) relatively showed high IPCA scores, contributed largely to GEI. These environments were favorable for high yielding varieties based on mean yield as they had more than the grand mean. Environment E2 (Erer 2017) is the least favorable environment for almost all the varieties with low yield and smaller $IPCA_1$ score (Fig 1).

The variation of yield for each variety was significant at different environments. Varieties G1 (Bulki), G6 (Babile2) and G4 (Werer962) were specifically adapted to high yielding environments (Fig 2). Considering the IPCA1 score, G2 (Shulamiz) was the most unstable variety and also adapted to higher yielding environments. G1 (Bulki) was more stable in comparison to other varieties. Generally, Fadis was the most favorable environment for ground nut production with maximum mean of yield potential.

Figure 1: Biplot of interaction principal component axis ($IPCA_1$) against mean Seed yield of eight groundnut varieties and six environments

Genotype and Genotype by Environment interaction (GGE) bi-plot analysis

In GGE bi-plot (Figure 2), $IPCA_1$ and $IPCA_2$ explained 48.07% and 25.93%, respectively, of groundnut variety by environment interaction and made a total of 74.00%. The other study conducted on the same crop showed 81.8% total of $IPCA_1$ and $IPCA_2$ (Amare et al., 2014). Environments and genotypes that fall in the central (concentric) circle are considered as ideal environments and stable genotypes, respectively (Yan, 2002). A genotype is more desirable if it is located closer to the ideal genotype. Thus, using the ideal genotype as the center, concentric circles were drawn to help visualize the distance between each genotype and the ideal genotype. Therefore, the ranking based on the genotype-focused scaling assumes that stability and mean yield are equally important (Ezatollah et al., 2011). Fig. 2 revealed that G6 (Werer 962), which fell into the center of concentric circles, was ideal variety in terms of higher yielding ability and stability, compared with the rest of varieties. In addition, G1 located on the next concentric circle, may be regarded as desirable varieties. An environment is more desirable and discriminating when located closer to the center circle or to an ideal environment (Naroui et al., 2013). In the present study, E4 and E6 were the most discriminating and representative environments followed by E5 (Fig.3). E1wasnon-discriminating and less representative site . This implied that, varietal stability could be challenged not only due to the change in the test environment but also due to differential response of tested varieties per environment.



Key: G and E letters stand for genotypes and environments respectively.

Fig. 2. The vector view of the GGE bi-plot based on environment focused scaling for environments to show relationship among testing environments.

GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability

Figure 3 provides the summary of the interrelationships among the environments. The varieties that connect the bi-plot origin and the markers for the environments are called environment vectors. The angle between the vectors of two environments is related to the correlation coefficient between them. The cosine of the angle between the vectors of two environments approximates the correlation coefficient between them (Dagnachew et al., 2014). Based on the angles of environment vectors, the six environments are grouped in to two groups. Group one includes E1 and E3 and Group two involve E2, E4, E5 and E6. For instance, the smallest angle between E1 and E3 is implying that there are the highest correlations between them. The angle between E1 and E2; E3 and E2 are bigger than others showing the poor correlation between them (Figure 3). Two criteria are required to suggest existence of different mega-environments. First there are different winning genotypes in different test locations. Second, the between-group variation should be significantly greater than the within-group variation, common criteria for clustering. Dividing the target environment into different mega-environments and deploying different genotypes in different mega-environments is the best way to utilize GE interaction.

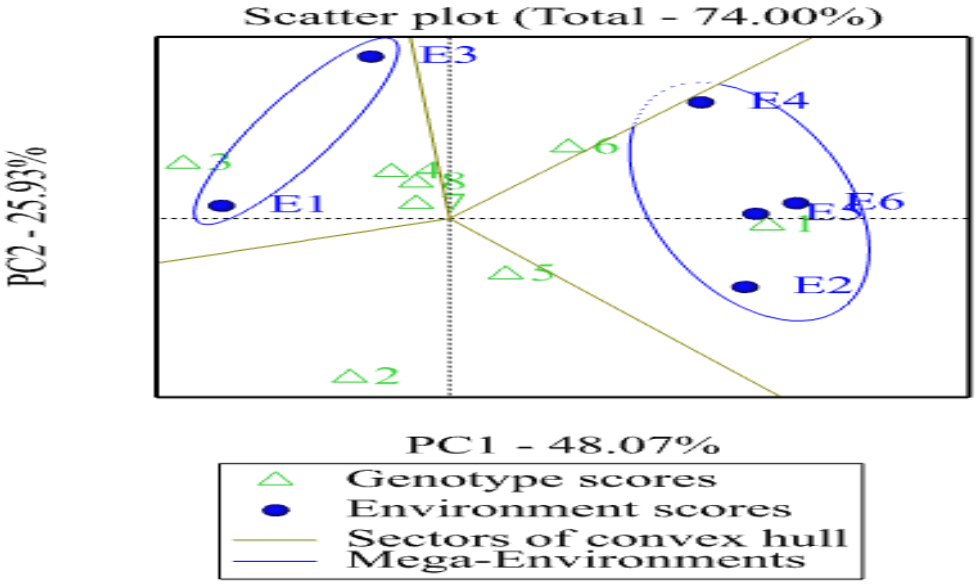


Fig. 3. GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability

SUMMARY AND CONCLUSION

Analysis of variance find out Environment and Genotype for seed yield showed statistically highly significant differences (P<0.01) indicating the presence of genetic variation and possible selection of high yielding and stable varieties. The average environmental seed yield across varieties ranged from the lowest of 6.44 Qtha^{-1} at E2 (Erer 2017) to the highest of 12.85 Qtha^{-1} at E1 (Fadis 2017), with a grand mean of 9.59 Qtha^{-1}. AMMI analysis of variance for seed yield of eight groundnut varieties tested in six environments showed that environments, varieties and their interaction effects were significantly different (P<0.01). The environment modeled significant effect, which explained 48.67% of the total variation indicating the existence of a considerable amount of deferential response among the varieties to changes in growing environments and the differential discriminating ability of the test environments. Accordingly, Bulki and Babile2 were most stable and Werer961 and Baha Jiddu were the most unstable. The stability and high yielding ability of the varieties has been graphically depicted by the AMMI bi-

plot. Environments E3 (Fadis 2018) and E1 (Fadis 2017) relatively showed high IPCA scores, contributed largely to GEI. These environments were favorable for high yielding varieties based on mean yield as they had more than the grand mean. The variation of yield for each variety was significant at different environments. Varieties G1 (Bulki), G6 (Babile2) and G4 (Werer962) were specifically adapted to high yielding environments. G2 (Shulamiz) was the most unstable variety and also adapted to higher yielding environments. G1 (Bulki) was more stable in comparison to other varieties. Generally, Fadis was the most favorable environment for ground nut production with maximum mean of yield potential. In GGE bi-plot; $IPCA_1$ and $IPCA_2$ explained 48.07% and 25.93%, respectively, of groundnut variety by environment interaction and made a total of 74.00%. GGE bi-plot revealed that G6 (Werer 962), which fell into the center of concentric circles, was ideal variety in terms of higher yielding ability and stability, compared with the rest of varieties. In addition, G1 located on the next concentric circle, may be regarded as desirable varieties. In the present study, E4 and E6 were the most discriminating and representative environments followed by E5. E1 was non-discriminating and less representative sites.

Generally, Fadis was the most favorable environment for ground nut production with maximum mean of yield potential. In GGE bi-plot; $IPCA_1$ and $IPCA_2$ explained 48.07% and 25.93%, respectively, of groundnut variety by environment interaction and made a total of 74.00%. GGE bi-plot revealed that G6 (Werer 962), which fell into the center of concentric circles, was ideal variety in terms of higher yielding ability and stability, compared with the rest of varieties. In addition, G1 located on the next concentric circle, may be regarded as desirable varieties. Therefore, Werere962 and Bulki were recommended for further demonstration at studies areas and similar agro-ecologies.

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Adaptability study of market types Common bean varieties in Eastern, Ethiopia

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ABSTRACT

Common bean has very importance in contributing for country's economy in fetching foreign earnings by exporting to outside market. Furthermore, they can also used for home consumption, soil fertility improvement though its improvement is highly challenged by diseases, insect pests, and prolonged drought in Ethiopia. Different classes of common bean is existed such asmarket types, food types, climbing types, bush types, red, white, canning types and etc. In this study, eight common bean varieties were arranged in randomized complete block design (RCBD) with three replications to identify high yielding, biotic and abiotic resistance or tolerance varieties. The trial was conducted at Dire dawa and Harari Qile during the rainy season of 2019, and important data viz: - plant height, pod per plants, seed per pod, number of branches per plants and yielded per plots were collected. Analysis of variance revealed the presence of significant ($P \leq 0.05$) difference in days to maturity, plant height, pods/plant, seed/pod and seed yield. The maximum and minimum number of pods/ plant of (17.03) and (10.06) were recorded for the varieties Awash-meten and SER-125, respectively. The highest grain yield of 16.10qt/ha was recorded for the variety Awash-2 and the least grain yield of (13.92qt/ha) was noted for local variety. Generally, Awash-2 followed Awash-meten, KAT-B9, and Awash-1 which gave higher yield than the standard check.. Therefore, Awash-2, KATB1, SAB736 and Awash-1 were recommended for further production under the study areas and other similar agro-ecology.

Key word: Common bean, Seed yield, Varieties

INTRODUCTION

Common bean (Phaseolus vulagris L) is a very important legume crop grown worldwide and it is one of the most important and widely cultivated in Ethiopia. It is grown predominantly under small holder producers as an important food crop and source of cash. It is one of the fast expanding legume crops that provide an essential part of the daily diet and foreign export earnings for the country (Abebe G. 2009). It is the Ethiopia's most important grain legume for direct human consumption of dry beans harvested in Ethiopia (CSA, 2015). It is cultivated primarily for dry seeds, green pods (as snap beans) and green-shelled seed. In Ethiopia a wide ranges of common bean types are grown including mottled, red, white and black varieties (Ali K., et al., 2006).The most commercial varieties are pure red and pure white color beans and these are becoming the most commonly grown types with increasing market demand (Ferris S, and Kaganzi E. 2008). The white navy beans are grown for export canning industry and other types are mainly for households' food for national and regional markets. In addition, beans are important crop in farming systems. They are intercropped with sorghum, maize, enset, coffee and chat.

Even though more than 50 common bean varieties are released by the Federal and Regional Research Centers, due to less cooperation between agricultural extension and development offices and NARS of the country, few varieties dominate the production system; in Ethiopia

(Demelash B 2018). Similarly, Fadis Agricultural Research Center is trying to address the eastern parts of the country by adapting varieties released so far in similar agro-ecologies. FARC is targeted to make the farmers beneficial from the high yielding improved common bean varieties.

MATERIALS AND METHODS

Experimental Site

The study was conducted at Harari Regional state, Sofi district, Kile kebele, and Dire dawa administrative city of Adada 2 rural area where these kebeles is known for its frequent low moisture stress. Kile kebele is situated at a distance of about 20 km away from Harar city in the eastern direction and Adada 30 km for diredawa administrative city. The experiment was conducted during the 2019 main cropping season.

Experimental Materials

The experimental materials were comprised of seven released Common bean varieties, and one local check which obtained from Melkasa Agricultural Research Center. RCBD with three replications was used by using plot size of 7.2 m^2 (6 rows at 40 cm spacing and 3 m long).

Data Analysis

To estimate the variation among varieties the data recorded was analyzed using ANOVA (Steel et al., 1997). Duncan Multiple Range Test (DMRT) was used to compare the means of different treatments. Analysis of variance (ANOVA) was conducted using the Statistical Analysis System (SAS) computer software program

RESULT AND DISCUSSION

Analysis of variance showed that significant variations were obtained among the varieties for Days to maturity, plant height, pods/plant, seed/pod and Seed yield. Similarly Sixbert K. and George M. (2012) reported significant ($P \leq 0.05$) variability among genotypes with respect to number of pods/plant, seeds/pod, grain yields and 100-seed weights. Contrary Misgana M, and Tadesse M (2017), number of days to maturity, pods/plant and seeds/pod was not significantly affected due to varieties.

Table 1 Combined mean Seed yield and other agronomic traits for common bean varieties tested at two locations in 2019 main cropping season

Varieties	Days to maturity	Plant height	Pod/plant	Seed/pod	Seed yield
Awash-1	67.00ab	38.25ab	12.81abc	6.82ab	15.03ab
SER-119	62.33c	37.58ab	11.28bc	5.72b	14.65ab
KAT-B9	70.00a	34.64ab	11.11bc	6.28b	15.07ab
Awash-meten	65.83bc	28.00b	17.03a	8.17ab	15.73ab
Nasir	65.83bc	48.69a	11.03bc	5.89b	14.74ab
SER-125	63.50bc	38.61ab	10.06c	6.00b	14.19ab
Awash-2	67.33ab	48.86a	15.64ab	9.44a	16.10a
Local	66.00bc	39.61ab	15.53ab	5.45b	13.92b
CV	15.1	22.4	20.6	15.8	11.3
LSD	5.599	21.25	6.662	3.843	2.822

Maximum pods/plant was counted from Awash-meten variety followed by Awash-2, andLocal variety. Awash-2has score of maximum plant height, number of pods per plant, number of seeds per pod and seed yield. Similarly, Awash-meten and Awash-1 were recorded maximum number of pods per plant, number of seeds per pod and Seed yield. While, the minimum was counted by SER-125 (Table 1). From the combined mean of seed yield maximum seed was obtained from Awash-2 followed Awash-meten, KAT-B9, and Awash-1. The highest grain yield of 16.10qt/ha was recorded for the variety Awash-2 and the least grain yield of (13.92qt/ha) was noted for local variety. Awash-2 followed Awash-meten, KAT-B9, and Awash-1 which gave high yield than the Local check in terms of number of pods per plant and grain yield.

CONCLUSION RECOMMENDATION

From this study, combined mean of seed yield maximum seed was obtained from Awash-2 followed Awash-meten, KAT-B9, and Awash-1. The highest grain yield of 16.10qt/ha was recorded for the variety Awash-2 and the least grain yield of (13.92qt/ha) was noted for local variety. Therefore, the following varieties, Awash-2, KATB1, SAB736 and Awash-1 were recommended because of their merits over the checks for further production under the study areas and other similar agro-ecology.

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Genotypes by Environment Interaction and Grain Yield Stability for Advanced Faba Bean Genotypes in the Highlands of Bale, Southeastern Ethiopia

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ABSTRACT

The concept of genotype by environment interactions leads to measure the agronomic stability of the genotype. Accordingly, this research activity was conducted to select faba bean genotypes that are stable with high grain yield across the tested environments in the highlands of Bale, Southeast Ethiopia. Eighteen faba bean genotypes were grown in a randomized complete block design with four replications at threemajor faba bean growing areas (Sinana, Sinja and Agarfa) for three consecutive years (2016 to 2018). The Additive Main effect and Multiplicative Interaction (AMMI) analysis revealed that the main effects of genotypes and environments, and the interaction effect were highly significant at ($P \leq 0.01$) indicating that genotypes varied in their responses to diverse environments, thus giving justification for performing stability analysis. In this study, the environment accounted for 74.85% of the variation from total sum of square10.33% of the total variation was accounted for genotypes and 14.83% for the genotype x environment interaction. From the AMMI component Analysis, the first two PCA showed significant variation and accounted for 60.90% of grain yield variation at 46 degree of freedom. Genotypes, G15, G5, G1, G7, G6, G16 and G17 had lower AMMI Staility Value (ASV) indicating their stable performance across the testing sites. Whereas, genotypes G2, G4, G9 and G13 showed higher ASV indicating moderate stability.All stable genotypes are not necessarily high yielder. Therefore, when both mean grain yield and stability is considered using the Genotype selection Index (GSI)G5, G7, G1, G9 and G13 showed the lowest GSI values indicating high yielding and moderatestability. Accordingly, G9 and G13 gave yield advantage of 21.77% and 36.05%, respectively over the standard check and identified as candidate varieties for possible release for the highlands of Bale and similar agro-ecologies.

Keywords: Environment, Genotype, GSI, Interaction, Stability

INTRODUCTION

The Central Asian, Mediterranean, and South American centers were found to be cnter of diversity for faba bean and believed to be a native to North Africa and southwest Asia, and extensively cultivated elsewhere (Harllan, 1969; Zohary and Hopf, 2000). Cubero (1974) postulated a near Eastern as a center of origin, with four radii to Europe along the North African coast to Spain, along the Nile to Ethiopia. Faba bean (Vicia faba L.) is one of the most remarkable crops for its seed nutritional value, as it has a high protein content and is considered

to be one of the main sources of protein in the human diet (Crepona et al. 2010). It also has value as an export crop for feed markets (Gong et al. 2011).

G X E could be considered as effect of particular variants tested across environments implied that any given trait when evaluated across more than one environment can be analyzed as genetically correlated traits (Malosetti et al., 2013). In this case, the magnitude of such a correlation indicates the degree of shared genetic control and the sign of the correlation indicates the direction of the allelic effect for the environments being considered. This perspective has provided an important framework for interpreting and handling G X E in plant breeding programs (Des Marais et al., 2013). G×E is defined as a phenomenon that phenotypes respond to genotypes differently according to different environmental factors (Kim. et al., 2014). Grain yield stability is influenced by the capacity of a genotype to react to environmental conditions, which is determined by the genotype's genetic composition (Ulaganathan et al., 2015). In varying environments it may be expected that the interaction of genotype with environment will also be varying and ample. As a result, one cultivar may have the highest yield in one environment, while the other cultivar may excel in other areas. This necessitated the study of genotypes by environment interaction to know the magnitude of interactions in the selection of genotypes across several environments besides calculating the average performance of the genotypes under evaluation (Chandrika et al., 2015).Thus, this study was aimed to identify faba bean genotypes that are high yielder, stable across the growing areas and resistant or tolerant to major faba bean diseases in the areas.

MATERIALS AND METHODS

Fifteen faba bean genotypes were evaluated along with released varieties, Gebelcho and Mosisa, and local cultivar (Table 1) using randomized complete block design with four replications from 2016 to 2018 cropping season at Sinana, Sinja and Agarfa. Recommended seed rate of 175 kg ha^{-1} and 100 kg ha^{-1} DAP was used. The plot size was 6.42 m^2 (4 rows at 40cm spacing and 4m long).

Statistical analysis

Combined Analysis of Variance (ANOVA) across the testing environment was computed to determine genotypic difference, and the genotype X environment interaction for grain yield was analyzed by using the AMMI model (Zoble et al., 1988). The analysis was computed using CropStat7.2 computer program (CropStat, 2009).

The percentage of total variation attributed to environment (E), genotype (G), or GxE interaction was calculated using the sums of squares from the ANOVA table. AMMI Stability Value (ASV), the distance from the coordinate point to the origin in a two dimensional of IPCA1 scores against IPCA2 scores was calculated by the method suggested by Purchase et al. (2000). This weight is calculated for each genotypes and environment according to the relative contribution of IPCA1 to IPCA2 to the interaction SS as follows,

$$ASV=\sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1score)\right]^2+[IPCA2]^2}$$

Where, $\frac{SSIPCA1}{SSIPCA2}$ is the weight given to the IPCA1 value by dividing the IPCA1 sum squares by the IPCA2 sum of squares.

Genotype Selection Index (GSI): GSI was calculated for each genotype which incorporate both mean grain yield and stability index in single criteria (GSI_i) as,
$GSI_i = RY_i + RASV_i$ (Farshadfar, 2008),where, RYi is the rank given for the grain yield of the genotypes, RASV is the rank given for the ASV of the genotypes.

Table 1 Lists of faba bean genotypes used in the study along with and their codes

Genotype	Genotypes Code	Genotype	Genotypes Code
EH 00126-1	G1	EKLS/CSR0201	G10
EKLS/CSR0202	G2	EKLSO1009-2	G11
EH 01000117-	G3	EKLS01009-2	G12
EK01021-8-1	G4	EH00021-1	G13
EH 00126-7	G5	EKLS/CSR0200	G14
EH01008-3	G6	EH00049-4	G15
EKLS/CSR0200	G7	Gebelcho	G16
EKLS/CSR0201	G8	Mosisa	G17
EH01088-3	G9	Local check	G18

RESULT AND DISCUSSION

Combined analysis of variance partitions the variation into genotype main effects, environment main effects, and genotype by environment interaction effects with the largest environment main effects followed by the interaction effects (Yan and Kang, 2003; Gauch, 2006). In this study, the combined analysis of variance over years and locations revealed highly significant variation at (P<0.01%) for genotypes, environment, and Genotype x Environment Interaction (GE) (Table 2). This result was in agreement with the findings of Tamene et al. (2015), Teklay et al. (2015), Tadele et al. (2016) who reported that significant variation of genotypes, location and GE of grain yield by faba bean genotypes.

Table 2. Combined ANOVA for Faba bean genotypes over locations and years

Source of Variation	Degree freedom	Sum Squares	Mean Squares
Year (Y)	2	227.752	113.876**
Location (L)	2	104.415	52.2077**
Replication	3	5.48766	1.82922**
Genotype (G)	17	58.6071	3.44747**
Y X L	4	72.9866	18.2467**
L X G	34	26.6878	0.784935**
Y X L X G	102	50.8691	0.498716**
RESIDUAL	483	227.411	0.470831
TOTAL	483	774.2	

The highest combined mean grain yield was obtained from G13 (4 tons ha^{-1}) followed by G9 (3.58tons ha-1tons ha^{-1}), G5 (3.09tons ha^{-1}), and G8(3.09tons ha^{-1}). While among the environments, maximum grain yield was obtained from Sinana in 2017 (4.67tons ha^{-1}), followed by Sinana in 2016 (3.47tons ha^{-1}), Agarfa in 2016 and Agarfa in 2017 (3.43tons ha^{-1}) (Table 3)

Table 3. Mean grain yield of 18 Faba bean Genotypes tested at three locations for three years

Entry	Genotype code	Sinana 2016	Sinja 2016	Agarfa 2016	Sinana 2017	Sinja 2017	Agarfa 2017	Sinana 2018	Sinja 2018	Agarfa 2018	TRT MEAN
EH00021-1	G13	3.91	3.45	4.28	5.64	4.55	4.28	3.78	3.45	2.687	4.00
EH01088-3	G9	3.85	3.16	3.91	4.36	3.83	3.91	3.56	3.16	2.434	3.58
EH 00126-7	G5	3.62	2.47	3.19	5.17	2.87	3.19	2.85	2.6	1.865	3.09
EKLS/CSR0201	G8	3.36	2.12	2.97	4.66	3.92	2.97	2.93	3.17	1.733	3.09
EKLS01009-2	G12	3.68	2.21	3.59	5.15	1.87	3.59	2.13	3.08	2.268	3.06
EKLS/CSR0202	G2	2.78	3.17	3.77	4.52	3.24	3.77	2.12	2.29	1.73	3.04
EH 01000117-	G3	3.47	2.29	3.75	4.01	2.3	3.75	3.14	2.57	1.99	3.03
EKLS/CSR0200	G7	3.46	2.67	3.44	4.68	3.16	3.44	2.16	2.47	1.535	3.00
Gebelcho	G16	3.74	2.85	3.4	4.16	2.3	3.4	2.41	2.37	1.835	2.94
EKLS/CSR0200	G14	3.02	2.56	2.99	5.33	3.42	2.99	2.48	2.01	1.579	2.93
EKLSO1009-2	G11	3.56	1.96	3.25	4.94	3.2	3.25	2.29	1.94	1.707	2.90
EH 00126-1	G1	3.27	2.19	3.65	4.63	2.83	3.65	2.36	2.05	1.388	2.89
EH01008-3	G6	3.67	2.36	3.28	3.92	2.49	3.28	2.91	1.99	1.997	2.88
Mosisa	G17	3.4	2.51	3.63	4.7	2.29	3.63	2.14	2.04	1.385	2.86
EK01021-8-1	G4	3.05	2.66	3.02	4.27	3.34	3.02	2.35	1.96	1.683	2.82
EKLS/CSR0201	G10	3.67	2.37	3.2	4.62	3.16	3.2	1.67	1.77	1.501	2.79
EH00049-4	G15	3.28	2.68	3.09	4.39	2.62	3.09	2.45	2.09	1.412	2.79
Local check	G18	3.66	1.55	3.36	4.84	1.79	3.36	2.47	1.64	1.682	2.7
Mean		3.47	2.51	3.43	4.67	2.95	3.43	2.57	2.37	1.80	3.02
LSD 5%		0.96	0.99	0.53	1.09	1.5	0.67	0.67	0.52	0.47	0.54
CV%		19	23	16	16	22	14	18	16	18	24

The AMMI analysis

The analysis of AMMI in this study revealed significant variation of grain yield among genotypes, environment, and Genotype X Environment Interaction at P<0.01%) (Table 4). The environment accounted for 74.85% of the total variation whereas 14.33% was accounted for the interaction, and 10.83% was explained by the genotypes (Table 3). The variation explained by the environment is almost 5 times and 10 times higher than the GXE interaction and genotypes, respectively. This indicates how much the testing environments are diverse and need specific recommendation for the testing sites. The same result also reported by (Kuang Hongyu et al.,(2014), Dagnachew et al. (2014), Teklay et al. (2015), who have reported the significant variation of genotypes, environment and the GE interaction in their study. The significant variation of the genotypes by environment interaction partitioned into the Principal Component Analysis. Likewise in this study, the first three principal component analysis (PCA) showed significant variation at P<0.01%. Furthermore, the first interaction principal component explained 38.78% variation, whereas the second and the third interaction principal component accounted for 22.09% and 16.95%, respectively. The first two Principal component analyses were responsible for 60.87% of the GE variation with degree freedom of 46 (Table 3). Gauch and Zobel (1996) reported that the most accurate model for AMMI can be predicted by using the first two PCAs. This suggestion was later modified such that factors like type of crop, diversity of the germplasms and range of environmental conditions affect the degree of complexity of the

best predictive model and hence the number of PCAs to be used (Crossa et al., 1990). As it was reported by Gauch (2006), the first two IPCAs were used to portray genotype by environment interaction and placement on the biplots which implies the first two multiplicative component axes were adequate for the validation of the variation explained by GEI.

Table 3. ANOVA for the AMMI Model

Sources of variation	Degree Freedom	Sum of Square	Mean Square	TSS explained %
Genotypes	17	14.6518	0.86187	10.83
Environment	8	101.288	12.6611	74.85
G X E interaction	136	19.3892	0.14257	14.33
AMMI component 1	24	7.51965	0.313319**	38.78
AMMI component 2	22	4.28214	0.194643**	22.09
AMMI component 3	20	3.28682	0.164341**	16.95
AMMI component 4	18	1.8055	0.10031	9.31
GXE residual	52	2.49511		
Total	161	135.329		

The AMMI Stability Value (ASV) and Genotypes Selection Index (GSI):

There are different stability parameters that can describe the stability of a given genotypes across different mega environments. Among these, ASV and GSI are used to describe in the AMMI model by using the PCA scores of the genotypes tested in different environment. In the present study, based on the AMMI stability values, genotypes G15 (0.08), G5 (0.16), G1 (0.2), G7 (0.29), G6 (0.66), and G16 (0.66) were among genotypes with lower ASV values in order of importance. This revealed that these genotypes are relatively more stable than others. However, G2 (0.43), G4 (0.77), G9 (0.8), and G13 (0.83) were classified as moderately stable genotypes (Table 4). Since stability is not the only parameter for selection of high yielding genotypes, as the most stable genotypes may not necessarily give the best yield performance, the other stability parameters which can consider both mean grain yield and stability is incorporated and used to discriminate the stability of genotypes over the diverse environments. Furthermore, under the biological concept, stable genotype is one whose phenotype shows little deviation from the expected character it is tested over a number of environments (Mohammedsani Zakir, 2018).Thus, based on GSI, genotypes G5, G7, G9 and G13 are the best and top-ranking genotypes integrating both stability and grain yield performance parameters. However, G5 and G7 though they had low GSI values and showed stable performance, they gave very low grain yield difference from the check (G16), with yield advantage of 2% and 5.1%, respectively . Thus, G9 and G13 showed moderate stability to the different environments and gave very high mean grain yield with yield advantage of 21.77% and 36.05%over the check (G16),respectively were identified and proposed as candidate varieties to be verified for possible release for the highlands of Bale and Similar agro-ecologies.

Table 4.Combined mean grain yield (tons ha^{-1}), stability parameters, ASV, GSI of faba bean genotypes

Trt Code	Genotypes	Mean grain yield (tons ha^{-1}(	Rank Yi	Slope (bi)	MS-DEV (S^2di)	IPCA1	IPCA2	ASV	Rank ASV	GSI
G1	EH 00126-1	2.89	12	1.177	0.03	0.08	0.14	0.20	3	15
G2	EKLS/CSR0202	3.04	6	0.948	0.21	-0.24	0.01	0.43	11	17
G3	EH 01000117-	3.03	7	0.773	0.17	0.46	-0.63	1.02	15	22
G4	EK01021-8-1	2.82	15	0.863	0.08	-0.43	-0.09	0.77	12	27
G5	EH 00126-7	3.09	3	1.066	0.07	0.01	0.16	0.16	2	5
G6	EH01008-3	2.88	13	0.77	0.1	0.26	-0.49	0.66	8	21
G7	EKLS/CSR0200	3.00	8	1.066	0.04	-0.14	0.15	0.29	4	12
G8	EKLS/CSR0201	3.09	3	0.837	0.3	-0.64	-0.2	1.14	16	19
G9	EH01088-3	**3.58**	**2**	**0.632**	**0.06**	**-0.24**	**-0.69**	**0.8**	**13**	**15**
G10	EKLS/CSR0201	2.79	16	1.185	0.12	-0.15	0.44	0.51	7	23
G11	EKLSO1009-2	2.9	11	1.201	0.06	-0.12	0.39	0.44	6	17
G12	EKLS01009-2	3.06	5	1.073	0.35	0.72	0.26	1.29	18	23
G13	EH00021-1	**4.0**	**1**	**0.924**	**0.11**	**-0.47**	**-0.1**	**0.83**	**14**	**15**
G14	EKLS/CSR0200	2.93	10	1.181	0.17	-0.48	0.47	0.96	15	25
G15	EH00049-4	2.79	16	0.97	0.03	-0.02	-0.07	0.08	1	17
G16	Gebelcho	2.94	9	0.853	0.1	0.35	-0.27	0.66	8	17
G17	Mosisa	2.86	14	1.2	0.07	0.35	0.23	0.66	8	22
G18	Local	2.4	18	1.27	0.23	0.7	0.3	1.26	17	35

Biplots

AMMI biplots were recently preferred to visualize adaptability and stability of genotypes over test environments (Gauch and Zobel, 1988; Gauch and Zobel, 1996; Gauch, 2006; Gauch et al., 2008). The AMMI 1 biplot was generated using the first IPCA and mean grain yield of the genotypes and environments (Fig 1), whereas AMMI 2 biplots was used genotypic and environmental scores of the first two IPCAs (Fig. 2). Furthermore, the relative magnitude and direction of genotypes along the abscissa and ordinate axis in biplot is also important to understand the response pattern of genotypes across environments and to differentiate high yielding and adaptable genotypes (Samonte et al., 2005). In the present study, the genotypes and environment which found at the right side of the perpendicular line are those which gave mean grain yield above the grand mean (3.02 tons ha^{-1}). Accordingly G3, G2, G12, G8, G5, G9 and G13 were found in this category. Furthermore, environment A, C D and G which found at the right side of the perpendicular line, were also gave mean grain yield above the grand mean. Thus, they are better environments for commercial production of faba bean lines found specifically or widely adapted to them. The rest of the genotypes and environments gave mean grain yield lower than the grand mean (Figure 1).

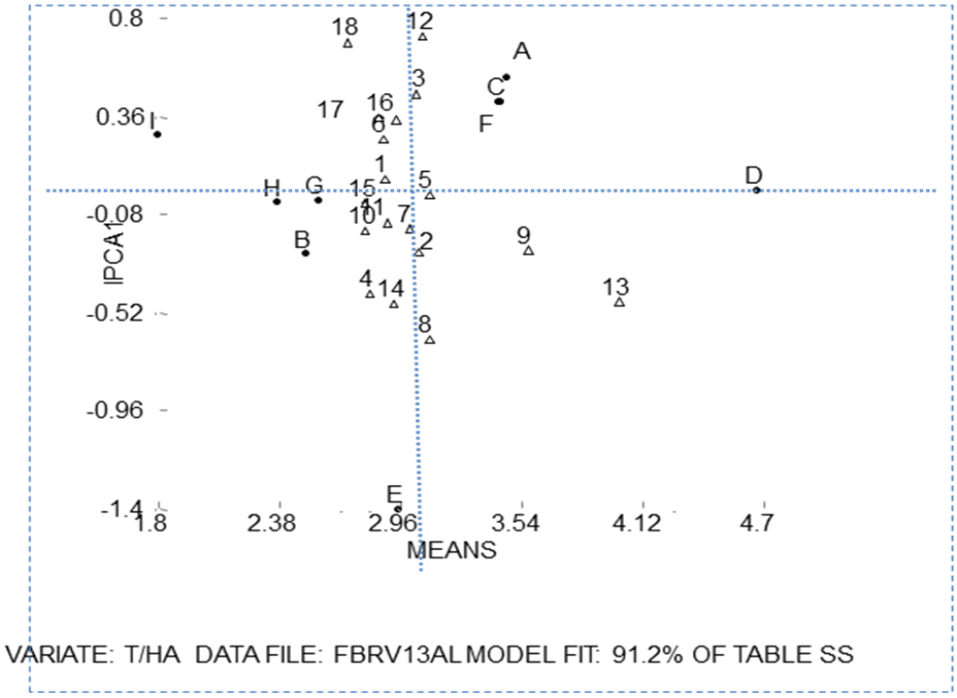

Figure 1. Biplot analysis of GEI based on AMMI 1 model for the PCA1 scores and grain yield

In AMMI2 biplot, the distances from the biplot origin are indicative of the amount of interaction exhibited by genotypes over environments or environments over genotypes. Genotypes located near the biplot origin are less responsive than the vertex genotypes indicating general adaptability to all environments (Voltas et al., 2002). Environments with longer vectors are very interactive and discriminate the differences among genotypes more than environments with shorter vectors. Shorter vectors are less interactive and provide little or no information about the differences among genotypes' performances (Yan, 2002). Hence, in Figure 2, the faba bean genotypes (G8, G4, G14, G10, G6, G3, G18, G11, G12 and G16) placed farthest away from the biplot origin & expressed a highly interactive behavior (positively or negatively) whereas G2, G7, G5, G1, 13, G17, G9 and G15 placed relatively close to the biplot origin expressed less interaction and more adaptable to all locations.

In AMMI 2 biplot, those environments having shorter length of arrow do not create strong interaction while those with long length of arrow has strong interaction and they are not favorable to all genotypes. In the present study, Sinana 2016 (A), Agarfa 2016 (C), Agarfa 2017 (F), Sinja 2018 (H) and Agarfa 2018 (I) having shorter spokes interact less with the genotypes whereas Sinja 2016 (B), Sinana 2017 (D) and Sinja 2017 (E) having longer spokes or length of the arrow line exerts high interaction with the genotypes (Figure 2).

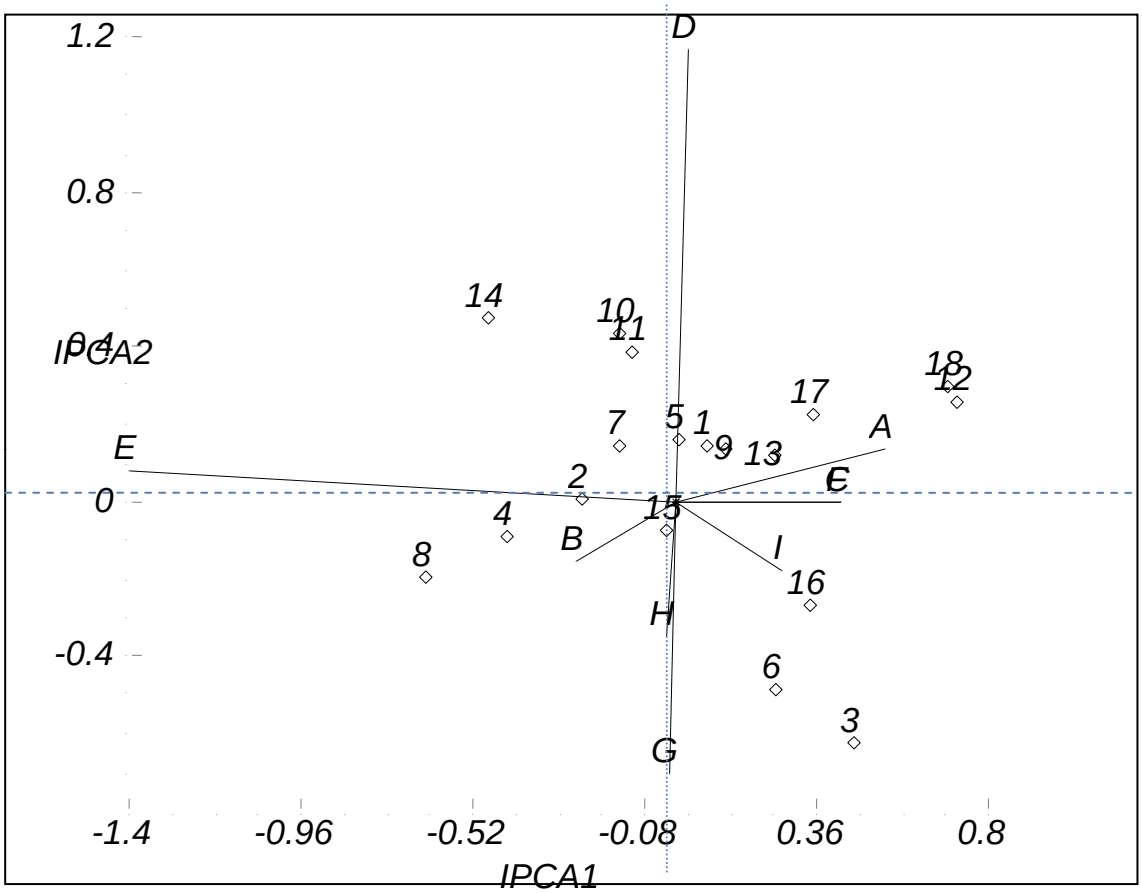

Figure 2. Interaction biplot of the AMM2

CONCLUSION

Plant productivity is a direct consequence of how well adapted the genotype of an individual is to the surrounding environment. Useful genotype recommendation is therefore location-specific and represents the integration of the entire lifecycle of the plant and the local environmental conditions.Combined analysis of variance revealed highly significant variation for genotypes, environment and GXE interaction indicating as the genotypes react differently to the testing environment, and the influence of the environments were very high for the amount of variation existed. The AMMI Stability Values and the genotype Selection Index along with different stability parameters like slope, deviation from regression revealed that G9 and G13 were widely adapted and stable with high grain yield, and thus these two genotypes are recommended for possible release with wider environmental adaptability.

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Different Levels and Methods of NPS Application Impact on Yield and Yield Components of Faba bean (Vicia faba L.) in Bale Highlands, South eastern Ethiopia

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ABSTRACT

A field experiment was conducted at two locations in Bale, south eastern Ethiopia (Selka and Agarfa) for two consecutive years (2018-2019) to study the responses of improved faba bean to rates and methods of NPS application and assessing the economic feasibility. The treatments were six levels of NPS (25, 50, 75, 100, and 125 kg ha^{-1}) and two methods of application (Broadcasting and Band application) laid in randomized complete block design (RCBD) with three replications. Faba bean variety 'Alloshe' was used as a test crop. The analysis showed that almost all parameters studied were not significantly ($P<0.05$) affected by the main effect of blended NPS fertilizer and methods of application at both locations over years. This could be due to relatively medium to high accumulation of studied nutrients in the soil and conducive environmental conditions in the specific area. Therefore, based on this findings future research should focus on prior soil test based fertilizers recommendations.

Key words: NPS, Banding, Broadcasting, Non-significant, Nutrient status

INTRODUCTION

Grain legumes are the most important protein and mineral food crops in the world, especially in developing countries. Faba bean is a crop of great economic merits in Ethiopia (Gemechu et al., 2006). The crop serves as a source of food and feed with valuable cheap sources of protein substitute as a complement to cereals for the majority of the poor population mainly for those who cannot afford to use proteins from animal source. Faba bean is the most important pulse crop in terms of both area coverage and volume of annual production in Ethiopia. Ethiopia is the first producer of faba bean in Africa and the second in the world next to the People's Republic of China (Mussa and Gemechu, 2006). However, the national yield per hectare of this crop was very low. The main reasons for the low yield of this crop were attributed to several factors such as; poor soil fertility, low use of inputs, weed, and depth of sowing, inadequate soil moisture and limited use of modern agronomic or cultural practices (population density and planting method Asfaw et al., 1994). However, high yield of the crop was realized when those yield limiting factors are solved with the optimum management.

In Ethiopia, low soil fertility is one of the factors limiting the yield of crops, including faba bean. It may be caused as a result of removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residue from farmland, and lack of proper crop rotation program (Tamirie, 1982). Mineral nutrients or chemical fertilizers along with adequate amounts of all other growth limiting factors play an important role in increasing crop productivity (Fageria, 2009). Phosphorus (P) and sulphur (S) are among the commercial fertilizers which contribute to the yield of major crops in particular pulse crops. Both nutrients are required by legume crops in larger quantitities than any other nutrients and the crops give good response to them (Scherer et al., 2006 and Murat et al., 2009).

The type and rate of fertilizer applications, among several agronomic practices are influenced by the crop types. Fertilizer types applied in Ethiopia agriculture system are only urea and di-ammonium phosphate (DAP) which contain only nitrogen and phosphorous. However, they may not probably satisfy the nutritional requirements of crop plants such as faba bean. To avert this situation, the Ministry of Agriculture has recently introduced a new compound fertilizer containing nitrogen, phosphorous and sulfur with the ratio of 19% N, 38% P_2O_5 and 7% S (NPS fertilizer) that substituted DAP in Ethiopian agriculture. Matching fertilizer application rates to crop needs is an essential component of optimizing crop production. However its rate and methods of application for the production of most of the crops including for faba bean is not yet known. Therefore, the present study was initiated with the objectives of evaluating the responses of improved faba bean to rates and methods of application of NPS and assessing the economic feasibility.

MATERIALS AND METHODS

Faba bean variety 'Alloshe' which was released by Sinana Agricultural Research Center was used for the experiment. The experiment consisted of five rates control, 25, 50, 75, 100, and 125 NPS (kg ha^{-1}) of each NPS including one unfertilized control with two methods of application (Broadcasting and Band application) laid out in randomized complete block design (RCBD) with three replications. A field layout was prepared and the treatments were assigned randomly to each plot within a block. The replications, blocks and experimental units were separated by 1.5 m, 1 m, and 1 m respectively. Seeds were sown using row planting. Each plot consisted of 8 rows that are 40 cm apart and 4 m in length. The outer most rows on both sides of each plot and 0.25m length on each side of a row served as a border. The remained net plots were used for data collection.

Soil samples were taken in a zigzag pattern from five sampling spots of the entire experimental field at 0-30cm depth using an auger before sowing. The composite soil samples were prepared by quartering and air-drying at room temperature, ground using a pestle and a mortar and allowed to pass through a 2mm sieve. Working samples were obtained from bulk sample and analyzed for total nitrogen, available P, cation exchange capacity (CEC) and pH.

RESULTS AND DISCUSSIONS

Soil Chemical Properties

The results of soil analysis (Table 1) shows that the soil reaction of the experimental sites was moderately neutralat Sinanaand Agarfa,where the pH was 6.83 and 6.7, respectively this indicates that the soil reaction of the experimental sites is suitable for optimum growth and yield of most crops. The CEC value of the soil was high at Agarfa and very high at Sinana; this indicates that the soil has relatively high capacity to hold nutrient and supply to the crop. The experimental soil is medium in available P (10.12 and 11.7 at Sinana and Agarfa respectively).Data also indicates that the soils of the experimental sites had Medium total N which means fertilizer addition may increase growth and yield**.**

Table 1. Chemical properties of the experimental soil before planting

Parameters	Selka	Agarfa
Chemical Properties		
pH in water (1:2.5)	6.83	6.7
CEC (cmol. (+) kg soil^{-1})	48.24	37.26
Total N (%)	0.18	0.16
Av. P (ppm), Olsen	10.12	11.7
Av. S (mg kg^{-1})	22.17	21.42

Effects on yield and yield components of Faba bean at Selka and Agarfa

The statistical results revealed that most of the parameters considered were not significantly (P<0.5) affected by the main effect of blended NPS fertilizer and methods of application conducted over two years at Selka and Agarfa (Table 2 and 3). This might be due to relatively medium to high accumulation of studied nutrients in the soil. Under nutrient sufficient and conducive environmental conditions, plants in the range of studied factor levels did not interact or compete.

Table 2. Effect of Different Levels and Methods of Application of NPS on Yield and Yield Components of Faba bean at Selka, 2018/19

	DFL	DPM	PHT	TPP	PPP	SPP	BYD	GYD	TSW
NPS (kg ha^{-1})									
0	50.3	129.3	140.3	1.8	13.2	3.2	34679	2032.1	998.37
25	49.3	129.8	131.7	1.8	13.1	3.3	35417	2066.1	974.80
50	47.2	129.8	131.9	1.9	12.3	3.1	39583	2462.0	969.33
75	49.8	128.8	132.3	2.1	11.1	3.3	35729	2418.0	961.73
100	49.7	128.8	136.9	2.1	13.9	3.4	36979	2155.9	952.80
125	50.0	126.3	137.2	1.9	13.8	3	36458	2014.9	991.93
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	ns	ns
Application Method									
Broadcasting	49.6	128.9	137.6^{a}	1.8	13.7	3.2	35969	2212.0	973.92
Banding	49.2	128.7	132.5^{b}	2.1	12.1	3.2	36979	2171.0	975.73
$LSD_{0.05}$	ns	ns	5.1	ns	ns	ns	ns	ns	ns
CV (%)	5.1	11.3	8.4	33	20.8	14.6	27.3	26.8	7.0

Keys: DFL= Days to flowering, DPM= Days to physiological maturity, PHT= Plant height, TPP= Tillers per plant, PPP=Pods per plant, SPP=Seeds per pod, BYD= Biological Yield, GYD= Grain yield, TSW=Thousand seed weight, LSD= Least significant difference ($P \leq 0.5$), and CV= Coefficient of variation

Table 3. Effect of Different Levels and Methods of Application of NPS on Yield and Yield Components of Faba bean at Agarfa, 2018/19

	DFL	DPM	PHT	TPP	PPP	SPP	BYD	GYD	TSW
				NPS (kg ha^{-1})					
0	48.5^{ba}	135.7^{a}	125.3	1	13	2.9	22917	2073.5	994.80
25	47.5^{bc}	135.8^{a}	129.7	0.4	12.2	3.2	18333	1959.1	1031.20
50	47.7^{bc}	136.2^{a}	127.2	0.6	12.5	3.1	20938	1887.2	962.30
75	47.2^{c}	135.2^{a}	128.9	1	11.9	3.2	20833	1943.7	981.13
100	47.8^{bc}	134.8^{a}	129.2	0.9	13.8	3.2	20833	2228.5	1066.60
125	49.2^{a}	132.3^{b}	126.1	0.8	13.5	3.1	18333	2087.3	1032.47
$LSD_{0.05}$	1.15	2.01	ns	ns	ns	ns	ns	ns	ns
				Application Method					
Broadcasting	47.9	135.1	127.9	1^{a}	13.9^{a}	3.2	21389	2021.3	1000.89
Banding	48	135.0	127.6	0.6^{b}	11.7^{b}	3	20938	2043.2	1021.94
$LSD_{0.05}$	ns	ns	ns	0.29	1.92	Ns	ns	ns	ns
CV (%)	5.0	3.6	7.3	22.9	21.6	13.7	18.4	18	7.6

Keys: DFL= Days to flowering, DPM= Days to physiological maturity, PHT= Plant height, TPP= Tillers per plant, PPP=Pods per plant, SPP=Seeds per pod, BYD= Biological Yield, GYD= Grain yield, TSW=Thousand seed weight, LSD= Least significant difference ($P \leq 0.5$), and CV= Coefficient of variation

CONCLUSION

The results of the present study showed that NPS fertilizer rates and methods of application were not significant. This may be due to the fact that legumes satisfy their nutrient demand through nitrogen fixation as well as relatively medium to high accumulation of studied nutrients in the soil. Under nutrient sufficient and conducive environmental conditions plants in the range of studied factor levels did not interact or compete. The fertilizer application by the farmers in the field without knowledge of soil fertility status and nutrient requirement of different crops usually leads to adverse effect on soil as well as crops by way of nutrient deficiency or toxicity due to over use or inadequate use of fertilizer. Therefore, based on this findings future research should focus on prior soil test based fertilizers recommendations.

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NPS Fertilizer and Intra-row Spacing Effect on Growth, Yield and Yield Components of Chickpea varieties under Midland Conditions of Bale, Southeastern Ethiopia

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ABSTRACT

Variety and location specific plant density recommendation is one of the agronomic practices used to increase the production and productivity of chickpea. However, there is a blanket recommendation across locations and varieties of chickpea in Ethiopia.Hence, Effects of blended NPS fertilizer rates and intra-row spacing on some agronomic traits of chickpea varieties were evaluated with the objective to find out the optimum amount of NPS fertilizer and intra-row spacing for chickpea production under midland conditions of Bale. The experiment was conducted using split plot design using chickpea varieties (ACOS Dubie and Habru) as main plots and NPS fertilizer rate and intra-row spacing as sub-plots with three replications. The main effect of variety showed significant effect on the number of days to mature, number of days to flower, plant height, biological and seed yield and hundred seed weight whereas, main effect of intra-row spacing did not show significant difference on all studied agronomic parameters. Similarly, main effect of blended NPS fertilizer rates did not reveal significant difference for the studied parameters. Blended NPS fertilizer rates utilized in the study areas did not show differences in most of studied traits. From this, it can be preliminarily concluded that reasonable intra-row spacing of 10 cm for both varieties of chickpea could be used for the studied areas.

Key words: Acos Dubie, Habru, intra-row spacing, NPS fertilizer,

INTRODUCTION

Chickpea (Cicer arietinum) is an ancient crop that belongs to the legume family. It is produced worldwide and it is the world's third most important food legume next to haricot bean and soybean (Namvar and Sharifi 2011). Ethiopia is the leading chickpea producer in Africa with a share of 39% of the total production in 2011 (Ibsa 2013). Chickpea was the third most widely cultivated legume crop in Ethiopia next to faba bean and haricot bean. It is considered a Multi-functional crop, has an important role in Ethiopian diets and serves as a protein source, generates cash and plays a major role in Ethiopia's foreign exchange earnings (Ibsa 2013).

In Oromia regional state, Bale Zone of Ginnir and Goro districts chickpea is the leading pulse crop grown in large areas by the farmers' next to cereals and spice crops.The crop is known for its soil nitrogen enrichment, rotational advantages and cheaper cost of production (Minale et al. 2009). Despite the importance of the crop in farming systems, the average yield of the crop is generally low due to several factors, among which low genetic potential of farmers' varieties, biotic and abiotic factors, insufficient application of Phosphorus fertilizer. Moreover, Asgelil (2000) reported that most of the Ethiopian soils are low in nitrogen and phosphorus, which limit crop production and productivity. Thus, application of inorganic phosphorus fertilizer is a crucial component to reduce yield loss caused by the nutrient.This is because, an adequate amount of

Phosphorus nutrition enhances the physiological activities of legume crops, including stimulation of early root formation, growth, nodulation, photosynthesis and flowering (Giller et al., 1994). In addition, the biological nitrogen fixation is a process that is dependent on the energy supplied from the sugars that need to be translocated downward from the host plant shoots (Graham, 1984). Phosphorus is therefore, the basis for the formation of useful energy, which is essential for sugar formation and translocation.

On the other hand, Plant density is an important factor that affects yield and yield components of legumes. If the plant population is too high, plants compete with each other for resources and low yield was realized. On the other hand, if the population is too low, more growing space was wasted and it lowers yield. In line with these facts Kakiuchi and Kobata (2004) found that lower plant density increased the pod number per plant whereas; the higher plant density decreased the parameter. Similarly, Mehdi et al. (2010) also reported that plant density had shining influences on plant height, biological and seed yield (kg/ha) where the parameters increased by increasing plant densities. But, in the study areas, research work regarding integrated role of Phosphorus fertilizer and seed rates on growth, yield and yield components is very limited. Therefore, in view of this, this paper explores the effect of blended NPS fertilizer and Intra-row space on chickpea production under midland conditions of Bale.

MATERIALS AND METHODS

The experiment was conducted at Ginir District of Bale Zone on-farmers field. The experiment was laid out in split plot with chickpea varieties (ACOS Dubie and Habru) as main plots and NPS fertilizer rate and intra-row spacing as sub-plots with three replications. The treatments consisted of five rates of NPS fertilizer (0, 25, 50, 75 and 100 kg ha^{-1})and three intra-rows spacing (5, 10 and 15cm). Gross plot size was 3 m x 1.2m (3.6 m^2). Spacing of 1 m and 1.5 m were allocated between plots and blocks, respectively. Before planting, ten soil samples (0-20 cm depth) were taken randomly in a W-shaped pattern from representative spots of the entire experimental field using an auger and composited to one representative samples for the purpose of soil characterization. The composite samples were air-dried at room temperature, thoroughly mixed and ground to pass through a 2 mm sieve and then, analyzed for: particle size distribution, pH, organic carbon, cation exchange capacity, total nitrogen, and available P.

RESULT AND DISCUSSION

Soils Chemical Properties of Experimental Site

The laboratory analysis of soil samples from the top soil (0-30 cm) taken before planting was done for the major soil physical and chemical properties. The results of the analysis are summarized below in Table 1.

Effects on yield component and yield of Chickpea at Ginir

Days to 50% flowering: The analysis of variance revealed that there is a significant differences main effect of Varieties on days to 50% flowering. Varieties Acos Dubie flowered early (67. 8 days) as compared to variety Harbu (74. 02 days). This might be attributed to the fact that a day to flowering in chickpea is considered to be varietal characteristics, which is genetically controlled. Previous studies showed that, the differential response to flowering among varieties was distinct. For instance, Tripathi et al. (2012) reported differences among varieties of chickpea

in days to 50% flowering .Nevertheless, there was no significant difference among intra-row spacing and blended NPS fertilizer rates as well as all the interaction components on daysto50% flowering (Table2).

Table 1.Chemical and physical characteristics of the soil of experimental Site.

Properties	Result	Rating
1. Physical properties		-
Sand (%)	21	-
Silt (%)	27	-
Clay (%)	52	-
Textural Class	Clay	-
2. Chemical properties		
PH (1:2.5 H_2O)	6.82	Neutral
Organic Carbon/OC/ (%)	1.18	Low
CEC(cmolkg1)	47.46	Very high
Total nitrogen/TN/ (%)	0.16	Medium
Available Phosphorus/P/(ppm)	10.23	Medium
Available sulfur/S/(ppm)	21.42	Very Low

Table 2. Days to 50% flowering, days to 90% physiological maturity, plant height and number of primary and secondary branches as affected by the main effects of variety, NPS fertilizer rate and intra-row spacing

Row Labels	Flowering Date	Maturity Date	Plant Height	Number of primary branch	Numberof secondary branch
Varities					
Acos Dubie	67.87	125.51	57.93	2.91	10.42
Habru	74.02	128.07	62.24	3.00	11.58
LSD(0.05)	0.73*	0.62*	1.64*	NS	0.65*
Blended NPS Fertilizer Rate					
0 kg/ha NPS	70.56	127.00	60.28	2.94	10.28
25 kg/ha NPS	71.11	127.28	59.78	3.17	10.67
50 kg/ha NPS	71.33	126.44	59.00	2.83	11.22
75 kg/ha NPS	70.67	126.72	60.33	2.94	11.94
100 kg/ha NPS	71.06	126.50	61.06	2.89	10.89
LSD(0.05)	NS	NS	NS	NS	NS
Intr-row spacing					
5 cm	70.23	126.67	59.83	2.97	10.63
10 cm	71.10	126.43	60.73	2.90	11.13
15 cm	71.50	127.27	59.70	3.00	11.23
LSD(0.05)	NS	NS	NS	NS	NS
CV%	2.39	1.45	6.36	15.75	13.80

Days to 90% physiological maturity: Highly significant differences (P<0.01) were recorded on the number of days to 90% physiological maturity by the main effects of variety. The number of days taken to reach 90% physiological maturity for varieties Acos Dubie and Habru were 125.51 and 128.07 days, respectively (Table 2). Acos Dubie matured significantly earlier than Habru.

Similarly, Tripathi et al. (2012) reported differences among varieties of chickpea in time to physiological maturity; However, there was no significant difference between intra-row and Blended NPS fertilizer. Besides, interaction effects of variety and blended fertilizer application rates did not significantly influence days to physiological maturity (Table2).

Plant height: Analysis of variance showed significant differences ($P<0.05$) due to the main effects of variety on plant height at 90% physiological maturity (Table 1). The highest plant height was recorded for Habru (62.24 cm) while the lowest height was recorded for Acos Dubie (57.93 cm). The variation in height might be due to genetic characteristics of the varieties for this trait. This result was in agreement with Rasul et al. (2012) reported significant differences among the genotypes of chickpea in plant height .Plant height was not affected significantly by the main effects of blended NPS fertilizer rate and intra-row spacing. The non-significant effect of crop density on mean plant height observed in this study might be attributed to the fact that crop density has often, but not always been associated with increased plant height.

Number of primary and secondary branches per plant: Branching is basically a genetic character and plays an important role in enhancing seed yield. The main effects of variety had a significant influence on the number of secondary branches plant^{-1}. The significant differences among varieties could be due to the differences in growth habit since varieties Habru relatively have spreading or bushy growth habit while variety Acos Dubie has relatively semi erect type of growth habit. In agreement with this, significant variations in number of primary and secondary branches per plant among the different genotypes of chickpea was reported by Syed et al. (2012),While other main effect and interaction effect had not showed significant influence on number of primary and secondary branches per plant. Acos Dubie gave significantly lower number (10.42) of primary branches than Habru (11.58). Nevertheless, the intra row spacing main effect and interaction of fertilizer rate and varieties effects depicted a statistically non significant variation (Table 2).

Number of pods per plant: Number of pods plant^{-1} is a key factor for determining the yield performance in leguminous plants. The productive capacity of chickpea is ultimately dependant on the number of fertile pods plant^{-1}. Analysis of variance showed that varieties highly significantly differed ($P<0.01$) for number of pods plant^{-1}. The highest number of pods plant^{-1} was recorded for Habru (42.98) while the lowest number of pods plant^{-1} was recorded for Acos Dubie (37.12). The differences in number of pods plant^{-1} might have been caused due to varietal differences. In line with this result, Tripathi et al. (2012) reported significant differences among genotypes of chickpea for number of pods plant^{-1}. However, intra-row spacing, blended NPS fertilizer rate and the interaction effects of all factors (variety, blended NPS and intra-row spacing) were non-significant difference for number of pods per plant (Table 3).

Biological yield: The productivity of a crop is largely determined by the biological yield. Production of large amount of biomass is among the attributes of seed yield. Biological yield showed significant effect due to the main effects of variety (Table 2). However, Habru (4701.23 kg ha-1) had the higher biological yield whereas Acos Dubie had the lower biological yield (4014.57 kg ha-1). The decrease in biological yield of Acos Dubie due to low branching habit might have been compensated by the increase in other parameters such as plant height and stem thickness. This might be the reason for the non-significant difference in biological yield among

the varieties. In line with this, Shamsi (2009) reported statistically non-significant differences of the biological yield among varieties of chickpea. Regarding main effect intra-row spacing and blended fertilizer rates and their interaction effect did not show a significant difference on biomass production.

Table 3. Number of pods per plant, number of seeds per pod, biological yield, thousand seed weight and seed yield as affected by the main effects of variety, NPS fertilizer rate and intra-row spacing

Row Labels	Number of pod per plant	Biomass Yield kg/ha	Grain Yield kg/ha	Thousand grain Weight(gm)
Varieties				
Acos Dubie	37.76	4014.57	2226.75	426.28
Habru	42.98	4701.23	2374.63	279.52
LSD(0.05)	3.38*	253.61*	124.65*	11.75*
Blended NPS fertilizer Rate				
0 kg/ha NPS	38.11	4086.42	2156.44	355.20
25 kg/ha NPS	41.06	4581.48	2501.12	346.33
50 kg/ha NPS	41.83	4149.38	2238.77	341.59
75 kg/ha NPS	40.17	4358.03	2365.17	359.92
100 kg/ha NPS	40.67	4314.20	2241.93	341.46
LSD(0.05)	NS	NS	NS	NS
Intra-row spacing				
5 cm	40.40	4240.37	2325.53	387.97
10 cm	41.83	4500.00	2401.94	331.61
15 cm	38.87	4133.33	2174.59	339.12
LSD(0.05)	NS	NS	NS	NS
CV%	19.54	13.55	12.61	7.56

Grain yield: Dry matter production and its transformation into economic yield is the ultimate outcome of various physiological, biochemical, phonological and morphological events occurring in the plant system. Seed yield of a variety is the result of interplay of its genetic makeup and environmental factors in which plant grow. Table 3 indicated significant differences among the varieties on the grain yield. The higher seed yield of 2374.63 kg ha-1 was recorded for Habru while the lower seed yield was obtained for Acos Dubie (2226.75kg ha^{-1}). Despite that the intra-row spacing main effect did not show any statistical difference for grain yield. In addition, interaction effect of variety and blended fertilizer did not show significant effect on yield.

Thousand seed weight: Among the various parameters contributing towards final yield of a crop, thousand seed weight is of prime importance. Table 3 reveal that varieties had a highly significant difference ($P < 0.01$) on thousand seed weight. The higher thousand seed weight was recorded for Acos Dubie (426.28 g) while the lower thousand seed weight was recorded for Habru (279.52 g). In line with this, Tripathi et al. (2012) reported significant differences among genotypes of chickpea on hundred seed weight. However, intra-row spacing and blended NPS and had statistically non-significant differences on thousand seed weights (Table 3).

CONCLUSION

The study on the growth and yield response of two chickpea varieties, namely Acos Dubie and Habru were statically significant. From the result Acos Dubie chickpea variety flowered and matured earlier than Habru chickpea variety, but in terms of yield parameters and yield Habru is better. Based on the present findings, blended fertilizer rates utilized in the study area did not show differences in most of studied traits. Reasonably intra-row spacing of 10cm for both chickpea varieties could be used for the studied area.

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Participatory Variety Selection of Improved Potato (Solanium tuberosum L) Varieties in Harari People Regional State and Eastern Hararghe Zone

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ABSTRACT

Participatory varietal selection involves both scientific measurements and farmers evaluations; hence it has emerged as the best method to identify farmers' preferred crop varieties and their popularization. The experiment was conducted during 2019 cropping season at Dire Xayara and Gurawa districts of Harari People Regional State and Eastern Hararghe zone of Oromia Regional State, respectively. The objective of the study was to identify adaptable, high yielding and diseases and pest tolerant potato varieties based on farmer`s management, and to evaluate and select potato varieties based on farmer's preference. The treatments arranged in randomized complete block design with three replications. Treatments were consisted of eight potato varieties including standard check. Both agronomic data and farmers preferences toward the varieties were collected and analyzed using Genstat software and matrix ranking respectively. The analysis result showed that there were significant ($p<0.05$) difference among the varieties in all agronomic parameters except flowering date. Variety Belete gave the highest yield (39.6t/ha) followed by Bubu (29.91t/ha) and Gudanie (28.63t/ha). Matrix ranking of farmers' preference also showed that Belete and Bubu varieties ranked first and second in both districts. Dagim and Horro were not only the low yielding variety but also the least preferred varieties by farmers in the study districts. Farmers also liked Marachere for earliness and Gudanie for marketable yield and vegetative performance. However, they indicated that tuber size of Marachere is very small and Gudanie is susceptible to late blight. Therefore based on the findings, Belete and Bubu varieties could be recommended to potato growers in study area and similar agro ecology for further promotion and the two varieties (Marachere and Gudanie) could be used by potato breeders in their breeding program to exploit their merits.

Keywords: Farmers' Preferences, Participatory Variety Selection, Potato, Variety

INTRODUCTION

Potato (Solanum tuberosum L.) is one of the important food crops in the world. It is popularly known as 'The king of vegetables', the fourth most important food crop in the world after rice, wheat and maize in terms of human consumption (Kandil et al., 2011). In Ethiopia, potato has promising prospecting improving the quality of the basic diet in both rural and urban areas (Abebe et al., 2017). Potato is an important crop for smallholder farmers in Ethiopia, serving both as a cash crop and food security crop. It is one of the root crops widely grown in the country because of increasing demand and emerging markets that have provided a great opportunity for resource-poor farmers to generate additional income (Bekele et al et al., 2011). It is a short duration crop that can mature within short period of time. It contains practically all essential dietary constituents like carbohydrates, essential nutrients, protein, vitamins, and minerals (Sriom et al., 2017). Potato production has been considered as the first priority compared to other

food crops because of its contribution to food security, income generation and double cropping and its utilization in different forms((Lung'aho et al., 2007 and Muthoni J and Nyamongo,2009)

In Ethiopia the variety development study was began in 1975 with the objective of developing varieties that are high yielder, widely adaptable and resistant to late blight, which is most devastating disease (Gebremedhin et al., 2008) and about 31 varieties were formally released for production for wider adaptation (MOA, 2013). Wider adaptation and researchers' criteria may not fit to all agro ecologies and fulfill farmer's preferences. Agro-ecologies varied with respect to soil type, moisture and temperature regimes, fertility condition and the onset, intensity and duration of rain as well as irrigation facilities, where farmers thrive to grow potato (Gebremedhin et al., 2008). Heterogeneous environment, large diversity of farmer's needs, lack of adapted varieties to those diverse agro ecologies facing the formal breeding methods and often fails to meet the needs of farmers and to develop cultivars or varieties showing specific or local adaptation (Desclaux, 2005). That is why most technologies developed without farmers' participation have failed to address the issues of rural poverty appropriately (Pretty et al., 1985). Farmers have their own indicators of performance and quality not well anticipated by researchers' criteria (Jusu, 1999). They are relatively consistent in their selection and their selections correspond with their stated criteria (Maru Aduening et al., 2006). Hence, there is a disproportional development between the large number of technologies generated by the agricultural scientists and the relatively small number of them actually adopted and used by the farmers (Ceccarelli, 2012).

Many varieties are officially released, but few are adopted by farmers. In contrast, farmers often grow varieties that have not been officially released, a phenomenon known to be associated not only with an inefficient and biased testing system prior to variety release, but also with breeders using different selection criteria from the farmers and particularly G×E interactions in the case of farmers in marginal environments (Ceccarelli, 2012). That is why in many part of Ethiopia farmers grow their own local varieties (Gebremedhin et al., 2001). Many potato varieties were released at national but varieties were tested in eastern Ethiopia by Haramaya University and ISSD project while the left released potato varieties not tested until today in Harari region and Eastern Hararghe zone. In study area that root and tuber crop especially potato took great account in their production and food system but still many farmers' used local varieties. However, Still, Farmers as well as Seed Producer Cooperatives (SPCs) are highly demanding better yielding varieties. Participatory Variety Selection (PVS) can effectively be used to identify farmer-acceptable varieties and thereby overcome the constraints that cause farmers to grow old or obsolete varieties (Witcombe et al., 1996). Therefore, this study was conducted with the objectives to identify adaptable, high yielding and diseases and pest tolerant/resistant potato varieties based on farmer`s management, and to evaluate and select potato varieties based on farmer's preference

MATERIALS AND METHODS

Description of the Study Area

The Experiment was conducted in two locations Harari People Regional State, Dire Xayara district on farmers' land and Oromia Regional State, Eastern Hararghe zone, Gurawa district in Birbirsa village on farmers training center**.** Dire Xayara district ofHarari People Regional State is

located at 16km north of Harar town. The altitude of the district ranges from 1,600 to1, 900 meters above sea level. The mean annual rainfall of the district was 880mm. Like some part of Ethiopia, Dire Xayara district was characterized by the bimodal rainfall pattern. The first season was characterized by the short rainy season (Belg), which extends from March to May, while the second season which is the most important main rainy season (Meher) extends from July to October. The dry-spell period was extends from June to July and based on its duration, it may affect crop growth. The minimum and maximum temperature of the area was 13^0C and 25^0C respectively with the annual average of 19°C (Yeneayehu, 2019)**.**

Gurawa district is found in Eastern Hararghe zone of Oromia Regional State. It is located at 76km far away from Harar town. The altitude of district ranges from 500 to 3230 meters above sea level (Mengistu et al., 2016, Mohammed 2015 and Nigussie et al., 2014). The mean annual rainfall is 931 mm and has a bimodal distribution. The short rainy season starts in February/March and extends to May, while the long/main rainy season begins in June and stretches to September. The rainfall peaks in the months of July and August. The average annual temperature ranges from 9.40C to 24^0C.

Experimental Materials

Table 1. Eight improved varieties of potato selected for the trial

No	Varieties	Released year	Breeders/Releasing center
1	Jalenie	2002	Holeta Agricultural Research Center
2	Marachere	2005	Awassa Agricultural Research center
3	Gudanie	2006	Haramaya University
4	Gorobela	2009	Sheno Agricultural Research Center
5	Belete	2011	Holeta Agricultural Research Center
6	Bubu	2011	Haramaya University
7	Dagim	2013	Adet Agricultural Research center
8	Horro	2015	Bako Agricultural Research center

Treatments and Experimental Design

The experiment was conducted in Dire Xayara district of Harari Regional State and Gurawa district of Eastern Hararghe Zone of Oromia Regional State during 2019 cropping season**.** The experimental treatments consisted of eight improved potato varieties including standard check (Variety Bubu) were used in the study (Table 1)..The experiment was laid out in randomized complete block design with three replications. The area of each plot was $9m^2$ consisting of four rows, which accommodated 10 plants per row and totally 40 plants per plot. The spacing between plots and adjacent replication was 1m and 1.5m, respectively. All treatments were assigned randomly to the experimental plots. The experimental field was prepared following the conventional tillage practice using oxen plow. The medium sized potato tubers (35-45) mm in diameter and well sprouted tubers were planted at the spacing of 75 cm between ridges and 30cm between tubers. Urea fertilizer was applied in split that is 50% during time of planting and the rest 50% urea was applied near to tie of flowering while all the NPS at time of planting.

Data Collected

Agronomic Data Collected

Data collected were days to 50% flowering, plant height(cm),days to maturity, number of stems per plant, tuber number per plot, tuber diameter(cm), tuber weight per plant (g), total tuber yield (t/ha), marketable, unmarketable yield(t/ha) and diseases.

Farmers' varieties evaluation and selection criteria

Potato varieties were evaluated before harvest and at harvest by 14 farmers (8 males and 6 females) at each site. All the farmers were divided into two groups of eight farmers at both sites. Before the evaluation of varieties was carried out, selected farmers at both sites were familiarized with the selection procedure and criteria. At both sites, the first evaluation of varieties was carried out at time of flowering and physiological maturity. The second varieties evaluation cycle of farmers was during harvesting (tuber yield and tuber size uniformity). The selection criteria set by farmers were vegetative performance, earliness to maturity, tuber yield; tuber uniformity, marketable tuber yields, and diseases reaction.. The ranking procedure was explained for farmer participants and then each selection criterion was ranked from 1 to 5 (5=very good, 4=good, 3=average, 2=poor and 1=very poor) for each variety. Ranking was done consensus where differences are resolved through discussion (Demolish et al. 2013).

Data Analysis

Farmers' selection data were analyzed using simple ranking method with given value. Agronomic data were subjected to ANOVA by using Genstat statistical software Version15th. Means that differed significantly were separated using the LSD (Least Significant Difference) test at 5% level of significance.

RESULTS AND DISCUSSION

The results of combined analysis of variance (ANOVA) showed that there were significant ($p<0.05$) differences among the tested varieties for all traits except days to flowering (Table 2). The presence of significant differences among varieties indicates the presence of genetic variability for each of the characters among the tested varieties. Similarly, Amdie et al. (2017) reported that significant difference among potato varieties for all traits. Study by Kena et al. (2018) showed significant differences among seven potato varieties for number of main stem, number of tuber per hill, tuber size, tuber weight, marketable and unmarketable yield and total tuber yield

Days to maturity and Plant height

Maturity date and plant height were significant ($P<0.05$) differences among varieties, the early maturing was obtained from Horro (88days) while the late maturing variety was Gudanie (97.33days) followed by Bubu (94.33days) and Belete (93.33days). The highest plant height (76.92cm) was recorded from Bubu followed by Gudanie (73.67cm) and Belete (63.58cm) while the lowest plant height (44.87cm) was recorded from Dagim. The difference in plant height among the varieties might be associated to genetic differences, which may lead to the variable performances in growth and development (Habtam Setu, 2012).This study was in agreement with the findings of Gezahegn et al. (2016) who indicated that plant height lay between 54.1cm and 77.4cm. The result of current study was contradict with study by Arega et al. (2017) who reported that the highest plant height was recorded from Belete and Gudanie which accounts 98cm and 83cm, respectively. This might be variation between the two environments.

Number of stems and tubers per plant

Analysis of variance revealed that there were significant ($P< 0.05$) differences among varieties for number of stems and tuber numbers per plant (Table 2).The highest number of stems per plant was recorded from Bubu (6.77) while the lowest (2.8) was from Horro variety. On the other hand the highest tuber number per plant was recorded from Marachere (9.8) while the lowest from Horro variety (75.17).This finding was in agreement with the findings of Amdie et al. (2017) who reported that the number of stems per plant lay between 6 and 10. De la Morena et al.(1994) stated that the difference in number of main stem among the varieties might be due to the inherent genotypic variation in the number of buds per tuber which is in turn influenced by the size of the tubers, physiological age of the seed, storage condition, and number of viable sprouts at planting, sprout damage at the time of planting and growing conditions.

Tuber diameters and average tuber weight

Based on the analysis of variance, there were significant ($P<0.05$) differences among the varieties for tuber diameters and average tuber weight (Table 2). Significantly the highest tuber diameter and average tuber weight were recorded from Belete (49.31mm) followed by Bubu (45.49mm) while the lowest tuber diameter (40.6mm) for Gorobela. The highest average tuber weight also recorded for Belete (148.g) followed by Bubu (134.9g) while the lowest were recorded for Dagim (83.3g) and Gorobela (96.1g). This result is in the same range with report of Habtamu et al (2016) that the highest average tuber weight recorded from Belete (105.24g) followed by Bubu(70.21g) as compared to sixteen improved potato varieties at eastern Ethiopia. Kena et al. (2018) also reported that the highest tuber diameter was recorded from Belete among the tasted varieties at western Ethiopia.

Marketable, Unmarketable and Total tuber yield

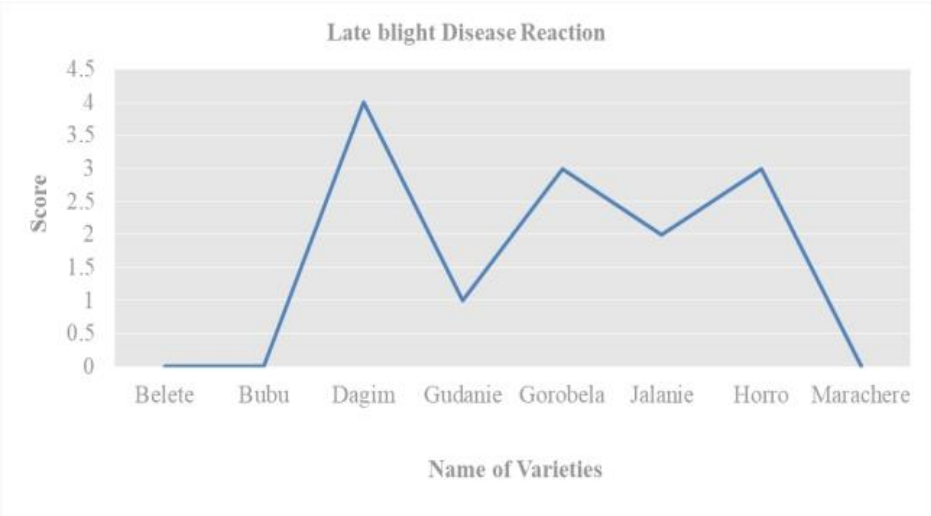
Analysis of variance revealed that there were significant differences ($P< 0.05$) among varieties for marketable, unmarketable, and total tuber yield (Table 2). The maximum marketable yield was recorded from Belete (39.32t/ha) followed by Bubu (28.88t/ha) and Gudanie (28.03t/ha) while the lowest recorded from Dagim (9.36t/ha).The lowest yield in Dagim could be due to its susceptibility to late blight diseases. The highest unmarketable was recorded from Horro (1.33 t/ha) followed by Dagim (1.27 t/ha) while the lowest (0.28t/ha) and (0.78t/ha) from Belete and Marachere respectively. However, this result was in contrast with the study conducted by Henok Fikre (2018) who reported that the highest loss was recorded from Belete (5.5t/ha) and Marachere (0.52t/ha).This might be the variation between the two environments. The maximum total yield was recorded from Belete ($39.6t^{-1}$) followed by Bubu (29.9t/ha) and Gudanie (28.63t/ha) while the lowest recorded from Dagim (10.63t/ha). In line with this study, Henok Fikre (2018) reported that the maximum total yield was recorded from Belete (40.26t/ha) as compared to seven potato varieties in south western Ethiopia. In consistence with this result, Salamo et al.(2019) also reported that the highest outstanding marketable and total yield was recorded from Belete (43.99t/ha) followed by Bubu(35.31t/ha) as compared to six potato varieties in northern Ethiopia. Similarly, Kena et al. (2018) reported that the highest total tuber yield was recorded from variety Belete (38.59t/ha).

Table 2:-Combined mean performance of parameters for Potato PVS at Dire Xayara and Gurawa districts in 2019 cropping season

Varieties	DF	DM	PH(cm)	NSP	TNP	TD(mm)	TW(g)	UMY(t^{-1})	MY(t^{-1})	Y(t^{-1})
Belete	48.8	93.33^{abc}	63.58^{ab}	4.367^{b}	8.33^{a}	49.31^{a}	148.6^{a}	0.28^{c}	39.32^{a}	39.6^{a}
Bubu	46.3	94.33^{ab}	76.92^{a}	6.767^{a}	8.33a	45.49^{ab}	134.9^{ab}	1.01^{ab}	28.88^{b}	29.91^{b}
Gudanie	46.2	97.33^{a}	73.67^{a}	6.267^{a}	8.17^{a}	43.97^{ab}	116.1^{abc}	1.03^{ab}	28.03^{b}	28.63^{b}
Marachere	45.3	92.67^{abc}	43.13^{c}	4.533^{b}	9.8^{a}	42.12^{ab}	119.1^{abc}	0.78^{b}	24.9^{bc}	25.51^{bc}
Jalenie	48.8	94.17^{ab}	56.85^{bc}	3.6^{bc}	8^{a}	44.75^{ab}	110.3^{abc}	1.16^{ab}	20.61^{c}	21.63^{c}
Gorobela	47.3	89.83^{bc}	55.47^{bc}	3.4^{bc}	5^{b}	41.51^{ab}	96.1^{bc}	1.14^{ab}	12.53^{d}	13.67^{d}
Dagim	46.8	89^{bc}	44.87^{c}	3.8^{bc}	3.83^{b}	43.77^{ab}	83.3^{c}	1.27a	9.36^{d}	10.63^{d}
Horro	46.8	88^{bc}	56.23^{bc}	2.8^{5c}	5.17^{b}	40.60b	111bc	1.33a	10.17^{d}	11.44d
LSD (5%)	12.5	5.34	7.69	1.275	2.2	1.17	32.8	0.99	5.06	5.03
CV	22.9	5	22.6	24.5	26.8	14	24.4	34.5	19.9	19

Keys: DF =Days to flowering date, DM= Days to maturity, PH=plant height (cm), NSP=Number of stems per plant, TNP=Tubers number per plant, TD(mm) =Tuber diameters, TW(g)= Tuber weight, UMY(T/ha) =Unmarketable yield, MY(t/ha)=Marketable yield and TY(t/ha)= Total yield. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05).

Disease Reaction Score



From this graph the varieties Dagim, Gorobela and Horro were highly susceptible to late blight disease whereas Belete, Bubu and Marachere varieties have resistant reaction against the disease (Figure 1)

Farmers' preference

Table 3. Matrix ranking of potato varieties based on criteria selected by farmers (n=28).

Evaluation criteria	Gurawa								Dire Xayara							
	Belete	Bubu	Marachere	Gudanie	Jalenie	Gorobela	Horro	Dagim	Belete	Bubu	Marachere	Gudanie	Jalenie	Gorobela	Horro	Dagim
Vegetative performance	5	5	5	5	4	4	4	4	5	5	5	5	4	4	4	4
Maturity	3	3	4	4	4	4	4	4	3	3	4	4	4	4	4	4
Tuber Uniformity	5	4	4	4	3	3	3	2	5	5	4	4	3	3	3	3
Marketable yield	5	5	4	4	3	3	2	2	4	4	3	3	2	1	1	1
Unmarketable yield	5	4	3	3	3	2	2	2	4	4	3	2	2	1	1	1
Total yield	5	4	3	3	3	2	2	1	5	4	4	4	3	2	1	1
Disease resistance	5	5	5	3	1	1	1	2	5	5	5	3	1	2	2	2
Over all mean	4.7	4.3	4	3.7	3	2.7	2.5	2.4	4.4	4.3	4	3.5	2.7	2.3	2.2	2.2
Over all rank	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	7

Key: Rank based on degree of satisfaction: 5=very good, 4=good, 3=average, 2=poor and 1=very poor

Farmers' perception on the performance of potato varieties were tested at study area and analyzed using matrix ranking. As a result the majority of participant farmers in the districts have good interest to grow potato. From eight potato varieties evaluated only variety Belete performed well over the standard check (Bubu). The tested varieties showed similar performance in the two districts. Through evaluation and discussion, farmers ranked the varieties based on their preferences and degree of satisfaction by giving the values 1-5.Generally, matrix ranking result showed that overall mean of the ranks for all performance indicators at Gurawa district were higher for Belete (4.7), Bubu (4.2) and Marachere (4). On the other hand, the overall mean of the ranks for all performance indicators at Dire Xayara district were higher for Belete (4.4), Bubu (4.3) and Marachere (4) Table(3). Participatory evaluation of potato varieties conducted before harvest and at harvest stage of crop by 14 farmers (8 males and 6 females) at each site. The farmers agreed that vegetative performance, earliness to maturity, tuber uniformity, marketable tuber yields, unmarketable tuber yields, total yield and diseases reaction are important parameters. Among these traits, tuber yield, disease reaction, tuber uniformity and early maturity were selected as the top three important selection criteria. Accordingly, Belete and Bubu were selected as the best two preferred potato varieties by the farmers due to their higher yield and tolerance to diseases and tuber uniformity. Farmers also liked Marachere for its early maturing and moderate disease resistance and Gudanie for marketable yield and vegetative performance.

CONCLUSION AND RECOMMENDATION

PVS helps farmers to get familiar with adoption of new varieties and helps researchers in decision making. The result of this study indicated that Belete and Bubu were higher yielding and the most preferred potato varieties by farmers at both district. Dagim and Horro were not only the low yielding varieties but also the least preferred varieties by farmers in the study districts. Therefore, based on these findings, Belete and Bubu could be recommended to potato growers in Dire Xayara and Gurawa Districts for further promotion. Though, Farmers also liked Marachere for its earliness and Gudanie for marketable yield and vegetative performance.

Therefore, we recommend these two varieties should be improved by breeders so that farmers can utilize in the future.

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Effect of NPS and Nitrogen Fertilizer Rate on Yield and Yield Components of Sorghum (Sorghum bicolor (L.) in western oromia

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ABSTRACT

Several biotic & abiotic factors contribute to the low productivity of sorghum, of which inappropriate crop management practices are considerably important. Moreover, application of balanced fertilizers is the basis to attain better crop yield from existing land under cultivation and crop nutrient needs are according to their physiological requirements and expected yields. In line with this, field experiment was conducted during 2018-2020 main cropping season from the mid of May to mid of December at Bako and Gute research sites of Bako Agricultural Research Center to identify the optimum amount of NPS and N fertilizer rates. The experiment consisted of twenty treatments in factorial combination with five NPS (75, 87.5, 100, 112.5 and 125 kg ha-1) and four Nitrogen (35, 40, 46 and 52 kg ha-1) rates of fertilizer under uniform management of all cultural practices. The experiment was laid out in randomized complete block design in three replications. Pre-soil analysis indicated that the soil of experimental area is acidic (pH = 4.75 at Bako and 4.6 at Gute) and low in available Phosphorus (12 ppm at Bako and 10 ppm at Gute). The main effect of plant height, panicle length, thousand seed weight and stand count were not influenced ($P>0.05$) due to NPS and N rates, whereas days to heading and days to maturity varied significantly ($P<0.05$) due to the main effects of N rates even if they were not not influenced due to NPS rates at Bako and Gute locations. On the other hand, head weight and grain yield were highly significantly ($P<0.01$) influenced by the main and interaction effects of NPS and N rates at both locations. Among different NPS and N fertilizer rates tested, the combination of 125 NPS and 46 N rates gave the highest yield thereby resulting in the highest net benefit. Thus, economic analysis revealed that combination of 125 NPS (47.5 P_2O_5, 23.75 N, 8.75 S kg ha-1) and 46 N kg ha-1 rates on variety Gemedi gave grain yield of 3563.1 kg ha-1 with the net benefit of 61578.4 birr/ha and the highest marginal rate of return (2402.96%), which is economically feasible alternative to the other treatments. Therefore, it is recommendable to use combination of 125 NPS and 46N kg ha-1 rates on variety Gemedi since it is economically feasible to sorghum producers.

Keywords: biotic and abiotic, economic analysis, NPS rates, yield and yield components

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is a monocotyledon crop belonging to the Gramineae family. Evolved in semi-arid tropical Africa where it is still used as major food cereal, sorghum is one of the most important cereal crops grown in arid and semi-arid parts of the world where it is also extensively adapted.. The crop can successfully grow in areas that are too marginal for other major cereals. In Eastern Africa, more than 70% of sorghum is cultivated in the dry and hot lowlands where soil fertility is low, poor stand establishment and serious water deficit are among the major production constraints (Mukuru, 1993).

Sorghum serves as a staple food for more than 500 million people in the semi-arid tropics of Africa and Asia. In Ethiopia, sorghum is grown as one of the major food cereals and utilized in various forms such as local bread (Injera) and for preparation of local alcoholic beverages (Tela and Areke). It is also consumed as roasted and boiled grain. Sorghum Stover is used as feed for animals and as housing and fencing material. Sorghum is well adapted to a wide range of precipitation and temperature levels and is produced from sea level to above 2000 m.a.s.l. With frequent and cyclical occurrence of drought and erratic rainfall, it could be an insurance crop to the small-scale resource-poor farmers constituting the majority of the rural farming community of Ethiopia (Abdissa, 1997). Sorghum is the fourth most important cereal crop globally following wheat, rice and maize. CSA (2018) report indicated that sorghum ranks third after maize and tef in total area coverage and fourth in yield per hectare harvested after maize, rice and wheat, respectively. According to a survey recently conducted by Bakko Agricultural Research Center (BARC), sorghum is among the popular crops of main food utilized in the low to mid altitudes of western parts of Ethiopia (Megersa Debela et al., 2017). Despite developing and releasing several high yielding and drought resistant improved sorghum varieties, the use of proper rate of fertilizer and time of Nitrogen application has not been updated from time to time. Of all the nutrients, sorghum is most responsive to the application of nitrogen (N). However, the maximum response to N will not result, even in soils known to be deficient of N, if concentrations of other nutrients such as phosphorus (P), potassium (K) and sulphur (S) are limiting factor (Robert et al., 2015). Besides, the natural phenomena of declining soil fertility is keeping ongoing which need attention to adjust the crop nutrient requirement timely and feed an ever increasing population pressure on small land. In addition DAP and Urea fertilizer application system need to be changed to newly blended fertilizer rate of NPS due to the depletion of macro and micro nutrients of the soil through time. Therefore investigation of proper rate of NPS and Nitrogen application for sorghum is crucial to harvest its potential productivity.

MATERIALS AND METHODS

The trial was conducted at on-station of BARC & the sub-station, Gute site. In this experiment, Different NPS and Nitrogen rates were assessed for sorghum: Five rates of NPS (75, 87.5, 100, 112.5 and 125 Kg/ha) and Four rates of N (35, 40, 46 and 52 Kg/ha) and two time of N application were done which considered 50% N at planting and half percent at tillering. The experimental design used was Randomized Complete Block with three replications and five by four factorial combinations. The land preparation was started at the beginning of the rainy season to loosen the soil to prepare fine seed bed suitable for planting. Sorghum variety, Gemedi was sown in five rows with 75 cm between rows and 15cm between plants and with spacing of 1.5m

between block and 1m between plots, respectively. Gross plot area was 2.5m length by 3.75m width (9.375 m^2). A composite soil sample was taken before onset of rainfall from the selected area of the intended research sites and analysed to determine the nutrient status of the soil.

Data Collection and Measurements

Growth, Yield and Yield Component

Date of 50% emergence was recorded from date of sowing to when 50% seedlings emerged per plot. Similarly, Days to heading was considered when panicles are visible on 50% of the plants on the field. Days to maturity was recorded when number of days on which the seeds of most of the plants showed the appearance of black spot on the hilum of seed. Plant height (cm) was recorded from the base of plant to tip of the panicle of ten plants and the average was calculated at physiological maturity. Panicle length (cm) was recorded by measuring the length of the panicle of ten plants from the base to the tip of the panicle and the average was taken. Thousand kernel weight (g) was taken randomly from whole grains and counted using a seed counting machine until thousand seed was obtained and finally adjusted to using the standard moisture. Finally, grain yield (kg) was measured by threshing whole panicle from the harvestable area and the yield per plot was recorded in kilogram and adjusted according to the standard moisture content of the crop.

Data Analysis

Data were subjected to analysis of variance (ANOVA) using SAS, version 9.0, General linear model procedures SAS Institute (2002) and mean separation was by least significant difference (LSD) test.

RESULTS AND DISCUSSIONS

Soil Physico-Chemical Properties of the Experimental Site

The soil textural classes were in the proportion of 36% sand, 62% clay and 2% silt at Bako where as it was 28% sand, 68% clay and 4% silt at Gute site. The soil pH was highly acidic (4.75 at Bako and 4.6 at Gute) which is in line with EthioSIS (2013) rating that pH range of 4.5 to 5.5 is considered highly acidic. The total nitrogen value of the experimental soil was medium (0.17 and 0.19) at Bako and Gute, respectively which agrees with EthioSIS (2015) rating that indicates soil total nitrogen content of 0.15-0.3 is rated as medium. The organic carbon of the soil was low, 1.94% at Bako and 2.22 % at Gute that agrees with the rating of Tekalign (1991) which states that organic matter content of the soil is very low (<0.86%), low (0.86 to 2.59), medium (2.59 to 5.17) and high (>5.17) while the available phosphorus indicated that there was low phosphorus content of the soil (14 at Bako and 10 mg/kg at Gute) which in line with the rating of Bray (1945), state as phosphorus is very low (<7 mg/kg), low (8-19), medium (20-39), high (40-58) and very high (>59).

Growth, Yield and Yield Components

From the analysis of variance Days to heading and days to maturity showed significant variation ($p<0.05$) due to the main effect of nitrogen even if not responded differently ($p>0.05$) due to NPS rates. On the other hand, plant height (PH), panicle length (PL), thousand seed weight and stand count were not significantly influenced due to the main and interaction effect of Nitrogen

and NPS rate (p>0.05) at Bako and Gute during the main growing season of 2017-2019 (Table 1).

Table 1.The main effects of Nitrogen and NPS rate tested over location and years at Bako and Gute during 2017-2019 cropping season

Treatments	DH	DM	PH	PL	TSW	SC
NPS rate (Kg/ha)						
75	133.31	194.10	276.4	32.93	22.33	29.44
87.5	133.48	194.25	274.8	32.39	22.53	30.96
100	133.69	194.04	276.6	32.18	21.92	29.33
112.5	133.88	194.42	282.7	31.94	22.04	29.96
125	133.90	194.21	282.9	32.14	21.74	31.54
LSD	ns	**ns**	ns	ns	**ns**	ns
N rates (kg/ha)						
35	132.8c	193.5b	278.6	32.21	22.04	29.83
40	133.4bc	194.4a	276.5	32.26	22.32	29.73
46	134.0ab	194.4a	277.7	32.67	21.96	30.15
52	134.4a	194.6a	282.0	32.12	22.14	31.27
LSD	0.84	0.65	ns	ns	ns	ns
Cv	1.7	0.9	7.0	6.1	8.4	17.7

LSD (0.05) = Least significant difference at 5% probably level, CV =Coefficient of variation, Means in the columns and rows followed by the same letter(s) are not significantly different.

Even though some of the parameters showed non-significant difference due to the main and interactions of Nitrogen and NPS fertilizer rates, head weight, grain head weight and grain yield showed highly significant difference(p<0.01) due to the main and interaction effects of Nitrogen and NPS rates at both locations (Appendix Table 1).

The highest head weight (114.93 gm) was recorded from 87.5 NPS and 40 kg/ha Nitrogen rates though statistically at par with head weight (110.20 gm) recorded at the rates of 125 NPS and 46 kg/ha Nitrogen and (111.10 gm) obtained at the rates of 112.5 NPS and 40 Nitrogen kg/ha (Table 2). This could be due to the role of essential nutrients in enhancing the seed holding capacity of the panicle. The result is in line with the finding of Berhane et al. (2015) who reported that panicle weight of sorghum was significantly affected by the application of high amount of nitrogen. Likewise, Gebrelibanos and Dereje (2015) reported that application of high amount of fertilizer results in significance variation on yield per panicle of sorghum. On the other hand, the lowest (86.33 gm) was obtained from 100 NPS and 52 kg/ha Nitrogen even if at par with 100 NPS and 35 kg/ha Nitrogen rates at Bako and Gute locations (Table 2).

Table 2. The interaction effects of Nitrogen and NPS rates on head weight of sorghum at Bako and Gute locations

N Rates (kg ha^{-1})	NPS rates (kg ha^{-1})				
	75	87.5	100	112.5	125
35	94.01 efg	93.48 efg	89.35 gh	103.77 bc	102.47 bcd
40	97.54 cdef	114.93 a	93.07 fg	111.10 a	101.52 cd
46	91.20 fgh	90.06 gh	101.70 cd	108.81 ab	110.20 a
52	97.23 def	90.01 gh	86.33 h	103.56 bcd	99.66 cde
LSD	6.38				
CV	8.0				

The highest grain head weight (81.39 gm) was recorded from 125 NPS and 46 kg/ha Nitrogen rates although statistically similar with grain head weight (80.45 gm) resulted from the rates of 112.5 NPS and 40 kg/ha Nitrogen and (79.06 gm) obtained at the rates of 112.5 NPS and 46 kg/ha Nitrogen. On the other hand, the lowest head weight (58.37 gm) was obtained from 87.5 NPS and 46 kg/ha Nitrogen rates at Bako and Gute sites (Table 3). Comparable grain head weight at the highest rates of NPS and Nitrogen rates is probably associated with the supply of sufficient nutrient to the crop that may avail the required elements at proper time. The result of the current study is in agreement with that of Gebrekorkos et al. (2017) who reported that the application of blended fertilizer resulted in an increase in panicle weight of sorghum where maximum panicle weight of sorghum was recorded at the highest fertilizer application rate. Likewise, Gebrelibanos and Dereje (2015) reported that application of high amount of fertilizer has significance variation on yield per panicle of sorghum.

Table 3. The interaction effects of Nitrogen and NPS rates on Grain head weight of sorghum at Bako and Gute locations

N Rates (kg ha^{-1})	NPS rates (kg ha^{-1})				
	75	87.5	100	112.5	125
35	61.14 ij	61.00 ij	71.79 defg	74.21 bcde	77.91 abcd
40	66.78 fghi	78.45 abcd	77.92 abcd	80.45 ab	68.10 efgh
46	61.93 hij	58.37 j	73.06 cdef	79.06 abc	81.39 a
52	66.07 ghi	63.41 hij	63.55 hij	75.95 abcd	73.85 bcde
LSD	6.84				
CV	12.0				

The highest grain yield (3959 kg/ha) was recorded from the highest NPS (125 kg/ha) and Nitrogen (46 N kg/ha) rates even if statistically at par with the rates of 125 NPS and 52 N, 100 NPS and 52 N and 87.5 NPS and 52 N kg/ha while the lowest (2694 kg/ha) was obtained from 35 N and 87.5 kg/ha NPS rates at Bako and Gute sites (Table 4). The probable reason of the highest grain yield at the highest rates of NPS and 46 rates might be associated with the proper supply of required nutrients that met the crop nutrient demand at proper crop growth stages. The result of this finding is in agreement with that of Fageria et al. (2009) who reported that adequate and blended form of fertilizer absolutely enhances the total nutrient uptake of N. At the same time, productivity of the crop i.e. treatment that accumulates maximum N nutrient gave highest yield. Moreover, Sujathamma et al. (2015) reported that application of high amount of blended fertilizer result in maximum grain yield of sorghum as compared with the small amount of blended fertilizers. Similarly, the result is in line with the findings of Tekle and Zemach (2014)

who reported that the highest grain yield was obtained from improved sorghum varieties was associated with increased number of yield attributing parameters such as grain head weight and panicle weight.

Table 4. The interaction effects of Nitrogen and NPS rates on Grain yield of sorghum at Bako and Gute locations

	NPS rates (kg ha^{-1})				
N Rates (kg ha^{-1})	75	87.5	100	112.5	125
35	2878 ij	2694 j	3658 bcd	3499 def	3264 fgh
40	3337 efg	3744 abcd	3012 hi	3089 ghi	2911 ij
46	3281 efgh	3274 fgh	3478 def	3308 efg	3959 a
52	3573 cde	3838 abc	3860 abc	3486 def	3883 ab
LSD	294.9				
CV	10.8				

Economic Analysis

The experiment was conducted with two factor experiments including different NPS and Nitrogen rates combined factorally by keeping all cultural management practices uniform. Thus, the partial budget analysis was done on the basis of total variable cost considering the costs of different NPS, Nitrogen rates and transportation as well as application costs. The economic analysis was done on the basis of adjusting 10% yield downward for the fact that it is closest to the farmers' yield. The result of partial budget analysis showed that from twenty treatments tested seven NPS and N rates were non-dominated with an associated MRR greater than 100% (Table 5). An additional income of 24.02 Ethiopian Birr per unit Birr invested was obtained from 125 NPS and 46 N kg/ha rate on the test crop (Gemedi variety) compared to the other treatments. This analysis revealed that 125 NPS rate and 46 N kg/ha rate on Gemedi variety gave (3563.1 kg/ha) yield with the net benefit of 61578.4 birr/ha and the highest marginal rate of return of 2402.96 % are economically feasible alternative to the other treatments (Table 5). Therefore it is recommendable to use 125 NPS and 46 N kg/ha rate on Gemedi sorghum variety since it is economically feasible to the farmers.

Table 5. Results of partial budget analysis for NPS and Nitrogen fertilizer rates on sorghum (Gemedi Variety).

Trtms	NPS/ha	N/ha	Field yield	adj. yield	GB	TVC	NB	Domi nanace	MC	MB	MRR
1	75	35	2878	2590.2	46623.6	1752.272	44871.33		0	0	0
5	87.5	35	2694	2424.6	43642.8	1872.614	41770.19	D			
2	75	40	3337	3003.3	54059.4	1899.446	52159.95		157.1738	3420.626	2176.33
9	100	35	3658	3292.2	59259.6	1992.957	57266.64		193.5109	4500.689	2325.81
6	87.5	40	3744	3369.6	60652.8	2019.788	58633.01		126.8315	1366.368	1077.31
8	87.5	52	3838	3454.2	62175.6	2373.005	59802.59		353.2173	1169.583	331.12
18	125	40	2911	2619.9	47158.2	2380.815	44777.38	D			
15	112.5	46	3308	2977.2	53589.6	2437.082	51152.52	D			
12	100	52	3860	3474	62532	2493.348	60038.65		120.3424	236.0576	196.15
19	125	46	3959	3563.1	64135.8	2557.424	61578.38		64.07616	1539.724	2402.96
16	112.5	52	3486	3137.4	56473.2	2613.69	53859.51	D			
20	125	52	3883	3494.7	62904.6	2734.033	60170.57	D			

GB= gross benefit, TVC= total variable cost, NB= net benefit, D=dominance, MC= marginal cost, MB= marginal benefit and MRR= marginal rate of return

CONCLUSION

The major factors that contribute to low sorghum productivity include many biotic and abiotic factors such as inappropriate crop management practices. To tackle constraints associated with nutrient management, application of balanced fertilizers according to the nutrient demand of crops is the basis to appreciably increase crop productivity from the existing land under cultivation. Among different NPS and N rates tested, the combination of 125 NPS and 46 N rates gave the highest yield of sorghum, variety Gemedi thereby resulting in the highest net benefit. Based on this experiment, the economic analysis showed 125 NPS and 46 N kg/ha rates tested at Bako and Gute experimental sites gave the highest sorghum yield (3959 kg/ha) with the net benefit (61578.4 birr/ha) and highest marginal rate of return (2402.96 %) which are economically feasible alternative to the other treatments. Therefore it is recommendable to use 125 NPS and 46 N kg/ha rates on sorghum (Gemedi variety) since economically feasible to the farmers.

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Effect of NPS and Nitrogen Fertilizer Rates on Yield and Yield Components of Food Barley (Hordeum vulgare L.) in western Oromia

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ABSTRACT

Inappropriate crop management practices are among the key elements that contributed to low productivity of Barley. Moreover, application of balanced fertilizers and nutrient requirements of the crop is the basis to improve crop yield from the land under cultivation. In view of this, field experiment was conducted in 2018 & 2019 main cropping season from the mid of July to first of December at Gedo and Shambu research stations of Bako Agricultural Research Center to determine optimum amount of NPS and N fertilizer rates and to evaluate the economic profitability of NPS and N fertilizers for Barley production. The experiment consisted of twenty treatments combined factorial with five NPS (75, 87.5, 100, 112.5 and 125 kg ha^{-1}) and four Nitrogen (17, 23, 29 and 35 kg ha^{-1}) rates keeping the other managements and cultural practices uniform. The experiment was laid out in Randomized Complete Block Design with three replications. Pre-soil analysis indicated that the soil of experimental area is acidic (pH = 4.99 at Gedo and 4.98 at shambu) and low in available Phosphorus (12 ppm at Gedo and 13 ppm at Shambu). The main effect of days to heading, grain per spike, thousand seed weight and harvest index were not significantly ($P>0.05$) influenced due to NPS and N rates. Whereas, days to maturity, plant height and panicle length were significantly different ($P<0.05$) due to the main effects of N rates though not influenced due to NPS rates at Gedo and Shambu. On the other hand, number of effective tiller, grain yield and above ground biomass were highly significantly ($P<0.01$) influenced due to the main and interaction effects of NPS and N rates at both locations. Among different NPS and N fertilizer rates tested, the combination of 125 NPS and 35 N kg ha^{-1} rates gave the highest yield thereby resulting in the highest net benefit. Thus, economic analysis indicated that combination of 125 NPS (47.5 P_2O_5, 23.75 N, 8.75 S kg ha^{-1}) and 35 N kg ha^{-1} rates on HB -1307 variety gave grain yield (3631.79 kg ha-1) with the net benefit (39849.01 birr/ha) and the highest marginal rate of return (992.16 %) are economically feasible alternative to the other treatments. Therefore it is recommended to use combination of 125 NPS and 35N kg/ha rates on HB -1307 variety since it is economically feasible to the farmers. However, to reach at conclusive idea there is future line of work to get the peak point at which this fertilizer combination reach turning point.

Keywords: Economic analysis, NPS rates, yield and yield components

INTRODUCTION

Barley (Hordeum vulgare L.) is among important cereal crops cultivated in Ethiopia. It occupies 0.951 million ha of land and ranks 5th in terms of production area (CSA, 2018). It is grown in diverse environments at an altitude range of 1500–3500 m.a.s.l, but predominantly at 2000–3500 m.a.s.l (Berhane Lakew, Hailu Gebre and Fekadu Alemayehu, 1996). Barley has been the staple food of people in many countries for ages, but it drew away from favor due to changes in food preferences. It is the fourth most important cereal crop in the world after wheat, maize, and rice, and is among the top ten crop plants in the world (Ejigu, 2012). In Ethiopia, barley grain is produced mainly for human consumption and is one of the most important staple food crops (Birhanu et al., 2005). The majority of barley that farmers grow is food barley and it is the main ingredient for several staple dishes such as injera, porridge and bread. Barley covers an area of (951,993.15) hectare and has national average yield of 2157 kg per hectare (CSA, 2018). Ethiopia experiences one of the highest rates of soil nutrient depletion in sub-Saharan Africa. An estimated annual nationwide loss of phosphorus and nitrogen resulting from the use of dung and crop residues for fuel is equivalent to the total amount of commercial fertilizer being used (MoA, 2010). The most important abiotic stresses include low soil fertility, low soil pH, poor soil drainage, frost and drought. Soil degradation is one of the major challenges to improved agricultural production and food security in the country. Hence, poverty reduction and achieving food security is among the prime policy agenda of the Ethiopian government.

The ratio of total area under barley to other cereal crops (including wheat, teff, maize and sorghum) has been decreasing over the past 25 years. The reduction in the area under barley in the recent past could be attributed to a number of factors, including that most of the area under barley is sown to farmer cultivars that are low yielders. Fertilizer use on barley is the lowest among all cereals; in the 2005 main cropping season, only 16.48% of the total area covered by cereals received inorganic fertilizer. When the total area covered with teff, wheat and maize received 25.13, 25.60 and 17.74% of fertilizer, respectively; barley received only 6.92% of the fertilizer for the total area in the same year (CSA, 2006). In general, majority of farmers use fertilizer below the recommended rates and farmers applied different rates of fertilizers.

Di-ammonium Phosphate (DAP: P_2O_5 46% and N 18 %) and urea (CO (NH_2): N 46%) are the two main source of mineral fertilizer that have been in use for cereal production in Ethiopia. According to soil fertility status atlas of Ethiopia (ATA, 2014), available sulfur, and extractable iron, zinc and boron are deficient. Of all those production bottle necks, much hope has been vested on the agricultural sector to provide enough produce to meet the food demand of increasing population by raising the productivity of smallholder agriculture through intensive use of inputs (mainly improved seeds, fertilizers and pesticides), and agricultural extension services. The application of fertilizer also needs site specific prescription since soils in different areas are highly heterogeneous in nutrient status, pH, nutrient holding capacity and other chemical properties. In addition, no work has been done to evaluate NPS and Nitrogen fertilizer rate that can increase yield and yield components of barley. Therefore the study is aimed to investigate the effect of NPS and nitrogen fertilizer rates on yield of barley.

MATERIALS AND METHODS

The trial was conducted at two research sub-stations of Bako Agricultural Research Center namely Gedo and Shambu. In under taking the experiment, different rates of NPS and Nitrogen were evaluated for Barley production. Five rates of NPS (75, 87.5, 100, 112.5 and 125 kg/ha NPS) and Four rates of Nitrogen (17, 23, 29 and 35 Kg/ha N) were evaluated in factorial combination. Blanket recommendation of 100 kg/ha NPS and 46kg/ha UREA was included as a check. NPS Fertilizer was applied during planting time and urea was applied in splits, half at planting and the remaining half at tillering. The experiment was laid down using Completely Randomized Block Design with three replications. Land preparation was done thoroughly ahead of planting time and seed of Barley variety (HB -1307) was sown in six rows with 20 cm between rows and 1.5m between block and 1m between plots respectively. The gross plot area was 1.2 m length by 2.5m width ($3m^2$). A composite soil sample was taken before onset of rainfall from the selected area of the intended sub-site and analysed for nutrient status of the soil.

Data Collection and Measurements

Growth, Yield and Yield Component

Date of 50% emergence was recorded from date of sowing to when 50% seedlings emerged per plot. Similarly, Days to heading was determined when 50% of the plants appeared to be heading. Days to physiological maturity was recorded as the number of days from date of sowing until 90% of the plants changed their green color to yellowish. Plant height (cm) was recorded by measuring the length of individual culms of ten plants from the soil surface to the tip of the spike and the average was calculated. Number of productive tillers was recorded by counting the number of tillers bearing productive spike from ten randomly selected plants and the average was taken. Spike length (cm) was recorded by measuring the length of spike of ten plants from the spike collar to the tip excluding the awns and the average was calculated. Thousand kernel weight (g) was taken randomly from whole grains that were counted using a seed counting machine until thousand seed was obtained and finally adjusted to using the standard moisture. Grain yield (kg) harvested from the net plot area was threshed, cleaned and weighed and adjusted according to the standard moisture content of the crop and biomass yield was harvested by cutting the above-ground biomass within the harvestable plot area, dried to constant moisture content and weighed.

Data Analysis

Data were subjected to Analysis of Variance (ANOVA) using SAS, version 9.0, General linear model procedures SAS Institute (2002) and mean separation was done using Least Significant Difference (LSD) test.

RESULTS AND DISCUSSIONS

Soil Physico-Chemical Properties of Experimental Site

The soil textural classes were in the proportion of 46% sand, 36% clay and 18% silt indicating sandy clay in Shambu. Whereas, at Gedo the proportion of soil textural classes were 40 % sand, 54% clay and 6% silt depicting clay. The soil pH was highly acidic (4.98 at shambu and 4.99 at Gedo) according to EthioSIS (2013) rating which states pH ranges of 4.5 to 5.5 as highly acidic. The total nitrogen value of the experimental soil was medium (0.21 and 0.3) at Gedo and shambu respectively, according to EthioSIS (2015) rating which classifies soil total nitrogen content of 0.15-0.3 as medium. The organic carbon of the soil was medium (4%) at shambu and low (2.42 %) at Gedo that agrees with Tekalign (1991) rating, which classifies organic matter content of the soil as: very low (<0.86%), low (0.86 to 2.59), medium (2.59 to 5.17) and high (>5.17). Similarly, available phosphorus indicated that there was low phosphorus in the soil (13 at shambu and 12 mg/kg at Gedo). This coincides with the rating of Bray (1945) which states that the amount of phosphorus in the soil is very low when it is less than 7, low when it is in the range of 8-19, medium when it is in the range of 20-39, high when it is in the range of 40-58 and very high when it is greater 59 mg/kg.

Growth, Yield and Yield Components

From the analysis of variance days to heading, grain per spike, thousand seed weight and harvest index were not significantly influenced due to the main and interaction effect of NPS and Nitrogen rates ($p>0.05$). However, plant height, days to maturity and spike length positively responded ($p<0.05$) due to the main effects of Nitrogen rates even if they were not significantly different for NPS rates ($p>0.05$) at shambu and Gedo (Table 1). The highest Days to maturity (135 days) was recorded for the highest nitrogen rate (35 kg ha^{-1}) perhaps due to the delay in growth during vegetative stage. In similar manner, the highest plant height (93.4 cm) and spike length (8.41) were recorded at the highest rates of nitrogen (35 kg ha^{-1}) (Table 1). This result is in line with Diriba et al. (2019) who reported the highest days to maturity and plant height were recorded from the highest level of nitrogen treatment for wheat varieties. Similarly, Tayebeh, et al. (2011) and Sofonyas (2016) reported significant increments in plant height due to application of high nitrogen rate in wheat.

Table 1. The main effect of rates of NPS and Nitrogen on Days to Heading, Days to maturity, Plant height, Grain per spike, Thousand seed weight, Harvest Index and spike length of food barley, variety HB-1307.

Treatments	DH	DM	PH	GPS	TSW	HI	PL
NPS rates (kg ha^{-1})							
75	61.92	134.46	91.38	55.01	42.88	42.43	7.958
87.5	61.96	134.71	92.32	54.96	43.92	44.53	7.996
100	61.40	134.77	92.50	56.62	43.41	44.25	8.100
112.5	61.12	134.15	91.70	56.32	43.24	43.29	8.237
125	61.12	134.08	91.26	56.78	43.89	44.15	8.098
LSD	ns	ns	ns	ns	ns	ns	ns
N Rates (kg ha^{-1})							
17	61.67	134.3 ab	91.66 bc	56.26	43.78	43.68	8.028 b
23	61.87	134.5 ab	90.27 c	54.96	43.67	44.34	8.032 b
29	61.02	133.9 b	91.99 ab	55.66	43.08	43.10	7.847 b

35	61.47	135.0 a	93.40 a	56.87	43.35	43.80	8.405 a
LSD	ns	0.74	1.60	ns	ns	ns	0.337
CV	3.6	1.5	4.8	9.5	6.1	12.2	11.6

On the other hand, the number of effective tillers, grain yield and above -ground biomass varied significantly ($p<0.01$) due to the main and interaction effect of NPS and Nitrogen rates at Gedo and Shambu sites (Appendix Table 1). The highest number of effective tillers (5.7) was observed from the combination of the 100 NPS and 35 kg ha^{-1} nitrogen rate followed by the interaction of 125 NPS and 35 kg ha^{-1} nitrogen rate. This might be due to the fact that when plant nitrogen demand is met, tillering might be enhanced, providing more productive tillers that, in turn, will contribute to yield increment. The result is in agreement with that of Diriba et al.(2019) who reported the response of wheat, variety Kingbird in terms of number of effective tillers was higher (6) at 300 Kg of NPSB application with supplementary urea. The results are also in agreement with the findings of Abdullatif et al. (2010) who reported that the number of effective tillers increased with increased nitrogen fertilization. Bereket, et al. (2014) and Abdollahi, et al. (2012) also reported that nitrogen fertilization has significant effect on effective number of tillers of wheat. However, the smallest number of effective tillers were recorded from 112.5 kg ha^{-1} NPS and smallest rates of nitrogen (17 kg ha^{-1}) which might indicate that less nitrogen supply results in less initiation of the tillers (Table 2).

Table 2. The interaction effects of Nitrogen and NPS rates on Number of effective tiller of food barley (HB-1307) at Gedo and Shambu locations

N Rates (kg ha^{-1})	NPS rates (kg ha^{-1})				
	75	87.5	100	112.5	125
17	4.917 bcdef	5.333 abcd	5.383 ab	4.250 g	4.717 cdefg
23	4.607 efg	5.133 abcdef	5.700 a	5.367 abc	5.150 abcdef
29	5.142 abcdef	5.150 abcdef	4.667 efg	4.550 fg	4.627 efg
35	5.383 ab	5.037 abcdef	4.673 defg	5.267 abcde	5.633 a
LSD	0.663				
CV	16.3				

As grain yield is directly related to the number of productive tillers, it was positively responded to the interaction effects of NPS and nitrogen rates as well (Table 3). The highest grain yield (4026 kg ha^{-1}) was obtained from the combination of the highest rate of 125 NPS and 35 kg ha^{-1} nitrogen followed by (3716 kg ha^{-1}) grain yield which was resulted from the interaction of 100 NPS and 35 kg ha^{-1} nitrogen (Table 3). The highest grain yield at the highest rates of NPS and nitrogen might be due to availability of adequate plant nutrient requirement resulting in the induction of more productive tillers which is directly correlated with the production of better yields. In line with the results, Taalab et al. (2015) indicated that higher response of yield to Nitrogen application may indicate the growth and yield enhancing effect due to synchrony between the time of high need of the plant for N uptake and the time of availability of sufficient N in the soil at the specified growth stages. Similarly, Woubshet et al. (2017) reported that application of 150 kg ha^{-1} NPSB blended fertilizer with compost increased the grain yield by 48 kg ha^{-1}. In the same way, Klikocka et al. (2016) also found that a positive reaction of N and S fertilization provided the highest grain yield (54 kg ha^{-1}). On the other hand, the lowest grain yield (2967 kg ha^{-1}) was resulted when smallest NPS rates (75 kg ha^{-1}) combined with 23 kg ha^{-1} nitrogen was provided (Table 3).

Table 3. The interaction effects of Nitrogen and NPS rates on Grain yield of food barley (HB-1307) at Gedo and Shambu locations

N Rates (kg ha^{-1})	NPS rates (kg ha^{-1})				
	75	87.5	100	112.5	125
17	3176 efgh	3410 bcdef	3374 bcdefg	3283 defgh	3167 efgh
23	2967 h	3127 fgh	3561 bcd	3127 fgh	3381 bcdefg
29	3124 fgh	3484 bcde	3052 gh	3322 defg	3412 bcdef
35	3333 cdefg	3292 defgh	3716 ab	3681 abc	4026 a
LSD	353.6				
CV	13.1				

In similar ways to grain yield, the highest above ground biomass (9089 kg ha^{-1}) was attained when 125 NPS and 35 kg ha^{-1} rates of nitrogen interacted together. Comparative above-ground biomass (8269 kg ha^{-1}) was obtained from the combination of 112.5 NPS and 35 kg ha^{-1} nitrogen (Table 4). This might be related to vigorous vegetative growth of the crop as a result of addition of adequate crop nutrient to the soil. The supply of micronutrients like sulfur may increase the induction and growth of more tillers which contributes to development of high above ground biomass. This result is in agreement with the findings of Woubshet et al. (2017) who found that application of 150 kg ha^{-1} NPSB blended fertilizer with compost increased the biomass by 115 kg ha^{-1}. This was due to the fact that Sulfur enhanced the formation of chlorophyll and encouraged vegetative growth and B helps in N absorption. On the other hand, the smallest above ground biomass (6518 kg ha^{-1}) was recorded from the combination of 75 NPS and 23 kg ha^{-1} Nitrogen rates. The results are in agreement also with the findings of Siam et al. (2012) who reported that straw and grain yield of barley were the lowest for lowest nitrogen treatment.

Table 4. The interaction effects of Nitrogen and NPS rates on above- ground biomass yield of food barley (HB-1307) at Gedo and Shambu locations

N Rates (kg ha^{-1})	NPS rates (kg ha^{-1})				
	75	87.5	100	112.5	125
17	7444 bcdef	7203 bcdef	7637 bcde	7507 bcdef	7345 bcdef
23	6518 g	6835 efg	7980 bc	6873 def	7304 bcdef
29	7237 bcdef	7935 bcd	6748 fg	7451 bcdef	7711 bcde
35	7940 bcd	7165 cdef	8152 abc	8269 ab	9089 a
LSD	846.0				
CV	13.9				

Economic Analysis

The experiment was conducted with two factor experiments including different NPS and Nitrogen rates combined factorally by keeping all cultural management practices uniform. Thus, the partial budget analysis was done on the basis of total variable cost considering the costs of different NPS, Nitrogen rates and transportation as well as application costs. The economic analysis was done on the basis of adjusting 10% yield downward for the fact that it is the closest to the farmers' yield. The result of partial budget analysis showed that from twenty treatments tested, six treatments (NPS and N rates combination) were non-dominated with an associated

MRR greater than 100% (Table 5). An additional income of 9.92 Ethiopian Birr per unit Birr invested was obtained from 125 NPS and 35 N kg ha $^{-1}$ rate on the test crop barley (HB-1307 variety) compared to the other treatments. This analysis indicated that 125 NPS and 35 N kg ha $^{-1}$ rate on (HB -1307 variety) gave (3623.4 kg ha $^{-1}$) yield with the net benefit of (39849.01 birr ha^{-1}) and the highest marginal rate of return (992.16 %) are economically feasible alternative to the other treatments (Table 5). Therefore it is recommendable to use 125 NPS and 35 N kg ha $^{-1}$ rates on HB -1307 variety since it is economically feasible for the farmers.

Table 5. Results of partial budget analysis for NPS and Nitrogen fertilizer rates on barley (HB -1307).

Trtms	NPSkg /ha	N Kg/ha	Field yield	adj. yield	GB	TVC	NB	Dominance	MC	MB	MRR
1	75	17	3176	2858.4	34300.8	2061.337	32239.46		0	0	0
2	75	23	2967	2670.3	32043.6	2237.946	29805.65	D			
5	87.5	17	3410	3069	36828	2350.929	34477.07		289.59	2237.61	772.67
7	87.5	29	3484	3135.6	37627.2	2674.712	34952.49		323.78	475.42	146.83
10	100	23	3561	3204.9	38458.8	2758.261	35700.54		83.55	748.05	895.34
12	100	35	3716	3344.4	39132.8	3111.478	36021.32		353.22	320.78	90.82
15	112.5	29	3322	2989.8	35877.6	3195.028	32682.57	D			
18	125	23	3381	3042.9	36514.8	3278.576	33236.22	D			
16	112.5	35	3681	3312.9	39754.8	3290.635	36464.16		179.16	442.84	247.18
19	125	29	3412	3070.8	36849.6	3455.185	33394.42	D			
20	125	35	4026	3623.4	43480.8	3631.794	39849.01		341.16	3384.84	992.16

GB= gross benefit, TVC= total variable cost, NB= net benefit, D=dominance, MC= marginal cost, MB= marginal benefit and MRR= marginal rate of return

CONCLUSION

Inappropriate crop management practices are among key elements that contribute to low productivity of Barley. To overcome such problems particularly nutrient management, application of balanced fertilizers according to the nutrient demand of the crop is the basis to increase crop productivity from the existing land under cultivation. Among different NPS and N rates tested, the combination of 125 NPS and 35 N rates resulted in the highest yield and led to highest net benefit. Based on this experiment, the economic analysis showed that 125 NPS and 35 N kg ha $^{-1}$ rates tested at Gedo and Shambu locations gave the highest barley yield (3631.79 kg ha $^{-1}$) with the net benefit (39849.01 birr ha $^{-1}$) and with the highest marginal rate of return (992.16 %) which are economically feasible alternative to the other treatments. Therefore it is recommendable to use 125 NPS and 35 N kg ha $^{-1}$ rates on Barley (HB -1307 variety) since it is economically feasible for the farmers. Further investigation is required to find out the peak point at which fertilizer rates show turning point.

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Participatory Evaluation and Selection of Fungicide Efficacy against Wheat Rust Diseases on Bread Wheat at Highland of Guji Zone, Southern Oromia

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ABSTRACT

Bread wheat (Triticum aestivum L.) is an important cereal grown in the highlands of Ethiopia. However, the production and productivity of wheat is curtailed by various biotic and abiotic stresses. Among the biotic stresses, wheat yellow rust and stem rust diseases caused by Puccinia striiformis f.sp. tritici and Puccinia graminis f.sp. tritici, respectively are the most feared and wheat production bottlenecks. Therefore, a field experiment was conducted at two highland of Guji zone (Bore and Ana Sora) under rain-fed condition during the 2019/20 main cropping season to evaluate effects of different fungicides on wheat rust diseases, yield and yield components of bread wheat. The treatments consisted of five fungicides including standard check and nil application using bread wheat variety Kubsa. The experiment was laid out as a RCBD and replicated three times per treatment. The partial budget analysis was carried out to assess financial profitability of fungicide application for the management of rusts. Analysis of the results revealed that the application of fungicides significantly affected rust diseases, growths parameters and yield attributes except date to heading and date maturity. Fungicide spray treatments significantly reduced both yellow rust and stem rust diseases severity to the lowest level possible and increment of yield over the nil application. The minimum yellow rust and stem rust diseases severity recorded from the test fungicide Take-Off 293% SC while maximum yellow rust and stem rust diseases severity were recorded at unsprayed plot. There is highly significant difference ($p < 5\%$) in grain yield, biomass yield, thousand kernel weight, plant height, spike length and rust(yellow and stem) between fungicide treatments and nil application of fungicide. The highest grain yield (2738 kg/ha) was obtained from Take-Off 293% SC sprayed plots while the lowest (987 kg/ha) was from nil application. Take-Off 293% SC revealed better grain yield advantage than the standard Check fungicide and control by about 5.6 and 63.95 respectively. All fungicide treatments also revealed significant yield advantage than untreated plots. Take-Off 293% SC was found to be very effective in controlling both yellow rust and stem rust diseases of wheat by increasing yield of wheat. Therefore, based on partial budget analysis, yield and rust disease control, using of Take-Off 293% SC fungicide which leads to the optimum yield of bread wheat by decreasing rusts and can be recommended for the study area and other areas with similar agro-ecologies.

Keywords: bread wheat, disease severity, Rust, fungicide, stem rust, yellow rust.

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the most important cereal crops in terms of area and production in the world. It was grown on more than 216 million ha of land larger than for any other crop and total production of 659 million tons with average productivity of 3160 kg ha-1 grain in 2014/15 cropping season (FAO, 2017). In Ethiopia, wheat covered an area of 1.7 million ha with a total production of 42.1 million quintals with yield average of

26.75 kg ha-1 during Meher season of 2016/17 (CSA, 2017). Though the country ranked second in area of production (1.7miillion ha) next to Morocco (2.9million ha) and third in total production (42.1 million quintals) next to Egypt (92.7 million quintals and Morocco (51.1 million quintals), but stood sixth in yield in Africa next to Zambia, Namibia, Egypt, Mali, and South Africa that takes the rank 1 to 5, respectively (FAO, 2017); Indicating that Ethiopia increasing the area of farming with low productivity.

However, the production and productivity of wheat is curtailed by various biotic and abiotic factors. Among the biotic factors, wheat rust diseases are the most feared und wheat production bottleneck. Guji is now becoming hot spot for wheat rusts as new, virulent races evolve and spread to other parts of the country and to the world as well, where the periodic epidemics cause significant yield losses and reduction. (Hei et al, 2020)

Both yellow rust and stern rusts of wheat caused by *Puccinia strliformis f.sp. tritici* and *Pucclnia graminis f.sp tritici* respectively are the most important diseases on bread wheat in in Ethiopia. Yield loss of up to 71% was recorded in bread wheat due to yellow rust Guji highlands (Yared et al, 2018). However, in severe cases 100% yield loss was recorded on the highly susceptible varieties due to yellow rust (BoARC Progress report). Stem rust is also the most important and aggressive wheat disease in Guji. Currently, most of popular bread wheat varieties grown in Guji are susceptible to virulent stem rust races, Ug99 (TTKSK) and its derivatives. Moreover, in 2018/19 main cropping season a new stem rust race (TTKTT) was detected on popular bread wheat varieties (Huluka, Sanate, Shorima, Ogolcho, Hidasie, Danda'a etc) (Hei et al, 2020). Resistance sources to rusts are the most preferred diseases management options in wheat. Several efforts were made towards resistant cultivars development in Ethiopia and several bread wheat cultivars with various levels were released for production. But many of them are attacked due to development of these new races. Thus it is important to use the other option like fungicide to sustain production and productivity of bread wheat.

MATERIALS AND METHODS

Treatments and Experimental Design

Treatments will be consists of five fungicides (Jeba, Diprocon, Orozole and Take off) and one standard check (Rex Duo) with fungicide 0.5 litrs/ha for each fungicide and unsprayed will be included as control. The experiment was laid out in Randomized Complete Block Design (RCBD) and replicated three times. The plot size was 5.0 m x 5.0 m. The row spacing, spacing between plots and blocks was 20cm, 1.0 m and 1.5 m, respectively. The outermost one row on both sides of each plot were considered as border plants, and not used for data collection to avoid border effects. Wheat variety Kubsa which is susceptible to rusts especially yellow rust and stem rust was used. Blended NPS fertilizer was applied at the rate of 121 kg ha^{-1} and mixed thoroughly with soil to avoid direct contact with the seeds. The fungicide was tank mixed and applied at commenced as soon as the disease appeared and then at two weeks interval. All the other agronomic practices were followed as per the recommendation for the crop.

Data collection

Data was collected in two ways: agronomic data & farmer's data. For agronomic data phenological, Growth, yield and its component were collected following their own principles.

Disease score was rated using 1-9 rating scale (Bernier et al., 1993) and according to Bernier et al., (1984).

Data Analysis

Data collected from mother trials was subjected to ''GenStat' 'software (version 18) to evaluate the variability of the tested fungicides. This was done through computing analysis of variance for all characters studied according to the method given by Gomez and Gomez (1984). Fisher protected Least significant difference (LSD) was used to compare treatment mean differences at the probability level of $\alpha = 0.05$. For data's collected from baby trials, matrix ranking suggested by De Boef et al., (2007) was employed.

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 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 chemicals/fungicides. The benefit of straw yield was not included in the calculation of 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 fungicides, was calculated by dividing the net increase in yield of bread wheat due to the application of each fungicides. 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 per hectare and P = Field price per unit 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.

RESULTS AND DISCUSSIONS

Diseases

Both yellow/stripe rust and stem rust disease pressure was very high and excellent disease epidemics was developed to the level of creating significant difference among treatments across all test locations in highlands of Guji zone 2019/20 cropping season. Both yellow/stripe rust and stem rust disease pressure were vary on fungicides used and control. Fungicide spray treatments (test and check fungicides) significantly reduced both yellow rust and stem rust diseases severity over the nil application (Table 1). Take-Off 293% SC reduced yellow rust disease severity to the lowest level compared to the s.check fungicides and unsprayed by about 23.35 and 90.96% respectively. It also reduced stem rust diseases severity by about 63.96 and 72.98% as compared to s,check and unsprayed plot respectively. Similarly, from visual field observation, Take-Off 293% SC also showed more level of efficacy in controlling both yellow rust and stem rust diseases than the standard check, Rex Duo even though it is not statistically different. In general, yellow rust range 7.68% - 85.03% whereas stem rust ranges from 5.00% - 18.51% under test fungicides and control/unsprayed treatment respectively.

Yield Component and Yield Data

Days to 50% heading

The analysis of variance revealed that the effect of fungicides did not significantly ($P < 0.05$) affect days to 50% heading of wheat (Table 1). This might be due to using of the same variety.

Days to 90% physiological maturity

The effect of fungicides were not significantly ($P < 0.05$) influenced days to 90% physiological maturity of wheat (Table 1). This might be due to using of the same variety.

Plant height

The effect of Fungicides significantly ($P < 0.05$) influenced plant height (Table 2). The result indicated that height of wheat plants increased as rust diseases controlled even though there was no statistically different among test fungicides (Table 1). The tallest plant (79.94 cm) was recorded from plot treated with Take-Off 293% SC while the shortest plant (68.55 cm) was obtained at untreated/control plot. This is because of the vital role of fungicides in controlling rusts which favor vegetative growth and resulted for significant influence on plant height.

The result of this study agreed with that of Yared et al (2018) where they reported significant effect of fungicides on height of bread wheat.

Spike length

The analysis of variance revealed significant ($P < 0.05$) effect of fungicides on the spike length of bread wheat (table 1). The result showed that using of fungicides increased spike length. Thus, the longest spikes (8.99 cm) were obtained at Take-Off 293% SC and this was statically at par with other fungicides (Table 2). The increase in spike length by using fungicides might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to control of rust diseases.

Table 6.Effect of fungicides against bread wheat rusts, yield component and yield of bread wheat at highlands of Guji zone

Fungicides	Yellow Rust severity (%)	Stem Rust severity (%)	Date to heading	Date to maturity	Plant height (cm)	Spike length (cm)	Thousand kernels weight	Grain yield (kg/ha)	Biomass (t/ha)
Diprocon 30 EC	15.06 bc	11.7 ab	72.67	141.7	78 a	7.663 a	28.8 a	2486 a	5.629 ab
Jeba 25 EC	18.44 b	13.38 ab	72	141.7	79.33 a	7.993 a	28 a	1730 b	3.673 c
Untreated	85.03 a	18.51 a	72.33	141	68.55 b	5.777 b	18.4 b	987 c	2.937 c
Take-Off 293% SC	7.68 d	5 .00b	72.33	142	79.94 a	8.997 a	28.27 a	2738 a	5.821 a
Orozole 25EC	15.06 bc	16.75 a	72.67	141.3	77.89 a	8.387 a	27.47 a	2055 b	4.816 b
Rex Duo	10.02 cd	6.67 b	72.33	142	76.16 a	8.33 a	28.13 a	2587 a	5.411 ab
Mean	25.21	12.00	72.39	141.61	76.65	7.86	26.51	2097.12	4.71
LSD(0.05)	6.05	8.60	NS	NS	6.26	1.66	6.05	327.44	0.915
CV (%)	13.2	39.4	1.8	0.3	4.5	11.2	12.6	8.6	10.7

Means with the same letter in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, NS= non-significant, LSD= Least Significant Difference at 5% level,

Thousand kernels weight

The effect of fungicides significantly ($P< 0.05$) influenced thousand kernels weight of wheat (Table 1). Using fungicides increased thousand kernels weight of bread wheat even though there was no statistically significant difference between them (Table 1). The highest thousand kernels weight (28.8 g) was recorded at application of Diprocon 30 EC followed by Take-Off 293% SC. On the other hand, the minimum thousand kernel weight (18.14 g) was observed at nil

application. Thousand kernels weight obtained from the overall treated plots were significantly higher than thousand seed weight from the unsprayed plot/control. This might be due to the improvement of seed quality and size due to control of rust diseases. In agreement with this result, Wubishet and Tamene (2016) reported significant thousand kernels weight for bread wheat.

Above ground dry biomass

The above ground dry biomass was significantly ($P < 0.05$) affected by the effects of fungicides (Table 1). The highest above ground dry biomass (5.82 t ha^{-1}) was obtained at Take-Off 293% SC whereas the lowest above ground dry biomass (2.937 t ha^{-1}) was produced from unsprayed plot (Table 1). The result is consistent with that of Wubishet and Tamene (2016) who reported increased above ground dry biomass of wheat by up to 34.78% as compared to control, revealing the benefit of fungicide.

Grain yield

The analysis of the result showed that the effects of fungicides significantly ($P< 0.01$) affected the grain yield of bread wheat (Table 1). Using of fungicides significantly increased grain yields of wheat than unsprayed/control. Thus, the highest grain yield (2738 kg ha^{-1}) was obtained at Take-Off 293% SC and it was statistically at par with Rex Duo with grain yield of 2587 kg ha^{-1} whereas the lowest grain yield (987 kg ha^{-1}) was recorded at control/unsprayed plot (Table 1). In general, grain yield obtained from Take-off 293% SC plots exceeded the grain yield from the unsprayed/control plots by about 63.95%.

In line with the result of this study, Wubishet and Tamene (2016) reported increment of grain yield of bread wheat through application of fungicides. Similarly, Yared et al. (2018) also reported significant effect of fungicides on grain yield of bread wheat.

Farmers' Selection Criteria

In this case, farmers were allowed to evaluate the fungicides using their own criteria. Because, they have a broad knowledge base on their environments, crops and disease built up over many years and do experiments by their own and generate innovations, even though they lack control treatment for comparison and statistical tools to test the hypothesis (Bänziger et al.,2000). Based on this concept, farmers were informed to set criteria for selecting best fungicide according to their area before undertaking selection. This was done by making group discussion among the farmers which comprises elders, women and men. After setting the criteria they were informed to prioritize the criteria according to their interest. By doing this, farmers were allowed to select fungicides by giving their own value. Accordingly, Diseases on leave, disease on stem, disease on head, head infection, stand of the crop, seed infection etc. are criteria's outlined by the farmers. Based on set criteria, the evaluated fungicides were revealed various values by the evaluators (farmers). With this regard, Take-Off 293% SC fungicide and Rex Duo were showed better performance in rust Diseases control.

Partial budget analysis

Analysis of the net benefits, total costs that vary and marginal rate of returns are presented in Table 2. Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation by farmers. The studies assessed the economic benefits of the treatments to help develop recommendation from the agronomic data. This enhances selection of the right

combination of resources by farmers in the study area. The results in this study indicated that the application of fungicides resulted in higher net benefits than the unsprayed/control treatments (Table 2).

As indicated in Table 2, the partial budget analysis showed that the highest net benefit (Birr 43383.91 ha^{-1}) was recorded at application of Take-Off 293% SC followed by Rex Duo (40318.48Birr ha^{-1}), and lowest was from control treatment. To use the marginal rate of return (MRR%) as basis of fungicide recommendation, the minimum acceptable rate of return should be between 50 to 100% (CIMMYT, 1988). In this study application of Take-Off 293% SC gave the maximum economic benefit (43383.91 ha^{-}) with marginal rate of return (9857.82%). Therefore, on economic grounds, using of Take-Off 293% SC would be best and economical, and recommended for production of bread wheat in the study area and other areas with similar agro-ecological conditions.

Table 2. Partial budget and marginal rate of return analysis for participatory fungicide selection

Treatments (Fungicides)	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	874.02	15732.31	0.00	15732.31	0.00
Diprocon 30 EC	2160.00	38880.00	425	38455.00	1314.402
Jeba 25 EC	1557.39	28033.04	375	27658.04	3180.195
Take-Off 293% SC	2435.22	43833.91	450	43383.91	9857.826
Orozole 25EC	1866.52	33597.39	400	33197.39	22157.39
Rex Duo	2281.30	41063.48	745	40318.48	D

CONCLUSIONS AND RECOMMENDATIONS

In areas where hot spot for bread wheat diseases like Guji Zone of Southern Oromia, it's important to take immediate action towards setting appropriate research methods. In such case, Participatory fungicide selection is an effective tool in facilitating the adoption and extension of the improved technologies; because, the users are allowed to participate in selecting appropriate technologies by employing their own indigenous knowledge. As the result, the current study was also verified that farmers were able to participate in selecting fungicides through employing their own selection criteria. Thereby, Take-Off 293% SC fungicide was selected by the farmers and recommended for the study areas and similar agro-ecologies. The analyzed data also revealed that using of fungicides increase yield by decrease wheat rust diseases. Application of Take-Off 293% SC has produced a yield advantage of 63.95% and 5.85% compared to control (unsprayed) and standard check respectively. Therefore, based on partial budget analysis, yield, rust disease control and farmers selection, using of Take-Off 293% SC fungicide which leads to the optimum yield of bread wheat by decreasing rusts and can be recommended for the study area and other areas with similar agro-ecologies.

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Participatory Varietal Evaluation and Selection of Improved Food-type Common Bean Varieties in low-mid altitude Districts of Guji zone, Southern Oromia

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ABSTRACT

Field experiment was conducted to select the best adapted and high yielding common bean variety(s) at mid-lowlands of Guji zone during 2019 main cropping season. The experiment was carried out in randomized complete block design with three replications at one potential site and three farmers' fields were received one replication for each. Twelve improved common bean varieties were used for this study. The varieties were evaluated for days to flowering and maturity, plant height, number of branches, number of pods, number of seeds, thousand seeds weight and grain yield and farmers selection criteria such as plant establishment, lodging, earliness, synchrony to maturity, free of disease and insect pests, drought tolerance, shattering, seed size, seed color, market value and overall field performances. The analysis result showed highly significant ($P \leq 0.01$) differences among varieties for all studied parameters except the insignificant difference for number of primary branches per plant. The varieties Nasir (37.4 kg ha^{-1}), Hawassa Dume (31.3 kg ha^{-1}), and Angar (30.5 kg ha^{-1}), were found to be high yielder. While farmers selected Ibado, Loko and KAT-B9/Dursetu in terms their own traits such as large seed size, uniformity red and red mottled colored seed, earliness and high market demand as the most preferred varieties. Eventually, the PVS help the farmers to choose the variety that possesses the character preferred by customer on market and meets their interest. Therefore, the varieties Ibado (25.2 kg ha^{-1}), Loko 25.3 kg ha^{-1} & KAT-B9 (Dursetu 21.3 kg ha^{-1}) can be suggested to the scaling-up trials as per their adaptability and farmers preferences.

Keywords: Adaptability; Farmers preferences; Participatory evaluation; Market value

INTRODUCTION

Common bean (Phaseolus vulgaris L.) is the most important food and export crop in Ethiopia. It is well adapted to areas that receive an annual average rainfall ranging from 500–1500 mm with optimum temperature range of 16°C–24 °C, and a frost free period. Usually high temperatures do not affect it if adequate soil water is present, although high night temperature will inhibit pollination (Katungi et al., 2009). Moreover, it performs best on deep, friable and well aerated soil types with optimum pH range of 6.0 to 6.8 (Kay, 1979).

Common bean is considered as the main cash crop and protein source of farmers in many low lands and mid altitude zones of Ethiopia. Consequently, it is known as "the poor man's meat" due to its high protein content, which compensates for the deficiency that could have occurred in

a population with low income. The crop is grown by subsistence farmers either as a sole crop or intercropped with cereal and tree crops. The national average yield of common bean 1.5 tons/ha (CSA, 2010) is low due to drought, lack of high yielding varieties, poor cultural practices and disease.

Its production is concentrated in two regional states: Oromia and the Southern Nation Nationality and Peoples Region (SNNPR), which accounts about 73% of the total national production (CSA, 2010). Both white canning and colored food type bean are grown. Farmers in central rift valley prefer white bean while farmers of Southern Ethiopia prefer red bean (Ferris and Kaganzi, 2008). The demand for red bean is high but the production is not satisfied. A local red seeded bean cultivars are popular in Southern Oromia. The main reasons for its popularity were due to its earliness in maturity and its dual importance. First, it provides an excellent nutritional complement to maize and enset which is the main local dishes, and secondly it is major cash crop of the lowland and mid-altitude districts of Guji zone. Furthermore, the demand for red beans in northern Kenya, associated with drought in these areas, has encouraged production of red beans in this region (Ferris and Kaganzi, 2008). However, improved common bean varieties developed at research centers has not evaluated for major common bean quality traits at farmers condition of the zone.

Participatory variety selection is a process by which the field test of finished or nearly finished varieties are done with the participation of farmers. Therefore, PVS is always an integral part of PPB but can also stands alone in an otherwise non-participatory breeding. It involved also in selecting varieties that they judge to be most appropriate for their own uses from among a range of fixed (stable) varieties that are being field tested.

Participatory Varietal Selection has shown success in identifying more number of preferred varieties by farmers in shorter time than the conventional system, in accelerating their dissemination and increasing cultivar diversity (Weltzien et al., 2003). Therefore, adding information on farmers' perspectives of plant and grain trait preferences to these criteria will be helpful to the variety selection process. Research costs can be reduced and adoption rates increased if the farmers are allowed to participate in variety testing and selection (Yadaw et al., 2006). Here, further indicated that farmers and the researcher used different parameters and methods to evaluate the tested genotypes. Thus researchers must contemplate farmers choice traits in their varietal development such as seed yield, seed size and overall field performance. The current selection process also confirmed that farmers were capable of selecting important traits for grain yield and based on those traits demonstrated to identify superior varieties adapted to their locality.

Participatory varietal selections are farmer-centered varietal selections limited to testing of the finished varieties. Farmers evaluate various traits that are vital to them and help to increase on-farm varietal diversity, faster varietal replacement and rapid scaling up. Farmers evaluated and selected the varieties depending on their criteria’s from the mother's trial. Improved common bean varieties are not yet put under production in the potential areas of Guji zone. Based on the weather condition and soil type, the area was highly suitable for this crop production. Hence, to introduce this crop to the potential areas of the zone. Therefore, this study was conducted with

the objectives to evaluate and select common bean varieties for high yield and other agronomic traits through farmer's participation in decision making during the selection process.

MATERIALS AND METHODS

Study areas

The experiment was carried out in the major common bean producing areas of Guji zone [Adola Rede (Adola site, Kiltu Sorsa & Dole kebeles] and Wodera (Calo Sigda kebele) of southern Oromia during 2019 main cropping season. One potential site and three farmers' fields were selected for the study based on the active involvement of the farmers in the production of common bean in the districts.

Experimental Materials and Management

Before selecting the experimental materials local needs were assessed using semi-structured (informal) interview. Based on their preference, early maturing varieties of red and red mottled common bean varieties were obtained from National and Regional Agricultural Research Centers. Twelve (12) improved common bean varieties were used for the study. The trial was organized in randomized complete block design with three replication on-station as mother trial. Other three farmer fields were planted with one replication each considered as baby trials. The plot size was 3m x 2.4m with 6 rows and 10cm spacing between plants, while the net harvested area $6m^2$. To reduce border effect, data was taken from the central four rows. Weeding and other management practices were done as required. The fertilizer rate 121 kg NPS/ha was applied at time of planting**.**

Table1. List of common bean varieties tested

No	Variety	Seed size	Seed color	Adaptation area (masl)	Breeder/Maintainer
1	Angar	Small	Red	1600-2200	BARC
2	Babile	Medium	Red	1600-2200	HU
3	DAB107	Large	Red	1600-2200	MARC
4	Hirna	Large	Red	1600-2200	HU
5	Haramaya	Medium	Cream	1650-2200	HU
6	Ibado	Large	Mottled	1600-2200	AARC
7	Nasir	Small	Red	1600-2200	MARC
8	Hawassa dume	Small	Red	1800-2200	HwU
9	KAT-B9/Dursetu	Medium	Red	1600-2200	HU
10	Loko	Large	Cream	1300-1900	BARC
11	SER119	Medium	Red	1600-2200	MARC
12	Tinike	Large	Red	1600-2200	HU

Key: BARC= Bako Agricultural Research Center, HU= Haramaya University, HwU= Hawassa University; MARC= Melkassa Agricultural Research Center, AARC= Areka Agricultural ResearchCenter

Data Collection and Analysis

Farmer's preferences were identified using Focus group discussions held with 36 households of 20 male and 16 female households through actively encouraging female participation. The households were randomly selected from each kebeles' in the districts. Farmers were participated

in evaluation and selection of improved common bean varieties at maturity and after harvest from baby trials through farmer research group. Field days were arranged at different growth stages to collect the data using agreed criteria by research participant. Farmers were discussed and agreed on criteria they thought to be important for selecting a given variety at a particular development stage. They set their selection criteria and ranking of varieties according to their setting criteria.

The participant farmers categorized common bean traits such as plant establishment, lodging, earliness, synchrony to maturity, free of disease and insect pest, drought tolerance, shattering, seed size, seed color, market value (high market demand) and overall performance. The rank sum method each trait for each variety was used to rank varieties based on farmers' selection criteria. The value of each trait has equal weight. The ranking procedure was explained for participant farmers and each selection criterion was ranked from 1 to 5 (1 = Very poor, 2 = Poor, 3 = Average, 4 = Good and 5 = Very good) for each varieties. Simple ranking is a tool often used to identify promising varieties based on farmers' preferences.

RESULT AND DISCUSSION

Analysis of Variance and Mean Performances

The experiment was conducted on twelve improved common bean varieties to select high yielder and best in farmers setting criteria. Mean squares of various agronomic characters are presented in Table 2 whereas, mean values of different traits are presented in Table 3 and 4.

Days to Flowering

Highly Significant variations ($P < 0.01$) in days to flowering between varieties were observed (Table 2). Dursetu (KAT-B9) variety showed significantly shorter days to flowering (42 days), and others showed medium days to flowering ranging between (48-51) days.

Days to Maturity

Analysis of variation revealed that highly significant variation in days to maturity was observed (Table 2). Variety Dursetu/KAT-B9 scored the shortest days to maturity followed by Hawassa dume and the earliest when compared to the other varieties. While Tinike, Haramaya and Hirna were late matured varieties. The average days needed for common bean variety to maturity was three months and above. Thus, early maturing varieties have the advantage or adaptable over the late once in environments where rain begins late and ends early.

Plant Height

The varieties were highly significant ($P < 0.01$) varied for plant height. Plant height ranged from 42.87.0 to 104.47 cm. Haramaya was the tallest variety and had climbing character (104.47 cm) followed by Babile (98.97.3 cm) while the shortest variety was KAT-B9 (42.87 cm).

Number of primary branches plant^{-1}

Analysis of variance showed insignificant differences among varieties for branches per plant (Table 2).

Pods Plant^{-1}

Highly significant differences ($P < 0.01$) were also observed among varieties for number of pods per plant. Higher pod number was recorded for Nasir, Angar, Hawassa dume and SER119 and the lowest was for Haramaya (Table 4).

Seeds Pod^{-1}

Varieties also showed highly significant differences (P < 0.01) in number of seeds per pod (Table 2). Seeds per pod ranged from 3-6 seeds (Table 3). Angar, Hawassa dume, Nasir and SER119 were recorded maximum number of seeds while Loko, Haramaya and Ibado were minimum in number of seeds per pod (Table4 1).

100 -Seed Weight

Mean square for 100 seed weight revealed highly significant differences (P<0.01) among the varieties (Table 2). The range of 100-grain weight was 25.63 g to60.97 g. The maximum 100-seed weight (60.97g) was observed for Loko followed by Hirna (59.83g) and Ibado (58.83g) while minimum 100-seed weight was observed for Angar (25.63g) (Table 4).

Grain Yield

Varieties also showed highly significant differences (P < 0.01) in seed yield performance (Table 2). Grain yield ranged from 2.03 tons ha^{-1} to 3.74 tons ha^{-1} with the grand mean of 2.71 tons ha^{-1}. Nasir (3.74 tons ha^{-1}), Hawassa dume (3.13 tons ha^{-1}) and Angar (3.05 tons ha^{-1}) were the top yielding varieties while Babile (2.03 tons ha^{-1}) was the lowest yielding variety.

Table 2. Analysis of variance for agronomic traits of mother trial

Source of variation	d.f	Mean Squares							
		DF	DM	PH	NBPP	NPOPP	NSPP	HSW	SY
Replication	2	2.03	23.03	20.32	11.60	14.02	0.20	67.02	0.59
Variety	11	17.97**	34.09**	930.47**	1.79^{ns}	87.08**	2.00**	559.92**	0.63**
Error	22	1.21	2.634	44.94	1.00	16.79	0.10	14.48	0.22
Total	35								

Key: ** = highly significant at the level of 1% probability, ns = non-significant, d.f = degrees of freedom, DF = days to flowering, DM = days to maturity, PH = plant height (cm), NBPP = number of branches per plant, NPOPP = number of pods per plant, NSPP = number of seeds per plant, HSW = hundred seed weight (g) and SY = seed yield (tons/ha)

Table 3. Mean values of different agronomic traits for mother trial

Variety	DF	DM	PH	NBPP	NPOPP	NSPP	HSW
Angar	49.33^{ab}	98.33^{b}	91.40^{bc}	4.30	23.87^{ab}	5.50^{a}	25.63^{d}
Babile	50.33^{ab}	97.67^{b}	98.97^{ab}	3.23	13.40^{de}	3.97^{b-d}	49.23^{b}
DAB107	48.67^{b}	99.67^{ab}	78.07^{de}	3.20	14.93^{cd}	4.40^{b}	48.07^{b}
Hirna	51.00^{a}	102.00^{a}	92.83^{bc}	3.27	19.23^{a-d}	3.67^{c-e}	59.83^{a}
Haramaya	50.00^{ab}	101.67^{a}	104.47^{a}	3.27	7.47^{e}	3.40^{e}	35.63^{c}
Ibado	50.67^{a}	97.00^{b}	54.47^{f}	5.43	13.57^{de}	3.43^{de}	58.83^{a}
Nasir	49.67^{ab}	98.33^{b}	82.17^{c-e}	3.30	24.67^{a}	5.13^{a}	26.23^{d}
Hawassa dume	49.33^{ab}	93.67^{c}	89.03^{b-d}	3.03	21.47^{a-c}	5.27^{a}	27.33^{d}
KAT-B9/Dursetu	42.00^{c}	90.33^{d}	42.87^{g}	4.53	15.87^{cd}	3.70^{c-e}	45.87^{b}
Loko	51.00^{a}	98.00^{b}	79.63^{de}	3.00	17.60^{b-d}	3.30^{e}	60.97^{a}
SER119	49.33^{ab}	97.33^{b}	74.83^{e}	3.40	25.37^{a}	5.20^{a}	27.43^{c}
Tinike	51.00^{a}	101.67^{a}	76.37^{e}	2.87	15.23^{cd}	4.10^{bc}	44.47^{b}
Mean	49.36	97.97	80.40	3.54	17.72	4.27	42.46
LSD(5%)	1.86	2.75	11.35	1.69	6.94	0.55	6.45
CV(%)	2.20	1.70	8.30	28.00	23.10	7.60	9.00

Table 4. Mean for grain yield (tons ha^{-1}) of the common bean varieties for mother trial.

No	Variety	Grain yield (tons ha^{-1})	Rank for yield
1	Angar	3.05	3
2	Babile	2.03	12
3	DAB107	2.53	7
4	Hirna	2.50	10
5	Haramaya	2.73	6
6	Ibado	2.52	9
7	Nasir	3.74	1
8	Hawassa dume	3.13	2
9	KAT-B9/Dursetu	2.13	11
10	Loko	2.53	8
11	SER119	2.82	4
12	Tinike	2.76	5
	Mean	2.71	
	LSD (5%)	0.79	
	CV (%)	17.30	

Key: LSD = Least Significant Difference and CV=Coefficient of Variation.

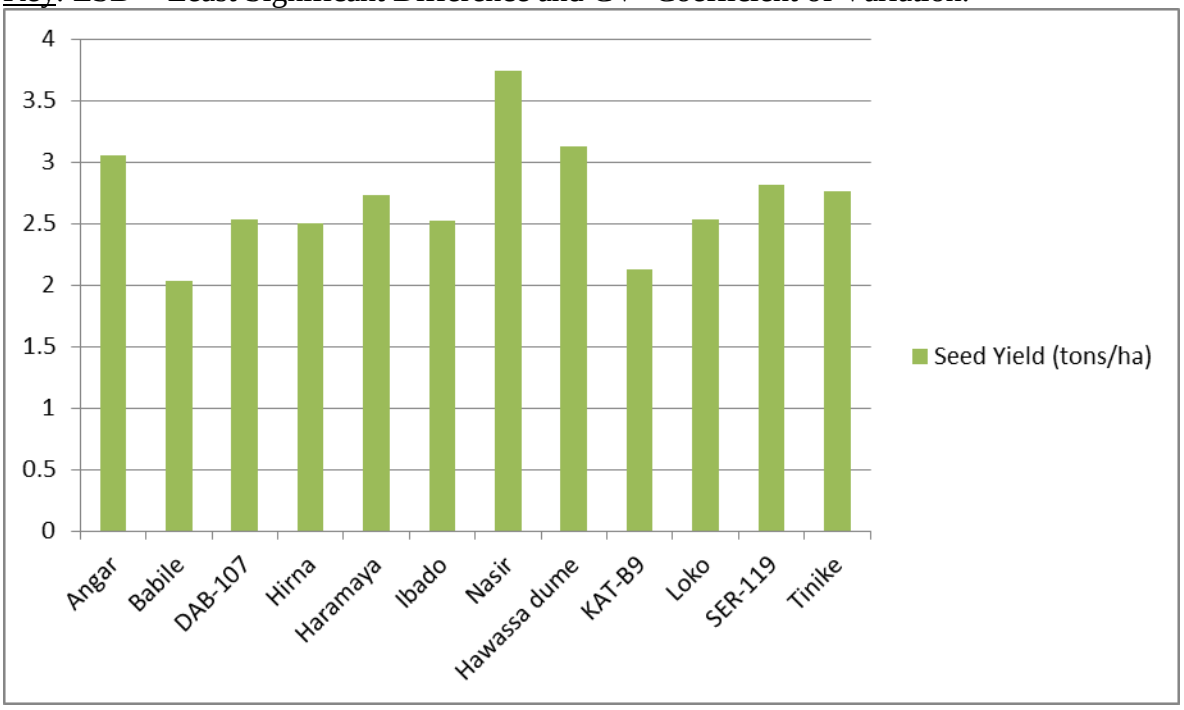

Figure 1. Means for grain yield of twelve common bean varieties tested during 2019 of main season

Variety Evaluation and Selection Criteria

Farmers' evaluations were conducted in the three mother trials and selection had diversified selection criteria to accept and reject bean variety (Table 5). This diversity during selection is an indication of the complexity of users' preference. Abraham (2016) reported that, when there is more diversity in selection criteria, there is better chance of maintaining on farm diversity since positive traits are seldom found on single variety. However, the result from farmers evaluation revealed that **large seed size,** and uniformity red and red mottled colored seed for **high market**

demand (market value) and **earliness** were the major decisive criteria in retaining and rejecting the variety. Similar findings were reported for pure red and red mottled seed color and high yielding variety were the major decisive criteria to accept or reject common bean in Southern Ethiopia (Asrat, 2008 and Abraham, 2016).

The evaluations mean score value for each variety ranged from 8.4 to 13.4 (Table 5). Ibado (13.4) scored the highest value and the lowest was scored by Haramaya (8.4). Loko (11.5), Dursetu (KAT-B9) (11.4) and SER119 (11.1) were ranked second, third and fourth best varieties by farmers, respectively. Both women and men were participated in the selection process.

Farmers and the researcher used different parameters and methods to evaluate the tested varieties. It is obvious that farmers have demonstrated the ability to select well-adapted and preferred varieties under their circumstances using their own criteria. A range of improved varieties should be available for selection under their participation. Researchers must consider farmers selection traits in their varietal development such as grain yield, seed size, seed color, market value and overall field performance. Generally, the variety should have tolerance to biotic and abiotic stresses and have good marketability and consumer preferences.

Table 5. Sum of scores at three farmer sites "baby trials" for each trait, overall mean value of each selection criterion (traits) and ranking of varieties.

		Farmer's Criteria (Traits)													
No	Variety	PE	LO	EL	SM	FDP	DT	SH	SS	SC	MV	OAP	Total	Mean	Rank
1	Angar	9	11	11	10	14	13	14	10	13	6	5	116	10.5	5
2	Babile	7	11	10	10	11	9	14	13	12	8	6	111	10.1	7
3	DAB107	8	11	11	10	11	11	12	14	13	10	6	116	10.5	5
4	Hirna	8	10	8	7	10	7	13	15	12	9	6	105	9.5	8
5	Haramaya	7	3	5	7	10	8	15	10	11	10	6	92	8.4	9
6	Ibado	10	15	13	13	13	13	15	15	15	15	10	147	13.4	1
7	Nasir	7	13	13	11	12	13	13	9	10	6	5	114	10.4	6
8	Hawassa dume	7	13	10	11	11	10	14	9	10	6	4	105	9.5	8
9	KAT-B9	6	13	13	13	12	13	11	13	13	12	6	125	11.4	3
10	Loko	7	13	12	13	12	12	14	13	13	10	7	126	11.5	2
11	SER119	9	14	13	11	12	13	13	11	12	8	6	122	11.1	4
12	Tinike	5	13	7	8	12	9	14	13	13	10	7	111	10.1	7

Key: PE = Plant establishment, LO = Lodging, EL= Earliness, SM = Synchrony to maturity, FDP = Free of disease and insect pest, DT= Drought tolerance, SH= Shattering, SS= Seed size, SC= Seed color, MV= Market value and OAP = Overall performance.

CONCLUSIONS AND RECOMMENDATIONS

Introducing new varieties through PVS help the farmers to choose the variety that possesses the character preferred by customer on market and meets their interest. Besides, the training given during PVS process enhances capacity of the farmers for identifying varieties and managing varietal diversity. It was observed that as the area is highly market-oriented, high-yielding

varieties were not top ranking in selection list due to their small seed size and low market demand. The promising variety Ibado was selected as the first top ranking according to farmers' perception at all three farmer sites. Therefore, based on farmers' preference, varieties Ibado, Loko and KAT-B9 are recommended for production for mid-lowland areas of Guji zone and similar agro-ecologies. The identified varieties will be promoted to the scaling up trials as per their adaptability and farmers preference.

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Genotype by environment interaction and stability analysis of malt barley genotypes in highlands of south eastern Ethiopia

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ABSTRACT

Evaluation of genotypes under multiple environments is the prerequisite for the development of stable and superior genotypes for sustainable barley production and a changing climate. GGE (G, genotype and GE, genotype (G) by environment (E), interaction) biplot and the AMMI (The Additive Main effects and Multiplicative Interaction) model are the effective methods to find out the genotype(s) which are stable and suitable to cultivate in specific or multiple environments. The study was conducted with the objectives to determine the magnitude effect of genotype, environment, and their interactions on economically important traits and identify stable malt barley (Hordeum distichon L.) genotypes. The GxE interaction of grain yield was further partitioned using AMMI and it showed the first two IPCA axes explained most of the sum of squares. According to stability analysis measures genotype NDCARM-191 was the most stable and selected.

Key words: GxE interaction, malting barley, stability analysis

INTRODUCTION

Barley is cultivated worldwide mainly for malt and beer production (Kilic, 2014). G×E interaction governs the identification of the stable yield performer genotypes suitable for a specific environment or for several environments (Akbarpour et al., 2014). An efficient assessment of G×E interaction is very essential to determine the yield potential of genotypes along with stable yield performance (Dehghani et al., 2010). If relative performances of the entries grown in different environments are highly different, then GxE becomes a major challenge to crop breeding programs (Zobel and Talbert 1984). Developments of multiline varieties, clustering of environments into homogenous groups and/or selecting genotypes that perform well across many environments are the solution to alleviate the problem (Mckeand et al., 1990). Some genotypes are adapted to a broad range of environmental conditions, while others have limited adaptation. Performance of genotypes across variable environments can be assessed using different stability parameters.

The AMMI model analysis is useful in visualizing the main effects of genotype x environment interactions. It can estimate the genotype responses and separate noise from real source of variation through partitioning of the GxE. IPCA scores of genotypes in AMMI analysis are the key to interpret the pattern of genotype response across environments (Gauch and Zobel, 1997). The model is important for cultivar evaluation, recommendations and selection of test sites (Gauch and Zobel, 1997). It provides a graphical representation or biplot to summarize information on the main effects and the first principal component scores of the interactions (IPCA1) of both genotypes and environments simultaneously (Crossa, 1990). Although the AMMI biplot can be very effective in summarizing the variation and in visualizing main effects**,** it does not show which variety is high yielding in which environment (Yan et al. 2000) nor identify which environment is most representative is not visualized in this model (Yan, 2001).

This is, however, possible through the GGE approach. GGE biplot is composed of genotype and genotype x environment factors, which are important for varietals response trials (Muez et al. 2014). It is more important in visualizing the cross over of G x E interaction (Ma et al. 2004).

The method of Eberhart and Russell (1966) was also used to calculate the regression coefficient (bi), deviation from regression (Sdi2) and coefficient of determination (Ri2). It was calculated by regressing mean grain yield of individual genotypes on environmental index, where stability values with minimum values are considered stable. To select genotypes to the target environment, assessment of stability and using adequate stability measure is paramount important. Hence, the objective of this study is to assess the stability of malt barley genotypes across diversified environments of Bale zone using different parametric stability models.

MATERIALS AND METHODS

Sixteen malt barley genotypes were evaluated including three standard checks (HB1963, Singiten and HB1964) under rain fed condition at four locations for two consecutive years (2018-2019) during bona cropping season at Sinana main station, Adaba sub site and Goba and Dodola on farmers' field. The experiment was conducted at each location on vertisoils, texturally classified as clay loam soil. Sinana Agricultural Research Center (07° 07'10.837"N latitude and 040^o13'32.933"E longitude7^oN latitude and 40^oE longitude; and 2400m a.s.l.) is located 463 km south east of Addis Ababa and 33km East of Robe, the capital of Bale zone. Goba is located 50-km from Sinana and about 15km from Robe in the southwest direction. Adaba and Dodola are found at a distance of 100km and 120km in the west of Sinana, respectively.

A Randomized complete block design with three replications was used at all locations. The plot size was 3 m^2; six rows with 2.5m length at 20cm inter spacing. Recommended fertilizer rate of 150kg/ha NPS at planting and seed rate of 125kg/ha was used. All agronomic practices were done uniformly as recommended for barley production in the area.

Data analysis

Before computing the combined analysis, error variance homogeneity test was verified using Hartley's test (F-max test) (Gomez and Gomez, 1984). In the combined analysis of variance location were considered as random variable and genotypes were considered as fixed variable. Data analysis was performed by using R-statistical software version 3.4.5 (R software, 2018) and Genotype by Environment analysis with R (GEA-R version 4.0) (Pacheo et al., 2016). Additive main effect and multiplicative interaction AMMI (Zobel et al., 1988) models were used to compute stability In the AMMI model, the magnitude obtained in the first principal component (IPCA1) of each genotype was used as indicator stability. The lower the absolute value of IPCA1indicated the stable genotype.

RESULT AND DISCUSSION

The result of pooled analysis of variance revealed significant difference (p,<0.01) for all tested parameter (day to heading and maturity, plant height, stand percent, grain yield and thousand kernel weight over combined location (Table 1). The highest pooled mean performance of grain yield was recorded for the genotype NDCARM-191 (2.8 t/ha) whereas the lowest mean was obtained from genotype ICARDA GP-180 and NDCARM-229 (1.9 t/ha) (Table 1). The result for combined analysis of variance showed that difference among genotypes, locations and

genotype by location interactions were statistically different at probability level of p<0.01 for all traits included in the study.

Table 1. Combined mean performance of agronomic traits and disease reaction of 16 malt barley genotypes tested at Sinana, Goba, Adaba and Dodola during 2018 and 2019 main season

GENOTYPE	DH	DM	PH	ST	GY	TKW	HLW	NB 00-99	SC 0-5	LR%	INF	DEAD
NDCARM-2.8	64.2	115.8	83.5	74.1	2	30.8	63.6	82	0	10ms	12.7	5.5
IBON HI 14/15-88	63	116	80.8	73.3	2.6	40.3	66.0	76	0	5ms	8.7	3.1
DN ICARDAMB-161	61.6	114.8	77.7	74.5	2.4	34.1	60.8	84	2	5ms	10.0	4
ICARDA GP-180	63.1	114.9	88.1	73.1	1.9	39.4	66.0	82	1	10ms	9.3	2.5
ICARDA-156	68.9	116.2	90.8	80.2	2.1	33.8	65.6	84	2	0	10.3	4.5
NDCARM-191	63.2	114.4	84	72.7	2.8	31.9	60.4	86	1	5ms	10.3	4
MBBELGIUM-5	62	113.2	79	72.6	2.4	31.3	58.8	82	0	5ms	10.8	5
MBBELGIUM-7	62.3	112.2	90.2	72.3	2.2	43.2	67.6	76	0	10ms	14.2	4.8
IBON HI14/15-146	64.9	115.9	84.8	76.7	2.3	40.8	68.8	82	1	10ms	9.8	3.8
MBHIBYT-23	63.1	115.1	90.3	76.3	2.3	41.2	68.0	84	2	10ms	11.7	4.17
IBON HI13/14-69	61.8	113.5	89.9	76.2	2.4	38.8	66.8	84	2	5ms	9.5	4
IBON HI14/15-98	65.8	115.8	92.8	79.1	2.4	39.9	67.2	84	1	5ms	9	3
NDCARM-229	65	113.8	78.5	72.3	1.9	34.8	66.0	84	0	5ms	7.8	2
HB1963	68.3	118.5	93.4	81.4	2.5	38.5	70.8	76	0	10ms	9.5	3
Singten	60.4	115.3	86	73.2	2.7	42.2	66.0	84	0	0	11	4.1
HB1964	65.1	113.6	94.1	77.6	2.4	45.7	63.2	83	0	10ms	7.5	2.8
Mean	63.9	114.9	86.5	75.4	2.3	37.9						
LSD	4.5	4.1	9.2	5.1	0.5	2.1						
CV	7.1	3.6	10.6	11.9	30.2	9.8						

DH= days to head, DM= days to mature, PH= plant height, ST (%) = stand percent, TKW= thousand kernel weight, GY= grain yield, HLW=hectoliter weight, NB= net bloch, SC = scald, LR=leaf rust, ST= stem rust, INF=shoot fly infestation, DEAD=dead plant, CV= coefficient of variation, LSD= least significance difference

Additive main effect and Multiplicative interaction (AMMI)

AMMI analyses of variance were significant effects for genotype (G), environment (E), and GxE interaction (Table 2). Overall, 74.2 % of the total sum squares (SS) was attributed to environment effects; only 5.2% and 20.6 % were attributed to genotypes and GxE interaction effects, respectively. The large sum square of the environment implying that the environment was with higher differential in discriminating the performance of the genotype and caused most of the variation in grain yield. Therefore, tested locations in this experiment were diverse for the barley grain yield and a large part of variation in barley grain yield might have resulted from change in environment. In multi location yield trials the variation captured by the environment is 80% and genotype and genotype by environment interaction explained 10% (Sabaghnia et al., 2013). Large environmental sum square was reported (Abay et al., 2009) and (Gebremedhin et al., 2014) in food barely and (Bantayehu, 2009) in malt barley had found large environmental variance. Several other researchers also found high environmental effects in different crops such as wheat and oilseeds (Brar et al. 2010; Mohammadi and Amir 2011; Letta et al. 2008; Dash and Pandey 2009; Sing et al. 2009).

Table 2. The Additive and multiplicative interaction Analysis of variance

Variables	DF	SS	MS	Explained %
Environment	7	328.6	46.9**	74.2
Genotype	15	23.1	1.5**	5.2
Genotype x Environment	105	91.4	0.9**	20.6
IPCA 1	21	44.0	2.1**	48.2
IPCA 2	19	20.4	1.1**	22.3
IPCA 3	17	13.2	0.8**	14.4
IPCA 4	15	5.7	0.4NS	6.2
Residuals	256	111.9	0.4	

**p<0.01, ns=non-significant, DF=degree of freedom, MS=mean square

The AMMI analysis of variance for the multiplicative effect was further exploited by decomposing into principal components analysis. The first interaction principal component (IPCA1) captured 48.2% and the second interaction principal component (IPCA2) explained 22.3% and the two interaction principal component analysis cumulatively explained 70.5% of the genotype by location interaction. The mean square of IPCA 1 and IPCA2 were highly significant and this two PCA's accurately predict the AMMI model (Table 2 and Figure 1). Yan and Rajcan (2002) reported that the best accurate model of AMMI can be predicted by using the first two PCA's.

AMMI Stability Value (ASV): The additive main effect and multiplicative interaction effect stability analysis (ASV) is used to decompose the interaction effect. The interaction principal component one (IPCA1) scores and the interaction principal component two in the AMMI model are indicators of stability (Saad, 2013). Considering the first interaction principal component (IPCA1) the genotype HB1963 was stable (0.06) was followed by DN ICARDAMB-161(-0.07).When the second interaction principal component (IPCA2) was considered IBON HI 14/15-88 and NDCARM-2.8 was the most stable genotypes (Table 3). The two principal components have their own extremis, but calculating the AMMI stability value (ASV) is a balanced measure of stability (Purchase, 1997). The Genotype with lower ASV value is considered stable and genotype with higher ASV is unstable. According to the ASV ranking, the genotype IBON HI 14/15-88 was the most stable with an ASV of 0.14 followed by the genotype ICARDA GP-180 and MBBELGIUM-7 with ASV of 0.24 and 0.26, respectively. The genotype IBON HI14/15-98 was the most unstable with ASV value of 7.3 (Table 3). Genotypes IBON HI 14/15-88, HB1963, NDCARM-191, MBHIBYT-23 and DN ICARDAMB-161 also revealed the least yield stability index (YSI) indicating that these genotypes are stable genotypes.

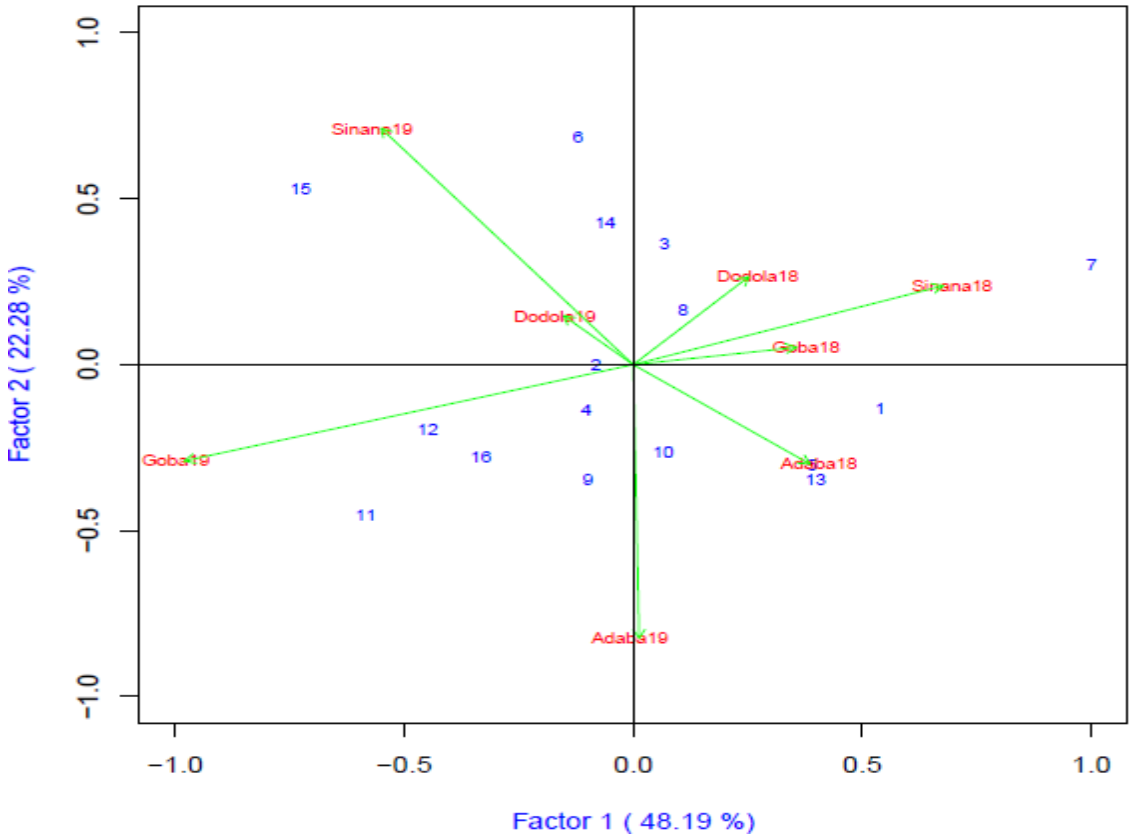

Figure 1 AMMI of the first two IPCA's (Number 1-16 represented genotypes mentioned in Table 1)

Table 3. Stability parameters of 16 Malt barley genotypes over environments

Genotype	IPCA1	IPCA2	ASV	rASV	YSI	bi	S2di
NDCARM-2.8	-0.62	0.15	0.92	12	26	0.63	0.10
IBON HI 14/15-88	0.10	0.01	0.15	1	10	0.85	-0.04
DN ICARDAMB-161	-0.07	-0.42	0.43	6	14	1.14	0.28
ICARDA GP-180	0.13	0.16	0.24	2	18	1.08	0.13
ICARDA-156	-0.45	0.36	0.76	9	22	0.69	0.04
NDCARM-191	0.16	-0.79	0.82	11	12	1.28	0.00
MBBELGIUM-5	-1.17	-0.35	1.74	15	19	1.63	0.07
MBBELGIUM-7	-0.12	-0.20	0.26	3	15	0.98	0.26
IBON HI14/15-146	0.10	0.40	0.42	5	16	1.14	0.05
MBHIBYT-23	-0.08	0.30	0.32	4	14	1.10	0.07
IBON HI13/14-69	0.67	0.53	1.12	13	18	0.96	-0.03
IBON HI14/15-98	0.53	0.23	7.31	16	22	0.64	-0.04
NDCARM-229	-0.46	0.40	0.79	10	25	1.35	0.05
HB1963	0.06	-0.51	0.51	7	10	0.58	0.63
Singten	0.83	-0.60	1.35	14	16	0.99	-0.07
HB1964	0.39	0.32	0.66	8	15	0.97	0.06

ASV= AMMI Stability Value, rASV=Rank of ASV, YSI=Yield Stability Index, bi= linear regression coefficient (slope), S2di= Deviation from the regression component of interaction

Linear regression

Genotypes performance is generally expressed in terms of three parameters, mean yield, regression coefficient (bi) and deviation from the regression (S di). According to this model a stable genotype should have a high mean yield, b = 1 and S2di = 0. Considering the three evolution of joint regression the genotypes IBON HI 14/15-88, DN ICARDAMB-161, ICARDA GP-180, MBBELGIUM-7, IBON HI14/15-146, MBHIBYT-23, IBON HI13/14-69 and Singten was stable with outstanding yield performance, having the regression slope b=1 and the minimum standard deviation. Generally according to the regression coefficient (bi) all the malt barley genotypes had similar response to the varying environmental condition. The Stability of barley genotypes measured by regression was not significantly different from 1.0 for most genotypes indicating a good potential for higher yields under improved environmental conditions.

Stability analysis based on GGE biplot

GGE biplot was the best way to visualize the interaction patterns between genotypes and environments and to effectively interpret a biplot (Yan and Kang, 2003). In this study, the 'which won where' feature of the biplot identified winning genotypes; NDCARM-191 (represented by genotype # 6) for instance, was the winning/corner genotype at Sinana, Goba, Adaba and Dodola (Figure 2). The vertex genotypes were the most responsive genotypes, as they have the longest distance from the origin in their direction as suggested by Yan and Tinker (2005). In contrast, result also showed some genotypes which fall in sectors where genotypes poorly adapted and genotype NDCARM-229 (represented by genotype # 13) poorly performed and adapted in the environments used using ranking genotypes; genotypes that are ideal for all environments also

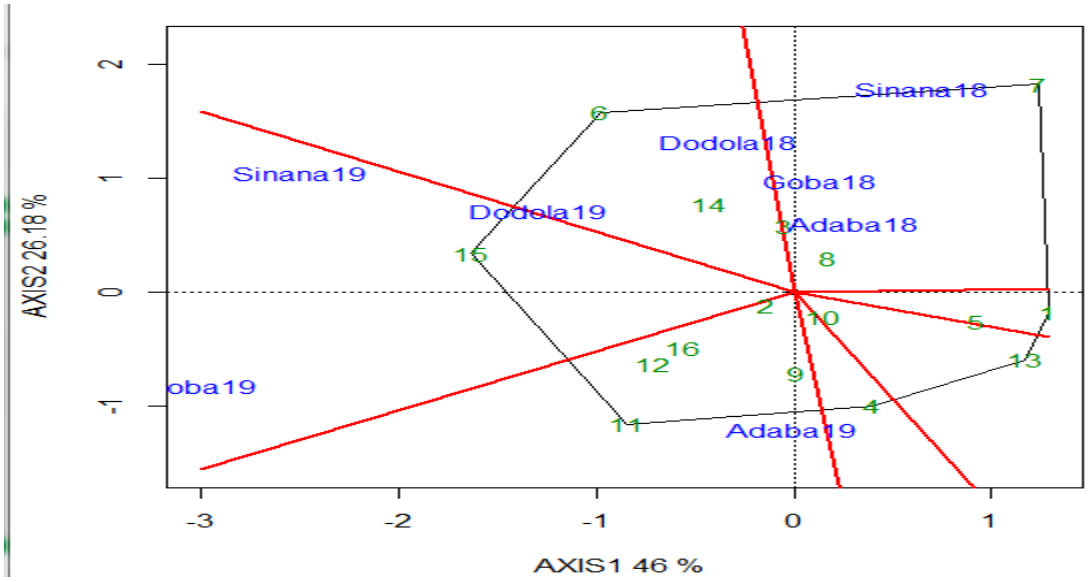

Figure 2 GGE biplots of 16 malt barley genotypes over the environments

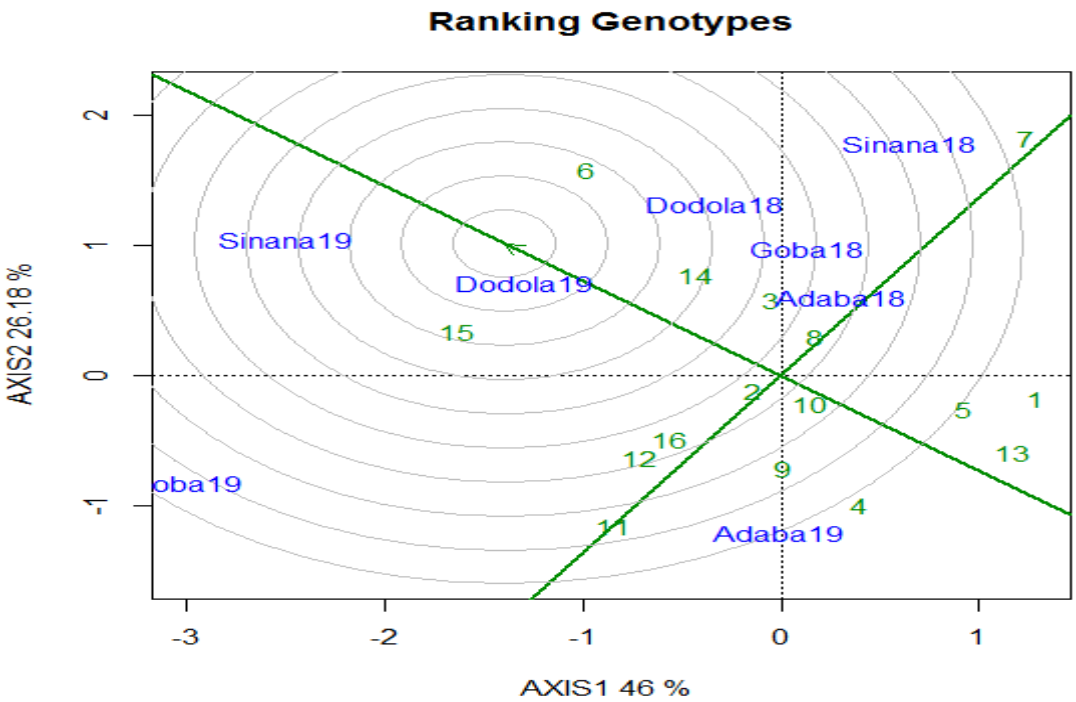

Figure 3. Ranking ideal genotypes for ideal environment

Visualized using imaginary line. Ideal genotypes should have the highest mean performance and stable. Therefore, genotype NDCARM-191 (2.8 t/ha) were found ideal to all locations (Figure 3).

CONCLUSION

The highest mean grain yield performance was recorded for genotype NDCARM-191 (2.8 t/ha). AMMI analysis revealed that mean square of the first interaction principal component axis (IPCA's) was found highly significant (P<0.01). Genotype NDCARM-191 was found stable and high yielder across all locations. This genotype also has better disease resistance and shoot fly tolerant. So this genotype is recommended for verification and to be released for farmers.

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FOOD SCIENCE RESEARCH

Assessment of microbial and physicochemical qualities of cow milk in selected Districts of Borena Zone, Oromia Regional State, Ethiopia

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ABSTRACT

This research study was initiated to evaluate the microbial and physicochemical qualities of randomly selected cow milk samples in three districts of Borana Zone (Gomole, Elwaye and Dubluk). The microbial and physicochemical analyses were performed following standard protocols. Milk samples collected from Elwaye Town showed the maximum standard plate and total coliform count values of 8.5 log10 CFU mL-1, and faecal coliforms have been detected in 98% of the samples across the three districts. The maximum mean counts of Salmonella (mean prevalence: 39.9%) and Shigella (mean prevalence: 95.8%) of 5.5 (Elwaye) and 8.4 (Elwaye & Dubluk) log10 CFU mL-1, respectively, were obtained showing serious contamination of milk. Yeast and mold test (100% prevalence) revealed that Gomole District samples (4.8 log10 CFU mL-1) were significantly higher (<0.0001) than samples of the other districts. In analysis for physicochemical parameters, fat (7.5%) (Dubluk), protein (3.4%) (Gomole and Elwaye), lactose (5.1) (Gomole, Elwaye & Dubluk), salts (0.8%) (Gomole and Elwaye), Solid-Not-Fat (9.2 -9.4) (Dubluk – Gomole) and 0.0% added water (all samples) were recorded; with fat, lactose and SNF being better as compared to earlier reports. In general, microbial population levels exceeded the set standards (East African Standards European Union Quality Standards) rendering it unsafe for raw consumption. Among the probable causes are prevalence of a serious hygienic problem in the process of milk production and subsequent handling in the study areas expressed in terms of inadequate cleanliness of the milking personnel, milking materials, udder, teat and concern of health of the cows. Thus, the pastoral society in the respective districts of the Zone should be given awareness through training regarding the importance of general hygienic practices required and the health hazards associated with production and consumption of low standard cow milk. Among the physicochemical parameters, milk from the three districts in the Zone showed superior fat, protein, lactose and Solid-not-Fat contents as compared to the standard set by East African Standards which demand further detailed investigation.

Key words: Cow milk, microbial quality, physicochemical quality

INTRODUCTION

Ethiopia has the largest livestock population in Africa with the cattle estimated to be about 63 million herds in 2018 (FAO, 2019). Milk is among the most important nutritional components in human diet. It is naturally a rich source of protein (3.2-3.4gm/100gm), fat (3.1-3.3gm/100gm), energy (247-274 kj), water (87.3–88.1gm/100gm), lactose (4.5-5.1gm/100gm) and other valuable

vitamins and minerals like calcium (91-120mg/100gm), potassium (132-155mg/100gm), phosphorus (84-95mg/100gm) and others (Meuhlhoff et al.,(eds.), 2012). This property makes milk and its products ideal media for growth and proliferation of an array of microorganisms of various taxonomic origin with some of them being beneficial and others undesirable and may also be pathogenic (Fernandese, 2009). Microbiology of milk is among the principal indicators of its quality. Milk drawn from a healthy mammary gland may be contaminated by a number of microorganisms entering the udder through the teat duct. Gram-positive cocci, streptococci, staphylococci and micrococci; lactic acid bacteria (LAB), Pseudomonas spp. and yeast are most frequently found in milk drawn aseptically from the udder; (Fernandese, 2009). In case of infection of the udder (mastitis), large number of microorganisms can be shed into milk. In general, microbial contamination of raw milk can emanate from a variety of sources, viz, air, cleanliness of milking equipment, feed, soil, faeces and grass (Coorevits et al., 2008). Previous surveillance systems had reported that 2-6% of bacterial food-borne outbreaks are shared from milk and milk products (De Buyser et al., 2001). More importantly, some wild type molds, such as, Aspergillus are capable of producing mycotoxins (Aflatoxin B1, M1, G1) that are secondary metabolites with carcinogenic, teratogenic and mutagenic effects (Frisvad et al., 2005).

Milk production obtained from the subsistence farmers of Ethiopia contributes about 98% of the annual milk production of the country. Moreover, dairy processing in the country is mostly limited to the smallholder level which experiences low hygienic quality (Alganesh et al., 2009). Weldearegay et al., (2012) reported maximum values of 10.28, 6.52, and 7.13 log10 CFU of aerobic mesophilic bacteria, coliforms and yeasts and molds, respectively per gm of sample in their study of hyegenic practices and microbiological quality of milk produced under different farm size in Hawassa City. Similarly, milk and milk products quality assessment in terms of microbiology from Debre Zeyit, Adama and Jimma areas reported that mean total bacterial count ranged from 8.3 to 10 Log CFU/mL. Additionally, the mean coliform count could reach 4 Log CFU/mL (Zelalem, 2009). These values far exceed the quality standard level set, i.e. of $2.0X10^6$ CFU/mL (Kiiyukia, 2003).

On the other hand, investigation of the microbial population of yoghurt confirmed that it is mainly dominated by lactic acid bacteria with Lactobacillus casei and/or Lactobacillus plantarum, Lactococcus, streptococcus, Leuconostoc, Lactobacillus, coliforms and yeasts, being the most prevalent inhabitants (Kasaye et al., 1991; Ashenafi 1995a; Gonfa et al., 1999). The microbial and physicochemical characteristics of milk and milk products obviously vary depending on the season of the year, agro-ecology, hygienic practices exercised, processing and storage conditions (Ali, 2011; Yilma, 2012), local cultural setting and so on. Moreover, most of the very few currently operating enterprises that process milk almost entirely depend on the traditional sector for the majority of their milk intake (Yilma, 2012). Lack of adequate information in the study districts on the microbial and physicochemical qualities of milk and facts mentioned above necessitate the need for periodic investigation into the quality status of cow milk produced in those districts. Thus, this research activity was initiated to assess the microbial quality, physical properties and chemical constituents of cow milk in the selected districts of Borena Zone.

MATERIALS AND METHODS

Description of the study area

Borena Zone is one the Zones in Oromia Regional State, Ethiopia, situated in the Southern part of the Region. It is bordered by Southern Nations and Nationalities and Peoples Region (SNNPR), Guji Zone and Somali Region to the West, North and East, respectively. The Zone is characterized by arid and semiarid climate with an area of 50,000 km^2 (Homann et al., 2008) having an average annual rainfall range of 350 to 900 mm. It possesses a bimodal type of rainfall with 60% occurring between March and May as a main rainy season. The second peak appears between September and November (Short rainy season) (Coppock, 1994). The study was conducted in three Districts (Gomole, Elwaye and Dubluk) of the Zone in the year 2019/20 covering areas with an altitudinal range of 1124 to 1659 m.a.s.l. Two Kebeles (the smallest administrative unit) were selected as sampling sites in each of the Districts in consultation with the respective Regional Bureau and Zonal Office.

Sample collection

The study was conducted during the year 2019/20 in three purposively selected districts, namely, Gomole, Elwaye and Dubluk, in Borena zone, Oromia Regional State, Ethiopia, following the procedure employed by Belli et al., (2013). A total of 47 raw milk samples (Kela Qufa (10); Bildim (8); Elwaye town (8); Golba (8); Dambala Badana (7) and Bokosa Gudda (6)) were collected from randomly picked households. The samples (approximately 200 ml each) were collected aseptically and immediately placed in sterilized screw capped sampling bottles and put into an ice box (1-5°C) to ensure the suppression of the growth and proliferation of microorganisms (ET ISO 707, 2012) and immediately transported to laboratory for analysis.

Microbiological analysis

Each of the collected raw milk samples were analysed for microbial quality which was evaluated in terms of standard plate count (SPC), total coliform count (CC), Salmonella and Shigella count and yeast and mold count (YMC).

Standard plate count (SPC)

Samples were serially diluted in physiological saline solution containing test tubes up to 10^{-7} concentration and 1 mL of the dilution with appropriate concentration was transferred into an empty petri dish and a molten standard plate count agar (10-15 mL) at a temperature of 45°C was poured into the dish with the inoculums using pour plate technique, in duplicate. The cultures were incubated at 32$\pm$2°C for 48 hrs and plates with acceptable number of colonies (30-300) were considered for enumeration using a colony counter (Rechardson, 1985; FDA, 2001). The estimated number of colonies per mL of sample was calculated by:

$$N = \frac{\Sigma C}{(1*n1)+(0.1*n2)} xd$$ (Maturin and Peeler, 2001)

Where:

N=Number of colonies per mL of milk sample; C=Sum of all colonies on plates counted; n1=Number of plates used in lowest dilution counted; n2=Number of plates used in highest dilu-ion counted; d=dilution factor of the lowest dilution used.

Coliform count (CC)
The procedure followed in the standard plate count analysis was employed for specimen dilution. One mL of the samples was transferred into an empty sterile petridish and a molten Violet Red Bile Agar (VRBA) (Himedia laboratories LTD) (10-12 mL) tempered to 45°C was poured onto the inoculum using a pour plate technique and incubated at 35$\pm$2°C for 24 hrs. Following growth of the culture, confirmatory test was conducted to assure the identity of the coliforms. Four to five typical colonies were incubated further in tubes containing 2% Brilliant Green Lactose Bile Broth at 35°C for 48 hrs (Richardson, 1985).

Yeast and mold count (YMC)
Samples were serially diluted following the procedure employed for SPC and CC analysis and 0.1 mL of the diluted sample was plated using a spread plate technique on potato dextrose agar (PDA) (Himedia laboratories LTD). The medium was acidified using 50% lactic acid. The plates were incubated at 25°C for 3-5 days using Yousef and Carlstrom, (2003) technique.

Physicochemical analysis
Some physicochemical parameters such as fat, protein, lactose, Solids-not-fat (SNF), added water, salts and density were analyzed using Lactoscan (ultrasonic milk analyser, Milkotronic LTD).

Data management and statistical analysis
Microbial count from each district was transformed into logarithmic values (log 10 CFU mL^{-1}) and subjected to statistical analysis using SAS version 9.0 and SPSS version 20. Variability among the data was separated using Duncan Multiple Range Test (DMRT) at 0.05 α level of probability (in the case of district wise comparison). Means, maximum and minimum values were calculated in descriptive statistics. Means of the data from physicochemical parameters were calculated using descriptive statistics.

RESULTS AND DISCUSSION

Microbial quality of milk samples
Standard plate count
Standard plate count is an important microbial quality parameter which is meant to evaluate the hygienic status of a food product. In this study, the lab analysis showed that in Gomole District the highest mean log10 CFU mL^{-1} value of 6.0 (range: 5.5 to 6.6) was recorded at Kela Qufa Kebele. Whereas samples collected from the second Kebele, Bildim, had a mean log10 CFU mL^{-1} value of 4.2 (range: 3.7 to 4.4) (Table 1). The findings in this specific District are in agreement with the result obtained by Hawaz et al., (2015) where the mean Standard plate count in cow milk samples collected from 4 Districts of Eastern Hararghe was 6.25 log10 CFU mL^{-1}. However it is slightly lower than the findings of Teshome and Tesfaye (2016) in three Districts of Bench Maji Zone with mean total bacterial count of 7.1 log10 CFU mL^{-1} and 7.3 log10 CFU mL^{-1} in Dawa Chefa District of Amhara region (Solomon et al., 2015). Result of this study showed that only 5.6% (10.0% in Gomole and 0.0% in Bildim) of the samples collected from the District has exceeded the East African Community Standards (EAS 67:2007) of 2 x 10^{6} CFU mL^{-1} (Table 6).

In Elwaye District, a slightly higher level of standard plate count was obtained. Among the two sampling sites, samples collected from Elwaye Town had the highest mean value of standard plate count of 8.5 log10 CFU mL^{-1} which is 2.0 log10 CFU mL^{-1} value higher than that of the second Kebele, Golba (Table 1). The analysis made it clear that standard plate count exceeded the acceptable standard in almost 93.8% of the milk samples collected from this District rendering it unsafe for raw consumption. Equivalent magnitude of mean total bacterial loads (8.7 and 8.6 log10 CFU mL^{-1}) had been reported in selected Sub-Cities of Addis Ababa by Fufa et al., (2019) and Biruktawit, (2016), respectively. Moreover, Wanjala et al., (2017) had come across a mean value of 8.1 log10 CFU mL^{-1} in samples collected from Nairobi area. The analysis of milk samples from Dambala Badana Kebele of Dubluk District showed the mean log10 CFU mL^{-1} standard plate count value of 8.2 with nearly comparable mean value of 8.4 recorded from samples of Bokosa Gudda Kebele of the District (Table 1). Standard plate counts in all the samples are out of acceptable range making the samples below standard for use without appropriate treatment. Results obtained in the samples from the two kebeles were comparable to the reports of Fufa et al., (2019) and Biruktawit, (2016).

Among the three Districts, the maximum mean log10 CFU mL^{-1} value of 8.3 was recorded in Dubluk which is significantly higher than that of Elwaye (7.5) which in turn had significant superiority over Gomole's samples (5.0 log10 CFU mL^{-1}) (Fig. 1). These results are considerably lower as compared to 9.8 log10 CFU mL^{-1} obtained in Ezha District of Gurage Zone, Southern Ethiopia, by Abebe et al., (2012). The values of total viable count obtained from samples collected from Dubluk and Elwaye were found to surpass the standard. Whereas the milk samples collected from Gomole District showed a mean log10 CFU mL^{-1} value of 5.0 which is below the standard set value of $2.0x10^6$ CFU mL^{-1} (6.3 log10 CFU mL^{-1}) set by East African Community Standards (EAS 67:2007) hence acceptable even for raw consumption. In general, 61.7% of the samples across the three Districts have failed to qualify for safe consumption (Table 6).

Table 1. Standard plate count (mean ±SE) in milk samples (log10 CFU mL^{-1})

District	**Kebele**	**N**	**Mean**	**Minimum**	**Maximum**	**P (≤0.05)**	**CV (%)**
Gomole	Kela Qufa	10	6.0±0.155	5.5	6.6	<0.0001	6.3
	Bildim	8	4.2±0.090	3.7	4.4		6.1
Elwaye	Golba	8	6.5±0.045	6.3	6.6		2.0
	Town	8	8.5±0.039	8.3	8.6		1.3
Dubluk	Dambala Badana	6	8.2±0.374	7.4	8.6		4.5
	Bokosa Gudda	7	8.4±0.080	8.0	8.6		2.3
Overall mean			7.0±0.700	6.5±0.711	7.2±0.694		

Note: CV=coefficient of variability; SE=standard error

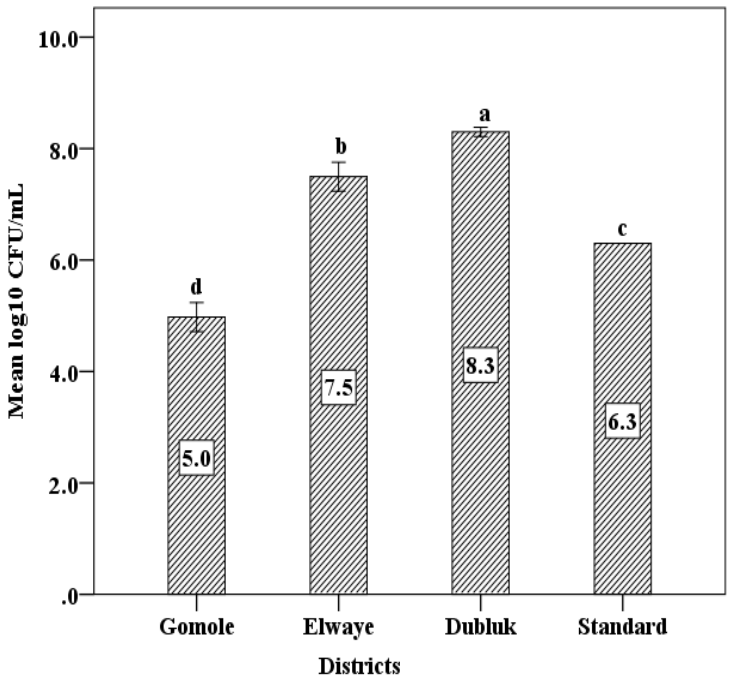

Figure 1. Standard Plate Count in samples across the Districts
Note: bars with the different letters are significantly different ($p \leq 0.05$)

Total coliform Count

All the milk samples collected from across the three Districts have been tested for the magnitude of indicator microorganisms, the coliforms. The presence of indicators in the food samples is the warning signal that there is a probability of occurrence of pathogenic species in the food lot and the resultant magnitude helps in the decision making for whether the food and/or its products is microbiologically safe for consumption or not. At Kela Qufa Kebele of Gomole District, the highest mean value of 6.0 log10 CFU mL^{-1} of total coliforms have been recorded (Table 2). The average value obtained at this Kebele was almost over 33% higher than that reported from the second Kebele of the same District, Bildim, with the mean log10 CFU mL^{-1} of 4.0. From the study in the District, it could be seen that 22.2% (Table 6) of the samples examined are significantly higher than the recommended level of 5.0 x 10^4 CFU mL^{-1} (4.699 log10 CFU mL^{-1}). The highest mean coliform count (8.5 log10 CFU mL^{-1}) was recorded in milk samples collected from Elwaye Town. Moreover, in Bokosa Guda and Dambala Badana Kebeles of Dubluk District, TCCs were nearly equivalent to the highest value with mean log10 CFU mL^{-1} values of 8.4 and 8.3, respectively (Table 2). The coliform contamination level of samples in all the Kebeles except Bildim has been found to be considerably higher as compared to several studies in Ethiopia. Fufa et al., (2019), Teshome and Tesfaye (2016), Lina et al., 2018, Tadele et al., 2016 and Asaminew and Eyassu (2011) had reported an overall mean values of 4.9, 5.1, 6.4, 4.2 and 4.5 log10 CFU mL^{-1}, respectively. In Tanzania and Bangladesh Happy (2014) and Khaton et al., (2014) have recorded a mean total coliform counts of 6.45 and 2.7 log10 CFU mL^{-1}. In addition, in rural areas of Nairobi (Wanjala et al., 2017) and Banaskantha District of India (Nalwaya et al., 2018), still comparatively lower total coliform counts of 4.56 and 3.47 log10 CFU mL^{-1} were reported.

Comparison of the mean values of coliform counts for the three Districts showed that the highest value of 8.4 log10 CFU mL^{-1} was obtained from samples of Dubluk district. Elwaye District took

the second place with a mean log10 CFU mL^{-1} value of 7.2 which was significantly lower than that of Dubluk (Fig. 2). Coliform counts recorded from both of the districts are beyond the standard set. From this investigation, all samples (100%) from Elwaye and 92.3% from Dubluk districts have had TCC value significantly exceeding the recommended standard of 5.0 x 10^4 CFU mL^{-1} (4.699) (Table 6). However, a mean log10 CFU mL^{-1} value of 4.661, which is slightly below the threshold was reported from Gomole District with non-significant variability (4.669 log10 CFU mL^{-1}).

Table 2. Total Coliform count (mean ±SE) in milk samples (log10 CFU mL^{-1})

District	Kebele	Mean	Minimum	Maximum	P (≤0.05)	CV (%)
Gomole	Kela Qufa	6.0±0.208	5.4	6.4		6.9
	Bildim	4.0±0.136	3.3	4.3		9.7
Elwaye	Golba	6.0±0.062	5.7	6.3		2.0
	Town	8.5±0.048	8.3	8.7	<0.0001	1.6
Dubluk	Dambala Badana	8.3±0.074	8.2	8.6		
	Bokosa Gudda	8.4±0.068	8.1	8.5		2.0
Overall mean		6.9±0.632	6.5±0.703	7.1±0.612		

Note: CV=coefficient of variability; SE=standard error

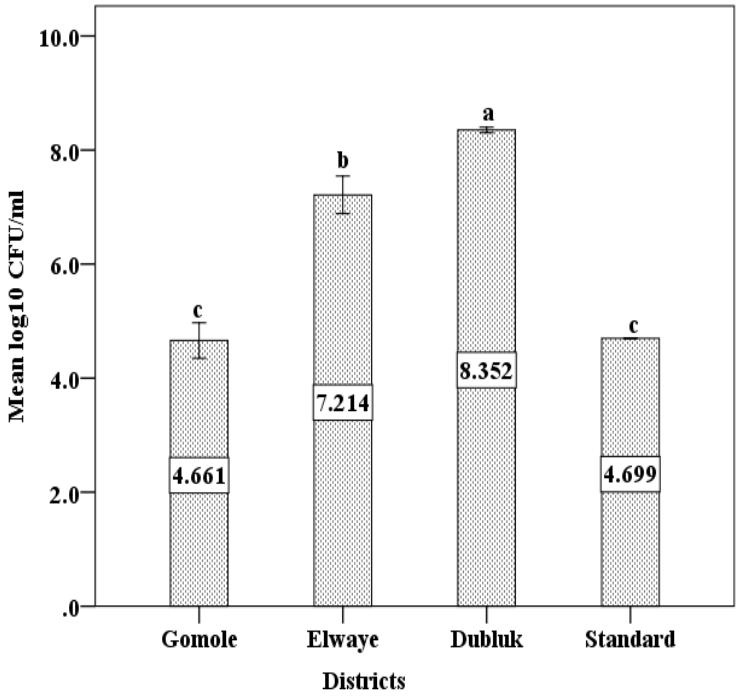

Figure 2. Total Coliform Count in samples across the three Districts
Note: bars with the different letters are significantly different (p≤0.05)

Salmonella species count

Salmonella species, as one of the cow milk contaminants have been detected only in the two Kebeles of Gomole District and Golba Kebele of Elwaye District with an overall mean prevalence of 39.9 % (Table 7). In the rest of the sampling Kebeles, the cultures ranged from no growth (NG) to too few to count (TFTC) level. Laboratory analysis revealed that samples from Dubluk District and Elwaye Town had similarly ranged from NG to TFTC. The highest mean log10 CFU mL^{-1} value of 5.5 was recorded at Golba Kebele, whereas, the lowest mean log value of 3.4 mL^{-1} was detected in milk samples from Bildim Kebele of Gomole District (Table 3). In general Elwaye District samples had significantly higher log10 CFU mL^{-1} value (5.5) of Salmonella count as compared to the samples from Gomole (3.8 log10 CFU mL^{-1}) (Fig. 3). In similar study conducted by Hawaz et al., (2015), at Harar milk shed of Eastern Ethiopia, nearly the same value of Salmonella (5.13 log10 CFU mL^{-1}) has been reported. However, in Nigeria Oladipo et al., (2016) have obtained a little higher value of 6.04 log10 CFU mL^{-1}.

Table 3. Salmonella count (mean ±SE) in milk samples (log10 CFU mL^{-1})

District	Kebele	N	Mean	Minimum	Maximum	P (≤0.05)	CV (%)
Gomole	Kela Qufa	10	5.3±0.148	5.1	5.6	0.0008	4.8
	Bildim	8	3.4±0.131	3.1	3.6	0.002	6.8
Elwaye	Golba	8	5.5±0.209	5.1	5.8	0.001	2.0
	Town	8	NG -TFTC	-	-	-	-
Dubluk	Dambala Badana	6	NG	-	-	-	-
	Bokosa Gudda	7	NG -TFTC	-	-	-	-
Overall mean			4.7±0.699	4.4±0.667	5.0±0.702		

Note: NG-TFTC= no growth - too few to count; SE=standard error

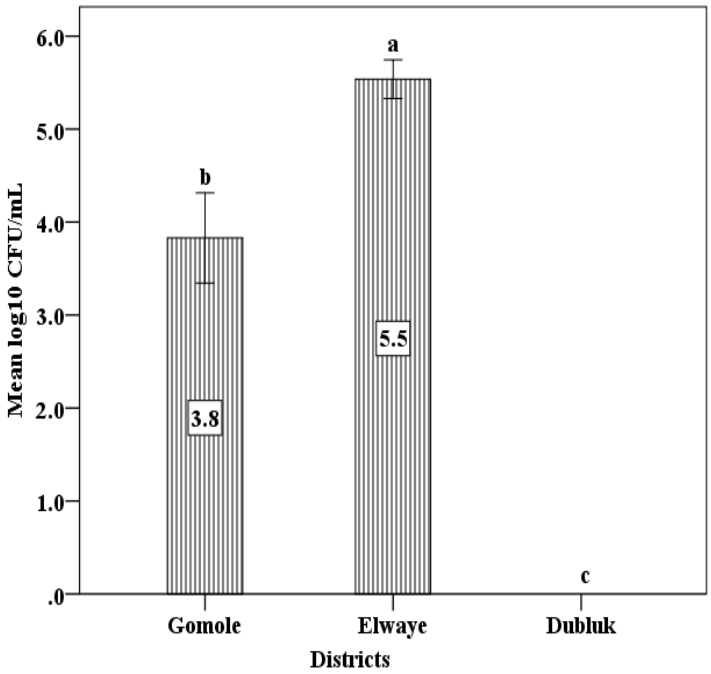

Figure 3. Comparison of milk samples across the three Districts for Salmonella species count

Note: bars with different letters are significantly different ($p \leq 0.05$)

Shigella species count

Shigella species was one of the pathogenic bacteria for which the milk samples were tested as potential contaminants. Table 7 shows that approximately 95.8 % of the samples were contaminated by Shigella species. On the contrary Melese et al., (2016) reported that only 17.5% of the milk samples were contaminated by Shigella spp implying a general hygiene problem with greater probability of using contaminated water for cleaning (Villalobo, 2011). The data revealed that the highest mean log10 CFU mL^{-1} (8.4) was recorded in samples collected from Elwaye Town and Dambala Badana Kebeles of Elwaye and Dubluk Districts, respectively (Table 4). Whereas, in Gomole District in Bildim Kebele, mean log10 CFU mL^{-1} of 3.8 was detected. The rest of the Kebeles in the three Districts had a mean log10 CFU mL^{-1} value above 5 (Table 4). District wise, 7.5 log10 CFU mL-1 was recorded in Dubluk which was significantly higher than that obtained from Elwaye (7.3) and Gomole (5.0) (Fig. 4).

Table 4. Shigella count (mean ±SE) in milk samples (log10 CFU mL^{-1})

District	Kebele	Mean	Minmum	Maximum	P (≤0.05)	CV (%)
Gomole	Kela Qufa	5.4±0.075	5.2	5.9	<0.0001	4.1
	Bildim	3.8±0.132	3.5	3.9	0.0012	6.1
Elwaye	Golba	6.0±0.052	5.8	6.2	<0.0001	2.3
	Town	8.4±0.074	8.1	8.7	<0.0001	2.5
Dubluk	Dambala Badana	8.4±0.127	8.2	8.9	<0.0001	3.4
	Bokosa Gudda	7.6±0.146	7.2	8.0	<0.0001	4.7
Overall mean	6.6±0.755	6.3±0.752	6.9±0.794			

Note: NG-TFTC= no growth - too few to count; SE=standard error

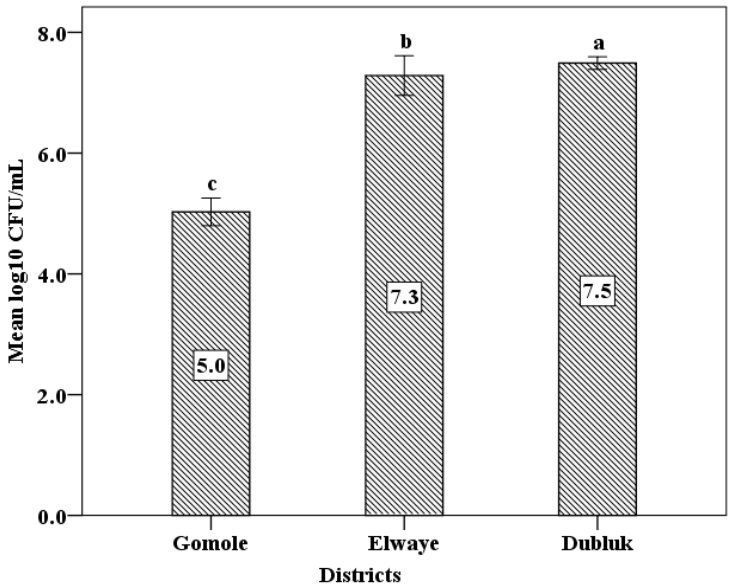

Figure 4. Shigella species count in samples across the three Districts

Note: bars with different letters are significantly different (p≤0.05)

Yeast and mold count

Milk samples from Bildim kebele of Gomole District exhibited the highest level of contamination by yeast and mold with the mean log10 CFU mL-1 value of 4.8. Kela Qufa Kebele from the same district had taken the second place in yeast and mold contamination with mean log10 CFU mL-1 value of 4.5 (Table 5). Samples from Kebeles of Elwaye and Dubluk had shown values ranging from 3.7 to 4.4. Among the districts thus, Gomole exhibited higher contamination (4.8 log10 CFU mL-1) with significant difference from the rest of the districts (Fig. 5). Teshome and Tesfaye (2016) found a comparatively lower overall mean value of yeast and mold counts (3.9 log10 CFU mL^{-1}). Higher yeast and mold count in a food product contributes to the spoilage hence shorter shelf life. Moreover, some molds are of critical public health concern due to production of mycotoxins which may not be easily destroyed during processing including cooking (Wouters et al., 2002). This study revealed that all the milk samples from Kebeles in the districts exhibited a yeast and mold count that was higher than the acceptable limit set by the Malaysia food quality standard of yeast and mould in raw milk sample which should be below 2.1 log cfu/mL (Torkar and Vengust, 2008).

Table 5. Yeast and mold count (mean±SE) in milk samples (log10 CFU mL^{-1})

District	Kebele	Mean	Minimum	Maximum	P (≤0.05)	CV (%)
Gomole	Kela Qufa	4.5±0.144	3.9	5.0	<0.0001	8.4
	Bildim	4.8±0.195	3.8	5.4		11.5
Elwaye	Golba	3.7±0.116	3.1	4.0		8.2
	Town	3.9±0.130	3.4	4.4		9.3
Dubluk	Dambala Badana	4.4±0.115	3.7	4.6		6.9
	Bokosa Gudda	4.2±0.095	3.9	4.6		5.5
Overall mean		4.3±0.165	3.6±0.131	4.7±0.198		

Note: NG-TFTC= no growth - too few to count; SE=standard error

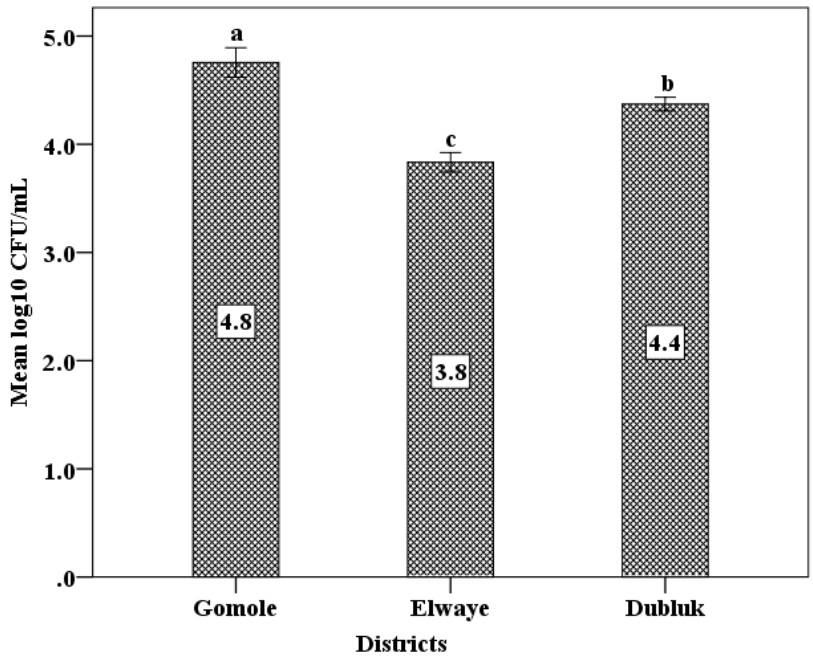

Figure 5. Yeast and mold count in samples across the three Districts
Note: bars with the different letters are significantly different ($p \leq 0.05$)

Prevalence of the microbial contaminants in the milk samples

Total coliforms and yeasts and molds have been detected in all the samples (100%) collected from all Kebeles of the three Districts. Similarly, faecal coliforms have been reported in all the samples except in Kela Qufa Kebele in which total coliforms prevalence of 90% was recorded (Table 7). However, Faisal and Ahmad (2018) reported a considerably lower coliform prevalence of 11.6% in the milk samples. Contrary to that of coliforms and yeast and molds, only 10, 16.7 and 37.5% of the samples have been positive for Salmonella in Kela Qufa, Bokosa Gudda and Elwaye Town, respectively. Over eighty seven percent of samples has shown Salmonella growth which was significantly higher value as compared to 5.9% recorded by Faisal and Ahmad (2018). Shigella species had been noticed in an entire samples of all the Kebeles except that 75% of the samples from Bildim had been contaminated by this microorganism (Table 7).

Table 6. Proportion of milk samples exceeding EAS (67:2007) threshold level of standard plate count and total coliforms

District	Number of samples analysed	Samples exceeding EAS in SPC (6.3 log10 cfu/mL)		Samples exceeding EAS in Total CC (4.70 log10 cfu/mL) (%)	
		Number of samples	Proportion (%)	Number of samples	Proportion (%)
Gomole	18	1	5.6	4	22.2
Elwaye	16	15	93.8	16	100.0
Dubluk	13	13	100.0	12	92.3
Total	47	29	61.7	32	68.1

EAS: East African Standards; CFU=colony forming units; SPC=standard plate count; CC=coliforms count

Table 7. Prevalence (%) of microorganisms of different categories in milk samples

District	Kebele	N	Total coliform		Faecal coliform		Salmonella species		Shigella species		Yeast and mold	
			KM	DM	KM	DM	KM	DM	KM	DM	KM	DM
Gomole	Kela Qufa	10	100	100	90	95	10	48.8	100	87.5	100	100
	Bildim	10	100		100		87.5		75		100	
Elwaye	Golba	8	100	100	100	100	87.5	62.5	100	100	100	100
	Town	8	100		100		37.5		100		100	
Dubluk	Dambala Badana	7	100	100	100	100	0	16.7	100	100	100	100
	BokosaGuddaa	6	100		100		16.7		100		100	
Overall mean			**100**	**100**	**98.3**	**98.3**	**39.9**	**42.7**	**95.8**	**95.8**	**100**	**100**

Note: DM=District Mean; KM=kebele mean; N=number

Physicochemical qualities

Each of the cow milk samples collected from across the three districts was subjected to analysis for a number of physical and chemical qualities including fat content, solid-non-fat (SNF), density, protein content, lactose content, added water and total salts as presented in Table 8. According to the data, mean fat content ranged from 5.85 to 7.60% and samples from Dambala Badana kebele in Dubluk district were noted as having the maximum (7.60%) fat content. Figure 1 shows that samples from Dubluk district had the highest fat content of 7.5% being significantly higher ($p \leq 0.05$) than the rest of the districts. The finding from this study showed that most of the samples from the study districts contained higher fat content compared to previous reports such as Hawaz et al. (2015) (5.17%), Teshome et al. (2015) (4.5%), Teshome and Tesfaye (2016) (6.024%) and Legesse et al. (2017) (5.54%). According to the European Union Quality Standards, for unprocessed whole milk, fat content should not be less than 3.5% (Tamime, 2009). East African Standard recommends that proportion of fat should not be below 3.25% ((EAS 67:2007)). Thus, all samples collected from the three districts had a much higher proportion of fat content as compared to both the milk quality specifications.

Mean solids-not-fat (SNF) had ranged from 9.17 to 9.43% across the Kebeles of the districts (Table 8). However, there was non-significant difference ($p \leq 0.05$) among the districts. East African Standards recommends that cow milk SNF should not be less than 8.50%. Accordingly, all the samples from the three districts had an SNF content above the set standard. With regard to density, milk samples from Bildim and Kela Qufa had shown to have a density above 30.0 kg/m3. There was non-significant statistical difference ($p \leq 0.05$) among the districts in milk density. Samples from Gomole showed the highest density (30.1 kg/m3), with Elwaye and Dubluk in the second (29.1 kg/m3) and third (28.4 kg/m3) places, respectively (Fig. 6). Analysis of milk samples for protein and lactose contents revealed almost equivalent values across the

samples from all the Kebeles ranging from 3.32 to 3.43% and 5.03 to 5.16%, respectively. Similarly, samples from all the districts were nearly equal in the case of protein content which ranged from 3.3 to 3.4% (Fig. 6). They were exactly equal in lactose content (5.1%) (Fig. 6) too. The protein content of the milk samples was a little bit lower than some of the previous reports such as Debela et al. (2015) (3.94%), Hawaz et al. (2015) (3.51%) and Teshome and Tesfaye (2016) (3.98%). However, the current result was in agreement with 3.43% which was reported by Teshome et al. (2015). On the contrary, mean lactose content of the samples across the districts was considerably higher than earlier research results of the same authors obtaining 4.53% (Debela et al., 2015), 3.79% (Hawaz et al., 2015) and 4.43% (Teshome et al., 2015). Likewise, samples from all the kebeles were almost equivalent in total salts content ranging from 0.74 to 0.77%. From this investigation, all the milk samples were free of added water and this agrees with the standard set by EAS which states that there shouldn't be any added water in the milk samples.

Table 8. Physicochemical parameters (mean±SE) of milk samples in the Kebeles of each District

Physico-chemical parameters		Gomole		Elwaye		Dubluk	
		Kela Qufa	Bildim	Golba	Town	Dambala Badana	Bokosa Gudda
Fat (%)	Mean	6.31±0.6	6.52±0.4	6.87±0.5	5.85±0.6	7.60±0.3	7.45±0.5
	Min.	3.73	5.13	5.22	4.43	6.56	5.96
	Max.	9.62	8.45	8.71	9.37	8.56	8.61
	CV	27.4	16.6	20.2	30.1	10.7	15.7
SNF (%)	Mean	9.37±0.1	9.43±0.2	9.17±0.1	9.40±0.1	9.17±0.1	9.27±0.2
	Min.	8.88	8.72	8.83	8.87	8.69	8.82
	Max.	10.08	10.56	9.45	9.66	9.54	9.95
	CV	4.0	6.0	2.7	2.6	3.3	4.4
Density (kg/m^3)	Mean	30.04±0.5	30.21±0.8	28.85±0.6	29.38±1.2	28.2±0.3	28.67±0.8
	Min.	27.93	26.83	27.00	21.78	27.08	25.96
	Max.	33.23	33.47	31.13	32.42	29.2	32.04
	CV	5.0	7.1	6.2	11.6	2.8	6.8
Protein (%)	Mean	3.41±0.04	3.43±0.1	3.33±0.0	3.40±0.0	3.32±0.0	3.36±0.1
	Min.	3.22	3.16	3.20	3.23	3.15	3.18
	Max.	3.65	3.83	3.44	3.51	3.45	3.62
	CV	3.9	5.98	2.9	2.8	3.3	4.5
Lactose (%)	Mean	5.14±0.1	5.16±0.1	5.03±0.0	5.16±0.0	5.03±0.1	5.08±0.1
	Min.	4.87	4.78	4.84	4.87	4.77	4.83
	Max.	5.53	5.79	5.18	5.29	5.23	5.46
	CV	3.9	5.8	2.7	2.63	3.3	4.38
Added water (%)	Mean	0	0	0	0	0	0
	Min.	-	-	-	-	-	-
	Max.	-	-	-	-	-	-
	CV	-	-	-	-	-	-
Salts (%)	Mean	0.76±0.0	0.77±0.1	0.74±0.0	0.76±0.0	0.74±0.0	0.75±0.0
	Min.	0.72	0.71	0.71	0.72	0.70	0.71
	Max.	0.81	0.86	0.77	0.78	0.77	0.81
	CV	3.8	5.9	2.9	2.6	3.5	4.6
P($\leq$0.05)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

SNF=solids-not-fat; CV=coefficient of variability; Max=maximum; Min=minimum; SE=standard error

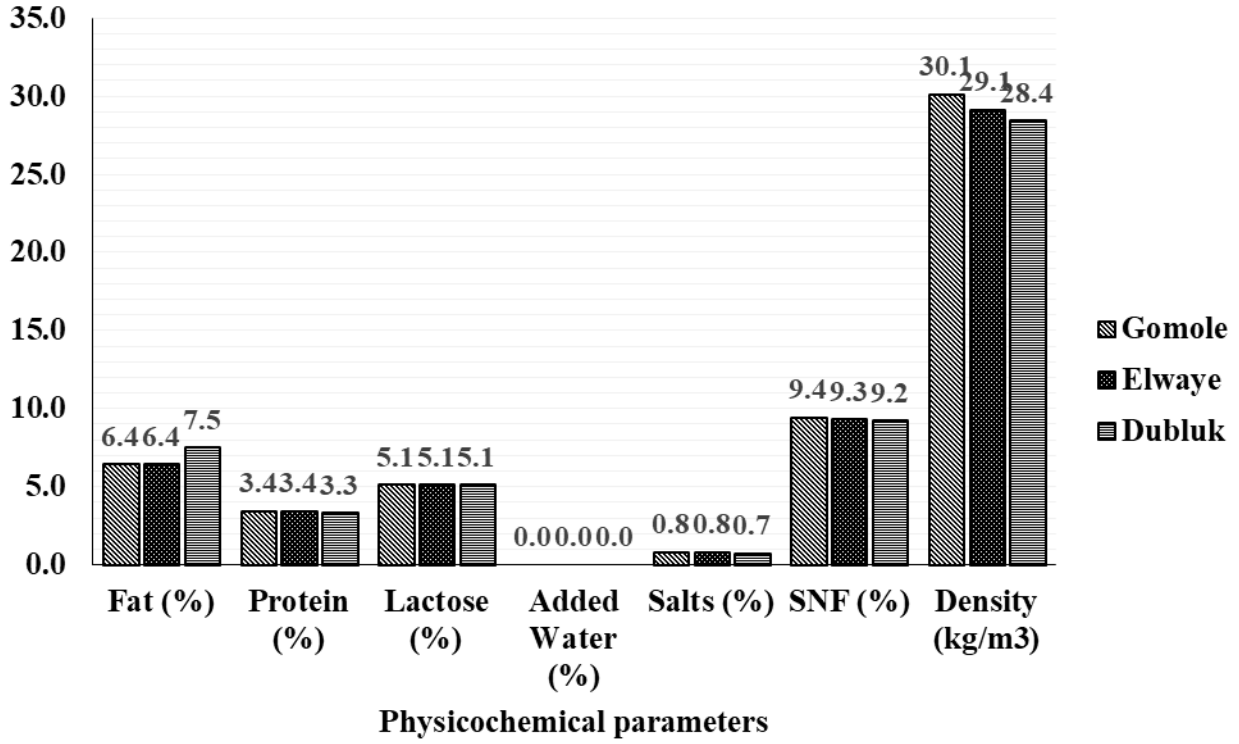

Figure 6. Physicochemical parameters of the cow milk samples collected from across the three Districts

CONCLUSION AND RECOMMENDATION

Bacteriological analysis of the milk samples in the three Districts showed that over 60% of the samples collected were found to be below standard set by East African Community Standards (EAS) with regard to standard plate count. This depicts that there is a serious hygienic problem in the process of milk production and subsequent handling in the study areas which can be due to inadequate cleanliness of the milking personnel, milking materials, udder and teat and the barn in general. This might be the result of lack of knowledge and awareness for the role of hygiene in the milk quality and its safety for consumption. Similarly, more than 68% of the milk samples were substandard due to very high load of indicator microorganisms (total coliforms) considerably exceeding the maximum acceptable count set by EAS. The level of total coliforms contamination is an important signal for the presence of pathogenic bacterial species in the milk samples. This poses a potential health hazard and warns for a safety concern in consumption of cow milk without boiling. However, most of the samples collected from Kebeles of Gomole District have been proved to be of acceptable quality in terms of low counts of standard plate and total coliforms. This is a reflection of better hygienic practices in the specific District and other good cultural practices which contributed to this quality should also be further studied for possibly sharing with the other areas.

However, further detailed investigations need to be made to create a clear understanding of the root cause as to why higher proportion of the milk being produced is of low microbial quality with higher health risk. Moreover, it requires that training should be delivered to the pastoral society to create awareness on the critical importance of hygienic practices in the production and handling of cow milk which plays a key role in assuring the production of enhanced quality milk for local consumption as well as increase its wider acceptability for market and industrial processing. The safety issues and health hazards related to the consumption of low standard raw cow milk should also be thought to the society. From the analysis of physical and chemical qualities, it could be perceived that cow milk being produced in the study areas are of better quality in terms of fat, protein, lactose and SNF content with most of the parameters being even better than the standards set by East African Standards (EAS 67:2007). This might be attributed to higher feed diversity and quality of the cattle breed in the area.

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Evaluation of Food Quality of Released Barley Varieties Grown in Oromia, Ethiopia

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ABSTRACT

This study was conducted to characterize and evaluate food quality of released food barley varieties through physical, chemical and sensory evaluation. Fifteen released food barley varieties were collected from different research centers. Physicochemical qualities of these varieties were analyzed with three replications. Sensory evaluation was also performed by using hedonic scale method. Hectoliter weight, thousand kernel weight, moisture, protein, sodium, potassium, iron, zinc, calcium and magnesium contents were determined in the range of 55.57 – 66.67 grams, 33.50 – 58.50 grams, 7.46 – 11.43 %, 9.44 – 16.80 %, 79.23 – 316.54 ppm, 3993 – 6040 ppm, 11.49 – 64.32 ppm, 31.07 – 55.73 ppm, 305.42 – 716.91 ppm and 811.50 – 1731.10 ppm respectively. Overall acceptability of porridge prepared from barley varieties were disliked slightly to liked moderately while liked slightly to liked moderately for Injera. There were significant ($P<0.05$) variation in physical, chemical and organoleptic properties due to test barley varieties variation. Aruso variety was the highest in mean value of thousand kernel weight and hectoliter weight. Walker variety had the highest protein mean score. The study revealed that Robera, Abdane, Bentu, Harbu, Golden Eye and Walker varieties had the highest value of calcium, magnesium, potassium, sodium, iron and zinc respectively. Walker variety porridge was disliked slightly and Bentu variety was mostly liked moderately but not significantly different among Aquila, Gobe, HB 1966 and Robera varieties. Abdane variety injera was liked slightly and Biftu variety was mostly liked moderately but not significantly different among nine barley varieties. Therefore Aruso, Biftu, Bentu and Robera varieties were preferred for physical, chemical and sensory quality attributes.

Keywords: Food barley, physico-chemical property, sensory evaluation

INTRODUCTION

Barley (Hordeum vulgare L.) is used for animal's feed and human consumption. It is estimated that about 85% of the world's barley production is destined for feeding animals, while the rest is used for malt production, seed production and food consumption but also for production of starch either for food use or for the chemical industry (1). Barley is used as an important food crop in daily diets in Morocco, India, China and Ethiopia (2). Barley is used as main crop for food and beverage preparation in Ethiopia. It can be used as main dishes like Injera, bread (kita) and porridge in addition to ceremonial and side dishes like local beverage (farso in Afan Oromo), roasted whole grain, Besso, Chuko, Kinche, etc(3). It's considered as health food and mostly used for infant food preparation. Because of these various interests, barley is mainly produced in Oromia regional state. Of the top 25 barley producing districts in the country, 18 are found in Oromia (4). In 2017/2018 cropping season, barley was produced on about 951,993.15 hectares of land from which 20,529,963.72 quintals of yield are obtained (5). According to Ethiopian Ministry of Agriculture report, there are about 46 released food barley varieties until

2018(6). Ten varieties (Walker, Golden Eye, Aquila, Robera, Abdane, Guta, Biftu, Dinsho, Harbu, and Adoshe) were released by Oromia Agricultural Research Institute's research centers.

The environmental factors, such as rainfall, temperature, soil conditions, fertilizer and genetic factors, can contribute to variations in the chemical composition and physical characteristics of cereal grains (7&8). Thus characterization of variations in the nutritional value of cereal grains that result from such factors may help to define appropriate breeding objectives for improving the value of cereal grains for nutrition (8).The exact physicochemical composition of barley may vary depending on the variety and the environmental conditions during production. Accordingly, different researchers have evaluated internationally and some nationally released varieties barley for their nutritional composition (9 & 10). Whole barley grain consisted of about 65–68% starch, 10– 17% protein, 4–9% s-glucan, 2–3% free lipids and 1.5–2.5% minerals (11).

It is important to investigate the nutritional value of barley in a given to geographic location because their nutritional value may depend on the variety, fertilization and environmental conditions. Considerable number of food barley varieties were verified and released from different Agricultural Research Centers of IQQO. However, some of nutritional compositions of these varieties were not evaluated and profiled as research information as well as consumers preferences were not reported. Therefore the objective of this study was to evaluate the physicochemical compositions and consumers' preferences of released and mostly produced barley varieties in the Oromia region, Ethiopia.

MATERIALS AND METHODS

Sample Collection and Study Site

Fifteen released food barley varieties were collected from Fedis Agricultural Research Center (FARC) and Sinana Agricultural Research Center (SARC) during 2017/18 cropping season as listed on Table 1. Finally, only undamaged food barley grain was chosen and stored under room temperate until analysis. Laboratory analysis and barley food products sensory evaluation activities were undertaken at Food Science Laboratory of Oromia Agricultural Research Institute (IQQO) and Dodola district. Four farmers' research groups (FRG) having each fifteen members were established at Dodola district (Denaba and Kecama Core kebeles). Food barley Injera and porridge prepared from different barley varieties were evaluated by IQQO's staff and farmers from Dodola district found in West Arsi zone.

Sample Preparations for Analysis

Food barley varieties were sorted, cleaned, decorticated by using mortar and pestle and sun dried (as shown on figure 1), milled, sieved and stored at room temperature until chemical and sensory analysis carried out.

Table1. List Barley varieties, Breeder and Released Year

S. No	Variety name	Breeder/Maintainer	Year of Released
1	Abdane	SARC/IQQO	2011
2	Aquila	FARC(IQQO)/MORRELL	2012
3	Aruso	SARC/IQQO	Local
4	Biftu	SARC/IQQO	2005
5	Bentu	KARC/IQQO	2006
6	Dafo	SARC/IQQO	2005
7	Dinsho	SARC/IQQO	2009
8	Gobe	KARC/IQQO	2012
9	Golden Eye	FARC(IQQO)/MORRELL	2012
10	Harbu	SARC/IQQO	2004
11	HB 1965	HARC	2017
12	HB 1966	HARC	2017
13	HB 1307	HARC/EIAR	2006
14	Robera	SARC/IQQO	2016
15	Walker	FARC(IQQO)/MORRELL	2012

Where, KARC= Kulumsa Agricultural Research Center, HARC= Holeta Agricultural Research Center, EIAR= Ethiopian Institute of Agricultural Research

Thousand Seed Weight

Thousand barley kernel counted by automatically seed counter and weighed by sensitive balance (0.001g) and thousand seed weight was reported in grams. The weight of each test was repeated with three replicates (12).

Proximate Analysis

Proximate Composition: Moisture, protein and fat content of the grain samples and proximate composition of bread blends were determined by using the AOAC, 2000 methods (13). Total carbohydrate is calculated by difference. Energy was calculated using Artwater factor: Fat x 9 + Carbohydrate x 4 + Protein x 4 (kcal).

Minerals: Iron, zinc and calcium content were analyzed by using AOAC Official Method 975.03(14**).** All determinations were done in triplicate.

Food (Injera and Porridge) Preparation from Barley Varieties

Injera was prepared as per the procedure of Bultosa et al., (15) and Fitsum et al., (16). Equal amount of flour and water were used for the preparation of dough and fermentation of the dough after adding a starter culture (a fermented dough from previous batch) with 1: 1.6 w/v and fermenting at room temperature for 24–72 h. After fermentation, 10% of the sediment was mixed with water (1:3) and cooked for 2–3 minutes with the objective of gelatinization (cooking) primarily to bring about the cohesiveness of dough and secondly to get rid of the easily fermentable carbohydrate from Injera. Then, gelatinized batter (Absit) were cooled to room temperature and added back to the fermenting dough. After fermentation for 0.5–1 h, bubbles were formed, indicating the end point. Additional water was added to fermented dough to bring

to correct batter consistency. About 500 g of fermented batter was poured in a circular manner on a hot clay griddle, covered, and baked for 3–4 minutes.

Consumer Preference Test on Processed Food

Before conducting sensory evaluation; orientation was given for panelists with practical demonstration. Sixty three (36=male and 27=female) and sixty eight (39=male and 29=female) consumers including researchers, farmers, and nutrition and plant science experts were purposely selected to determine the acceptability of barley porridge and Injera displayed on figure 2 and 3 respectively. Acceptability/preference was undertaken using nine point Hedonic scales; where 1=dislike extremely, 2= dislike very much, 3. Dislike moderately, 4. Dislike slightly, 5=neither like nor dislike, 6=like slightly, 7. Like moderately, 8. Like very much and 9=like extremely.

Figure 1. Barley varieties Injera displayed for consumers preference

Data Management and Statistical Analysis

Means and standard deviations were calculated for physic-chemicals and acceptability of the sensory attributes. All quantitative and qualitative data were analyzed using statistical analysis software known as SAS version 9.00 to analysis physic-chemicals and sensory qualities.

RESULTS AND DISCUSSIONS

Some Physical and Chemical Qualities of Barley Varieties Grain

Hectoliter weight, thousand kernel weights, moisture, protein, and some minerals content were determined in selected barley varieties were shown on Table 2. All of determined physico-chemicals of food qualities were significant ($p<0.05$) among barley varieties. The least hectoliter

weigh, thousand kernel weight and moisture were determined from Walker (62.48g), Bentu (34.71g) and Bentu (7.90 %) respectively, while the maximum amount hectoliter weigh, thousand kernel weight and moisture was obtained from Aruso Variety with value of 74.01grams , 66.20 grams and 11.43 % respectively. Thousand-grain and hectoliter weights, which can be used to determine the potential flour yield in wheat grain, are accepted as the main quality factors by the milling industry (17). Therefore, Aruso variety had flour advantages than others.

The protein composition barley varieties determined with the least from Aruso variety (10.72%) and the highest from Walker variety (18.72%). The level of protein in barley is highly variable, ranging from 7 to 25% according to a large USDA study involving over 10,000 genotypes (18). The difference is due to the varieties growth conditions, particularly the rate and timing of nitrogen fertilization (19) and also barley protein content is highly dependent on the cultivar (20). The minerals content of minerals in barley varieties ranged from 87.14 – 366, 4248 – 8778.18, 34.00 – 78.48, 428.77 – 822.54, and 928.05 – 2126.23 ppm for sodium, potassium, iron, zinc, calcium and magnesium respectively. The exact composition of barley will vary depending on the variety chosen and the environmental conditions during growth (9). The whole barley grain consists of about 65-68% starch, 10-17% protein, 4-9% β-glucans, 2-3% free lipids and 1.5-2.5% minerals (21 & 22).

Table 2. Physical and chemical qualities of grain barley varieties selected Oromia Agricultural Research Institute research centers

Barley varieties	Physico-chemicals qualities of Barley varieties at dry basis									
	Hectoliter weight (grams)	Thousand kernel weight (grams)	Moisture (%)	Protein (%)	Na ppm	K ppm	Fe ppm	Zn ppm	Ca ppm	Mg ppm
Abdane	70.22±0.20^{de}	49.95±1.01^{d}	9.57±0.05^{d}	16.25±1.91^{cd}	153.84^{efg}	7580.18^{c}	32.39^{g}	44.78^{cd}	730.47^{ab}	2126.23^{a}
Aquila	62.68±0.75^{h}	45.89±4.97^{e}	10.63±0.12^{bc}	16.55±0.02^{c}	200.29^{d}	7584.70^{c}	38.34^{f}	54.55^{cb}	467.97^{f}	1533.54^{bc}
Aruso	74.01±069^{a}	66.2±0.48^{a}	11.43±0.06^{a}	10.72±0.1^{g}	192.48^{de}	6326.87^{ef}	40.41^{ef}	45.09^{cd}	696.73^{abc}	1466.49^{bc}
Bentu	71.39±1.03^{bcd}	34.71±0.34^{h}	7.90±0.06^{h}	15.45±0.11^{def}	201.83^{d}	8778.15^{a}	18.18^{h}	63.06^{ab}	589.83^{bcdef}	1470.08^{bc}
Biftu	61.82±0.07^{h}	39.83±0.20	9.11±0.11^{e}	17.59±0.07^{b}	272.75^{c}	8360.97^{b}	41.86^{e}	61.79^{b}	672.12^{abcd}	1488.61^{bc}
Dafo	69.51±0.77^{ef}	59.48±2.24^{c}	11.37±0.06^{a}	15.46±00^{def}	145.83^{fg}	4331.42^{h}	42.57^{e}	34.00^{d}	644.51^{bcde}	1267.53^{cd}
Dinsho	68.52±0.23^{f}	57.85±2.06^{c}	11.43±0.06^{a}	15.81±0.19^{cde}	154.38^{efg}	8289.95^{b}	59.02^{b}	51.28^{cb}	590.46^{bcdef}	1255.17^{cde}
Gobe	72.45±0.25^{abc}	43.13±0.39^{f}	8.16±0.05^{g}	15.83±0.13^{cde}	123.77^{gh}	6060.29^{ef}	49.72^{c}	58.42^{bc}	545.93^{cdef}	1212.99^{cdef}
Golden E	68.37±3.15^{f}	46.88±0.05^{e}	10.82±0.36^{b}	17.97±0.19^{ab}	126.26^{gh}	4768.81^{g}	76.81^{a}	42.71^{cd}	714.02^{abc}	1138.15^{def}
Harbu	69.48±1.77^{ef}	46.77±0.82^{e}	8.94±0.02^{ef}	16.53±0.26^{c}	366.10^{a}	6028.61^{f}	32.68^{g}	45.06^{cd}	428.77^{f}	928.05^{f}
HB 1307	72.98±0.1^{ab}	62.82±0.02^{b}	10.47±0.06^{c}	11.24±0.06^{g}	116.51^{gh}	4248.11^{h}	57.36^{b}	43.92^{cd}	728.60^{ab}	1345.83^{ef}
HB 1965	64.41±0.01^{g}	36.87±0.08^{h}	7.46±0.05^{i}	15.34±0.18^{ef}	87.14^{h}	5942.66^{f}	46.07^{d}	44.44^{cd}	526.05^{def}	1045.38^{def}
HB 1966	65.66±0.22^{g}	36.71±0.21^{h}	8.19±0.06^{g}	15.07±0.12^{ef}	173.46^{def}	6429.52^{e}	41.34^{ef}	46.66^{bcd}	499.53^{ef}	981.80^{def}
Robera	70.81±0.22^{cde}	49.33±0.21^{d}	8.89±0.08^{f}	14.69±0.14^{f}	321.20^{b}	6915.11^{d}	49.19^{cd}	56.54^{cb}	822.54^{a}	1691.87^{b}
Walker	62.48±0.56^{h}	45.84±0.64^{e}	10.83±0.12^{b}	18.72±0.02^{a}	192.22^{de}	7632.89^{c}	57.85^{b}	78.48^{a}	695.12^{abc}	1645.17^{b}
Mean	**68.32**	**48.15**	**9.68**	**15.55**	**188.54**	**6618.55**	**45.59**	**51.38**	**623.51**	**1345.83**
LSD (p<0.05)	**1.64**	**2.99**	**1.24**	**3.35**	**41.50**	**378.02**	**3.47**	**16.67**	**168.91**	**324.58**
CV	**1.44**	**2.41**	**0.20**	**0.87**	**13.16**	**3.50**	**4.55**	**19.40**	**16.20**	**14.42**

Note: In each column means followed by different letters (a, b, c, d, e, etc.) are significantly different at $p < 0.05$

Proximate and Energy Composition of Barley Varieties' Porridge

Proximate (moisture, ash, protein, crude fat, crude fiber, carbohydrate) and energy content of barley varieties' porridge are presented in Table 3. Both proximate and energy composition were strongly significant (P<0.0001) among barley varieties' porridge. The mean moisture, ash, protein, crude fat, crude fiber, carbohydrate and energy composition of porridge were 8.21%, 3.17%, 13.90%, 3.03%, 0.93%, 70.76,% and 346.99 Kcal respectively. The maximum moisture and ash content were obtained from Walker and Robera variety with value of 8.96 % and 5.81 % respectively. But the least moisture and ash content was obtained from Bentu variety with value 7.32 % and 1.94 % respectively. The protein content of porridge ranged from 8.58 %(from Dinsho) to 16.64 % (from Golden). The protein composition was not significant among Golden Eye, Robera, HB 1307, Walker and Dafo varieties. The maximum crude fat and crude fiber were obtained from Dafo and HB 1966 respectively. Carbohydrate (CHO), energy, crude fat and fiber value were obtained with range of 68.09 - 75.11%, 335.24 - 356.75Kcal, 1.99 - 4.31% and 0.50 - 1.21% respectively. Bentu variety was superior by energy with the value of 356.75Kcal but not significant among Aquila, Gobe and HB 1665 varieties.

Table 3. Proximate and Energy Content Barley Varieties' Porridge Collected from Research Centers

S.N		Moisture (%)	Ash (%)	Protein (%)	Crude Fiber (%)	Crude fat (%)	CHO (%)	Energy(Kcal)
1	Abdane	8.13±0.68^{fbdec}	4.09±0.19^{b}	13.81±0.41^{ef}	3.31±0.45^{bcd}	1.16±0.19^{ba}	69.50±1.49^{fe}	343.69±4.00^{de}
2	Aquila	8.19±0.53^{bdec}	2.83±0.15^{dce}	15.00±0.08^{bdc}	2.76±0.18^{fecd}	0.89±0.11^{fde}	70.33±0.19^{de}	349.30±1.54^{ba}
3	Aruso	8.56±0.17^{bac}	2.97±0.04^{dce}	12.94±0.51^{gf}	3.36±0.59^{bc}	0.66±0.16^{fg}	71.62±0.72^{dc}	344.17±1.49^{de}
4	Bentu	7.32±0.26^{g}	1.94±0.37^{f}	13.60±0.07^{egf}	2.71±0.12^{fed}	0.93±0.03^{dec}	73.50±0.14^{ba}	356.75±0.60^{a}
5	Biftu	8.77±0.19^{ba}	3.03±0.02^{dc}	12.66±1.75^{g}	3.29±0.61^{becd}	0.50±0.00^{g}	71.76±2.13^{dc}	342.19±3.07^{e}
6	Dafo	8.11±0.70^{fdec}	2.65±0.04^{de}	15.72±0.29^{ba}	4.31±0.45^{a}	1.12±0.03^{bac}	68.09±0.13^{f}	345.31±1.27^{dce}
7	Dinsho	8.94±0.33^{a}	3.28±0.15^{c}	8.58±0.21^{h}	3.06±0.52^{fecd}	1.03±0.02^{bdac}	75.11±0.74^{a}	344.03±2.30^{de}
8	Gobe	7.81±0.03^{fgde}	2.70±0.17^{dce}	13.94±1.29^{edf}	1.99±0.46^{g}	0.98±0.34^{bdc}	72.59±1.58^{bc}	354.90±4.16^{a}
9	Golden	8.26±0.23^{bdec}	3.27±0.03^{c}	16.64±0.23^{a}	2.83±0.16^{fecd}	0.90±0.07^{dec}	68.09±0.24^{f}	347.97±1.43^{dce}
10	Harbu	8.35±0.44^{bdac}	3.14±0.04^{dc}	14.48±0.27^{edc}	3.21±0.08^{becd}	0.71±0.20^{feg}	70.12±0.71^{de}	344.75±0.38^{dce}
11	HB 1307	7.64±0.33^{fge}	2.59±0.12^{fe}	16.39±0.12^{a}	3.77±0.53^{ba}	0.88±0.05^{fde}	68.73±0.80^{fe}	348.36±4.03^{dc}
12	HB 1965	7.63±0.17^{fge}	2.39±0.63^{fe}	13.42±0.74^{gf}	2.76±0.11^{fecd}	0.97±0.04^{bdc}	72.83±1.59^{bc}	353.72±3.32^{ba}
13	HB 1966	7.52±0.45^{fg}	4.18±1.03^{b}	12.85±0.69^{gf}	2.89±0.50^{fecd}	1.21±0.04^{a}	71.34±0.59^{dc}	347.69±4.50^{dc}
14	Robera	8.96±0.11^{a}	5.81±0.16^{a}	13.14±0.20^{gf}	2.69±0.04^{fe}	1.02±0.05^{bdac}	68.37±0.37^{f}	335.24±1.04^{f}
15	Walker	8.97±0.28^{a}	2.85±0.02^{dce}	15.53±0.25^{bac}	2.51±0.07^{fg}	1.00±0.13^{bdac}	69.25±0.58^{fe}	347.72±0.92^{dc}
Mean		**8.21**	**3.17**	**13.90**	**3.03**	**0.93**	**70.76**	**346.99**
LSD		**0.65****	**0.59****	**1.15****	**0.62****	**0.23****	**1.45****	**4.94****
CV		**4.76**	**11.10**	**4.94**	**12.13**	**14.86**	**1.44**	**0.85**

Where: In each column means followed by different letters (a, b, c, d, e, etc.) are significantly different at $\alpha < 0.05$.
**= strongly significant at P<0.0001

Proximate and Energy Composition of Barley Varieties' Injera

Proximate and energy content of barley varieties' porridge are presented in Table 4. Both proximate and energy composition were strongly significant (P<0.0001) among barley varieties' porridge. The moisture, ash, protein, crude fat, crude fiber, carbohydrate and energy content of Injera determined with range of 8.40 - 10.26%, 1.23 – 3.45%, 8.95 – 18.08 %, 2.33 – 5.55%, 0.62 – 1.49%, 66.86 – 74.91% and 337.99 – 352.76 Kcal respectively. The maximum moisture

and ash content were obtained from Walker and Robera variety with value of 10.26 % and 3.45% respectively. But the least moisture and ash content was obtained from Bentu and BH 1965 variety with value 8.86 % and 1.23% respectively. The maximum and minimum protein content was determined in BH07 (18.08%) and Dinsho (8.95 %) respectively. The maximum and minimum crude fiber content was determined in HB 1965 (5.55%) and Golden Eye (2.33%) respectively. The least crude fat and CHO content was found from Aquila variety, while the maximum crude and CHO content was determined from Dinsho variety. The least and highest energy content obtained from HB1965 and Abdane variety with the value of 337.68Kcal and 352.76Kcal respectively. The energy composition was not significant among Biftu, HB 1307, Golden Eye and Abdane varieties.

The mean proximate and energy composition determined in both barley varieties' porridge and Injera conceded with nutrient content of barley products per 100 g as commonly consumed in Ethiopia food 368, 9.1, 8.5, 2.0, 79.0, 2.2, 1.4, 17.0, 294, 6.3(23 21). The proximate composition of barley grain ranges 78 – 83, 7.6 – 14.4, 1.3 – 2.8, 4.0 – 8.0 and 2.0 – 5.0 for carbohydrate, protein, fat, crude fiber and ash respectively(2422**)**. Lipid concentration of barley generally ranges from 2 to 3% (25) with reports of cultivars as high as 5.3% (26). The ash content, gross mineral matter of barley ranges from 2.0 to 3.0% with low ash occurring in hulless types. Barley hulls contain around 6.0% ash (27). Mineral contain in barley ranges for Na, K, Ca, Mg, Fe and Zn for raw barley 3, 270, 20, 65, 3.0, and 2.1mg/per 100g (23**)**. Variables which are difficult to control such as soil composition, moisture, temperature and amount of sunlight, can produce location and seasonal variation in the grain composition (28). As the proximate and energy compositions of barley varieties porridge and Injera shown on Table 3 and 4 indicated; Aquila, Bentu, Gobe and BH 1965 varieties among the best for porridge in terms of energy. While, Abdane, Biftu, Golden Eye and HB 1307 varieties had superior for Injera in terms energy .

Sensory evaluation eata

Sensory evaluation is defined as a scientific discipline used to evoke, measure, analyze, and interpret those responses to products that are perceived by the senses of sight, smell, touch, taste, and hearing (29). While acceptable color of a food varies depending on cultural, geographic and sociological aspects of a given population, certain food groups are acceptable only if they fall within a certain color range (30).

Sensory Evaluation of Porridge

Barley varieties' sensory acceptability of porridge are shown in Table 5. The tested porridge sensory attributes among barley varieties had significant ($P<0.0001$) differences in color, texture, mouth feel, taste, odor and overall acceptability. The mean preference of porridge for color, texture, mouth feel, taste, odor and overall acceptability were 6.59, 5.96, 6.31, 5.90, 5.97 and 6.47 respectively. Barley varieties porridge was accepted with least score given for Walker porridge texture with the value of 3.89(dislike moderately) and the most preferred score 7.68 (Like moderately) was given for Gobe porridge color. Bentu variety was mostly preferred for overall acceptability but not significant among Robera, HB 1966, Gobe and Aquila varieties for overall acceptability score

Table 4. Proximate and Energy content of barley varieties' Injera

SN		Moisture (%)	Ash (%)	Protein (%)	Crude Fiber (%)	Crude fat (%)	CHO (%)	Energy(Kcal)
1	Abdane	8.98±0.04^{ih}	1.85±0.01^{cb}	15.24±0.76^{cebd}	2.72±0.50^{gef}	1.39±0.03^{a}	69.82±0.91^{cfed}	352.76±1.65^{a}
2	Aquila	9.14±0.02^{h}	1.70±0.07^{cd}	15.91±0.13^{b}	3.40±0.10^{cbd}	0.62±0.13^{f}	67.08±0.15^{i}	346.16±0.80^{cd}
3	Aruso	10.02±0.09^{bc}	1.66±0.05^{cd}	13.53±0.63^{gf}	2.96±0.13^{gcefd}	1.11±0.03^{c}	70.72±0.55^{cbd}	346.97±0.39^{cbd}
4	Bentu	8.86±0.01^{i}	1.58±0.00^{d}	14.39±0.97^{gef}	3.44±0.08^{cb}	0.81±0.03^{d}	70.94±0.86^{cb}	348.50±0.027^{cb}
5	Biftu	8.96±0.19^{ih}	1.68±0.04^{cd}	13.04±0.55^{g}	2.93±0.12^{gcefd}	1.12±0.07^{c}	72.27±0.56^{b}	351.35±1.07^{a}
6	Dafo	9.14±0.28^{h}	1.52±0.04^{ed}	16.33±1.80^{cb}	3.15±0.30^{cefd}	0.83±0.04^{d}	69.03±1.85^{gfeh}	348.90±0.32^{b}
7	Dinsho	10.11±0.12^{bac}	1.49±0.01^{edf}	8.95±0.65^{h}	3.06±0.77^{cefd}	1.49±0.02^{a}	74.91±0.65^{a}	348.82±2.65^{b}
8	Gobe	9.95±0.15^{dc}	2.01±0.54^{b}	16.55±0.26^{b}	3.84±0.32^{b}	0.78±0.09^{d}	66.86±0.26^{i}	340.72±0.79^{e}
9	Golden	9.39±0.11^{g}	1.65±0.12 ^{cd}	16.53±1.72^{b}	2.33±0.12^{g}	1.05±0.02^{c}	69.05±1.99^{gfeh}	351.79±1.29^{a}
10	Harbu	9.52±0.11^{gf}	1.62±0.08 ^{cd}	15.22±0.64^{cebd}	2.62±0.06^{gf}	0.67±0.00^{ef}	70.34±0.62^{ced}	348.30±0.28^{cbd}
11	HB 1307	8.40±0.05^{j}	1.25±0.00^{gf}	18.08±0.26^{a}	3.15±0.07^{cefd}	0.76±0.06^{ed}	68.35±0.40^{gfih}	352.61±0.46^{a}
12	HB 1965	9.76±0.07^{ed}	1.23±0.02^{g}	15.01±0.13^{ced}	5.55±0.88^{a}	0.77±0.06^{ed}	67.69±0.95^{ih}	337.68±3.45^{f}
13	HB 1966	9.64±0.08^{ef}	1.55±0.02^{ed}	15.95±0.42^{cbd}	2.77±0.20^{gefd}	0.80±0.06^{d}	69.29±0.68^{gfed}	348.15±0.59^{cbd}
14	Robera	10.21±0.14^{ba}	3.45±0.04^{a}	14.75±0.47^{efd}	2.58±0.10^{gf}	1.28±0.11^{b}	67.91±0.66^{gih}	341.43±0.58^{e}
15	Walker	10.26±0.17^{a}	1.33±0.05^{egf}	15.02±0.42^{ced}	3.34±0.61^{cebd}	1.15±0.02^{c}	68.90±0.31^{gfeh}	346.07±1.45^{d}
Mean		**9.49**	**1.70**	**14.97**	**3.19**	**0.97**	**69.53**	**347.35**
LSD		**0.20**	**0.25**	**1.40**	**0.66****	**0.10****	**1.70****	**2.34****
CV		**1.27**	**8.73**	**5.58**	**12.41**	**6.43**	**1.57**	**0.40**

Where: In each column means followed by different letters (a, b, c, d, e, etc.) are significantly different at $\alpha < 0.05$. **= strongly significant at P<0.0001

Table 5. **Sensory evaluation of porridge preference for selected food barley varieties**

S.N	Sample name	Porridge Sensory Attributes					
		Color	**Texture**	**Mouth feel**	**Taste**	**Odor**	**Overall acceptability**
1	Abdane	6.38±1.74^{ef}	5.48±1.81^{fe}	6.58±1.22^{ba}	5.63±2.00^{ed}	5.86±1.84^{bc}	6.59±1.55^{edf}
2	Aquila	7.22±1.31^{bac}	6.79±1.42^{ba}	6.78±1.33^{ba}	6.30±1.58^{bc}	6.32±1.83^{ba}	7.13±1.25^{bac}
3	Aruso	6.48±1.62^{edf}	6.73±1.52^{ba}	6.37±1.50^{bc}	6.54±1.56^{ba}	6.32±1.81^{ba}	6.84±1.60 ^{ebdc}
4	Biftu	7.05±1.66^{c}	6.30±1.71^{bcd}	6.79±1.44^{ba}	6.11±1.80^{bdc}	6.05±1.68^{bc}	6.68±1.59^{edfc}
5	Bentu	7.57±1.29^{ba}	7.21±1.19^{a}	7.21±1.62^{a}	6.86±1.09^{a}	6.67±1.45^{a}	7.33±1.41^{a}
6	Dafo	5.43±1.70^{hi}	4.98±1.76^{f}	6.21±1.44^{bc}	5.21±1.94^{ef}	5.16±2.13^{d}	5.70±2.06^{h}
7	Dinsho	6.32±1.54^{gf}	5.97±1.61^{ed}	6.53±1.39^{ba}	5.90±1.82^{dc}	5.87±1.92^{bc}	6.25±1.90^{gf}
8	Gobe	7.68±1.23^{a}	6.51±1.58^{bc}	6.79±1.27^{ba}	6.54±1.78^{ba}	6.27±1.74^{ba}	7.06±1.58^{bdac}
9	Golden Eye	5.84±1.82^{hg}	5.16±1.81^{f}	5.63±1.46^{c}	5.10±1.96^{f}	5.62±1.83^{dc}	5.62±1.92^{h}
10	Harbu	6.49±1.42^{edf}	6.06±1.45^{cd}	6.58±1.17^{ba}	6.10±1.64^{bdc}	6.00±1.67^{bc}	6.57±1.60^{ef}
11	HB 1965	6.87±1.35^{edc}	5.95±1.66^{ed}	6.37±1.34^{bc}	6.03±1.64^{dc}	6.08±1.63^{bc}	6.65±1.48 ^{edfc}
12	HB 1966	7.14±1.70^{bc}	6.67±1.81^{b}	6.53±1.31^{ba}	6.35±1.80^{bc}	6.63±1.47^{a}	7.19±1.48^{ba}
13	HB 1307	6.24±1.82^{gf}	5.11±2.04^{f}	6.22±1.48^{bc}	5.40±2.01^{ef}	5.84±1.76^{bc}	6.03±1.93^{gh}
14	Robera	6.94±1.60^{dc}	6.56±1.57^{bc}	5.58±1.84^{c}	6.38±1.65^{bac}	6.22±1.89^{ba}	6.92±1.70 ^{ebdac}
15	Walker	5.27±2.00^{i}	3.89±2.16^{g}	4.53±2.17^{d}	4.06±1.98^{g}	4.59±1.97^{e}	4.52±1.97^{i}
	Mean	**6.59**	**5.96**	**6.31**	**5.90**	**5.97**	**6.47**
	LSD (p<0.05)	**0.50**	**0.49**	**0.83**	**0.49**	**0.48**	**0.47**
	CV	**21.50**	**23.73**	**20.60**	**23.75**	**23.46**	**21.05**

- Where: In each column means followed by different letters (a, b, c, d, e, etc.) are significantly different at $\alpha < 0.05$.

Table 6. **Sensory evaluation of injera preference for selected food barley varieties**

S.N	Sample name	Injera Sensory Attributes						
		Gas hole distribution	Color	Texture	Mouth feel	Taste	Odor	Overall acceptability
1	Abdane	5.94±2.52^{gh}	5.99±2.08^{e}	5.59±2.24^{fg}	3.82^{f}	5.54±1.95^{d}	5.49±1.94^{d}	6.25±2.04^{e}
2	Aquila	7.04±1.77^{bac}	6.94±1.45^{ba}	6.65±1.57^{ba}	5.91^{bc}	5.76±1.74^{dc}	5.72±1.83^{dc}	7.13±1.41^{a}
3	Aruso	6.96±1.64^{bdac}	6.68±1.46^{bc}	6.88±1.04^{a}	6.77^{a}	6.31±1.69^{a}	6.10±1.69^{bac}	7.03±1.52^{ba}
4	Biftu	6.79±1.81^{ebdac}	6.76±1.49^{bac}	6.53±1.68^{bdac}	6.59^{ab}	6.09±1.77^{bac}	6.22±1.69^{ba}	7.15±1.51^{a}
5	Bentu	7.15±1.83^{a}	7.13±1.07^{a}	6.57±1.34^{bac}	5.95^{bc}	6.00±1.61^{bdac}	6.22±1.55^{ba}	6.94±1.56^{ba}
6	Dafo	6.44±1.67^{egdf}	6.60±1.45^{bdc}	6.16±1.49^{bdec}	5.73^{cd}	6.15±1.50^{bac}	6.15±1.88^{bac}	6.88±1.62^{bac}
7	Dinsho	6.38±2.09^{egf}	6.62±1.75^{bdc}	6.38±1.56^{bdec}	5.82^{c}	6.03±1.54^{bac}	5.97±1.70^{bc}	6.74±1.86^{bdac}
8	Gobe	6.00±2.60^{gfh}	6.47±1.92^{dc}	6.01±1.83^{feg}	4.91^{e}	6.07±2.09^{bac}	6.47±1.67^{a}	6.79±1.99^{bdac}
9	Golden	7.12±1.70^{ba}	6.91±1.33^{bac}	6.63±1.45^{ba}	5.95^{bc}	6.25±1.66^{ba}	6.10±1.61^{bac}	6.99±1.23^{ba}
10	Harbu	6.69±2.13 ^{ebdac}	6.79±1.52^{bac}	6.10±1.77^{dec}	5.05^{de}	5.88±1.91^{bdac}	6.06±1.81^{bac}	6.78±1.53^{bdac}
11	HB 1965	4.97±1.82^{i}	6.19±1.02^{ed}	5.56±1.24^{g}	5.91^{cb}	6.34±1.38^{a}	6.26±0.99^{ba}	6.35±1.09^{ed}
12	HB 1966	6.59±1.65 ^{ebdc}	6.59±1.74^{bdc}	6.06±1.46^{fde}	6.41^{abc}	5.97±1.70^{bdac}	6.01±1.54^{bac}	6.71±1.70^{ebdac}
13	HB 1307	5.68±1.55^{h}	6.74±1.30^{bac}	6.06±1.58^{fde}	5.77^{cd}	5.96±1.53^{bdac}	6.13±1.54^{bac}	6.44±1.61^{edc}
14	Robera	6.51±1.50 ^{edfc}	6.60±1.35^{bdc}	6.32±1.47^{bdec}	5.82^{c}	5.87±1.66^{bdac}	6.04±1.77^{bac}	6.90±1.44^{bac}
15	Walker	6.75±2.00 ^{ebdac}	6.75±1.38^{bac}	6.22±1.43^{bdec}	5.68^{cd}	5.79±1.56^{bdc}	6.00±1.63^{bc}	6.66±1.60^{edc}
Mean		**6.47**	**6.65**	**6.25**	**5.74**	**6.00**	**6.06**	**6.78**
CV		**24.46**	**20.21**	**23.34**	**22.25**	**23.89**	**23.02**	**20.28**
LSD		**0.53****	**0.45****	**0.49****	**0.76****	**0.48****	**0.47****	**0.46****

- Where: In each column means followed by different letters (a, b, c, d, e, etc.) are significantly different at $\alpha < 0.05$.

Barley varieties' sensory acceptability of data of Injera are shown in Table 6. Among barley varieties had significant (P<0.0001) differences in gas hole distribution, color, texture, mouth feel taste and odor preferences, but not significant among Robera, HB 1966, Harbu, Golden Eye, Gobe, Dinsho, Dafo Bentu Biftu, Aruso and Aquila varieties for overall acceptability score. All varieties were preferred for tasted sensory qualities varied from the least disliked moderately (3.82) to the highest liked moderately (7.15) as shown in the Table 6. The highest score for gas whole distribution (eye) and color were 7.15 and 7.13 respectively belonging to Bentu variety and the lowest preferred were HB 1665 and Abdane variety for eye (4.97) and color (5.99) respectively. Similarly Aruso variety had preferred most for texture, mouth feel, and taste with the scores 6.88, 6.77 and 6.31 respectively. The least score found for mouth feel, taste, odor and overall acceptability were given for Abdane variety with 3.82, 5.54, 5.49, and 6.25, while the least texture (5.56) score provided for BH 1665. Gobe and Biftu variety had the highest preferred for odor (6.64) and overall acceptability (7.15) respective. The overall acceptability was not significant different among most barley variety except the inferior liked varieties such as Abdane, HB 19665, HB 1307 and Walker varieties. among A good Injera is soft, with uniformly distributed gas holes on its top surface and nonstick top and bottom surfaces, is supple (rolls easily), and has a slightly sour taste (31 & 32). The appearance, size, and distribution of gas holes on the Injera surface and its taste and texture all impact the preference and acceptability of Injera.

CONCLUSION AND RECOMMENDATIONS

Fifteen released food barley varieties were determined for physicochemical and sensory qualities. This study revailed that barley variety had different merits for tested physicals, chemicals and sensory qualities parameters. Accordingly, barley varieties such as Aquila, Bentu and Gobe were preferred for porridge preparation and utilization. While Biftu, HB 1307 and Golden barley varieties were better for Injera preparation and consumption. Generally, depending on the overall yield, physicals, nutrients, energy and sensory qualities Bentu, Gobe, Aquila and HB 1307 varieties recommended for the intended users. In the future, incorporation of nutritional evaluation may be necessary during regional variety verification trails

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Determination of Maize-Wheat-Soybean Blending Ratio for Improved Nutritional and Process Quality of Bread in Selected Zones of Oromia, Ethiopia

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ABSTRACT

Bread is staple food and its consumption is increasing in Ethiopia. Most of the rural families prepare their daily food from cereal products and do not consider the nutritional aspects of view. Hence, most of the children and mothers in the rural families are affected by malnutrition. Thus, it is essential to consider different methods of food preparations at home level that constitutes sufficient nutrients. Therefore, this study was conducted to determine maize, wheat and soybean blending ratio for improved nutritional and process quality of bread. Study site, farmers and samples (maize, wheat, and soybean varieties) were purposively selected. Proximate, energy and minerals contents were determined with three replications following AOAC methods. Thirteen formulations of composite flour were determined using mixture design with the aid of MINITAB 17 software package. The ingredients were 100% wheat, 100% maize and mixture of maize, wheat and soybean ranged from 0–65%, 0–100% and 0–25% for maize, wheat and soy bean, respectively. Sensory evaluation was done using 9-point hedonic scales. Results of the study showed a significant difference ($p< 0.05$) in nutrients and sensory quality of bread as the compositions of ingredients were changed. The bread had moisture, ash, protein, crude fat, crude fiber, carbohydrate, energy, iron, zinc and calcium ranged from 7.57 – 8.75%, 0.78 – 2.14%, 9.55 – 22.75%, 1.14 – 6.55%, 2.39 – 3.93%, 58.03 – 75.75%, 357.22 – 381.53Kcal, 19.39– 43.00ppm, 12.21 – 48.32ppm and 11.85– 68.62ppm respectively. The overall acceptability of bread ranged from neither like nor dislike to like very much. Bread baked from 25%, 50% and 25% flour of maize, wheat and soybean respectively is recommended for nutrient composition allied with consumers' preferences.

Key words: Blending ratio, consumers' preferences, sensory evaluation

INTRODUCTION

Bread is one of staple food in the world and prepared by baking cereal flour with addition of other ingredients such as sugar, oil, yeast, egg, water, etc. The consumption of bread is increasing in Ethiopia because of expansion of bread technologies. Rural families are preparing their daily food from cereal products and do not consider the nutritional point of view. Thus, many children and mothers are affecting by malnutrition. But, they have different agricultural products. Therefore, it is essential to consider different methods of food preparations at home level that constitutes sufficient nutrients. The energy distribution of carbohydrate in the diet of children, women and men from Oromia were 65.6 %, 74.6 % and 65.8 % respectively. While, the energy distribution of protein and fat in the diet of children, women and men from Oromia were 10.4 %, 9.8% and 9.7 % and 24.2%, 15.8 % and 24.8 % respectively (1). Thus, the diet of an average Ethiopian consists of foods that are mostly carbohydrate based; therefore there is a

need for strategic use of inexpensive high protein resources that complement the amino acid profile of the staple diet in order to enhance their nutritive value.

Maize had second (21 %) and first (31%) for production and yield respectively and one of staple food especially in maize belt areas. Among the top 25 maize producing districts in Ethiopia, 15 are found in Oromia (2). Approximately 88 % of maize produced in Ethiopia is consumed as food, both as green and dry grain (3). Maize is the most important staple in terms of calorie intake in rural Ethiopia (3). Although there is now a substantial amount of composite bread technology available, such breads still require at least 70% wheat flour to be able to rise and hence, implementation of such pre-commercial inventions has been limited (4).

Soybean is rich in high quality proteins with balanced amino acids, lipids, minerals and bioactive compounds but is limited in starches (5 & 6). Wheat flour for bread has starches and functional protein glutens that favor the processing of leavened aerated bread, but is limited in fat and balanced amino acids (7). Addition of oilseed flour to bread has shown to improve protein quality and overall nutritive value (8). Soybean is rich in protein with well-balanced amino acid profile, so in search for nutritious food products, it provides an opportunity to be used in baked products such as cookies, bread, pasta, soups and snack foods (9).

Oromia has different topography of land while the lowland areas have limitation of wheat cultivation, and the society need wheat grains for bread preparation from other parts of the country and/or import. This leads to poor bread preparation. However, there are many solutions to improve bread quality and quantity. Since maize is the main crops around the area, the utilization of maize may be increased and the cost of the bread and malnutrition might be minimized. Therefore, the aim of this study, was to select the best nutritious and access consumers preference of maize, wheat and soybean flour mixture of bread

MATERIALS AND METHODS

Samples Collection and Processing

Maize (Zea mays) and soybean seeds (Glycine max) were obtained from Bako Agricultural Research Center of IQQO (Oromia Agricultural Research Institute) while wheat varieties were collected from Sinana Agricultural Research Center. All grain seeds were cleaned, sorted and milled (whole meal flour) by using laboratory miller, but soybean was processed before converted to flour to remove all anti-nutritional factors according to IITA, 1990 method. Different ratios of maize, soy bean and wheat flour were prepared by using design expert version software. Flow diagram for the production of cooked soy flour is indicated below.

Soybean seeds → Sorting/cleaning → Roasting (until light brown) → Boiling (20 min) → Decortication (i.e. testa removal) → Draining → Drying (100-120°C for 3-4 h) → Dry milling → Flour

Study Site

The study was conducted at Bako Tibe and Horo districts which are found in West Showa and Horo Guduru Wollega zones respectively as shown on figure 2. Amarti Gibe and Bacara Oda Gibe peasant association (PA) were selected from Bako Tibe and Didibe Kistana PA was selected from Horo Guduru. From each peasant associations two farmers' research groups having 10-15 members were organized in the study area. Site selection of representative farmers

was done with a multi-disciplinary team from the research center and agricultural development agents based on maize production potential and interested host farmers. Laboratory analysis was undertaken at Food Science Research Directorate of IQQO.

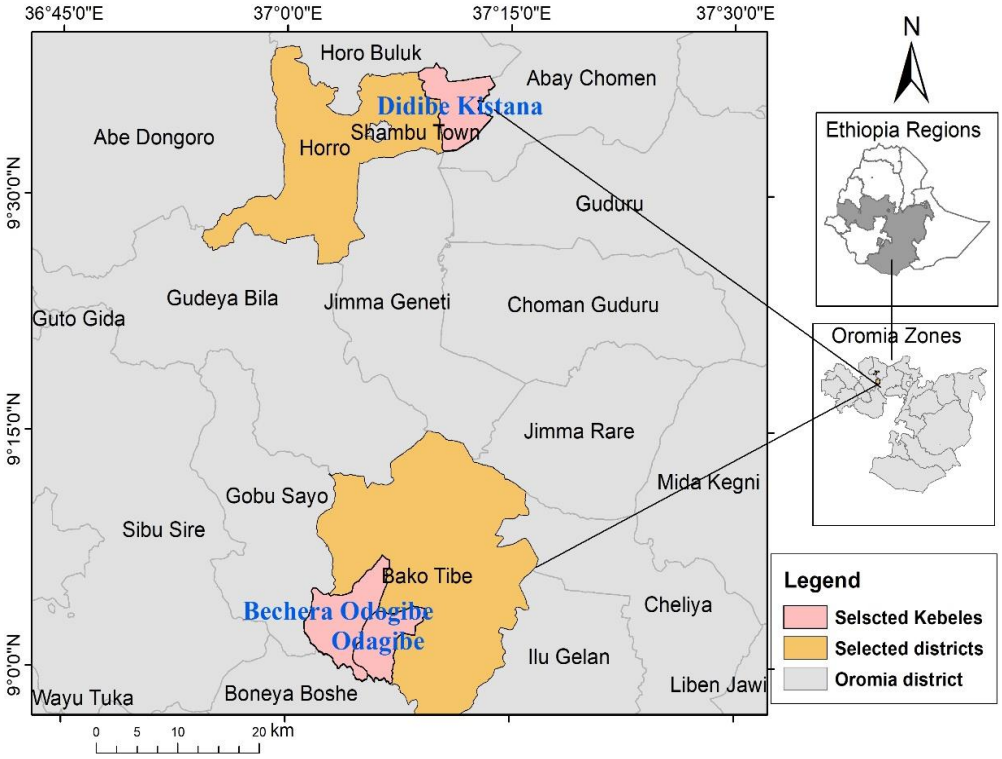


Figure 2. Map of study area

Blend Formulation

Blending ratio was determined by expert design using software. Accordingly, 16 treatments with in two controls and three replication were implemented. Therefore, only thirteen treatments were reported.

Table 1. Bread treatment and blend (mixture) of maize, wheat and soybean flour ratio

Treatment	Maize (%)	Wheat (%)	Soybean (%)	Code
1	65	25	10	1
2	54	25	21	2
3	65	25	10	3
4	48	27	25	4
5	25	50	25	5
6	56	34	10	6
7	25	50	25	7
8	38	50	12	8
9	45	38	17	9
10	43	32	25	10
11	49	32	19	11
12	34	41	25	12
13	33	48	19	13
14	38	50	12	14
15	100	0	0	15
16	0	100	0	16

Bakery Study

Straight dough making method was followed for baking bread. Equal amount of ingredients [(sugar (2g), salt 0.5 g, yeast (2g) and water 120 ml)] were used for baking bread per 100 gram of flour mixture as shown on the Table 1.

Determination of nutrient compositions

Proximate Composition: Moisture, protein and fat content of the grain samples and proximate composition of bread blends were determined by using the AOAC, 1990 methods (11). Total carbohydrate is calculated by difference. Energy was calculated using Artwater factor: Fat x 9 + Carbohydrate x 4 + Protein x 4 (kcal).

Minerals: Iron, zinc and calcium content were analyzed by using AOAC Official Method 975.03(12)**.** All determinations were carried out in triplicate.

Sensory Evaluation of Bread

Bread samples prepared from different mixture of maize, wheat and soybean flour were evaluated by twenty eight panelists consisting of researchers, selected farmers and development agents. Finally, the study had training and practical demonstration for farmers and development agents as shown on the figure 3.The panelists were requested to evaluate the bread on the basis of acceptance of its shape (appearance), color, texture, odor, taste and overall acceptability qualities by using 9 Hedonic scale with 1 representing dislike extremely and 9 the highest which is like extremely.

Data Analysis

Mean and standard deviations were calculated for proximate, minerals and acceptability of the sensory attributes. All recorded data were subjected to SAS software to test ANOVA and the mean was separated by list significant different.

RESULTS AND DISCUSSIONS

Proximate and Energy Composition of Bread Samples

Proximate and energy content of different maize, wheat and soybean flour mixture of bread shown on Table 2. There was significant difference ($p < 0.05$) in the proximate and energy composition of formulated bread samples. The mean moisture, ash, protein, crude fat and fiber, carbohydrate and energy composition of formulated bread samples were 8.11%, 1.36%, 18.33%, 4.06%, 64.84% and 369.34kcal respectively. The moisture content of the bread has the least (7.57 %) for blend 48/27/25 ratio while the highest (8.75 %) was from maize bread (100 % maize flour). The least ash and crude fat was obtained from wheat bread (100 % wheat flour) with value of 0.78 % and 1.14 % respectively. The maximum ash content (2.14 %) and crude fat (6.49 %) was found in 25/50/25 and 48/27/25 flour mixture bread samples respectively. the maximum and minimum protein content 22.75 % and 9.55 % found in 48/27/25 flour mixture bread and maize bread samples respectively. The protein content was not significant among 48/27/25, 25/50/25, 43/32/25, 49/32/19 and 34/41/25 bread samples. The crude fiber content ranged from 2.39 – 3.93 %. The bread prepared from 25/50/25 and 65/25/10 maize, wheat and soybean ratio respectively had the least and highest crude fiber. Dietary fibre in cereals is derived principally from the plant cell walls and can best be defined analytically as lignin and non-starch polysaccharide. This includes all polysaccharides other than a-linked glucose polymers (13).

Anderson reported different ratio of dietary fiber content for different types of wheat flour bread. Accordingly, whole meal, brown and white wheat bread contained 8-9g, 5-6g and 2-3g of dietary fiber/100g bread respectively. The concentration of carbohydrate and energy of formulated bread ranged from 58.03 – 75.75 % and 357.22 – 382.29 Kcal respectively. The maximum carbohydrate and energy were obtained from whole maize bread and 25/50/25 maize, wheat and soybean ratio of bread respectively.

The protein content of maize (N=6), wheat (N=2) and soybean grain (N=3) was obtained with the values of 8.5%, 13.1% and 34.94 % and for fat 3.96%, 3.03% and 20.11% respectively. While, the mean formulated bread had 18.33% and 4.03 % of protein and fat respectively. This result is in agreement with FAO's report which was the energy, protein and fat contents in 100 g edible portion of bread white, maize whole flour and soybean dried raw bread white: 261, 7.7, 2.0, whole flour maize: 353, 9.3, 3.8, soybean: 416, 36.5, 20.0(14). Eyele et al. also reported the composite dried bread flours processed from wheat, cassava and soybean had moisture, crude fiber, protein, fat, ash, total carbohydrate and energy contents in the range of 4.87–6.15%, 2.68–4.00%, 13.05–21.2%, 4.96–11.25%, 3.78–4.23%, 53.17–70.21% and 389.6–414.73 kcal/100 g, respectively(15). It is similar with this finding except energy which was lower in this study because mainly the protein, fat and energy source were from soybean flour and Eyele et al. (2017) have used up to 30 % of soybean during bread formulation. Thomison et al. (2004) also reported maize grain protein and fat concentration averaged for three years across hybrids maize were 8.7 % and 6.3% respectively (16).

Some Minerals Composition of Bread Samples

Iron (Fe), Zinc (Zn) and Calcium (Ca) contents of bread are shown on table 3. The iron values of the bread ranged from 13.11 ppm to 43.00 ppm. The wheat bread (100 % wheat flour) had the highest Fe compositions which was significantly ($p < 0.05$) different among other samples, except 33//48/19 and 34/41/25 maize, wheat and soybean flour ratio respectively. The least Fe contents was from 48/27/25 with value of 13.11 ppm. The highest and least Ca content recorded from 34/41/25 and maize (100% maize) bread sample with value of 68.62 ppm and 11.85 ppm respectively. This might be attributed to the high percentage of wheat and soybeans, as soybeans seeds were reported to contain appreciable amounts of minerals (17).

Sensory Evaluation

The sensory data for bread quality attributes are presented in Table 4. All sensory quality attributes (shape, color, texture, Taste, odor and overall acceptability) of bread ranged from neither like nor dislike to like very much. The preference mean value of 7.25, 7.05, 6.73, 6.56, 6.47 and 7.13 awarded for shape, color, texture, taste, odor and overall acceptability among bread samples recorded respectively. There was significant difference ($p< 0.05$) in the shape, color, texture, taste, odor and overall acceptability among bread samples. The study revealed that the highiest ratio of maize flour were less preferred for sensory scores and maize bread (100 % maize flour) had the least preferred for shape, color, texture, taste, odor and overall acceptability. While wheat bread had the most preferred for shape, color, texture, Taste, odor and overall acceptability. However, the overall acceptability of wheat bread was not significant among 25/50/25, 56/34/10, 38/50/12 and 33/48/19 maize, wheat and soybean flour mixtures respectively. The result revealed that the 25/50/25, 33/48/19, and 0/100/0 bread samples were among best preferred for all bread quality attributes.

Table 2. Proximate and Minerals content of Maize-wheat-soybean bread at dry basis

SN	Maize, Wheat and Soybean ratio	**Proximate and energy content of Maize-wheat-soybean bread**						
		Moisture (%)	**Ash (%)**	**Protein (%)**	**Crude Fat (%)**	**Crude Fiber (%)**	**Carbohydrate (%)**	**Energy (Kcal)**
1	54/25/21	8.06±0.29^{de}	1.54±0.25^{ba}	19.04±0.65^{dc}	4.91±0.13^{c}	3.87±0.07^{ba}	62.58±0.94^{gfh}	370.66±2.76^{b}
2	65/25/10	7.80±0.27^{de}	1.03±0.07^{dc}	15.96±0.08^{f}	2.88±0.04^{f}	3.93±0.51^{a}	68.40±0.21^{cb}	363.33±0.54^{c}
3	48/27/25	7.57±0.27^{e}	1.78±0.05^{ba}	22.75±1.15^{a}	6.49±0.02^{a}	3.3±0.04^{bdc}	58.03±1.11^{j}	381.47±0.97^{a}
4	56/34/10	7.91±0.19^{de}	0.86±0.70^{d}	16.13±0.78^{ef}	2.19±0.00^{g}	3.31±0.08^{bdac}	69.59±0.82^{b}	362.62±2.98^{c}
5	25/50/25	7.55±0.43^{e}	2.14±0.06^{a}	21.68±0.29^{ba}	6.12±0.03^{b}	2.39±0.37^{e}	60.11±0.92^{jih}	382.29±2.47^{a}
6	38/50/12	8.05±0.11^{de}	1.53±0.29^{bc}	18.46±3.86^{edc}	2.1±0.12^{g}	3.31±0.04^{bdac}	66.54±3.73^{cd}	358.90±1.91^{dc}
7	45/38/17	8.64±0.38^{ba}	1.77±0.11^{ba}	17.38±1.63^{edf}	3.5±0.10^{e}	3.07±0.39^{d}	65.64±2.29^{ed}	363.57±3.91^{c}
8	43/32/25	8.59±0.03^{bac}	0.83±0.61^{d}	20.61±2.33^{bac}	6.55±0.07^{a}	3.75±0.23^{bac}	59.67±1.48^{ji}	380.07±2.92^{a}
9	49/32/19	8.11±0.43^{dc}	0.93±0.19^{d}	20.25±0.85^{ba}	4.52±0.06^{d}	3.41±0.34^{bdac}	62.79±1.73^{gf}	372.84±4.12^{b}
10	34/41/25	7.92±0.44^{de}	1.53±0.13^{bc}	20.55±0.62^{bac}	6.15±0.08^{b}	2.87±0.14^{de}	60.99±1.36^{gih}	381.53±0.97^{a}
11	33/48/19	8.21±0.42^{bdc}	1.88±0.15^{ba}	18.67±1.08^{dc}	4.48±0.23^{d}	3.12±0.18^{dc}	63.63±0.88^{ef}	369.56±2.96^{b}
12	100/00/00	8.75±0.06^{a}	1.05±0.30^{dc}	9.55±0.22^{g}	1.78±0.09^{h}	3.12±0.93^{dc}	75.75±1.49^{a}	357.22±4.75^{d}
13	00/100/00	8.25±0.15^{bdac}	0.78±0.22^{d}	17.19±0.23^{edf}	1.14±0.06^{i}	3.05±0.11^{d}	69.6±0.46^{b}	357.38±0.45^{d}
	Mean	**8.11**	**1.36**	**18.33**	**4.06**	**3.27**	**64.87**	**369.34**
	LSD ($p<0.05$)	**0.51**	**0.54**	**2.46**	**0.17**	**0.63**	**2.63**	**4.81**
	CV	**3.77**	**23.38**	**7.96**	**2.43**	**11.39**	**2.40**	**0.77**

Note: In each column means followed by different letters (a, b, c, d, e, etc.) are significantly different at $\alpha < 0.05$.

Table 3. Some Minerals content of Maize-wheat-soybean bread at dry basis

S. Number	Maize, Wheat and Soybean ratio (%)	Minerals content of Maize-wheat-soybean bread at dry basis		
		Fe (ppm)	**Zn (ppm)**	**Ca (ppm)**
1	54/25/21	19.39±1.08^{f}	34.78±2.10^{f}	55.03±2.55^{e}
2	65/25/10	21.91±0.32^{f}	34.60±1.10^{f}	36.32±1.31^{h}
3	48/27/25	13.11±1.19^{g}	12.21±1.51^{h}	19.41±2.63^{i}
4	56/34/10	33.11±0.62^{d}	39.00±2.47^{e}	36.45±0.30^{h}
5	25/50/25	37.53±1.27^{c}	46.82±0.44^{ba}	64.23±1.46^{b}
6	38/50/12	27.80±3.35^{e}	43.36±1.21^{bdc}	49.65±0.89^{f}
7	45/38/17	39.16±0.61^{bc}	46.43±1.07^{bac}	56.47±1.29^{de}
8	43/32/25	37.50±0.84^{c}	42.85±0.97^{dc}	60.97±1.86^{c}
9	49/32/19	31.50±4.01^{d}	42.30±256^{ed}	51.65±1.82^{e}
10	34/41/25	40.92±1.25^{ba}	48.32±3.11^{a}	68.62±0.34^{a}
11	33/48/19	42.17±1.47^{ab}	46.26±1.44^{bac}	58.91±1.20^{dc}
12	100/00/00	20.25±0.82^{f}	27.44±4.39	11.85±2.35^{j}
13	00/100/00	43.00±3.16^{a}	48.17±2.72^{a}	41.96±0.46^{g}
	Mean	**31.33**	**39.43**	**47.04**
	LSD (p<0.05)	**3.3**	**3.79**	**2.83**
	CV	**6.34**	**5.69**	**3.57**

Note: In each column means followed by different letters (a, b, c, d, e, etc.) are significantly different at $\alpha < 0.05$.

Table 4. Bread sensory qualities score for bread experiment

SN	Maize, wheat and soybean flour ratio respectively (%)	Bread sensory qualities					
		Shape	**Color**	**Texture**	**Taste**	**Odor**	**Overall acceptability**
1	54/25/21	6.89±1.83^{efg}	6.18±1.85^{ef}	5.93±2.00^{efg}	5.50±2.13^{hi}	5.61±1.99^{fg}	6.79±1.29^{defg}
2	65/25/10	6.61±1.40^{efgh}	6.43±1.55^{def}	6.46±1.37^{def}	6.36±1.75^{defgh}	5.71±1.94^{defg}	6.68±1.28^{fg}
3	48/27/25	6.36±1.45^{gh}	6.14±1.67^{f}	5.71±1.98^{fg}	5.57±1.89^{ghi}	6.04±2.15^{cdefg}	6.54±1.75^{gh}
4	25/50/25	8.57±0.84^{a}	7.86±1.33^{a}	7.93±1.25^{a}	7.21±1.73^{abcd}	7.00±1.70^{ab}	7.50±1.67^{abcde}
5	56/34/10	7.82±1.44^{abc}	7.39±1.75^{abc}	6.89±2.04^{bcd}	7.07±1.70^{bcde}	6.75±2.01^{bc}	7.61±1.40^{abc}
6	38/50/12	7.71±1.27^{bcd}	7.18±1.44^{abcd}	7.04±1.69^{bcd}	6.71±2.21^{bcdef}	6.57±2.12^{bcd}	7.43±1.55^{abcdef}
7	45/38/17	6.50±2.29^{fgh}	6.50±2.30^{def}	6.61±1.91^{cde}	6.79±2.50^{bcdef}	6.54±2.36^{bcde}	6.89±2.18^{cdefg}
8	43/32/25	7.00±1.72^{defg}	7.21±1.55^{abcd}	6.75±1.65^{bcd}	6.39±1.69^{cdefgh}	6.43±1.95^{bcdef}	6.93±1.86^{cdefg}
9	49/32/19	6.82±1.66^{efg}	7.04±1.40^{bcd}	6.43±1.14^{def}	6.29±1.74^{efgh}	6.36±1.91^{bcdef}	6.75±1.55^{defg}
10	34/41/25	6.75±1.43^{efg}	6.86±1.76^{a}	6.50±1.60^{cdef}	5.93±1.98^{fghi}	5.68±1.89^{efg}	6.71±1.74^{efg}
11	33/48/19	8.21±1.20^{ab}	7.89±1.29^{ab}	7.54±1.69^{ab}	7.29±1.74^{abc}	7.21±1.37^{ab}	7.79±1.60^{ab}
12	100/0/0	5.93±1.90^{h}	6.82±2.04^{h}	5.54±1.73^{g}	5.21±1.91^{i}	5.43±2.28^{g}	5.86±2.19^{h}
13	0/100/0	8.54±0.79^{a}	7.71±1.12^{ab}	8.00±1.28^{a}	8.11±1.47^{a}	7.86±1.60^{a}	8.18±1.94^{a}
	Mean	**7.25**	**7.05**	**6.73**	**6.56**	**6.47**	**7.13**
	CV	**20.4**	**21.83**	**22.49**	**25.99**	**26.14**	**21.44**
	LSD(α=0.05)	**0.76**	**0.81**	**0.80**	**0.90**	**0.89**	**0.80**

key: In each column means followed by different letters (a, b, c, d, e, etc.) are significantly different at $\alpha < 0.05$.

Correlation Coefficients of Bread Sensory Qualities with Their Proximate, Energy and Minerals Content

Table 5. Person correlation coefficients of bread sensory qualities with their proximate, energy and minerals content

Bread quality indicators	Shape	Color	Texture	Taste	Odor	OAA	MC	Ash	Protein	Fiber	Fat	CHO	Energy	Fe	Zn	Ca
Shape	1.00	0.66****	0.62****	0.55****	0.49****	0.59****	-0.36*	0.08	0.25	-0.19	-0.02	-0.13	0.07	0.27	0.32	0.35*
Color		1.00	0.63****	0.50****	0.46****	0.59****	0.31	-0.10	-0.36*	0.13	-0.33*	0.34*	-0.38*	0.14	0.29	0.04
Texture			1.00	0.63****	0.55****	0.58****	-0.18	-0.09	0.37*	-0.18	0.08	-0.24	0.17	0.44**	0.34*	0.40*
Taste				1.00	0.67****	0.58****	0.06	0.02	0.05	-0.19	-0.08	0.01	-0.06	0.46**	0.41**	0.36*
Odor					1.00	0.67****	-0.01	-0.05	0.07	-0.23	-0.04	-0.01	0.03	0.38*	0.39*	0.32*
OAA						1.00	0.16	-0.10	-0.13	-0.19	-0.33*	-0.23	-0.28	0.42**	0.45*	0.23
MC							1.00	-0.25	-0.43**	0.17	-0.29	0.32*	-0.45**	0.20	0.17	-0.04
Ash								1.00	0.30	-0.26	0.42**	-0.42**	0.29	-0.04	-0.01	0.25
Protein									1.00	-0.07	0.73****	-0.95****	0.74****	0.13	0.09	0.53***
Fiber										1.00	-0.06	-0.02	-0.24	-0.42**	-0.21	-0.16
Fat											1.00	-0.89****	0.95****	-0.00	-0.11	0.45**
CHO												1.00	-0.83****	0.06	-0.02	-0.54***
Energy													1.00	0.06	-0.09	0.42**
Fe														1.00	0.86****	0.68****
Zn															1.00	0.79***
Ca																1.00

Where, OAA= Overall acceptability, CHO= Carbohydrate, ****=P<0.0001, ***=P<0.0005, **=P<0.01 and *=P<0.05

The correlation coefficients of bread sensory qualities with their proximate, energy and minerals content are presented on Table 5. Accordingly, all bread sensory qualities were positively correlated to each other and strongly significant (P<0.0001). Moisture content was negatively correlated to shape and energy and significant (P<0.05). However, it was positively correlated with carbohydrate and significant (P<0.05). Ash content was positively correlated to crude fat and significant (P<0.01) but negatively correlated to carbohydrate and significant (P<0.01). Protein content was negatively correlated to color, moisture content and carbohydrate. It was significant (P<0.05) for color and moisture but strongly significant (P<0.0001) for carbohydrate. Protein content was positively correlated to crude fat, energy and calcium and strongly significant (P<0.001) for the first two qualities but significant (P<0.0005) for calcium.

Even though crude fiber content was negatively correlated most bread qualities except color and moisture; it was only significant (P<0.01) for iron. Crude fat content was negatively correlated to color, overall acceptability and carbohydrate and significant (P<0.05), (P<0.05) and (P<0.0001) respectively. Crude fat also positively correlated to ash, energy and calcium significant (P<0.01), (P<0.0001) and (P<0.01) respectively (P<0.005). Carbohydrate was positively correlated to moisture and significant (P<0.05). But negatively correlated to energy and Calcium and significant (P<0.0001) and (P<0.0005) respectively. Energy was positively correlated to calcium and significant (P<0.01). Iron was positively correlated to texture, taste, odor, Zn and Ca and significant (P<0.01), (P<0.01), (P<0.05), (P<0.0001) and (P<0.0001) respectively. Zinc was positively correlated to texture, taste, odor, overall acceptability, and Ca and significant (P<0.05), (P<0.01), (P<0.05), (P<0.05) and (P<0.0001) respectively. Calcium was positively correlated to shape, texture and odor and significant (P<0.05).

Among bread mixture of maize, wheat and soybean flour studied; mixture of 48/27/25, 25/50/25, and 49/32/29 ratio of maize, wheat and soybean respectively had the highest protein, crude fat and energy. While, bread mixture of maize, wheat and soybean 0/100/100, 33/48/19 and 25/50/25 respectively were most preferred. Major Ethiopian food is from carbohydrate based (1) and the selection of bread prepared from different ratio of maize, wheat and soybean could be focus on best nutritious food with protein and energy advantages. Similarly, the selection should be agreed with the consumers' preferences. As shown on the figure 4 the maximum protein was obtained from 48/27/25 bread but the highest accepted bread was from 100 % wheat bread. While the maximum energy was obtained from 25/50/25 maize, wheat and soybean flour bread samples as illustrated on figure 5.

Different researchers recommended different amount of soybean flour which ranged from 7% up 30% to produce acceptable bread with quality attributes similar to 100 % wheat flour (18, 19 & 20). Food that contain large amounts of micronutrients compared to their energy content are called nutrient rich or nutrient dense food. They are preferred as they help in ensuring that diet provides all nutrients needed. Hence, the formulated bread had good source of carbohydrate, protein, fat, fiber, minerals and energy. Therefore, bread prepared from 25 %, 50% and 25 % flour of maize, wheat and soybean flour respectively(figure 6) had coincide with nutrition and sensory qualities parameters.

Daily recommended intakes for energy, protein, iron and zinc for children (1-3 years and 12.kg body weight are 1022kcal, 14.0g, 6mg, 8.4mg and for women (18-59 years old and 55 kg body weight) are 2408kcal, 41, 29/11c mg and 9.8 mg respectively (21). To satisfy the daily recommended intake of protein 100 gram of 25 %, 50%, and 25% of maize, wheat and soybean flour bread is enough for children but 200g bread is recommended for women.

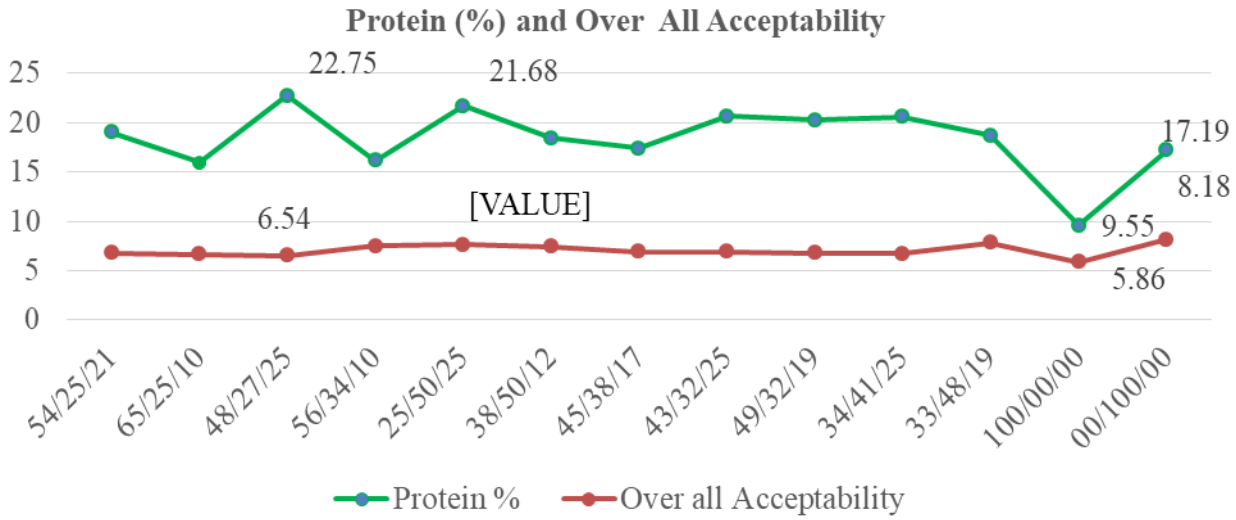
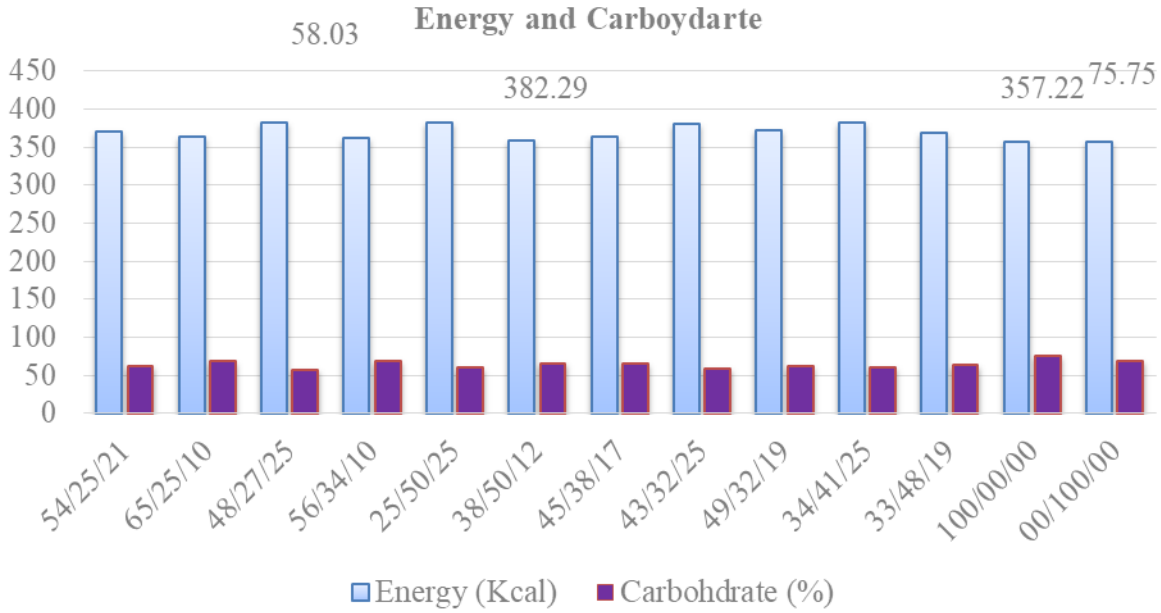


Figure 4. Comparison of highest protein content and overall acceptability among bread prepared



CONCLUSION AND RECOMMENDATIONS

This finding revealed that maize, wheat and soybean blending ratio for bread preparation affected both nutrition and consumers' preference. Bread prepared from those mixture superior in nutrients and energy and equivalent to wheat bread for preferences. Bread baked from 25%, 50% and 25% flour of maize, wheat and soybean respectively recommended for

nutrient composition allied with consumers' preferences. Substitution of wheat by maize and soybean enhance the proximate and minerals composition but there was a gap on consumers' preference for bread with high protein contents which is very important in study area. Therefore, training for attitude and custom for protein utilization in order to decrease malnutrition is important in the study area.

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LIVESTOCK RESEARCH

The release and registration of "Bako 01" and "Bako 04" Napier grass (Pennisetum purpureum) varieties

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ABSTRACT

The name 'Bako 01' and 'Bako 04' are given to the newly released Napier grass (Pennisetum purpureum) varieties with the pedigree designation of ILRI Acc.No 16801 and ILRI Acc.No 16804 which were developed and released by Bako Agricultural Research Center in 2019. Bako 01' and 'Bako 04' were evaluated together with eight genotypes including standard check (ILCA-16984) for two years (2016 and 2017) in regional variety trial at three locations (Billo,Gute and Bako) in mid-altitudes of western oromia. The combined analysis of yield data across years and locations showed that, Bako 04 and Bako 01 had higher mean herbage dry matter yields of 45.43 t/ha) and 39.5 t/ha) with 49.71 % and 30.07 % yield advantages over the standard check (30.35 ton ha-1), respectively. The highest crude protein of 8.32 % were recorded for Bako 04 and followed by Bako 01 (7.36 %) as compared with standard check (5.24 %). During variety verification trial, Bako 04 and Bako 01 were evaluated both on farmer's field and on research station along with the best standard check 'Zehone 01' which is recently released variety and gave superior herbage dry matter yields of 18.54 t/ha and 16.59 t/ha, respectively, as compared to the standard check (11.59 t/ha) in the trial. Moreover, genotype and genotype by environment interaction bi-plot analysis (GGE) also confirmed that Bako 04 and Bako 01 showed better stability and thus ideal varieties to be recommended in the tested environments and other areas with similar agro-ecologies.

Keywords: Bi-plot, crude protein, genotype, herbage dry matter yield, Napier grass

INTRODUCTION

In spite of the giant contribution of livestock to the livelihood of farmers, availability of poor quality feed resources remains to be the major obstacle to livestock production in Ethiopia (Seyoum and Zinash 1995). Traditional livestock production system mainly depends upon poor pasturelands and crop residues which are usually inadequate to support reasonable livestock production (Tsige 2000; Assefa 2005). Increased livestock production can be achieved through the cultivation of high-quality forages with high yielding ability that are adapted to biotic and abiotic environmental stresses in Ethiopia (Tesema et al., 2010). Amongst many perennial forage grasses in Ethiopia, the adaptation of Napier grass (Pennisetum purpureum) is better and promising than other forage grasses. One attraction of Napier grass is its versatility, in which it is tolerance to drought and adaptable to a wide range of soil conditions, high photosynthetic and water-use efficiency (Anderson et al., 2008). Napier grass could play an important role in providing a significant amount of biomass yield of 20-30 DM t/ha/year with good agronomic

management practices (Farrell et al., 2002). Napier grass cultivars have been reported to yield around 60 DM t/ha/year, with some studies indicating significantly higher yields (Rengsirikul K. et al., 2013; Oliveira M.L.F. et al., 2014). The yield of Napier grass mainly depends on the type of cultivar used which in turn is influenced by both the environment and management practices employed.

Napier grass is a pioneer species and performs well in low, mid and highland areas of Ethiopia and propagated vegetative by using stem cuttings, root splits which usually vary across agro-ecologies (Tessema, 2008; Getnet et al, 2012). The grass permits diverse utilization, in providing a continual supply of green forage throughout the year and either used in cut-and carry feeding systems or in silage form and best fits to all intensive small scale farming systems (Alemayehu, 1997; FAO, 2015). Genotypic variation in growth and morphological characteristics of Napier grass are correlated with DM yield and nutritional quality. Based on chemical composition and in-vitro dry matter digestibility (IVDMD), it could be categorized as high quality forage and extremely palatable when young and leafy (Tessema, 2002, Cook et al., 2005). The breeding efforts are mostly focused on yield stabilization, resistance to biotic and abiotic stresses, biochemical structure associated with feed quality. It has to be noted that modern cultivars, mostly of Bako 04 and Bako 01 produced high biomass yield and better feed quality as compared with other genotypes. Therefore, the objective of this study was to evaluate and identify the best performing Napier grass varieties for wide production in the tested environments and other areas with similar agro-ecologies.

MATERIALS AND METHODS

Ten Napier grass (Pennisetum purpureum) genotypes including two standard checks (ILCA-16984) and Zehone 02, at RVT and VVT, respectively. The genotypes were tested across locations (Bako, Billo and Gute) in western Oromia, Ethiopia during 2016 and 2017 main cropping season. The objective was to evaluate the performance of Napier grass for herbage DM yield, herbage quality and their stability across environments. The tested genotypes were ILRI 16804, ILRI 16801, ILRI 16787, ILRI 16785, ILRI 16798, ILRI 16800, ILRI 15743, ILRI 14389, ILRI 16840 and ILCA-16984. The genotypes were planted in a randomized complete block design with three replications. Stem cuttings with three nodes were planted on an area of 4 m x 3 m plot size to a depth of 15-20 cm at an angle of 45_o. The intra and inter row spacing of 0.5 m and 0.6 m respectively with 2 m width between blocks and 1 m width between plots were used. A blanket basal NPS fertilizer was used at the rate of 100 kg ha_{-1} and 100 kg of urea fertilizer were applied in which split application was followed for urea. All recommended agronomic managements were applied uniformly. For determination of biomass yield, genotypes were harvested at forage harvesting stage (at about 120 cm heights) from the two middle rows of 5 cm above the ground level. Weight of the total fresh biomass yield was recorded from each plot and 200 g sample was taken to the laboratory. The sample taken from each plot was dried in an oven for 72 hours at a temperature of 65_0C to a constant weight. Partially dried feed samples were ground to pass through a 1mm sieve screen using Wiley mill and stored in airtight plastic bags and pending for farther chemical analysis at Holota National Nutrition Laboratory. Survival rate data was measured in simple calculation by dividing the number of alive crops to the number of planted crops and multiplying by 100. This was conducted at the final stage of the experiment (during the second season of the experimental period). During variety verification trial, Bako 04 and Bako 01 were evaluated both on farmer's field and on research station along with the best standard check 'Zehone 02' which is recently released variety. Data on herbage DM yield;

quality parameters and other agronomic traits were collected and analyzed using SAS (SAS, 2002) software.

RESULTS AND DISCUSSION

Varietal Origin/Pedigree and Evaluation

Bako 01 and Bako 04 are the name given by the breeder to a released Napier grass (Pennisetum purpureum) varieties with the pedigree of ILRI 16804, ILRI 16801. These and the other Napier grass genotypes were originated from International Livestock research Institute (ILRI) and evaluated against the standard check (ILCA-16984) at three environments (Bako, Billo and Gute) in 2016 and 2017 main cropping seasons at RVT and verified along with newly released variety Zehone 02 in 2018.

Herbage DM yield performances

Results from the analysis of variance for herbage DM yield revealed that significant effect ($p \leq 0.001$) were observed among the tested accessions across environments and years with mean values ranged from 27.59 to 45.43 t/ha (Table 1). The two varieties, Bako 04 and Bako 01 were produced higher mean herbage dry matter yields of 45.4 and 39.5 t/ha with 49.71 % and 30.07 % yield advantages, respectively over the standard check (30.35 t/ha). Besides, all through variety verification trial, Bako 04 and Bako 01 were evaluated at both on farmer's field and on research station in 2018 and gave superior herbage dry matter yields of 18.54 t/ha and 16.08 t/ha while comparing with recently released standard check 'Zehone 02' (11.58 t/ha) used in the evaluation with 60.12 % and 38.87 % yield advantages over the standard check (11.58 t/ha), respectively (Table 2).

Table 1. Mean Herbage Dry matter yields (ton ha^{-1}) of different Napier grass genotypes across environments and years

	2016			2017				
Accession	Bako	Billo	Gute	Bako	Billo	Gute	Meam	Yield Adv %
Bako 04 (ILRI 16804)	31.47^{a}	41.22^{a}	41.65^{a}	38.81^{a}	60.17^{a}	59.29^{a}	45.43	49.71
Bako 01 (ILRI 16801)	26.13^{b}	40.02^{a}	32.35^{bcd}	34.19^{b}	49.14^{b}	55.02^{ab}	39.47	30.07
ILRI 16800	24.72^{b}	38.15^{ab}	32.66^{bc}	33.15^{b}	48.12^{bc}	52.97^{b}	38.29	26.19
ILCA-16984 (check)	19.73^{cd}	30.08^{c}	26.82^{ef}	27.60^{cd}	36.92^{e}	40.93^{cde}	30.35	-
ILRI 16798	16.22^{f}	27.00^{cd}	23.84^{f}	22.18^{e}	39.10^{de}	37.18^{e}	27.59	-9.10
ILRI 16840	20.09^{cd}	27.50^{cd}	28.59^{de}	25.12^{de}	41.11^{d}	40.00^{de}	30.40	0.18
ILRI 15743	18.87^{cde}	28.22^{cd}	28.69^{cde}	23.85^{de}	39.51^{de}	45.16^{c}	30.72	1.22
ILRI 16787	16.52^{ef}	25.80^{d}	26.60^{ef}	26.27^{d}	38.48^{de}	44.87^{c}	29.76	-1.95
ILRI 14389	20.83^{c}	36.08^{b}	33.20^{b}	30.37^{bc}	44.72^{c}	50.54^{b}	35.96	18.48
ILRI 16785	18.11^{def}	24.72^{d}	30.44^{b-e}	24.62^{de}	38.28^{de}	43.29^{cd}	29.91	-1.44
Mean	21.27	31.88	30.48	28.62	43.56	46.93	33.79	
CV %	7.2	6.7	7.7	7.9	4.7	5.9		
LSD (0.05)	2.644	3.687	4.038	3.887	3.482	4.712		
F-value	***	***	***	***	***	***		

Table 2: Mean Herbage DM yields of Napier grass candidate varieties and corresponding check across environments at variety verification trial in 2018.

Genotypes	Bako	Billo	Gute	Meam	Yield Adv. %
Zihone 02 "16791" (check)	10.71^{b}	13.20^{b}	10.82^{b}	11.58	-
ILRI 16800	18.54^{a}	16.38^{ab}	14.87^{a}	16.60	43.36
Bako 01	18.35^{a}	15.76^{ab}	14.12^{ab}	16.08	38.87
Bako 04	19.79^{a}	18.58^{a}	17.24^{a}	18.54	60.12

Mean	16.51	15.98	14.26
CV %	12.9	10.40	13.4
LSD (0.05)	4.265	3.320	3.823
LS	**	*	*

Herbage Quality Parameters

The chemical composition of the feed samples is presented in Table 3. The analysis of variance indicated that statistically significant ($p \leq 0.01$) differences were observed among the Napier grass accessions in percentages of CP and DOMD. Also significant ($p \leq 0.05$) differences were perceived for ash and OM. The mean DM content of the Napier grass accessions was 89.81 %, with values ranging from 87.67 % for accession ILRI 16798 to 91.35 % for accession ILRI 16800. The mean ash content was 7.89 %, with values ranging from 6.61 % for Bako 04 variety to 8. 77 % for ILRI 16798. This indicated that as ash value increased the quality of forage materials found to be decreased and vice versa. The CP content averaged 6.61 % ranging from 5.42 % for accession ILCA-16984 to 8.32 % for Bako 04 variety. The OM content was significantly ($p \leq 0.05$) higher for accessions ILRI 16800 with mean values of 84.52 % followed by Bako 04 (84.07 %) and Bako 01 (83.87 %). Similarly, the DOMD was significantly ($p \leq 0.01$) higher for Bako 04 and Bako 01 with mean values of 60.74% and 59.59 %, in that order. As regards to fiber quality, the lowest ADF and NDF were displayed by Bako 04 (43.2 % and 63.11), respectively, followed by Bako 01 (43.26 and 63.51 %) in that order.

Table 3: Mean nutritive value of different accessions of Napier grass regional variety trial of three locations.

		% DM						
Genotypes	DM %	Ash	CP	NDF	ADF	Lignin	DOMD	OM
16804	90.68	6.61^{c}	8.32^{a}	63.11	43.20	7.25	60.74^{ab}	84.07^{ab}
16801	90.99	7.12^{c}	7.36^{ab}	63.51	43.26	7.49	59.59^{ab}	83.87^{ab}
16800	91.35	6.83^{c}	7.05^{bcd}	64.38	43.26	7.94	52.1^{cd}	84.52^{a}
ILCA-16984 (check)	90.11	7.80^{bc}	5.42^{e}	65.50	43.29	8.04	52.73^{cd}	82.32^{abc}
16798	89.26	8.77^{ab}	6.12^{cde}	64.60	44.34	7.58	51.49^{cd}	80.49^{c}
16840	89.74	7.84^{bc}	5.92^{de}	65.52	43.24	7.85	47.95^{de}	81.90^{abc}
15743	89.44	9.37^{a}	5.99^{de}	64.68	43.65	7.27	51.83^{cd}	80.07^{c}
16787	89.12	7.90^{abc}	6.90^{bcd}	63.96	43.59	7.77	54.54^{bc}	81.22^{bc}
14389	87.67	8.01^{abc}	7.17^{abc}	64.03	39.78	7.58	52.49^{cd}	79.66^{c}
16785	89.79	8.66^{ab}	5.89^{de}	65.61	43.24	7.85	44.31^{e}	81.13bc
Grand Mean	89.81	7.89	6.61	64.39	43.09	7.66	52.78	81.92
CV %	1.8	10.9	10.3	4.9	6.0	4.6	6.0	2.2
LSD (0.05)	2.717	1.478	1.168	5.430	4.438	0.602	5.413	3.038
F-value	ns	*	**	ns	ns	ns	**	*

Key: DM%= Dry matter percentage, CP= Crude protein, NDF= Natural detergent fiber, Acid detergent fiber, DOMD= Digestible organic matter in dry matter

Stability Performance

Yield stability is important parameters that should be given great attention in variety development program. Thus yield stability was evaluated in multi- environment trails for two years with ten Napier grass genotypes to evaluate the yield and stability of the genotypes based on the methods of Eberhart and Russel (1966). Analysis using the GGE biplot, IPCA-1 and IPCA-2 explained 63.34 and 22.39 %, respectively, Napier grass accessions by environment interaction and made a total of 95.60 % (Fig 1). Environments and genotypes that fall in the central

(concentric) circle are considered as ideal environments and stable genotypes, respectively (Yan W.et al., 2001). Therefore, Bako 04 was fell into the center of concentric circles and thus ideal genotype in terms of higher yielding ability and stability, as compared to other accessions. Likewise, Bako 01variety was located on the next concentric circle and also considered as desirable variety.

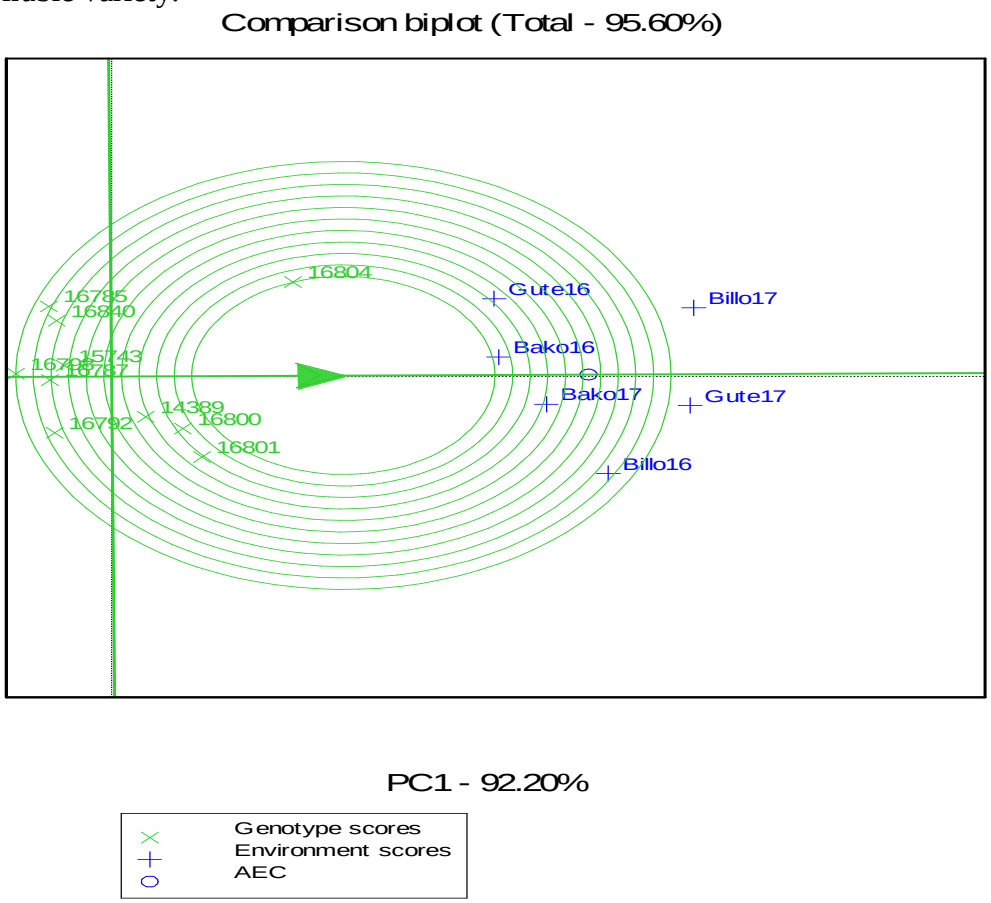

Fig1. GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability

Disease Reaction

Currently, Napier head smut, Napier stunt and snow white nould are the most common diseases and cause the most yield losses in Napier grass. Fortunately the released varieties and other tested genotypes were resistant to the indicated disease during the experimental periods across tasted locations.

Table 4. Agronomic and Morphological Characteristics of Bako 04, Bako 01 and ILCA-16984 varieties

Attributes	Description		
	Bako 04	Bako 01	ILCA-16984 (check
Adaptation:	Wide adaptation (for Low to highland areas)		
• Altitude (m.a.s.l):	< 1100 - > 3000		
• Rainfall (mm):	600-1200		
• Soil type:	Almost all soil type except water logging areas		
Seeding rate (cutting/ha):	20,000 cuttings		
Spacing (cm)	50 between plants and 100 between rows		
Planting date:	Med June to mid- July		
Fertilizer rate: (kg/ha): DAP:	P_2O_5: 46; N: 18, at planting		
Urea:	108.7 or 50 N (split application)		
Height at harvesting for biomass(cm):	109	107.6	104.6
Number of tillers per plant:	19	15	14
Propagation:	Vegetative by steam cuttings or root split		
Growth habit:	Erect		
Life span	Perennial		
Crop pest reaction:	No any disease and pest incidence		
Yield			
• Biomass yield in DM bases (t/ha/year):	45.4	39.5	30.4
Leaf to steam ratio:	1.2	1.3	1.1
Survival rate:	74.1	70.7	56.9
Fodder quality:			
DM (%):	90.68	90.99	90.11
CP (%):	8.32	7.36	5.42
OM (%):	84.07	83.87	82.32
IVDMD (%):	60.74	59.59	52.73
Ash (%):	6.61	7.12	7.8
NDF (%):	63.11	63.51	65.5
ADF (%):	43.20	43.26	43.29
ADL (%)	7.25	7.49	8.04
Special merits:	Wide and soft leaf which is more suitable for green feeding	Thick and soft steam which is suitable for silage making & green feeding	
Year of release:	2019 (2012 EC)		1984
Breeder/maintainer:	IQQO/BARC		ILRI

CONCLUSIONS AND RECOMMENDATION

Based on the results obtained it can be concluded that better herbage DM yield was recorded for two of the varieties evaluated: Bako 04 and Bako 01. The environments, genotypes and their interaction were significantly affected the Napier grass genotypes in herbage DM yields. The considerable variations were observed between years in DM yields among the Napier

grass genotypes. The study also indicated that, Bako 04, Bako 01 had a better nutritional quality due to higher content of CP, OM and ODMD and lowest fiber quality parameters. Analysis using the GGE biplot confirmed that Bako 04 and Bako 01 varieties were ideal genotype in terms of higher yielding ability and stability as compared to other accessions. Therefore, these two varieties should be recommended to be scaled up in the tested environments and areas with similar agro-ecology with its full agronomic and other management recommendations.

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Propagating stingless bee Meliponula beccarii colonies by Eduction and splitting methods

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ABSTRACT

A study was conducted in view of evaluating the propagation of Meliponula beccarii through Eduction and splitting queen-rearing methods at Holeta for three consecutive active seasons. The results indicated that stingless bee colonies induced to Eduction and splitting queen rearing techniques in general did not show good responses for new colonies adapted.The result of the study revealed that there was no difference in brood area development between the two techniques. The brood development rates for Eduction methods 100 % for four month and splitting method 75% for two months for adapted in daughter colonies, respectively. However, the rate of developing into daughter queen through splitting method was about 40%. From this study it is concluded that propagation of Meliponula beccarii through queen rearing is not an excellent option to overcome the problem of colony multiplication. From this study Eduction and splitting methods were in the success to obtained only during certain seasons of months which seemed to be the season of development of natural queen cells in the colony. Therefore further study is recommended to evaluate the propagation of Meliponula beccarii colony through queens reared using other alternative techniques.

Keywords: colony splitting, honey, meliponiculture, propagation stingless bee

INTRODUCTION

Stingless bees are reproducing differently to the more widely known Ethiopia honey bees. Stingless bees do not swarm in the way that honey bees do. A strong colony of native bees will send scouts to find another hive location (Roubik, 1992 and 2006). Workers then seal the new hollow, set it up to house the new hive and stock it with resources. Once the hive is ready, a virgin queen will then fly across to the new site accompanied by many workers and drones. Within days a mating swarm will be seen outside the new hive (Nogueira-Neto, 1997). The virgin queen will mate only once and stores this sperm for her entire life, for up to 5 years. Interestingly these virgin queens are present at most times in native bee hives, again very different to honey bees.

The easiest way to breed stingless bee colony is by doing a pot hive split. This method is simply taking the pot hive with bees and connecting with empty pot hive (Dollin and Heard, 1997). The method is traditionally used with the pot hives; it is a very successful method of hive propagation (Heard,1988). Meliponula beccarii colonies want to split a hive that is in underground soil. In these situations the best way forward is what is known as hive Eduction (Vijayakumar et al, 2013). This is a method used when you want to preserve the original nest and also produce a new pot hive. We can use this method to our advantage by giving a very attractive scheme to the bees. This is in the form of a hive pot through which the bees have to

enter and exit their own original nest. Therefore, Eduction method is an alternate method for splitting method for propagating stingless bees.

MATERIALS AND METHODS

Study Area

The study was carried out in Holeta Bee Research Center sub sites. The stingless bees were collected from underground nests and brought to HBRC apiary sites that have major perennial water sources used for irrigation. The apiary fields were intercropped with different bee forage plantation so that the plants provide both nectar and pollen to the stingless bees annually.

Stingless bee colonies management

Totally fifteen singles bee colonies were used- five colonies for the Eduction experiments, five for splitting methods and five for control without receiving any treatment. The extra space available inside the annexure hive was used for storing wastes. The diluted honey(1:1)in feeder and cluster of pollen pots were introduced to the annexure hive to lurethe bees from parent colony into the annexed hive.Honey was taken into the parent nest and stored inside.Introduction of some food pots and brood cells has certainly accelerated their building activity (Vijayakumar et al, 2013).

Propagating stingless bees through Education method

Five strong and active colonies were selected based on the forager strength. The entrance tube of the colony was carefully removed by pinprick method and properly fixed on a black plastic tube (10 mm diameter) in the original position of the entrance and forced allincoming and outgoing for agers throught henewly fitted plastic entrance hole (Michener, 1974 and 2000).The entrance of the oldnest was care fullyfixed on the tipoff the plastic tube, so that the bees caneasily identify the scent of the old entrance After pot hives with bees incresesd in adult bee population connecting empty pot hive , using 15 mm thick plastic tube with two20mm entrance holes in the centre of both front and back panel was attached into the original position of the parent colony.Proper supportis provided toplace the clay pothive closer to the mother colony (Muthuramanand Thirugnanasambantam (2003) and Vijayakumaret al, 2013).

Colony splitting

Five strong and active colonies were selected based on the forager strength for splitting. During the process of splitting, the rearrangement of resources was accordingly, a colony was divided into two equal parts so thateach pot hivegets half the nectar and brood and also shars equal number of worker bees.While conducting the splitting process, queen cells are placed in one pot hive and virgin queens in another original pot hive.(Camargo, 1988 and Heard, 1988).

Data management and statistical analysis

T-test will be used to compare brood development between the two systems. Brood area datausing the non-parameter test

RESULTS AND DISCUSSIONS

The results indicated that stingless bee colonies induced to Eduction and splitting queen rearing techniques in general showed failure response for new daughter colonies.This couldbe may be Meliponula beccariidid not prepare themselves for rearing mechanically through Education and splitting like Trigona species of stingless bee colonies. From both methods a total of 10 colonies were subjected to division by following these methods. Out of these 10 daughter colonies were developed successfully (Figure a & b). But the rate of success was highest (100%) in Eduction methods for 3-4 months developing into new daughter colonies, after which all were unsuccessful to survived. Through splitting method 75% of bee's colony was stayed mostly for two months developing into new daughter colonies after which all were also unsuccessful. There was no development of queen or successful development of the daughter colony in none of the colonies where separation of resources was made with queen cells. In both the methods, there was no successful development of daughter colonies after certain period of months except the mother colonies in control treatment which continued development.

The brood area is made up of cells where ovipositor takes place as well as cells that are used as storage pots for honey and pollen. The cells in Meliponula beccarii stingless bee colonies are arranged in clusters and are directly attached to each other with no pillar separating them.The different blocks of clustered cells are grouped together in a very irregular manner with gaps in between the different blocks. Apparently the blocks of cells represent different batches according to queen ovipositor. The older clusters were found beneath, while the recent ones are on top. The brood area measurement was not significantly different for both the queen rearing methods.

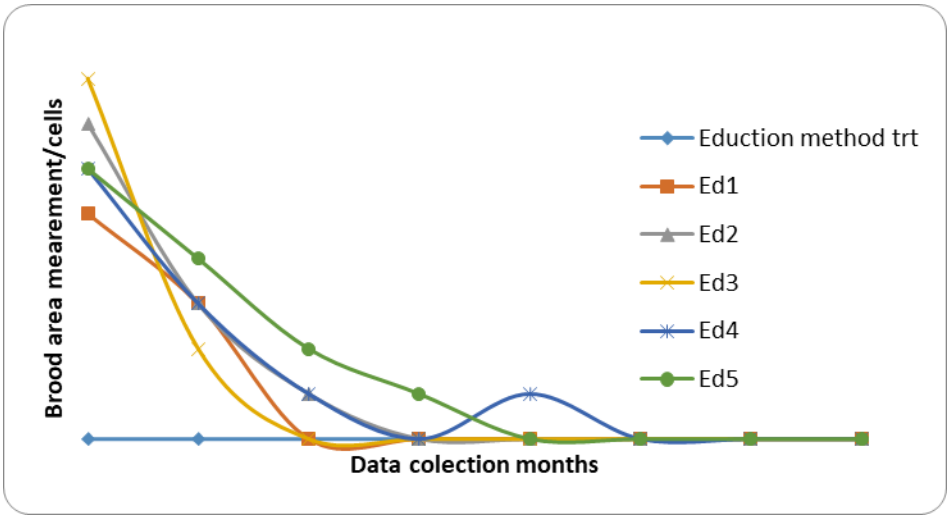

Figure 1a.Brood area measurement for different blocks of clustered cells grouped in Eduction method treatments over the data collection months

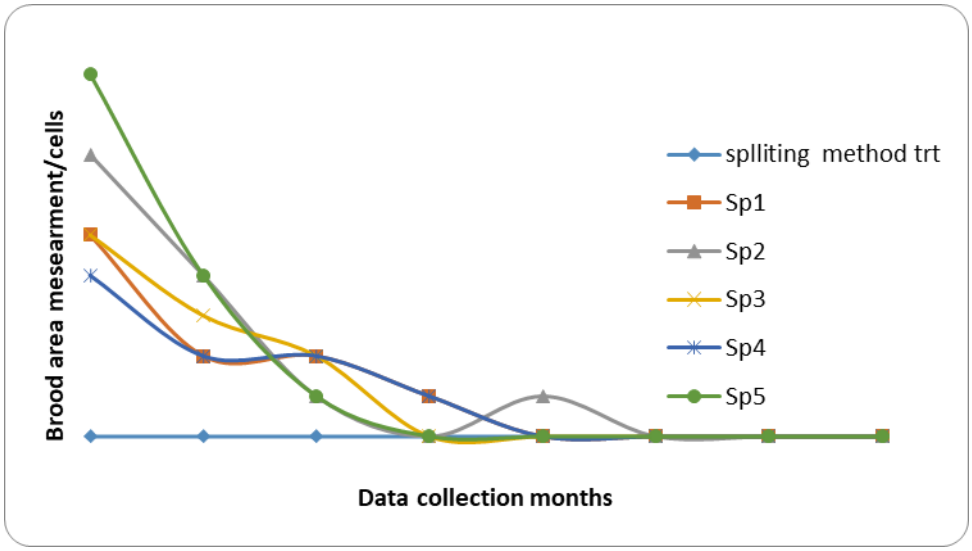

Figure 1b.Brood area measurement fordifferent blocks of clustered cellsgroupedin splitting method method treatments over the data collectionmonths

As observed from the control methods, the mother colonies, the number of brood area were increasing without separation of resources (brood, pollen, nectar and bees)

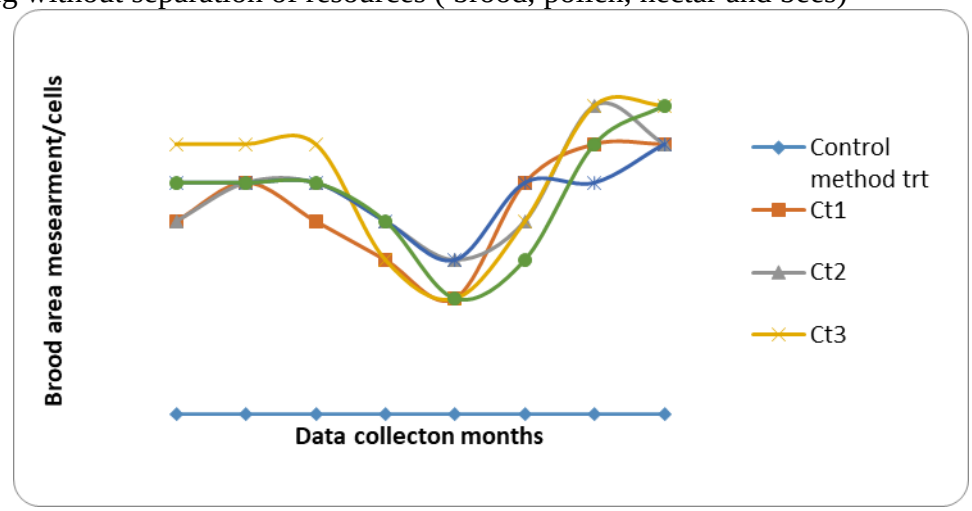

Figure 1c.Brood area measurement for different blocks of clustered cells grouped in control method treatments over the data collection months

At the study site, no varying rate of success was obtained by dividing the stingless bee, Meliponula beccarii colony at different seasons. In the present investigation no success has been obtained in the divided daughter colonies, with the absence of queen, the success rate was zero per cent. From these studies, Education and splitting queen rearing methods were not conformity with the work of (Ahmad, et al, 2018).

Therefore, meliponiculture expands, a reliable method is necessary to sustain the consistency and standard of the stingless bee (Ahmad, 2018). Rearing stingless bee is in pot hive where a few patterns have been built and utilized with success. In general, stingless bee colonies under

the control treatments showed an increasing amount of brood, nectar and number of bee population than the other treatments.

CONCLUSION

From the present investigation it can be concluded that the stingless bee colonies may not divided successfully, whenever the queen cells are present. Separation of resources like brood; with the presence of queen cells can come after formation of new daughter colonies.

Awareness on alternative stingless bee rearing techniques is extensively important for beekeepers for sustaining the growth rate of meliponiculture. Also, continuous awareness creation on harvesting stingless bee honey in the most appropriate way is essential.

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Integration of improved beekeeping technologies to the rehabilitation of Gorfo watershed in Toke Kutaye District

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ABSTRACT

Currently, the scarcity of bee flora is rated in the top place in hindering the beekeeping development due to natural resource degradation. Thus, the project was implemented at Gorfo Watershed in Toke Kutaye District. The main objective of this developmental study was to demonstrate the contribution of improved beekeeping technologies for income generation and sustainable watershed management through planting major bee forage plants and keeping the watershed from human and livestock disturbances. Households were purposively selected. Two Farmers Research and Extension Groups (FREG) were established comprising a total of 28 members, in which 18% were females. Training on seasonal honeybee colony management, bee product processing, value addition, and colony multiplication and conservation importance of beekeeping was provided. Watershed resources were assessed before and after the intervention of the project. In addition to this, data on honey yield, annual income obtained from honey sales, a skill gained, and problems faced during the project implementation were assessed. Before the intervention of the project, 16 bee plant species were found in the watershed. After the intervention of the project, the watershed assessed and found about 29 plant species with an increase of 13 bee forage plant species 7 plant species were added through the plantation, and 6 plant species added through natural regeneration). The net return obtained from honey production was about 20,500 Ethiopian Birr for the first FREG while the second FREG was 9,000 ETB. Besides, income, money-saving practices, and their awareness and skill on improved beekeeping and watershed management practices were improved. Since the watershed user groups managing honeybee colonies in groups, however, at this time the beekeeper's user groups decide to establish and manage their colonies with the knowledge and skill gained from the project. Currently, the watershed is rehabilitating found under good conditions. However, to rehabilitate this watershed, it is important to enhance the sustainability of the group and the watershed at least for the coming three years.

Keywords: beekeeping, bee plant, beeswax, honey, watershed

INTRODUCTION

Nowadays in most parts of Ethiopia, watersheds are facing extreme degradation due to intensive deforestation, overgrazing, unwise cultivation, increased population pressure, and other human actions (Takele, 2007; Mekonnen, 2014). These processes are affecting the balance between natural resources and human needs in areas. As a result of these changes, watersheds are subjected to climate change and other ecological degradation (Temesgen et al., 2008). More specifically, soil degradation is becoming the most livelihoods' threatening factor in the fragile watersheds of Ethiopia resulting in the loss of production capacity of the soil to sustain agro biodiversity.

The Ethiopian government has recently focused the need to develop beekeeping as one of the strategies to reduce poverty and to combat the effect of climate change through integrating watershed rehabilitation and forest conservation. Beekeeping plays a significant role in generating additional cash income for many beekeepers in rural areas and contributing to the national economy of the country (Godifey and Tassew, 2016). Honeybees and flowering plants have a well-developed system of interdependence. Flowering plants provide food to honeybees in the form of nectar and or Pollen (Bareke and Addi, 2018). On the other hand, honeybee improves the reproduction of flowering plants through pollination. Pollination is the transfer of pollen from the anther to the stigma (Bareke, 2018). However, the lack of effective pollination services is proposed as primary factors for low production and productivity of many economically important crops in Ethiopia (Bareke and Addi, 2019). Loss of pollination services has negative implications for beekeepers which mean loss of bee forage diversity, loss of nesting sites for bees, loss of places to keep hives, and low honey production (Kumsa and Gorfu, 2014; Albers and Robinson, 2011). Thus, the integration of beekeeping with watershed conservation has a multi-advantage. Watershed rehabilitation using bee forage plants used for honey production and reduce the effect of microclimate. In addition to this, honeybees boost the reproduction of flowering plants in the watershed. Therefore, such integration is used to boost the income of the local community.

Problem statement

In Ethiopia, the scarcity of bee flora is rated in the top place in hindering the beekeeping development due to deforestation and land degradation, overexploitation, overgrazing, and habitat loss. (Bareke et al., 2014). Hence, planting of multi-purpose bee forage trees integrated with honey production plays an important role in restoring productivity, biological diversity, and economic stability (Parrotta, 1992; Bareke et al., 2014; Kumsa, 2014). Moreover, it increases economic returns from beekeeping and provides an incentive for the sustainable use of watersheds.

The watershed management based on the planting of bee forages is not only support for the conservation of existing bee forages in the area, but also propagation of important bee forage which has a great value to watershed rehabilitation integrated with the productive beekeeping development. This activity also aims to improve farmers' livelihoods by introducing improved beekeeping technologies as an incentive to watershed conservation through high quantity and quality honey production that enables households to increase their incomes. Therefore, this activity was proposed to increase the income of local farmers from the watershed using improved beekeeping technologies and integrated with the planting of multi-purpose bee forage plants as an economic incentive while conserving the watershed through honey production.

MATERIALS AND METHODS

Study area

The study was conducted in Toke Kutaye District in West Whoa Zone on Gorfo watershed area during the study period from 2018/19- 2020 (Figure 1). This watershed was delineated by the District and it is owned by the local community user group. It was established with the

collaboration between Holeta Bee Research Center and Toke Kutaye Livestock and Fishery Development office. The activity was implemented by involving the local communities in conservation by providing economic incentives that are friendly for watershed conservation.

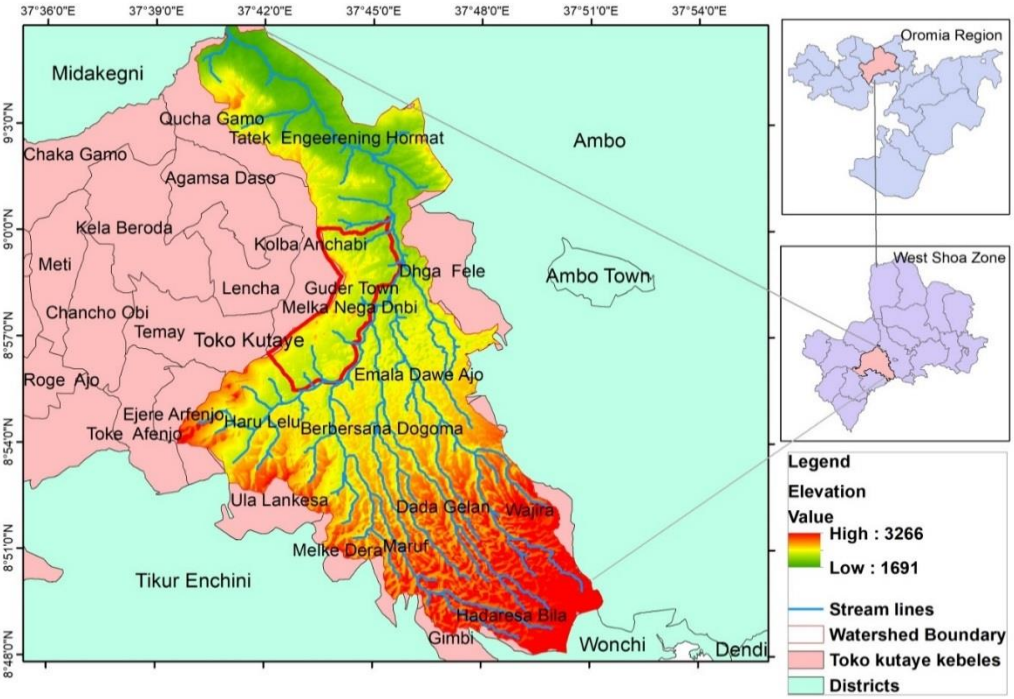

Figure 1: Maps of Gorfo watershed

APPROACHES AND METHODS FOR IMPLEMENTATION

Household selection and FREG establishment

For the study, households were purposively selected based on their interest in beekeeping and proximity of residence to watershed areas. Two FREG groups having a total of 28 (18% of women) were established to conduct the demonstration of beekeeping technology. However, three males were banned from the FREG due to breaking the bylaw set by user groups. Therefore, only a total of 25 (20% women) members participated in the study. A Memorandum of the agreement was signed by the member of the FREG, Holeta Bee Research Center, Livestock and Fishery Development Office of the district, and an initial sensitization workshop was held and Kebele administration.

Capacity building

Capacity building is the basis for the implementation of the integrated watershed conservation program. Practical training was given for the target community around the watershed on bee forage nursery management techniques, bee forage tree planting layouts and management, the advantage of tree planting. Honeybee transferring from traditional to improved hives, seasonal honeybee colony manipulation, and intermediate beehive construction, and apiary site selection, bee product processing, and post-harvest management was carried out. Moreover, honeybee colony multiplication (selection of mother colonies, techniques of colony

strengthening, preparing mother colony for splitting, harvesting queen pupae, nuclei colony formation, nuclei colony management, and protection of pest and predators).

Demonstration of improved beekeeping technology

After practical training was held, 20 bee colonies per FREG were established using box hives. Moreover, five (5) intermediate hives were constructed and used for bee colony establishment per FREG. Following the colony establishments improved beekeeping technologies were introduced as follow:

- Multiplication and planting of multipurpose major bee forage plants in the watershed
- Honeybee colony multiplication using splitting techniques
- Honey and beeswax processing using honey presser and submerged beeswax processing, respectively.

Selection of honeybee plants for multiplication and planting in the watershed

The following different major honeybee plant species were selected for multiplication and planting in the watershed based on their potential to honey production, adaptive potential in the watershed area, and for their multi-purpose uses (Table 1).

Seedling rising

Nursery of the identified bee forage species was raised at Holeta Baa Research Center. The pots were prepared for seedling multiplication by mixing local soil, sand soil, and manure/forest soil in a 2:1:1 ratio respectively (Bekele et al., 1993; Negash, 2010). Watering, weeding, and thinning of the dense seedlings were done until presumed field capacity is reached.

Preparation of a planting site

The land was prepared before two months of planting to make a suitable place for seedlings that help them to easily survive in the area (Bekele et al., 1993; Negash, 2010; Zhigunov et al., 2014).

Hardening off seedlings

This is used to make plants grow better and stronger when it was planted in the field. Harden off gradually, so that seedlings become accustomed to strong sunlight, cool nights, and less-frequent watering over 7 days (Zhigunov et al., 2014).

Planting the seedlings

Seedlings were transported to the watershed site using a seed transporting box. The plantation was done dependent upon the nature of the plants (tree, shrub) and according to recommended planting space (Bekele et al., 1993; Negash, 2010).

Table 1: Bee forage plants with their uses other than honey production

Botanical name	Common name	Altitudinal range (m a.s.l)	Uses other than bee forage	Remarks
Becium grandiflorum	Tebebe	1600-3100	In local medicine, the herb is used against malaria	Indigenous
Vernonia amygdalina	Ebicha	500-2800	The leaves and bark are bitter and in local medicine, they are used against menstruation pain, as a purgative and vermifuge, in wound dressing, and against urinary inflammations. Together with roots, they are used against malaria	Indigenous
Callistemon citrinus	Bottle brush	1500-2500	Cultivated for ornamental purposes it is to some extent salt-tolerant and can grow on very poor dry soils	Exotic
Cordia africana	Wadessa	550-2600	Shade tree for coffee, the most attractive ornamental, and for conserving soil. It provides excellent timber. In local medicine, the fruits and the roots are used against ascariasis. Fried leaves are used, together with butter, to treat all kinds of wounds, and wood-ash mixed with butter is used against skin diseases.	Indigenous
Schinus molle	Kunde berbere	500-2400	It is cultivated for shade and amenity, its wood is termite resistant and generally suitable for firewood and charcoal. The leaves are used as an insect repellent. It is recommended as a windbreak, particularly in semi-arid areas.	Exotic
Dovyalis caffra	Koshommi	1500-2600	Used for fences	Exotic
Ziziphus spina-christi	Kurkura	1900-2400	It produces excellent firewood and good charcoal. The fruit is eaten fresh or dried and can be made into a floury meal, butter, or a cheese-like paste, used as a condiment. The leaves are used as nutritious fodder for sheep and goats. It is a suitable species to aid in the fixation of coastal dune sand. The tree is planted for shade and as a windbreak.	Exotic

Source: Fichtl and Adi (1994) and Addi et al. (2014)

Watershed bee forage resource assessments

The bee plant resource of the watershed was assessed before and after the intervention of the project. The diversity of the bee forage plants were estimated using a quadrat size of 20 m x 20 m was laid at every 50 meters along diagonal transects lines. Then, all different types of bee forage trees, and shrubs were recorded.

Honeybee colony multiplication

Honeybee colony multiplication was done using splitting techniques (Alemu et al., 2015).

- Selection of mother colonies,
- Techniques of colony strengthening,
- Preparing the mother colony for splitting,
- Splitting,
- Harvesting queen pupae,
- Nuclei colony formation,
- Nuclei colony management
- Protection of pest and predators and transfer to improved hives

Crude Honey and Beeswax processing

Procedures for processing crude honey extraction using the manual honey presser

- Comb honey was harvested from established bee colonies during honey harvest seasons
- The crude honey was put into clean material of 'debela shash' and the honey tied with a thin rope
- It was pressed manually by the honey presser
- Then, the pressed honey was flowed separately from the beeswax and poured into clean and dry honey containers

Submerged wax extraction method

- The beeswax obtained from different sources (Crushed bee combs, Tej residues (sefef), and crude honey) were placed separately in clean water and left to soak for 24 hours
- Water was poured (amount depending on the quantity of crude beeswax) into the cooking pot
- Water was heated until the wax melted
- The sack was agitated with a stick to cause the wax to float to the top
- The warm water and wax mixture was poured
- Then, the water and wax mixture was allowed to cool and the wax cake was removed (Gemeda and Kebebe, 2019; Dadant, 1975).

Method of Data Collection

Data was collected using a checklist, datasheet, field observation of the site, group discussion, and plant inventory.

Method of data analysis

Estimation of Richness and Diversity of bee forage plants

Species diversity of plant was quantified using the Shannon-Wiener diversity index; species richness and Shannon's evenness. Shannon - Wiener diversity index is the most popular measure of species diversity that cannot be affected by sample size. The Shannon-Wiener Index is used to calculate the diversity of bee plants (Ramirez-Arriaga et al., 2011).

Shannon Index ($\boldsymbol{H'}$) = $-\sum_{\boldsymbol{i}=\mathbf{1}} \boldsymbol{P_i ln P_i}$

Where,

H'=Shannon diversity index**,**

S = the number of species**,**

Pi = the proportion of individuals or the abundance of the ith species

ln= log base

Evenness (J) $=\frac{H'}{H'max}=\frac{H'}{lnS}$

Where,

H'=Shannon-Wiener diversity index and

H'max=ln s where s is the number of species.

ln= log $base_n$

The value of evenness is ranged from 0 to 1 (Kent and Coker, 1992).

Menhinick's diversity index (D_{mn}) was used to estimate species diversity without depending on a sample size

$D_{Mn}=\frac{S}{\sqrt{N}}$, where N = the total number of individuals in the sample and S = the number of species recorded.

Quantitative data were analyzed with descriptive statistics. After analysis of the data obtained, the data was then presented using frequency distribution tables, graphs, and pie charts for easy understanding and representation. The qualitative data was analyzed through an explanation of an idea, opinion, and concept explanation method.

RESULTS AND DISCUSSION

Demographic characteristics of the sample households at the end of the intervention

The ages of FREG members were categorized into 4 groups (Table 2). The majority of the age (40%) was found between 31 and 40 years whereas only one informant was found in the category of 51-60 years. This indicated that beekeeping is a difficult task for the older beekeepers since its operation is during night time and labor-intensive. Therefore, the age of the informant affects beekeeping practices. A study conducted by (Kumwenda, 2016) indicated that the age of a household would limit someone to venture in such a business. According to gender analysis until the end of the study intervention, 80% and 20% of males and females were participated in the study, respectively. Male has more experience in traditional beekeeping than female in Ethiopia. Due to this, males were more interested than females during informant selection for this study. A study conducted by Chanthayod et al. (2017) in Northern Lao PDR was also reported that almost all beekeepers were male (98%). To increases the participation of the women in improved beekeeping technologies; awareness creation was given to this society. Since improved beekeeping technology is appropriate for any gender, in the project women are equally participate with a male in beekeeping practices. In many places, there are a lot of model women beekeepers that widely participating in improved beekeeping system producing honey and improve their livelihood. However, still to increase the participation of women concerned body should support this sector to increase their participation.

From all sample households, about 80% can able to read and write in which many of them have accessed through formal education. Many authors have explained that education level influences the engagement of the household in beekeeping and other non-farm activities (Kumwenda, 2016; Emmanuel, 2011).

From these FREG members, only about 12% of the members have honeybee colony before joining the FREG which indicates most of the FREG members access the beekeeping experience through FREG training. All FREG members have agricultural experience (Table 2). However, the majority (48%) of the informants have 11 to 20 years of agricultural experience.

Table 2. Characteristics of FREG members at the end of the intervention (N=25)

Item	Frequency of participant	Percentage (%)
Age (years)		
20-30	7	28
31-40	10	40
41-50	7	28
51-60	1	4
Gender		
Female	5	20
Male	20	80
Education level		
No	5	20
1-8	12	48
9-12	8	32
Family size		
1-3	7	28
4-6	5	20
7-9	12	48
>10	1	4
Beekeeping experience (years)		
2	22	88
5	1	4
20	2	8
Agricultural experience (years)		
1-10	8	32
11-20	12	48
21-30	5	20

Source: own data, 2020

The majority of the households (56%) have 1 to 5 cattle. On the other hand, the majority of households have no goat, sheep, donkey, horse, and hen (Table 3). Most of the households have <1 hectare of land. The average land size was about 0.74 hectare per household which is not adequate to feed their family through the cultivation of this land to support their family. The majority of landless households are daily labors and traders of cattle and goats. Since beekeeping does not compete with other agricultural activities, most of watershed users recognized beekeeping can be practiced by landless people.

Table 3: Size of livestock owned

Item	Frequency of participant	Percentage (%)
Cattle		
No	6	24
1-5	14	56
6-10	4	16
>10	1	4
Goat		
No	18	72
1-5	6	24
>5	1	4
Sheep		
No	23	92
1-5	2	8
Donkey		
No	18	72
1-5	8	32
Horse		
No	22	88
1-5	3	12
Hens		
No	15	60
1-5	8	32
6-10	2	8
Land size		
No	1	4
<1	14	56
1-2	7	28
3-4	3	12

Source: own data, 2020

The income of Honey sales

Both farmer research extension groups have harvested honey from the established colonies. The amount of harvested honey has varied between the FREGs. FREG1 harvested more honey and more income (20500 Ethiopian Birr) from honey sales than FREG2 (9000 Ethiopian birr) (Figure 6). Though the environment is similar, honey production was varied based on apiary management. Both groups have saved this money in a common bank account. In addition to this, both groups have monthly savings.From this study, it is known that beekeeping is an environmentally friendly and economically feasible income-generating activity for poverty alleviation and food security. It could diversify the watershed community economic base, change the attitudes of the local people towards watershed conservation, and therefore, encourage to be allied with the current efforts in disseminating conservation-based development (Bareke et al., 2014; Kumsa, 2014).

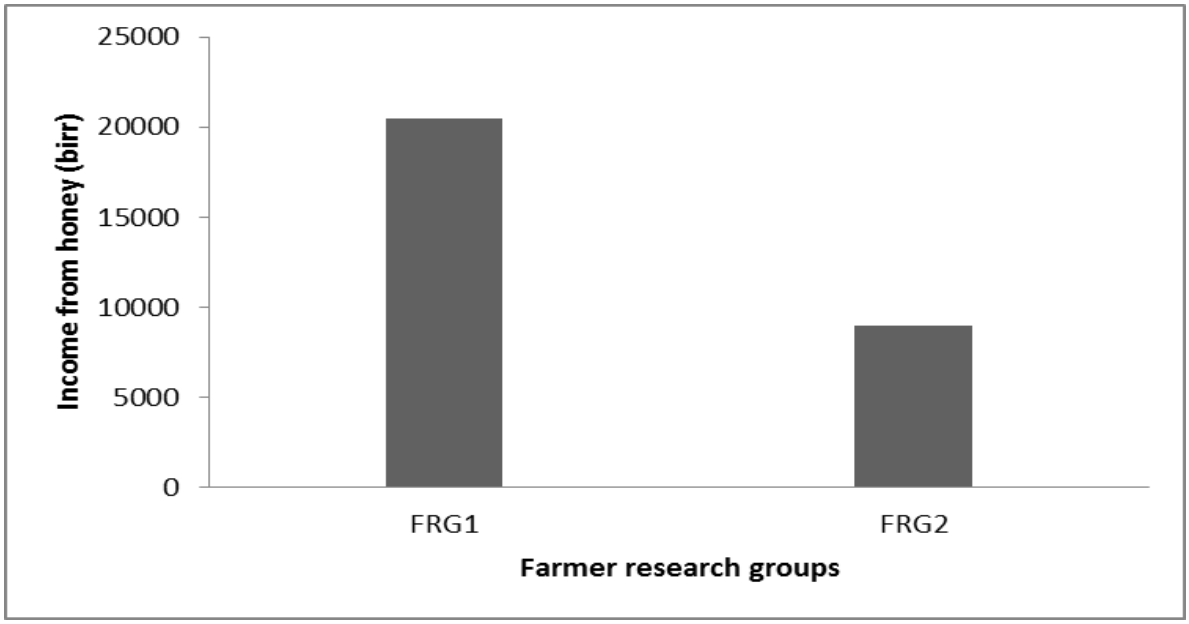

Figure 6: Income obtained from honey sale for both FREG

Skill attained by FREG members

From the given capacity building and active involvement of members in all beekeeping activities regularly on scheduled queue, the FREG members have been obtained good skills and experiences from the beekeeping project implemented. Before the training, most (93%) of the members are not aware of the improved beekeeping technologies including seasonal bee colony management practices. Only about 7% have little skill in the beekeeping. On the other hand, after the training above 85% have a good understanding of improved beekeeping implementation and honey harvesting which shows our intervention has good impact (Figure 7). Above 80% of the FREG members have developed a skill on seasonal bee colony management such as transferring, honey harvesting, feeding, and super and confident to perform their colonies independently. The skill development on improved beekeeping technologies enables the beekeepers to harvest good honey. Particularly, knowledge of bee floral is very important to apply seasonal colony management operation following flowering cycles of plants (Bareke and Addi, 2019; Yoshimasa, 2014; Famuyide et al. 2014). Moreover, 76% of the informants poorly understood the queen multiplication practices due to previous low beekeeping experience and unable to replicate multiplication practices due to the short intervention period (Figure 7).

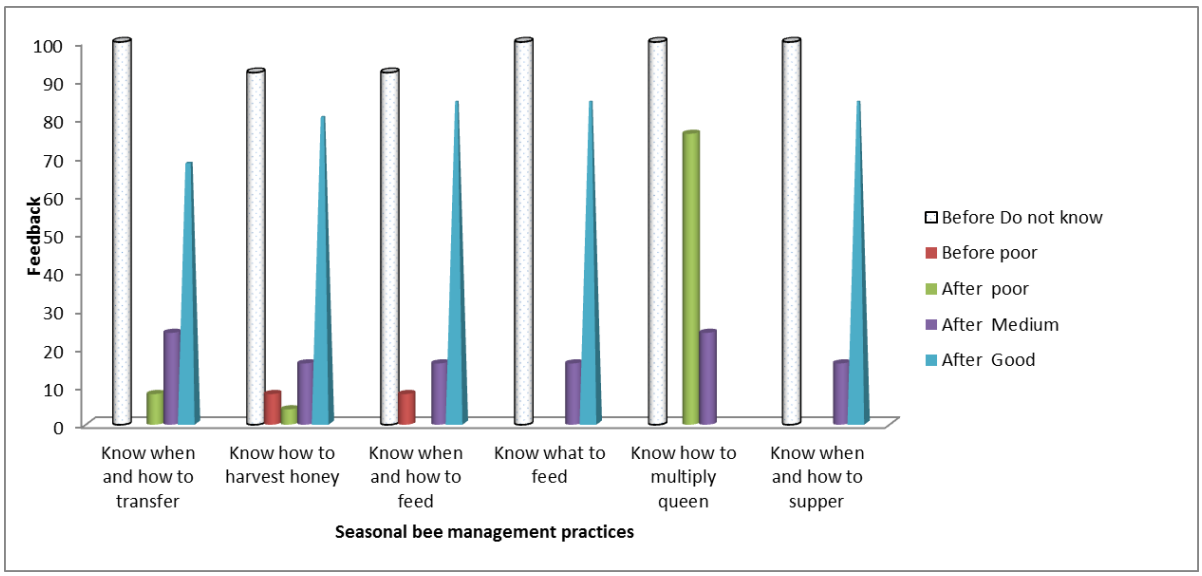

Figure 7: Feedback of informants on seasonal bee colony management skills

Bee forage diversity

Before the intervention, the number of bee plant species was 16, whereas its number increased to 29 at the end of the intervention. The diversity of bee plant species was higher after the intervention as compared to before intervention (Table 4). The watershed was highly dominated by Ilex mitis and Acacia etbaica (Table 5). However, due to watershed conservation and new species plantation, the number of bee plant species was increased by 13 additional plant species. The integration of plantation with other rehabilitation components contributes to the improvement of the environment which needs more work in the future. Tree planting is a positive way to improve biodiversity and natural environment. Particularly, native species planting provides a wide range of benefits including increasing biodiversity conservation, creating habitat for native wildlife including honeybees, stabilizing soil, recreating linkages, and vegetation regeneration, enhancing water quality and landscapes of the watershed.

Table 4. Number of bee plant species and diversity before and after the intervention

Intervention	No. of species	D_{Mn}	H'	E
Before	16	0.4	1.07	0.1
After	29	0.5	1.63	0.2

Table 5: Lists of bee plant species with their percent of dominance before and after the intervention

The scientific name of plants		Before	After Intervention
	Local name	% of dominance	% of dominance
Euphorbia abyssinica	Adammi	0.06	0.03
Carissa edulis	Agamsa	0.82	1.69
Rumex nervosus	Angaggo/Dhangaggo	0.82	1.04
Croton macrostachyus	Bakkannisa	0.06	0.03
Eucalyptus camaldulensis	Bargamo dima	0.06	0.03
Calpurnia aurea	Cheka	2.12	1.60
Acacia etbaica	Dodota	15.86	13.26
Olea europaea	Ejersa	0.53	1.91
Capparis sepiaria	Harangama gurracha	1.18	1.55
Jasminumabyssinicum	Hidda Kamatte	1.058	1.5
Hypericum quartinianum	Imme	1.18	0.6
Dodonaea anugustifolia	Itacha	1.00	0.54
Acokanthera schimperi	Kararu	1.29	0.57
Maytenus gracilipes	Kartamme	1.18	1.82
Ilex mitis	Miessa	72.15	60.73
Acacia seyal	Wachu	0.65	0.44
Grewia ferruginea	Dokonu	-	0.27
Dovyalis caffra	Koshommi	-	1.69
Croton dichogamus	Ule foni/Riga jaldessa	-	0.05
Asparagus africanus	Sariti	-	0.19
Otostegia fruticosa	Tunjiti	-	0.027
Premna schimperi	Urgessa	-	0.27
Ocimum urticifolium	Wancabbi	-	0.03
Vernonia amygdalina	Ebicha	-	0.63
Callistemon citrinus	Bottle brush	-	4.66
Schinus molle	Kundebarbare	-	0.74
Ziziphus spina christi	Kurkura	-	0.11
Becium grandiflorum	Tebebe	-	3.68
Cordia africana	Wadessa	-	0.44

Among the identified plant families, Lamiaceae (13.8%), Fabaceae and Euphorbiaceae (10.3%), Myrtaceae, and Oleaceae (6.9%) are the most frequent families, represented by the highest species composition in the watershed (Figure 6-8).

Thirteen (13 bee plant species were increased after the intervention of the study. From this, 54% was increased by new plantation, while 46% was from seed bank regeneration due to conservation from disturbances (Figure 8). Tree planting and ecological restorations are some of the ways to adapt to climate change. Beekeeping encourages tree planting and it is used to alleviate the effect of climate change environmental degradation. Trees absorb carbon and other gases from the atmosphere; protect marginal communities from severe flooding and storms. It provides shade, which helps the soil to retain moisture rather than drying out, anchors for plant and wildlife biodiversity, which creates healthy ecosystems that convert the sun's energy through photosynthesis, absorbs and transfers carbon.

Table 6: Scientific and local names, family, habit and food source (nectar (N), pollen (P)) and provide to honeybees which found before the intervention

Scientific name of plants	Local name	Family	habit	Food source
Euphorbia abyssinica	Adammi	Euphorbiaceae	Tree	N&P
Carissa edulis	Agamsa	Apocynaceae	Shrub	N&P
Rumex nervosus	Dhangaggo	Polygonaceae	Shrub	P
Croton macrostachyus	Bakkannisa	Euphorbiaceae	Tree	N&P
Eucalyptus camaldulensis	Bargamo dima	Myrtaceae	Tree	N&P
Calpurina aurea	Cheka	Fabaceae	shrub	N&P
Acacia etbaica	Dodota	Fabaceae	Tree	N&P
Olea europaea	Ejersa	Oleaceae	Tree	N&P
Capparis sepiaria	Harangama gurracha	Capparidaceae	shrub	N&P
Jasminumabyssinicum	Hidda Kamatte	Oleaceae	Climber	N&P
Hypericum quartinianum	Imme	Guttiferae	shrub	N&P
Dodonaea anugustifolia	Itacha	Sapindaceae	Shrub/Tree	N&P
Acokanthera schimperi	Kararu	Apocynaceae	shrub	N&P
Maytenus gracilipes	Kartamme	Celastraceae	Shrub	N&P
Ilex mitis	Miessa	Aquifoliaceae	Tree	N&P
Acacia seyal	Wachu	Fabaceae	Tree	N&P

Integration of improved beekeeping technologies with watershed rehabilitation is a very important phenomenon to take into consideration through multipurpose bee forages planting (Bareke et al., 2014). Many countries introduced improved beekeeping technologies as reforestation incentives, paying special attention to plant flowering trees and shrubs that provide nectar and pollen while generating income for local communities from bee products (Steffan and Kuhn, 2003; Decourtye et al., 2010; Admassu et al., 2014).

Honey production is a promising and watershed beekeepers have a clear financial gain from protecting the watershed habitat and always interested in the bee forage plantation and conservation (Kumsa, 2014). The recommended watershed trees are providing good nectar and or pollen for honeybees (Bareke et al., 2014). Planting of flowering shrubs, herbs, and trees should be enhanced around homesteads, gully sides, riverbanks, hillsides, and farm boundaries which are important to the benefit of productive beekeeping.

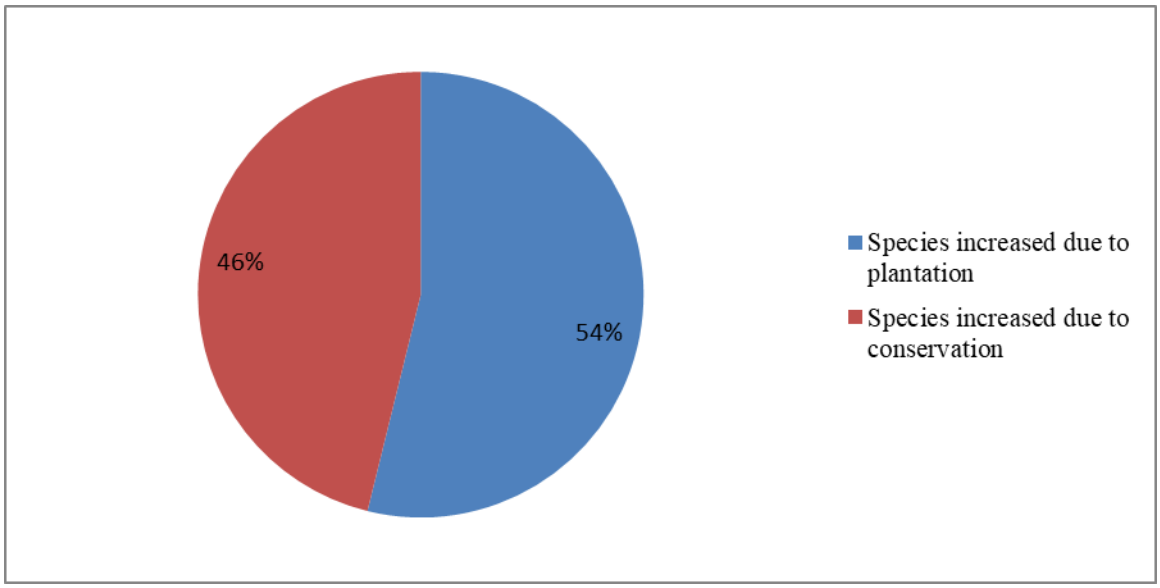

Figure 8: Percent of bee plant species increment by plantation and conservation after the intervention

Table 7: List of planted bee forage seedlings and their habit

No.	Scientific name	Local name	Family	Habit
1	Vernonia amygdalina	Ebicha	Asteraceae	shrub
2	Callistemon citrinus	Bottle brush	Myrtaceae	Shrub
3	Schinus molle	Kundebarbare	Anacardiaceae	Tree
4	Ziziphus spina christi	Kurkura	Rhamnaceae	shrub
5	Becium grandiflorum	Tebebe	Lamiaceae	shrub
6	Cordia africana	Wadessa	Boraginaceae	Tree
7	Dovyalis caffra	Koshommi	Flacourtiaceae	shrub

Lamiaceae family has the highest species (50%) that naturally regenerated from the soil bank due to conservation (Table 8). This indicates the capacity of plants to regenerate when a suitable condition is created for them.

Table 8: Regenerated bee forage plants from soil bank due to conservation with their scientific names, family habit, and their uses

No.	Scientific name	Local name	Family	Habit
1	Grewia ferruginea	Dokonu	Tiliaceae	shrub
2	Croton dichogamus	Ule foni/Riga jaldessa	Euphorbiaceae	Tree
3	Asparagus africanus	Sariti	Aspargaceae	climber
4	Otostegia fruticosa	Tunjiti	Lamiaceae	shrub
5	Premna schimperi	Urgessa	Lamiaceae	shrub
6	Ocimum urticifolium	Wancabbi	Lamiaceae	shrub

Lesson learned from demonstration

FREG members have developed awareness on the value of watershed rehabilitation through the planting of major bee plants. This makes a good condition for the integration of improved beekeeping technologies with watershed conservation. Beekeepers are very interested to

expand the technology by themselves at least using intermediate beekeeping technologies and gradually expanded to modern beekeeping technologies and planting of bee forage around their home garden and in the watershed.

CONCLUSION AND RECOMMENDATION

The numbers of bee plant species were increased by 13 (%) bee plant species due to plantation and conservation from disturbance. From this, 7 types of bee forage plants were supplemented by plantation while 6 species were through natural regeneration. The income obtained from honey production is very encouraging. In the apiary management practices, more than 80% of the households were attained good skills and awareness on beekeeping management. On the other hand, project life is very short and the watershed needs at least the coming three years. Therefore, governmental and non-governmental development agencies should provide support for the promotion of the current efforts of watershed conservation through integrating improved beekeeping for surplus honey production as income generation.

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Fish production enhancement through modern fishery technology around Adami Tullu Jiddo Kombolcha District of Lake Ziway

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ABSTRACT

Lake Ziway is one of the lakes in the rift valley which are used for multiple purposes including fishing. The lake has several commercially important fish species for fisheries. However, the fishery of the lake seems to be threatened by anthropogenic and climatic factors, which in turn affect biotic factors as reflected in fish catch. The study was conducted to enhance fish production through available modern fishery technologies. The technologies were gillnet of 10 cm mesh size for Oreochromis niloticus and 12 cm mesh size for Cyprinus carpio; boats made of recycling plastic bottles; retaining cage and smoking technology. One farmer research extension groups (FREG) that had 72 fishermen members, with consideration to gender participation was formed and training on each technology was given for appropriate utilization of the fishery resources of the lake. Hence, the result revealed that tabled sized fishes were caught through appropriate fishing gear to avoid over exploitation of the resources and quality product were obtained by applying those post-harvest technologies. Therefore, the study confirmed that the modern fishery technology is highly important for better utilization of the fishery resources and needs to be promoted as one of the capture fisheries strategies that can enhance fish production.

Key Words: Fishes, fishing gears, post-harvest technologies

INTRODUCTION

Ethiopia has a number of lakes and rivers with substantial quantity of fish stocks. There are 10 major lakes with a total area of 7,400 km^2 and major rivers a combined length of 7,185 km of (Brook Lemma, 2012). Many artificial water bodies have also been stocked with fish for fishery. Most of the lakes are located in the Ethiopian Rift Valley, which is part of the Great East African Rift Valley system.

The natural resource of the Rift Valley has immense economic and cultural values. These lakes are considered as centers of biodiversity, corridors of countless migratory birds; and are used in ameliorating the effects of drought and protein shortage for the population in the region (Zinabu, 1998; 2002; 2003). Lake Ziway is one of the lakes in the rift valley used for multiple purposes like irrigation, fishing, domestic water supply, transportation, recreation and supply of fresh water to Lake Abijata through the out flowing of Bulbula River. Although its importance is in the wide range of purposes, the fishery resources are not utilized appropriately for the proper management of the lake.

There are seven indigenous fish species in the lake comprising Barbus paludinosus, Garra dembecha, Garra makiensis, Labeobarbus ethiopicus, Labeobarbus intermedius, Labeobarbus microterolepis and Oreochromis niloticus (Golubtsov et al., 2002; Abebe, 2010; Jacobus et al., 2012). The lake also harbors five exotic fish species (Tilapia zillii, Cyprinus carpio, Carassius carassius and Carassius auratus) which were introduced to enhance its production, and Clarias gariepinus that slipped into the lake accidentally (Golubtsov et al., 2002). Therefore, the lake has several important fish species for fisheries.

Lake Ziway had a high fish yield potential of 3000 to 6680 tons per year (FAO, 1982). The fisheries activity in the lake was intensified through funding acquired from Lake Fisheries Development Project (LFDP) with the European Union (EU). The fisheries production has been the second largest from the Rift Valley lakes, which accounted for 3180 tons, next to Lake Chamo that produced 4500 tons per year (LFDP, 1998). However, the annual fish catch of the lake shows different trends at different times and currently became less than 1,000 tons per year (Lemma et al., 2018). According to Lemma (2016), there was a continuous decline in the annual catch of some fish species like O. niloticus from the lake since 1997. On the other hand an increase of C. gariepinus was observed in the fishermen catches since 2010 (Mathewos, 2011). In the same way, very recently increase in the catches of C. carpio was recorded (Lemma et al., 2014).

The fishermen used wooden boats for fishing and motorized boats for collecting catch from reed-boat fishermen in some areas. The use of illegal fishing gears, such as beach seine with smaller mesh size, has been widely spread and poorly monitored. Recent studies have shown that 96% of the gears operating in the lake are under the recommended mesh size and traditional means of fishery technology (Mathewos, 2013). Thus, there is a need to apply an appropriate fishery technology to meet the increasing demand for food from fish resources, and maximize the utilization of the available untapped fishery resources. The objective of the study was therefore, to enhance fish production through available modern fishery technologies in the lake.

MATERIALS AND METHODS

Description of study area

Lake Ziway belongs to the Central Ethiopian Rift. It is the third largest lake in the Ethiopian part of the Rift Valley and fourth in the country in terms of surface area. Lake Ziway is bordered by two administrative zones of Oromia Regional State. The Western part belongs to East Shoa Zone while the Eastern part belongs to Arsi Zone. The Western shore is shared by two districts, namely, Adami Tullu Jiddo Kombolcha and Dugda. The Eastern shore belongs to only Ziway Dugda district. On the average, the lake is located at about 163 km south of Addis Ababa, at an elevation of 1650 meter above sea **level** at $7^0$89' - $8^0$05' N latitude and $38^0$72' - $38^0$92' E longitude. The lake is shallow and has an open water area of 434 km^2 and shoreline length of 137 km (Von Damm and Edmond, 1984). The maximum length and width of the lake is 32 km and 20 km, respectively (LFDP, 1997). Location of Ethiopia in the Horn of Africa, the Ethiopian Rift Valley Lakes including Ziway Lake is shown in Fig.1.

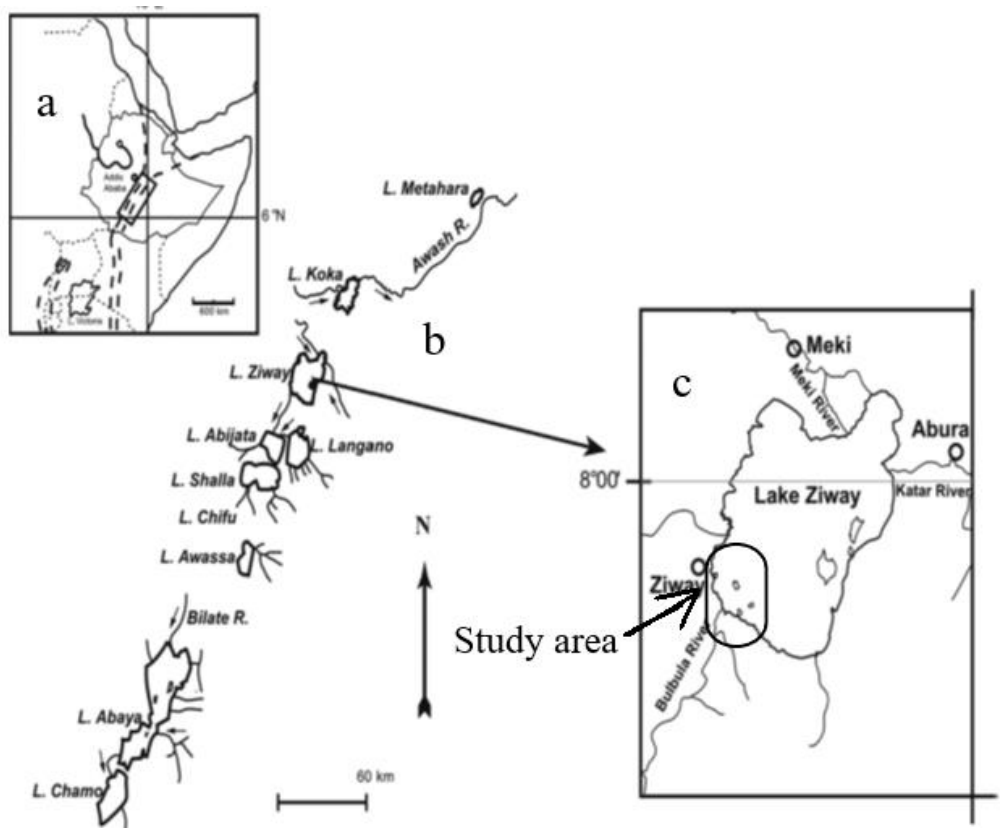


Figure 1. (a) Location of Ethiopia in the Horn of Africa, (b) Location of Ethiopian Rift Valley Lakes and (c) Lake Ziway (Source: Lemma, 2016)

Currently the lake has four commercially important fish species for fisheries (O. niloticus, C. carpio, C. carassius and C. gariepinus).

Selection of fishery cooperative and training

Ziway-Batu Fishermen Cooperative that actively operate in fishing activity at landing site was purposively selected. The members of the cooperative were seventy-two. Training was given for the selected cooperative members on the technologies (gill net, boat made up of waste plastic bottles, retaining cage and Smoking technology) starting from the beginning of the activity through the ongoing process. Interviews were conducted through questionnaire to assess the existing constraints of the fisheries in the lake.

Established fishery management committee

The fisheries management committee was established from the fishermen and other stakeholders who are directly related to the sector. The approach was like co-management approach, where responsibility was shared between the government and other stakeholders, to harness the knowledge and capacities of those who have a shared interest in the sustainability of a fishery towards promoting the common end. The approach, therefore, can be considered as a response to manage fisheries, enforce regulations and responds to the desire of fishing communities to empower them.

Fishing gear technologies

There was fishery technologies availed for better utilization of the fishery resources. Hence, gill nets of different mesh size (10 cm for O. niloticus and 12 cm for C. carpio) were used for fishing with boat made up of waste plastic bottles.

Fishing gears selectivity and length at maturity

The gears were set for fishing in the afternoon (5:00 pm) and collected in the next morning (6:00 am). Knowledge of the reproductive biology of exploited fish species was an essential prerequisite for effective fisheries management. Size at first maturity (commonly abbreviated as L_{50}) is one of the fundamental variables of fish life history that determines the reproductive potential of a stock and its capacity to withstand exploitation (Stearns, 1976). It refers to the length at which 50% of the population is mature. L_{50} is most widely used parameter for the definition of harvest strategies to optimize exploitation and/or ensure sustainability (Froese, 2004). Its analysis was made after classifying data by length class. Then the percentages of the fishes with mature gonads were plotted against length to estimate L_{50} (Tweddle and Turner, 1977).

Retaining cage

Circular retaining cage was constructed from net of mesh size about 1 cm^2. The cage had a volume of $2m^3$ with metal ring from the inner wall. Harvested fishes were immediately transferred to the retaining cage while it was in the water. The retaining cage with the fish was set at mean depth of 1.5 meters using anchors. The fish were taken out and fish that were alive, died and spoiled were identified and recorded separately.

Chorkor smoker

The chorkor smoker (oven) was constructed from locally available materials at low cost. It consists of a combustion chamber and a smoking unit with a set of trays. The combustion chamber was rectangular, twice as long as it is wide and divided by a wall down the middle and with two stokes holes in the front. The combustion chamber is the base of the smoker and was generally constructed from mud. The top of the oven wall is square, level and flat. The smoker was designed in such a way that the woods frame of the trays rest along the middle line of the base walls. The capacity of chorkor smoker was 10 kg of prepared fish per trays. The distance of the fire from the base to the last tray was 50cm

Processing shade and tables

It is common that fishermen process the fish on the ground without any shade. The processing shade with a total area of 210 m^2 to accommodate processing tables was constructed around the selected landing site (Figure 6)

RESULTS AND DISCUSSIONS

Major constraints of the fishery in the lake

Open access to the resource and pollution were the most common problems on the landing site (Fig. 2). Pollution of the lake was taking place due to improper farming methods and poor tillage systems, which contribute towards the erosion of top soils of the steep cultivated land around the catchment of eastern part of the lake. Urbanization and human settlement are amongst the most serious problems around the lake. Associated industrial development was also problematic in the lake, intensifying pollution, especially around the study site. Farming along the lakeshore not only disturbs the ecology of the shore but also exacerbates siltation and increases turbidity Lemma (2016).

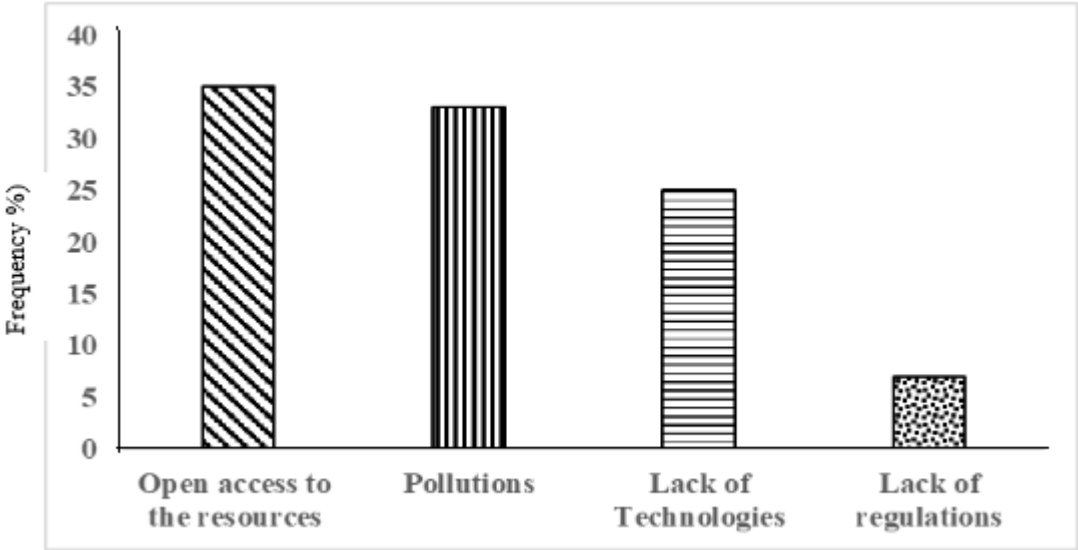


Figure 2. Major constraints of Lake Ziway fishery according to responses of fishermen.

Lack of fishery technologies is also a common constraint of fishery in the lake. Twenty five percent of the fishermen indicated that they face technological constraints (Fig.2). Fishes from the lake were usually caught and transported by reed boats. In most cases these boats were old and inefficient (personal observation). Motors for boats were not easily available being one of the major technological problems. Floats and lead rope used with nets were also difficult to obtain for appropriate fishing practices.

According to the survey and personal observations, fishing on Lake Ziway was predominantly artisanal and the fishermen use non-motorized traditional boats and gears. In addition, key informants revealed that some fishermen were using destructive fishing gears of small mesh sized beach seines. Personal observations also corroborated this. The small mesh size indiscriminately catches both the immature and mature fishes. This indiscriminate immature fish catch endangers the reproductive capacity of the stock that directly affects the resources of the lake.

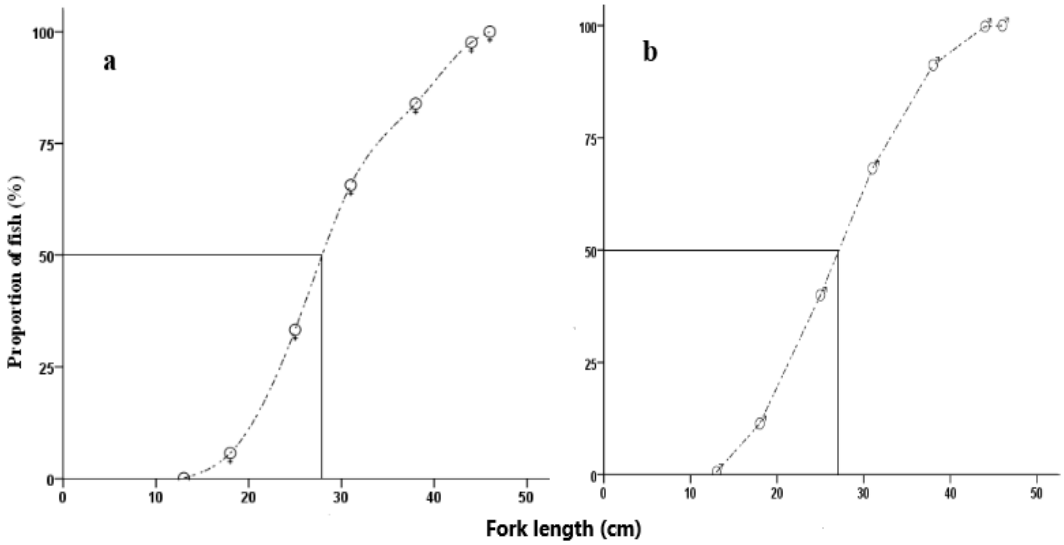
There was a critical shortage of processing facilities. This intensifies the spoilage process. There are limited buyers at the area with limited capacity. This had impact on the price of fish in such a way that fishermen were forced to sell the products with cheaper price before they lose of the quality. There are limited options for preservation and improving the shelf life of fish products. In the area, the market issues depend on physical access to landing points, number of retailers in the area and the amount of catch (personal observation). Low prices were paid for fishes, particularly due to the loss of quality because of limited options for processing and conservation facilities in the study area.

Fishing gear technologies

Length at first maturity and fishing gears selectivity

Length of first maturity (L_{50}) was estimated to be 28 cm FL for female and 27 cm FL for male for C. carpio, whereas it was 17.9 cm and 17.3 cm respectively, for female and male fish of O. niloticus fish species (Fig. 8). On the average, males appeared to attain sexual maturity at a relatively smaller size than females in both species. As reported for both temperate and tropical aquatic ecosystems, males attain maturity at a smaller size than femailes (Tempero et al., 2006; Britton et al., 2007). Size at first sexual maturity of O. niloticus in Lake Ziway was lower than those in Lake Koka and Langano. This might be due to the high fishing pressure on the former lake.

The catch size frequency distributions of the two fish species caught by the two gillnet mesh sizes were indicated in figure 2. Totally, 530 gill nets of different mesh size were operated for fishing of different fish species. From the measurements total gill nets measurements that were taken from 54 randomly selected boats, all were found to be of less than 10 cm mesh size. The range of mesh sizes used by the fishermen varies between 6-10 cm stretched mesh size. The current mesh size used in the lake was lower than the minimum mesh size used to capture C. carpio and O. niloticus at their L_{50} around 27 cm and 17 cm respectively for both sexes. Hence, care should be taken not to lower the mesh size any further as the immature fishes will be affected by the fishery.



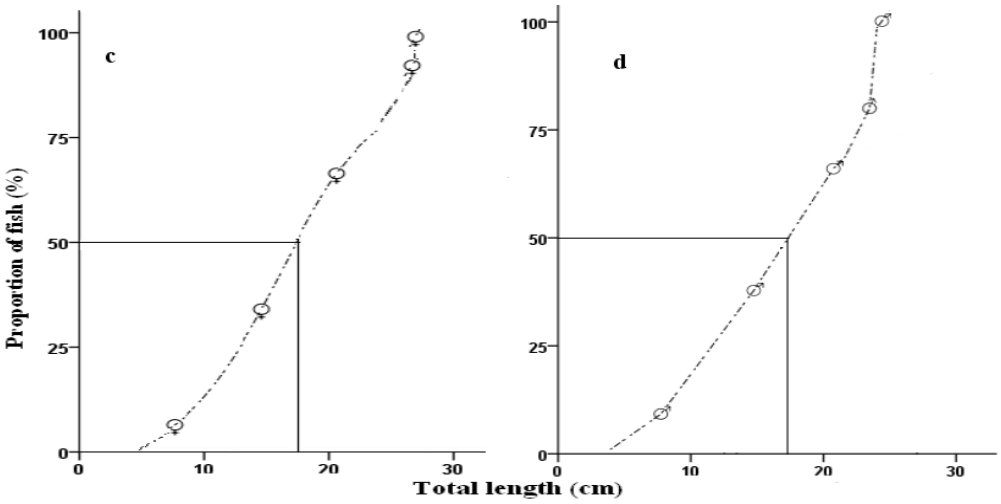


Figure 3. The proportion of fish in different length groups of females (a) and males (b) of C. carpio; females (c) and males (d) of O. niloticus in Lake Ziway

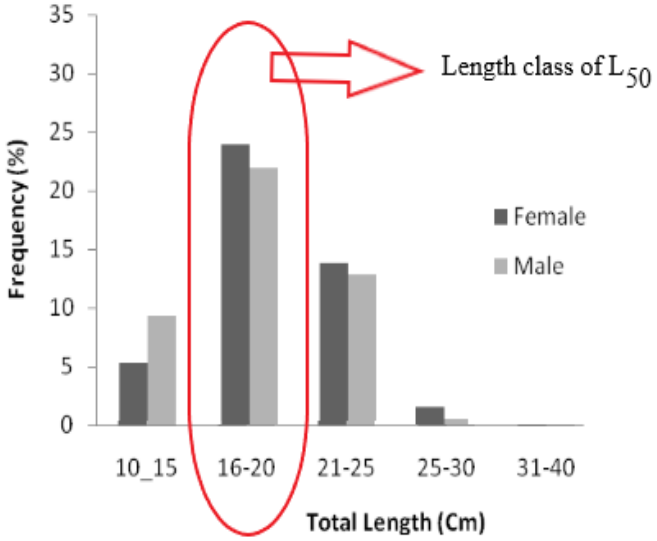


Figure 4. Number of fish catch per length class of O.niloticus using 10 cm mesh size gill net

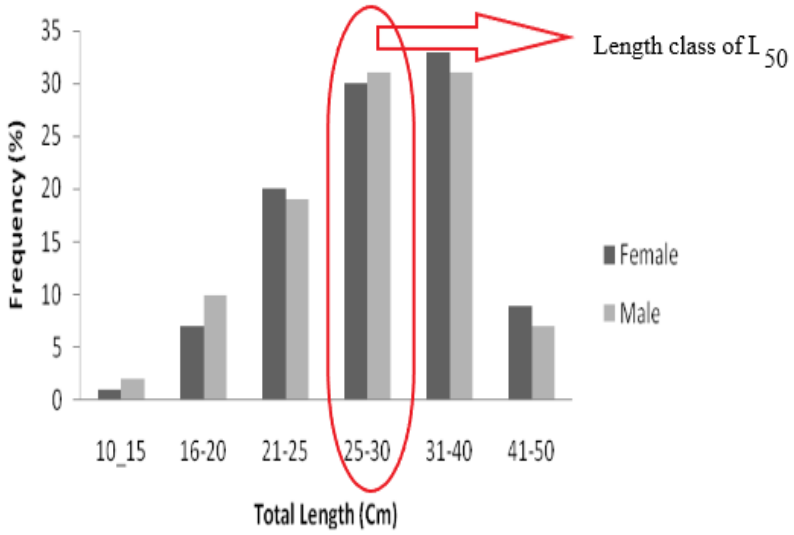


Figure 5. Number of fish catch per length class of C. carpio using 12 cm mesh size gill net

The results of gill selectivity show that the use of gillnets with mesh sizes that select fish below the size at first maturity (L_{50}) of the target resources for both species that reduced the spawning stock (Figure 9 and 10)

Retaining cage

On average 250 kg of lived O.niloticus were harvested from the lake and transferred in to the retaining cage. After 12 hours on average 241 kg of fish were sold as fresh marketable fish. Death recorded was 5 % of the total fish but fish were still fresh and marketable, whereas spoiled fish (fish discarded) during the experimental period was 1% (Figure 11). The discarded amount was almost similar with to what found by Getachew, 2013 (1.3%) in lake Beseka and much smaller than what was found by Yared et al., 2006 (30%). Generally, the overall performance of the cage was rated by the fishermen as best material in reducing post-harvest loss at landing site

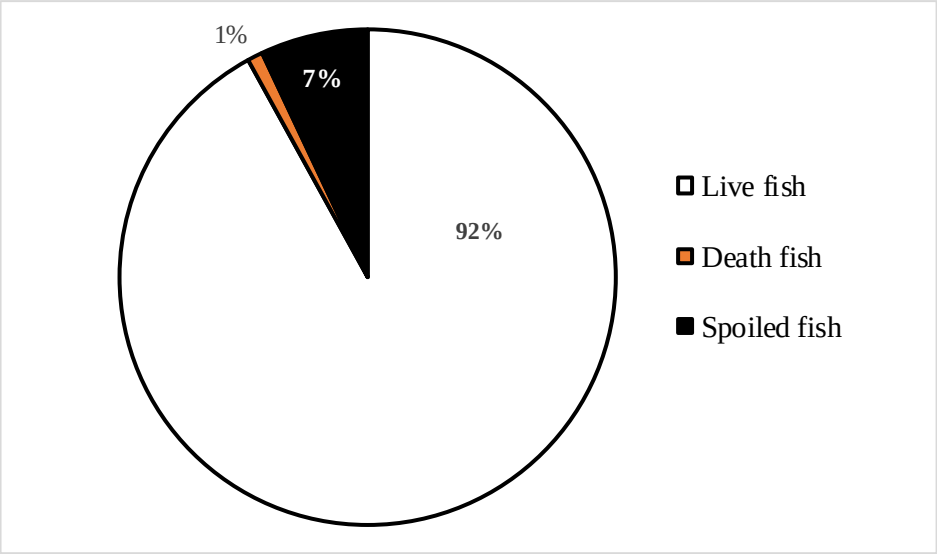


Figure 11. Percent spoiled, dead, and live fish on the landing site

Smoking technology

In principle, 37 and 40 Kg firewood was used to smoke 100 Kg of prepared fish using the smoker to reduce the moisture content to 14 and 40 % in 3 and 4 hours, respectively. During the study period all fish smoked with the oven were good in quality and marketable products. The final product obtained by "wet hot'' smoked fish can be stored for 3 months under -5^{0}C and from 6 to 9 months for "dry hot" smoked fish without being affected by bacteria and molds.

The chorker smoker has proved to be useful innovation in fresh water fisheries, because of being easily adjustable to local needs and conditions. The technology was built from bricks made of mud with teff straw. These bricks were more durable and have better heat retention properties, which further improves fuel efficiency. The smoker was easy to operate and time saving, thus alleviating the need for more human power. It has reduced labor requirements by about 30% and fire wood use by about the same. Smoking gives also an appealing smoked color and smoky flavor to the fish.

Training of farmers and other stakeholders

Multidisciplinary research team (Culture fishery, fishery extension and socio-economic) and other stakeholders from zonal and district Agricultural offices have actively participated in delivering the training by sharing their experience and knowledge. Development agents, experts and farmers were participated on the training given on production, management and post-harvest handling technologies of the fishery.

Table 1. Type of profession and number of training participants

Professionals	Participants		
	Male	Female	Total
Farmers	64	8	72
Das	1	-	1
Experts	4	-	4
Total	69	8	77

Among the training participant stakeholders, 83 % were farmers of which 11% were females (Table 1). Unlike the other economic activities where both male and female can engage, fishing activity was solely carried out by male due to the labor intensive nature of the work. Different extension materials were prepared and distributed for the participants. During the training, different questions, opinions and suggestion were raised and reacted up on by concerned bodies. Most farmers showed high interest towards the technologies of capture fishery, because of better income generation as compare to other agricultural commodities. Generally, all farmers were very much interested to get the technologies for their future fishery production. Therefore, all concerned bodies were shared their responsibilities for the future interventions based on the assessed major fishery constraints to be addressed with respected to the lake.

CONCLUSIONS AND RECOMMENDATIONS

The fish yielding status of Lake Ziway has changed over time. Currently, the contribution of O. niloticus has decreased. This is due to the increase in effort applied through time and due to other anthropogenic impacts exerted on the lake. Fishing technology on Lake Ziway was not modern in its nature and only makes use of traditional boats of rafts and wooden manual boat. The fishery of this lake was not under any government regulations. The lake holds the same management system as the other lakes, open access. In Lake Ziway, a large number of small sized fish of all species are being exploited and hence proper management actions are required to protect the immature fish. Particularly, capture size of the stock should be determined taking into consideration the size at first maturity of the target fishes. Thus, management tools like closed seasons, catch quota restriction, mesh size regulations, gear restrictions and limits on the number of fishers has to be continuously implemented to ensure sustainable exploitation of the stocks.

The fishermen use planked canoes for fishing activity. The fishes were exposed to direct sun and wind. The hygiene of the boats was also poor. On landing sites, the fishes were dumped on the ground where they are sold to buyers. In general, before introduction of the improved technology, there were no proper fish handling and preserving facilities both on boat and landing sites and the product were easily spoiled and discarded on the ground being a source of different pollutions. As a result of the introduction of these technologies some improvements on the production of fishes as well as on post-harvest products have been observed. Therefore, the fishermen must apply these recommended technologies (those appropriate fishing gears and post-harvest technologies for the better utilization of the resources.

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Reproductive characteristics of Oreochromis niloticus populations in three Ethiopian rift valley lakes

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ABSTRACT

Nile tilapia (Oreochromis niloticus) is an indigenous and dominant fish species in the Ethiopian fishery and also a targeted candidate species in aquaculture development. Fish populations within Ethiopian rift valley lakes are found at different fishery status and the fishes exhibited different phenotypic characters. The current study is therefore aimed at investigating some reproductive characters of O. niloticus in Lakes Chamo, Koka and Ziway with respect to sustainability of their fishery and potential use in aquaculture. A total of 1,547 adult O. niloticus were sampled from commercial catches of the three lakes during May 2018 to March 2020. Sex ratios, length at sexual maturity (L_{50}), breeding seasons, fecundity and the relationship between fecundity and morphometric characters were analyzed. The sex ratios in each of the three lakes did not deviate from 1:1 ratio. The size at maturity (L_{50}) was high for O. niloticus population of Lake Chamo (23.48 cm), followed by that of Koka (21.91 cm) for mixed sexes while it was low for that of Lake Ziway (males 17.49 cm and females 16.00 cm); all the values being lower than the values obtained in previous reports. These decreases were perhaps due to fishing pressures and environmental stresses, alarming for the need to implement proper management measures. The populations breed year round but peak activity varied among the lakes; in October -November and February-March at Chamo, in May at Koka and in February-March at Ziway. The mean absolute fecundity (eggs/female) of O. niloticus population was 1,321.8 ± 342.9 for Chamo and 1,146.9 ± 115.2 for Koka. Both values were significantly ($p = 0.00$) higher than 450.1 ± 180.8 for Ziway. The fecundity has positive relationship with total length, total weight and gonad weight. Based on their higher L_{50} and fecundity values (the desired reproductive qualities in aquaculture), populations of Chamo followed by those of Koka appear to be of great potential for further genetic improvement.

Key words: Aquaculture, fecundity, Nile tilapia populations, sex ratios

INTRODUCTION

The current Ethiopian fish production potential estimates, using empirical models from its inland fisheries, is about 94,500 ton per year, of which 73,100 ton is from lentic (lakes, reservoirs and ponds) and about 21,400 ton is from lotic (rivers) ecosystems (Gashaw Tesfaye and Wolff, 2014). The majority of the Ethiopian lakes are confined within the rift valley that extends from the Kenyan border in the south to the Afar depressions in the north, the major lakes included being Abaya, Chamo, Ziway, Shala, Langeno, Abijata Hawassa and Beseka/Matahara (Tenalem Ayenew, 2009). Fish production in the country are mainly

artisanal and commercial fisheries are concentrated to Lakes Tana, Chamo, Hawassa, Ziway and Turkana (Abebe Getahun, 2017). All these lakes except Tana are found in the rift valley.

Nile tilapia (Oreochromis niloticus) is among the commercially important indigenous fish species in the country and constitutes the major proportion (65%) in the country's fish production (Husein Abegaz, 2015). The fish contributes from 61% - 90% of the total landings in the rift valley lakes (reviewed in Gashaw Tesfaye and Zenebe Tadesse, 2008).
The tilapia fish is among the most studied group of fish in the country due to its economic importance and its different biological properties in different natural and manmade environments. The studies so far undertaken on this fish species covered their length-weight relationship, reproductive and feeding biology (Yirga Teferi and Demeke Admassu, 2002; Gashaw Tesfaye and Zenebe Tadesse, 2008; Lemma Abera, 2012; 2013; Workiyie Worie, 2014; Endalh Mekonnen et al., 2018; Yirga Enawgaw and Brook Lemma, 2018; Assefa Tessema et al., 2019), gear selectivity against maturity (Mathewos Hailu, 2014; Gashaw Tesfaye et al., 2016) and their maximum sustainable yield in fishery stock assessment (Gashaw Tesfaye and Wolff, 2015; Yitayal Alemu et al., 2017; Buchale Shishitu, et al., 2019). However, a comprehensive investigation regarding reproductive characters of the populations was not conducted so far. Such information are useful for proper fishery management and is also as basis for genetic improvement in aquaculture development.

Environmental factors affect growth performances and reproductive characters of O. niloticus populations in the process of adapting to different environments (Lowe-McConnell, 1982; Duponchelle et al., 1998; Dwivedi et al., 2016), though the O. niloticus tend to breed throughout the year in tropical region. Aquatic environments of the three rift valley lakes (Chamo, Koka and Ziway) in terms of their basic morphometric features, altitude, water quality parameters and fish species diversity are different (Tenalem Ayenew, 2009; Brook Lemma and Hayal Desta, 2016). Under these different environmental conditions of the three lakes, their O. niloticus populations are expected to develop different phenotypic and genetic characters. Phenotypic variation is wide in organisms spread in different geographical locations, and often involves ecologically relevant behavioral, physiological, morphological and life history traits. In a study conducted parallel to this one (unpublished data), differences in phenotypic characters were observed between the O. niloticus populations of Chamo, Koka and Ziway.
In an effort to develop the aquaculture sector in Ethiopia, seeds of O. niloticus were collected from natural environments, especially from the Ethiopian rift valley lakes to stock aquaculture ponds. Moreover, in an attempt to select better performing strains for aquaculture, tilapia populations from different Ethiopian rift valley lakes were evaluated for their growth performances. The tilapia populations from different Ethiopian rift valley lakes: Chamo, Hawassa, Hora, Koka, Matahara and Ziway showed different growth performances in pond culture (Kasaye Balkew and Gjoen, 2012; Daba Tugie et al., 2014; Daba Tugie et al., 2017) whereby the Chamo, Koka and Ziway strains were reported to have performed better.
Investigations on biological parameters such as length-weight relationship, condition factor and size at first sexual maturity are the easiest means of determining the stress of fishing pressure and water pollution on fish populations (Gupta and Tripathi, 2017). Studies on breeding season and associated factors are needed to protect new recruits and predict

recruitment variability. Number of recruitment in fish stock depends on availability of sexually mature fishes in the water bodies (LFDP, 1997; Tesfaye Muluye et al., 2016).
Characterization of the O. niloticus population helps in utilization of the resource in aquaculture, and further contributes to protect the population in their natural environments. Hence, the aim of the present study was to investigate the reproductive characteristics of the O. niloticus of rift valley lakes with specific objective of investigating sex ratios, breeding season, size at first sexual maturity and fecundity of the O. niloticus populations in Lake Chamo, Koka and Ziway as an input for proper fishery management and indication of the reproductive quality of the species in aquaculture development.

MATERIALS AND METHODS

Study areas

This study was conducted in three Ethiopian Rift Valley lakes: Chamo, Koka and Ziway (Figure 1) from May 2018 to April 2020. These water bodies were selected for their significant contribution to the fishery production and Nile tilapia (O.niloticus.) populations were targeted as these are candidate fish species in the development of aquaculture in Ethiopia.

Lake Chamo is situated in Southern part of the Ethiopian rift valley lakes within the Abaya-Chamo drainage basin at an altitude of 1110 m.a.s.l. The lake has surface area of about 297 km^2 (Alemayehu Hailemicael, 2011), maximum depth of 13 m, mean depth of 6 m (Sileshi Bekele et al., 2007) and is recharged mainly by a feeder river called Kulfo.

Lake Koka is a man-made reservoir located at about 90 km Southeast of Addis Ababa between 8° 18′ 57″ to 8° 28′ 21″ N latitude and 39° 0′ 0″ E to 39° 9′ 18″ E longitude at an altitude of 1,590 m.a.s.l. It was constructed on Awash River in 1960 for the purpose of hydro-electric power generation. The reservoir has a water-covered area of about 200 km^2 (Mesfin Gebrehiwot, 2020) with a maximum and mean depth of 14 m and 9 m, respectively (LFDP, 1997). However, the lake approaches to drying level in late dry seasons in some years as it did in May 2019. It has two feeder rivers, Awash and Modjo Rivers from East.

Lake Ziway (also known as Lake Danbal) is located in the Ethiopian rift valley between 7^0 52’ to 8^0 8’ N latitude and 38^0 40’ to $38^0$56’ E longitude at an altitude of 1636 m.a.s.l. with a maximum length of 32 km and maximum width of 20 km (LFDP, 1997). The lake is the second largest lake in Ethiopian rift valley after Abaya Lake, having an area of 434 km^2 and shore line length of 137 km. The Lake is, however, the shallowest of the rift valley lakes with maximum and mean depth of 8.95 m and 2.5 m, respectively (LFDP, 1997). The lake has two feeder rivers, Meki River from Northwest and Katar River from East side. The lake has one outlet river in its Southern part, the Bulbula River, which seasonally flows into Abijata Lake.
Sites for data collection and fish landing from each lake were purposely selected to represent the fish catches from inlet region, middle of the lake and outlet region. The landing sites are called Leto-1, Leto-2 and Elgo for Lake Chamo; Awash, Metoaleka and Bekele for Lake Koka and Golbe-Tsedecha, Meki-Girisa, Batu-Bochesa for Lake Ziway. Fish samples were collected seasonally from three landing sites per lake.

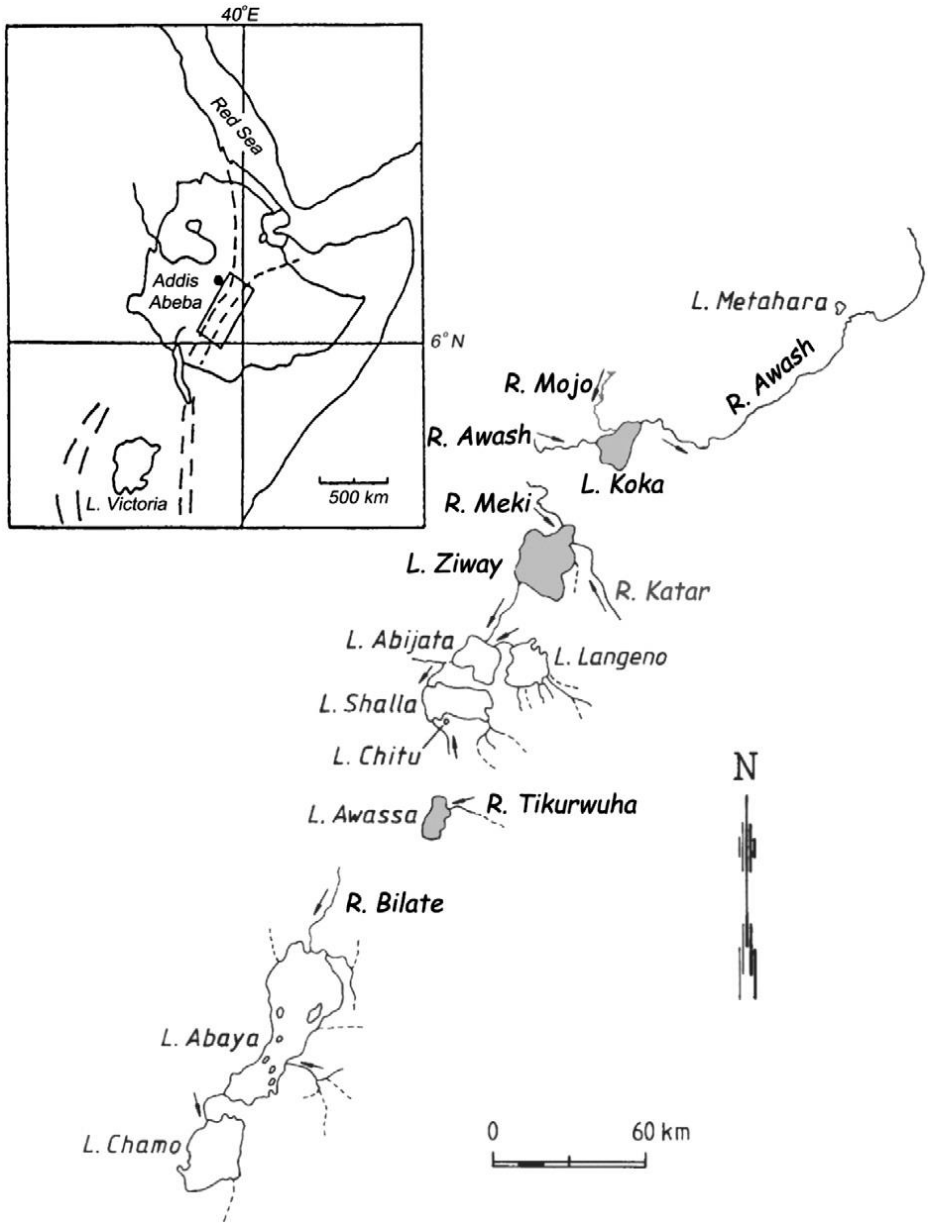

Figure 1. Location of the Ethiopian rift valley lakes (modified after Elizabeth Kebede et al. 1994)

Data collection methods

Fish samples were sampled from fishermen at the landing sites on arrival through facilitation of the cooperative chairpersons. The data were collected for two years 'seasonally', from May 2018 to March 2020. The data collection periods were classified into four 'seasons' in a year as pre-rainy season, main rainy season, post-rainy season and dry season, represented by sampling months of May, July-August, October-November and February-March, respectively for Lakes Koka and Ziway in this study. The rain distribution and season in the three study areas differ in such a way that the main rainy season is during the months of June, July and August at Lakes Koka and Ziway while it is during April and May at Chamo Lake. Moreover, October-November months are characterized as season of short rain at Chamo. Accordingly, the months of May, July-August, October-November and February-March represent the

'seasons' of main rainy season, post-rainy season, short-rain season and dry/pre-rainy season, respectively at Lake Chamo.

Sex ratio determination

A total 1,547 random fish samples from the three lakes, Chamo, Koka and Ziway were used in sex ratio determination. At least 30 to 40 fish samples per landings were sampled every time as a minimal sample size to represent the normally distributed population for statistical computation, except when there was no/less fishing in some landing sites because of 'lake drying' as in Bekele landing site of Lake Koka for the month of May or because of increasing of Lake level (discouraging the fishermen to set nets), and coinciding with busy crop cultivation period.

The samples were immediately taken to temporary shed or processing shed (at Lakes Chamo and Koka) or to fishery lab in the case of Lake Ziway for data (sex, length, weight) collection. Sex identification of O. niloticus was made by visual observation into their genital papilla and observation of gonads after dissecting their abdomen. The proportion of females and males in the samples was calculated (Zar, 1999) after recording the frequencies of the sexes in each of the lakes in every sampling season. Sex ratio was expressed as Female : Male and tested against an expected ratio of 1:1 using the chi-squared test at p-value of 0.05.

Length at first sexual maturity

Lengths of the sampled fish were measured on a portable measuring board of 50 cm length graduated at 0.1 cm level. Total length (TL) of the fish was measured to the nearest 0.1 cm from all sampled fish. Fish total weight (TW) was measured to the nearest 0.1g using a sensitive balance, LD610-2, Max=610 g, d=0.01 g.

The L_{50} is the onset of sexual maturity at which 50% of the fish have reached sexual maturity. The female's and male's gonad maturity stages were identified based on macroscopic gonadal maturation stages (Abebe Getahun, 2017). The female's gonad is classified into five maturity stages and that of males into four stages. The five stages in ovaries are classified as immature, maturing, ripe, spent or resting. The male's four gonad maturity stages are classified as immature, maturing, ripe or spent.

Based on the maturity stages, the fish were grouped into immature (maturity stage-I and stage-II) and mature (maturity stage- III and above). The relationship between the percentage of mature fish (P) per length class and fish total length (L in cm) was described with a logistic curve and L_{50} was estimated according to Gunderson et al. (1980):

$$P = \frac{1}{1 + e^{(bL+a)}}$$

Where "P" is proportion of mature fish at specific length class; "L" is total length; a and b are model parameters (a is intercept and b is slope of the logistic regression). The L50 was derived from the relationship of "a" and "b".

$$L_{50} = -\frac{a}{b}$$

Gonado-somatic Index (GSI)

Data for gonado-somatic index (GSI) of fish, which helps in determination of the breeding season, was collected by weighing the fish samples, dissecting the sample and taking its gonad weight both for females and males in each of the study site. The GSI was analyzed only for mature fish groups after the L_{50} was determined (Demeke Admasu, 1996) for each sex for

all the three lakes. Gonado-somatic index (GSI) of each fish was computed as weight of the gonads as the percentage of the total body weight as follows:

$$GSI = \frac{GW\ (g)}{TW\ (g)} \times 100$$

Fecundity determination

The data for fecundity was taken from ripe gonads. After taking the total length and total weight data of ripe females, the females were dissected and their gonads weighed. Sub sample taken from the gonad and fecundity was determined by gravimetric method (Abebe Getahun, 2017) by counting all eggs in the sub samples taken from ripe ovaries. Absolute fecundity was then calculated using the following formula.

$$Fecundity\ (F) = \frac{\text{No.of eggs in sub sample x gonad weight}}{Weight\ of\ sub\ sample}$$

The relationships between absolute fecundity and female's morphometric measurements, and total length (TL), total weight (TW) and gonad weight (GW) were determined using least squares regression.

$F = aTL^b$, $F = aTW^b$, $F = aGW^b$

Where a and b are parameters of the fitted lines, TL is total length of fish in cm; TW is total weight of fish in gram and GW is gonad weight in gram.

One way ANOVA was employed to investigate differences in mean total lengths, mean weights of fishes among the populations and mean Gonado-somatic index (GSI) of the fish between sampling months at the three lakes.

RESULTS

Sex ratios

The two years' sampling results were grouped into four seasons, October-November, February-March, May and July-August months for each lake. The sex ratios of O. niloticus were expressed as Female: Male =1 (Table 1).

Table 1. Sex ratios (female: male) of O. niloticus from Chamo, Koka and Ziway lakes.

Lakes	F : M	N	Chi-square	p-Value
Chamo	1.05 : 1	361	0.224	0.636
Koka	0.99 : 1	494	0.008	0.928
Ziway	1.07 : 1	692	0.576	0.448

When the results were tested by Chi-square test, the sex ratios of female : male in all the three lakes in each of the four sampling seasons did not significantly deviate from 1:1 ratio.

Length at first sexual maturity (L_{50})

The length at first sexual maturity (L_{50}) of females and males were not significantly different for the O. niloticus populations of Lake Chamo and Lake Koka in which the L_{50} was derived from mixed sexes (Table 2). However, the females and males had exhibited significantly

different L_{50} in Lake Ziway. The L_{50} of Nile tilapia for the three lakes differed as illustrated in Table-2 below.

Table 2. The L_{50} of O. niloticus populations of Chamo, Koka and Ziway with size range at 97.5% CI.

	Chamo Mixed sex	Koka Mixed sex	Ziway Female	Ziway Male
L_{50} (cm)	23.48	21.91	16.00	17.49
Size range at 97.5% CI	23.08 : 23.87	21.41 : 22.35	15.59 : 16.30	17.14 : 17.84

Note: L_{50} = length at 50% of the population reach their first sexual maturity, CI = confidence interval.

Length at first sexual maturity (L_{50}) where 50% of the population of Nile tilapia reaches sexually mature for the first time was at total length (TL) of 23.48 cm in Lake Chamo (figure 2a) for mixed sex; there was no significant difference between males and females. The L_{50} for mixed sex Nile tilapia in Lake Koka was 21.91 cm (Fig 2b). The L_{50} values for female and male groups were significantly different in Lake Ziway where it was 16.00 cm for females (Fig 2c) and 17.49 cm for males (Fig 2d). Distribution pattern of the proportion of mature fishes along the total length of the fishes was different for the populations in the different lakes. The smallest sexually mature female O. niloticus found were at size of 13.4 cm, 19.8 cm and 21.9 cm TL in Lakes Ziway, Koka and Chamo, respectively. Similarly, the smallest sexually mature male O. niloticus observed were at sizes of 14.7 cm, 20.0 cm and 22.0 cm TL in Lakes Ziway, Koka and Chamo, respectively.

Gonado-somatic index (GSI)

The gonado-somatic index (GSI) of the O. niloticus species from Lakes Chamo, Koka and Ziway was analyzed separately for sexes in the four different sampling seasons. The mean GSI was relatively higher in October-November (short rainy season) and February-March (pre-rainy season) at Chamo Lake for both male and female sexes. The highest mean GSI for the females (Fig 3a) of Koka population was recorded in May (pre-rainy season) and in July-August (main rainy season) for males (Fig 3b). The relatively highest mean GSI was recorded both for females and males in February-March (dry season) for tilapias of Ziway population.

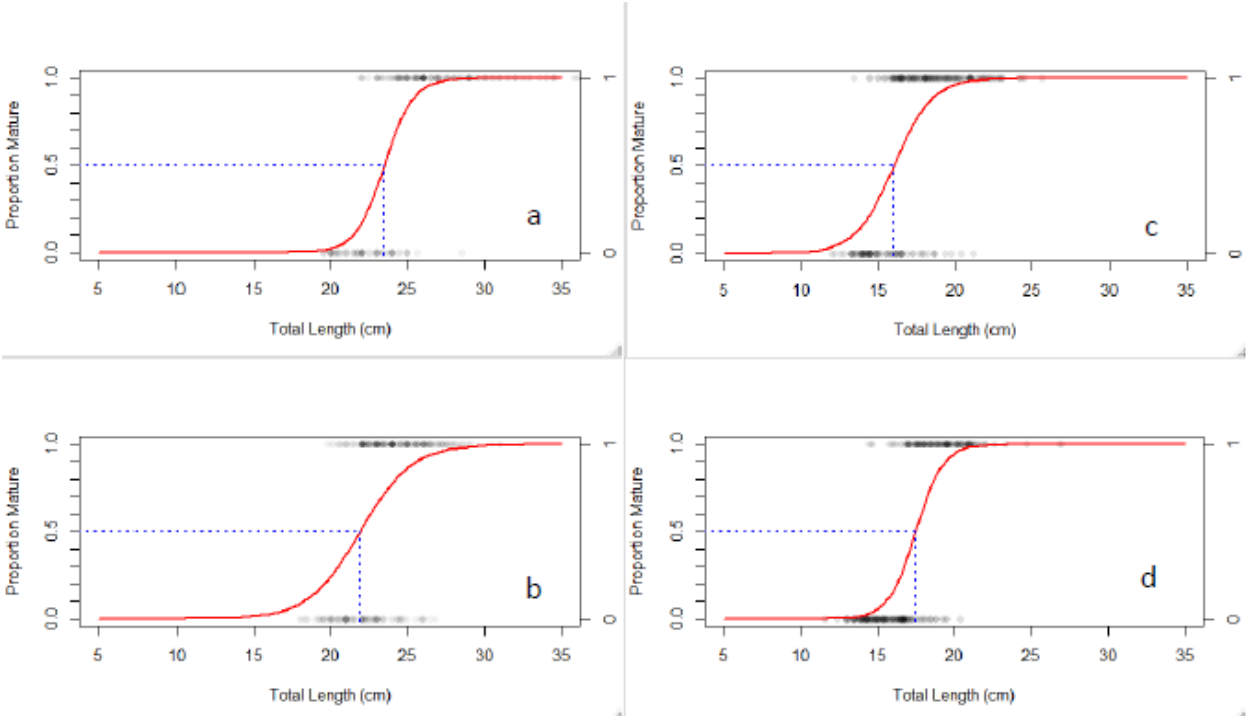

Figure 2. Length at first sexual maturity (L_{50}) of O. niloticus in Lakes Chamo for mixed sex(a), Koka for mixed sex (b), Ziway female(c) and Ziway male(d).

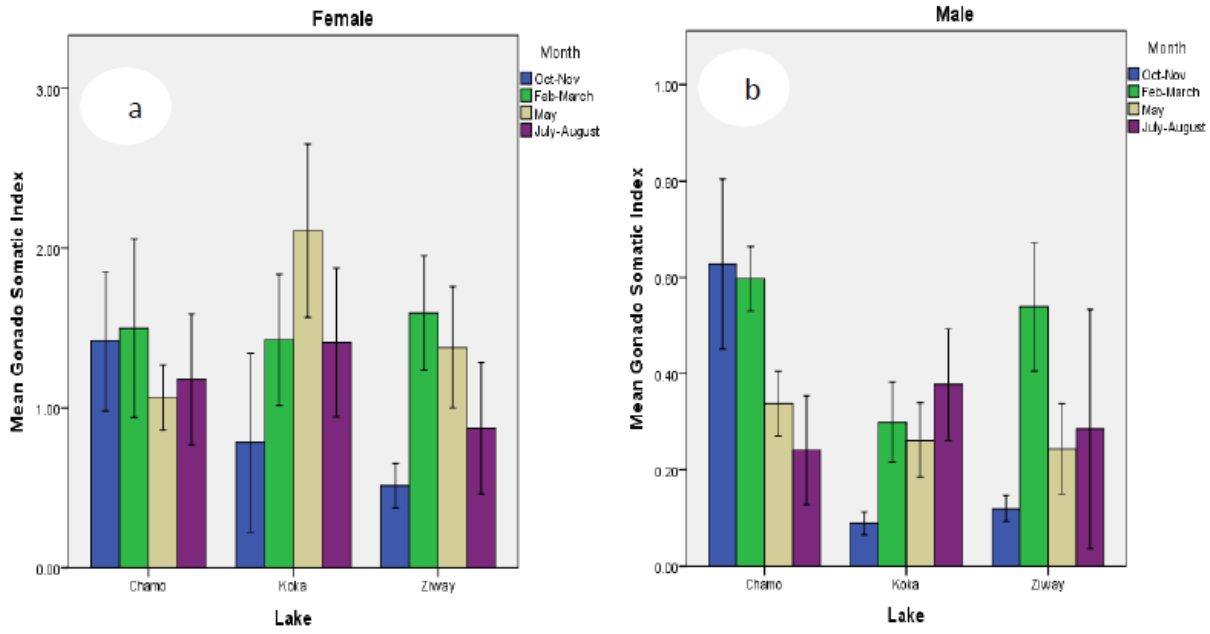

Figure 3. Mean GSI (Gonado Somatic Index) of O. nilotcus by lake (Chamo, Koka, Ziway) and 'season' (Oct-Nov, Feb-March, May, July-Aug) for female (a) and male (b) groups. Error bars represent the 95% CI (Confidence Interval).

Fecundity

Fecundity (number of eggs a female can produce at a time) was calculated based on the egg samples taken from gonads of ripe females following standard procedures and presented in Table 3. The absolute fecundity ranged from 209 at Ziway to 1886 eggs per female at Chamo. The mean absolute fecundity was high for O. niloticus of Lake Chamo (1,322 eggs/female) followed by Lake Koka (1,147 eggs/female) and lowest for Lake Ziway (450 eggs/female).

Table 3. Absolute fecundity of female O. niloticus from Lakes Chamo, Koka and Ziway.

Lake	Chamo	Koka	Ziway
Mean ± Std.	1321.76 ± 342.92	1146.89 ± 115.227	450.07 ± 180.829
Minimum Maximum	739 1886	962 1357	209 800

Fecundity has a direct curvilinear relationship with the females' total length (TL), total weight (TW) and gonad weight (GW). The figures 4-6 display fecundity of female O. niloticus pooled from Lakes Chamo, Koka and Ziway. The relationship between absolute fecundity (F in eggs/female) and TL in cm was $F = 0.409TL^{2.4117}$, $R^2 = 0.908$ (Fig 4); F and TW in gram (g) was $F = 10.186TW^{0.8125}$, $R^2 = 0.9013$ (Fig 5); and between F and GW (g) was $F = 118.9GW^{0.9121}$, $R^2 = 0.8415$ (Fig 6).

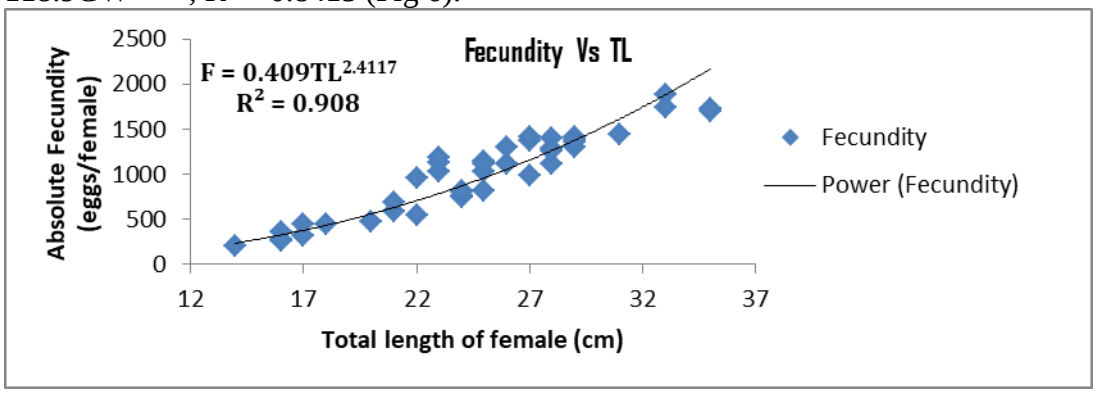

Figure 4. Relationship between fecundity and total length of O. niloticus pooled for Chamo, Koka and Ziway populations.

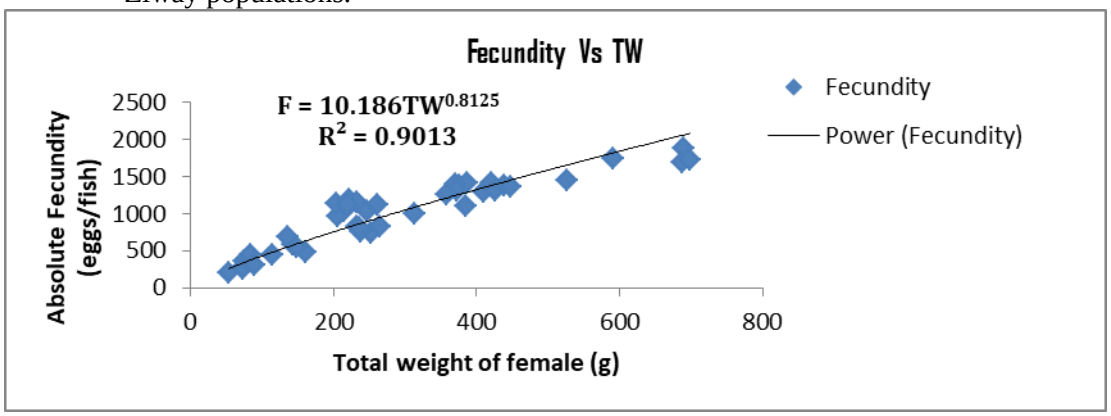

Figure 5. Relationship between fecundity and total weight of O. niloticus pooled for Chamo, Koka and Ziway populations.

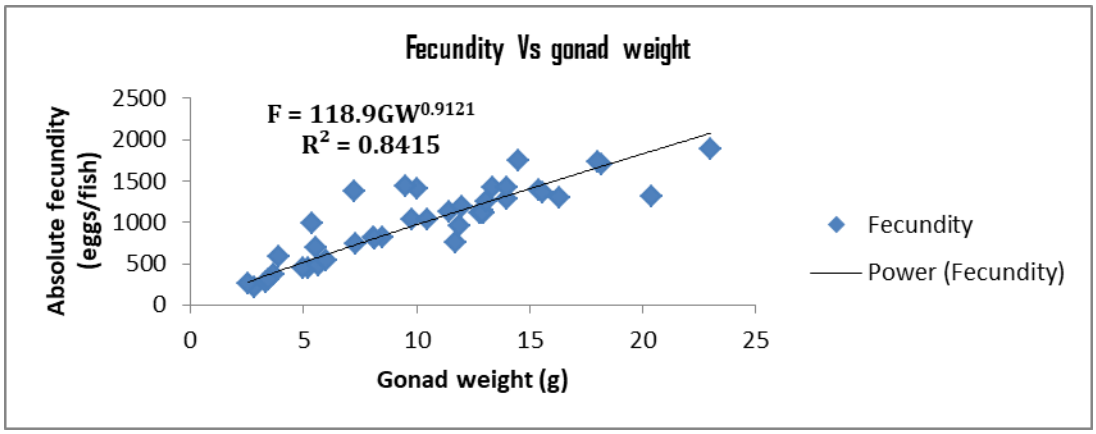

Figure 6. Relationship between fecundity and gonad weight of O. niloticus pooled for Chamo, Koka and Ziway populations.

DISCUSSION

The **sex ratios** of the O. niloticus in all the sampling seasons at the three lakes did not statistically deviate from the expected 1 : 1 ratios. The current result of 1 : 1 sex ratios in the three lakes is attributed to the inclusion of fish samples from all available fishing gears (beach seine, monofilament and multifilament gillnets) and the representativeness of the random samples. Balanced sex ratio is expected in a wild O. niloticus population, though environmental sex determination was reported, the case by which the male ratio increases with temperature (Baroiller and Clota, 1998; Misikire Tessema et al. 2006). The current water temperatures in the study areas (28.09 ± 1.48 ^{0}C at Chamo, 22.77 ± 1.20 ^{0}C at Koka and 24.24 ± 2.78 ^{0}C at Ziway) during the study time were not that high to shift the sex ratios (Abucay, 1999).

The current sex ratio results agree with the previous report from Lake Chamo (Yirga Teferi and Demeke Admasu, 2002). Sex ratios of O. niloticus samples can also deviate from the expected 1 : 1 ratio across seasons due to sexual segregation during spawning, fishing site and gear type (Demeke Admassu, 1994; Assefa Tessema et al., 2019). Variations in sex ratios were also reported with more females than males at Lake Beseka (because of fish sampling using gillnet, for which females are more vulnerable than males Lemma Abera, 2013), Lake Hayq (Workiye Worie and Abebe Getahun, 2014), Lake Ardibo (Endalh Mekonnen et al., 2018) and males predominated over females at Lake Tana (Zenebe Tadesse, 1997), Lake Victoria (Njiru et al., 2006), Amerti Reservoir (Mathewos Hailu, 2014), Lake Hayiq (Assefa Tessema et al., 2019) because of the above reasons.

Length at first maturity (L50)

The length at first sexual maturity (L_{50}) of the O. niloticus populations in the present study were 23.48 cm, 21.91 cm, 17.49 cm and 16.00 cm (TL) for Lakes Chamo, Koka, Ziway (males) and Ziway (females), respectively (Table 2). The values were different for the three lakes with the highest for population of Lake Chamo and lowest for females of Lake Ziway. The present L_{50} values of the tilapia populations were within the previous L_{50} report ranges from different lakes and reservoirs in the country; 14.0 cm for females and 17.0 for males in Lake Beseka (Senait Gebremeskel, 2015), 14.1 cm and 20.3 cm for females and 17.8 cm and

20.8 cm for males in Lake Hawassa (Bjorklis, 2004 and Tesfaye Muluye et al., 2016 respectively), 18.9 cm for females and 21.5 cm for males in Amerti Reservoir (Mathewos Hailu, 2014), 19.5 cm in Lake Langeno (Gashaw Tesfaye and Zenebe Tadesse, 2008), 21cm in Lake Tana (Tesfaye Wudneh, 1988, Degsera Aemro et al., 2019), 21.8 cm for females and 24.5 cm for males in Finchawa reservoir (Fasil Degefu et al., 2012), and 30.81cm for females and 34.5 cm for males in Lake Victoria (Njiru, 2006).

The present L_{50} values of all the three O. niloticus populations were lower than the previous reports. The L_{50} for Chamo population decreased from 42.0 cm reported by Yirga Teferi and Demeke Admasu (2002) to the present result of 23.48 cm in a period of twenty years. The value for Koka population decreased but slightly, from 23.5 cm (Gashaw Tesfaye and Zenebe Tadesse, 2008) and 24.6 cm (Gashaw Tesfaye et al., 2016) to the present value of 21.91 cm in about five years. Similarly, the L_{50} of Ziway population decreased from 18.8 cm (Yirga Teferi and Demeke Admasu, 2002), and 19.6 cm for males and 18.1 cm for females (Gashaw Tesfaye and Zenebe Tadesse, 2008) to the present value of 17.4 cm for males and 16.00 cm for females. The current decrease in L_{50} of O. niloticus populations in Lakes Chamo, Koka and Ziway may be attributed to the fishing pressure (Vijverberg, et al., 2011) and change in the lakes environment (pollution, siltation, fish stock composition).

Size at first sexual maturity is determined both by genetic and environmental factors, and it appears to be variable trait that stocks can adjust depending on demographic and environmental conditions (Gashaw Tesfaye and Zenebe Tadesse, 2008). Early sexual maturation negatively affects growth performance of the fish, influencing the quality and quantity of the fish product both in natural environment and in aquaculture productions. The quantity and quality of fish product determines income of the fishermen as well as the profitability of the fish farm. Hence, the decrease in size at first maturation alarms the need for the implementation of proper and effective fishery and environmental management measures to sustain the fishery of the lakes. On the other hand, the Chamo and Koka tilapias, with their relatively higher L_{50} values, were found to be potential populations for further genetic improvement to enhance aquaculture development.

Gonado-somatic index (GSI)

Gonado-somatic index (GSI) is used to determine the breeding season of the fishes. Females with ripe ovaries and males with ripe (larger, full and white) testes were observed in all the four sampling seasons but with different frequencies in all the three lakes implying that O. niloticus is breeding all year round. The mean GSI of O. niloticus from Lakes Chamo, Koka and Ziway were different for different sampling seasons (Figure 3).

For Chamo population, the mean GSI were not statistically different among the four sampling seasons for females ($p > 0.05$); however, it was relatively higher (1.42 ± 1.05) in October-November (short rainy season) and 1.50 ± 1.09 in February-March (pre-rainy season) than the other two sampling seasons (1.07 ± 0.58 in May and 1.18 ± 1.02 in July-August). The mean GSI values for males during these two sampling seasons were significantly ($p < 0.05$) higher than the mean values recorded during the rainy season and post rainy season (Figure 3).

For Koka population, the highest mean GSI value (2.11 ± 1.61) for females was recorded in May (pre-rainy season) which was significantly higher ($p < 0.05$) than the lowest mean value recorded (0.78 ± 0.88) in October-November (post-rainy season). The lowest mean GSI value for males was also recorded in the October-November sampling season, the value which was significantly lower ($p < 0.05$) than that of the other three sampling seasons (Figure 3).

The relatively highest GSI value (mean ± standard deviation) of 1.60 ± 1.28 was recorded in February-March (dry season) and the lowest value of 0.52 ± 0.44 in October-November (post-rainy season) for females of Ziway population. The males have similar peak patterns among the sampling seasons in the lake (Figure 3). The peak breeding season for Ziway was similar to that of Lake Hawassa (Demeke Admasu, 1996).
The current result shows that the O. niloticus populations of Chamo, Koka and Ziway breed all year round with peak activity in October-November and February-March in Chamo, in May in Koka and in February-March seasons in Ziway. The peak spawning usually coincides with the onset of the rainy season (Zenebe Tadesse, 1997; Lemma Abera, 2012).

Fecundity
The mean absolute fecundity of the O. niloticus populations in the present study was higher at Chamo (1,321.76 ± 342.92) followed by Koka (1,146.89 ± 115.23) and significantly ($p = 0.00$) lower (450.07 ± 180.83 eggs/female) than the two lakes at Ziway lake . The relative fecundity of the females showed positive curvilinear relationship with total length ($F = 0.409TL^{2.4117}$, $R^2 = 0.908$), total weight ($F = 10.186TW^{0.8125}$, $R^2 = 0.901$) and gonad weight ($F = 118.908GW^{0.9121}$, $R^2 = 0.8415$). The higher mean absolute fecundity values of females at Chamo and Koka correspond to the higher mean total length (28.65 ± 3.72 cm, 25.33 ± 2.19 cm) and total weight (429.41 ± 342.92 g and 282.75 ± 159.52 g) of the females. Similarly, positive relationship of the fecundity with total length, total weight and gonad weight was reported for tilapias in different water bodies (Zenebe Tadesse, 1997; Dwivedi et al., 2016; Kausar et al., 2019).

Generally, the differences observed in L_{50}, breeding season and fecundity of the O. niloticus populations might be attributed to differences in the lakes' environment, sizes, bathymetry, physico-chemical and biological properties, to the fishing pressure (Tenalem Ayenew, 2009, Vijverberg, et al., 2011; Megerssa Endebu et al., 2015) and perhaps to the genetic differences between the isolated populations (Agnese et al, 1997; Tibihika et al., 2020). The current improper fishing activity at the lakes is a negative genetic selection among the diversity in such a way that individuals with inferior growth performances are favored to breed and dominate the lakes by removing individuals with bigger sizes from the lakes in a serious of generations.

CONCLUSIONS AND RECOMMENDATIONS

In this study, the sex ratios, size at first sexual maturity, breeding season, absolute fecundity and the relationship of fecundity with total length, total weight and gonad weight of O. niloticus populations in Lakes Chamo, Koka and Ziway were investigated. The populations have shown similar and expected female : male ratios of 1 : 1 in their natural environments. The populations have shown different sizes at first sexual maturity (L_{50}), with the populations in Chamo and Koka showing higher L_{50} than those in lake Ziway.The differences in L_{50} was attributed to environmental and/or genetic differences. All the current L_{50} values of the three populations were lower than the values reported inprevious studies especially for Lake Chamo. This is a good sign for increasing fishing pressures and environmental changes.

Breeding of O. niloticus populations, as determined from the Gonadosomatic index (GSI) and frequency of ripe gonads in four sampling seasons, was found to take place in all seasons

in all the three lakes. However, the peak activities were different in the three lakes; in October -November (short rainy season) and February-March (pre-rainy season) at Chamo Lake, in May (pre-rainy season) at Koka Lake and in February-March (dry season) at Ziway Lake. The peak breeding periods were related with the onset of rain. The three lakes had different annual rain fall distribution patterns. The mean absolute fecundity was highest for populations of Lake Chamo (1,322 eggs/female) followed by Lake Koka (1,147 eggs/female) and lowest for Lake Ziway (450 eggs/female). The fecundity correlated strongly with the females' total length and total weight, and slightly with gonad weight. These differences in sizes, which also determine their fecundity, could be due to environmental and/or genetic factors. The current decreases in reproductive parameters of the O. niloticus populations from the previous reports indicate the decrease in quality and in turn the quantity of the fish stocks, challenging the sustainability of fisheries. Implementation of sustainable fishery management and environmental protection practices in the lakes and their watersheds are required. Nile tilapias of Chamo population followed by those of Koka, possessed better reproductive quality in aquaculture production with higher L_{50} and absolute fecundity and hence they are potential populations for further genetic improvement in tilapia aquaculture. Further, studies are required to assess the current environmental status of the lakes, and determine whether or not the populations maintain their reproductive characteristics in controlled environments. Furthermore, additional studies that include other populations of O. niloticus from other water bodies are required to come up with conclusive recommendations for the establishment of O. niloticus based aquaculture in the country.

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NATURAL RESOURCE MANAGEMENT RESEARCH

Integration of vermi –compost and inorganic fertilizer for Maize and Sesame production at Bako -Tibe and Wayu-Tuka Districts

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ABSTRACT

Impact of Vermi-compost rates and Inorganic Fertilizers integration on maize (at Bako and Wayu- tuka) and sesame (at Bako) were assessed for two years. Different rates of vermi compost, NPS and Urea were integrated. Untreated, check, recommended compost and fertilizer rates were also included as checks Yield parameters, grain yield, composite soil data before planting andpost-harvest soil data were taken and analyzed.The yield obtained (7299 kg ha^{-1}) in treatment 7 (50% recommended vermi-compost and 75% of NPS and Urea) was significant, with the highest net benefit (62364.2 Ethiopia birr ha^{-1}) in maize crop. Similarly, Treatment 6 (50% recommended vermi-compost + 50% inorganic fertilizers) gave 701kg ha-^{1} with (17,814.1 Ethiopia birr ha-^{1}), the highest net benefit from Sesame. Soil parameters soil pH (1:1.2.5), soil organic carbon (SOC), soil organic matter (SOM), total nitrogen in the soil (TN) and available phosphorus at two sites) were significantly different.Therefore, the result of the study showed that integration of vermicomposting with inorganic fertilizers in maize and sesame crop production is recommended and can improve soil chemical properties.

Keywords: Maize, Sesame, Vermi-compost, soil pH, soil OM, soil OC, TN,

BACKGROUND

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

To maintain soil fertility through natural nutrient cycle, composting of organic materials and returning it back to the soil is a common activity in developed nations (Inckel etal., 1996).Composting is a technology for recycling organic materials in order to achieve enhanced agricultural production. Biological and chemical processes accelerate the rate of decomposition and transform organic materials into a more stable humus form for application to the soil.

In addition to the changes exerted on the chemical and physical properties, composted materials have a clear impact on soil biological properties, such as increases in microbial biomass and activity (Knapp et al. 2010), as well as changes in the activity of soil enzymes

(Garcia-Gil et al., 2000, Roset al., 2006) and in the structure of the soil microbial community (Ros et al., 2006).

Vermicomposting is the use of mesophilic earthworms to produce an organic fertilizer from organic waste (Ndegwa, et al., 2001).Earthworms restore & improve soil fertility and significantly boost crop productivity. Earthworms excreta(vermicast) is a nutritive 'organic fertilizer' rich in humus (NPK), micronutrients, beneficial soil microbes nitrogen fixing & phosphate solubilizing bacteria' (actinomycets) and growth hormones ('auxins, gibberellins and cytokines). Both earthworms and its vermi-cast and body liquid (vermi-wash) are scientifically proving as both growth promoters and protectors for crop plants,there are also less incidences of pest and disease attack and reduced demand of water for irrigation in plants grown on vermi-compost (Gomez-Berandomon,et al.,2011). Presence of live earthworms in soil also makes significant difference in flower and fruit formation in vegetable crops (Jorge Dominguez et al., 2010). Composts work as a 'slow release fertilizer' whereas chemical fertilizers release their nutrients rather quickly in soil and soon get depleted. Significant amount of chemical nitrogen is lost from soil due to oxidation in sunlight. However, with application of vermi-compost the organic nitrogen tends to be released much faster from the excreted humus by worms and those mineralized by them and the net overall efficiency of nitrogen (N) is considerably greater than that of chemical fertilizers. Availability of phosphorus (P) is sometimes much greater. Earthworms and vermi-compost can promote growth from 50 to 100% over conventional compost & 30 to 40 % over chemical fertilizers besides protecting the soil and the agro ecosystem while producing nutritive and tasty food at a much economical cost (at least 50 to 75% less) as compared to the costly chemical fertilizers (Rajiv K. 2010).

According to Derib, 2017 in an experimentdone on the characterization of different feed materials combination with manure to crop residue in Bako Agricultural research center, 4.64 tons of vermi-compost prepared from Soybean straw and cattle manure can replace the recommended amount of Urea (200 kg) in terms of nitrogen which in the same time supply 139 kg DAP that outmatched the dose of phosphorus for the crop. The present study assessed Integration of organic vermicomposting rates application with Inorganic fertilizers NPS and Urea in two years at field experiments on two test crops (Maize and Sesame).

MATERIAL AND METHODS

The experiment was carried out at in western part of Ethiopia Bako Agricultural Research Center experimental fields, BARC and Gute site at altitude of 1650masl and 1890masl respectively. The area has a warm-humid climate with annual means two years cropping season minimum and maximum temperatures of 13.85^0c and 29.25^0c respectively. The rainfall received during 2017 and 2019 cropping seasons was 96.80 mm and 111.025 mm respectively. The experimental site is describe by reddish, reddish- brown and clay loam, nitisol which strongly acidic pH (4.32 and 4.98), organic carbon (0.93 and2.89), organic matter, (5 and 1.6), TN, (0.08 and 0.25) Gute and Bako site respectively with (7.14) pre planting available phosphorus.

Fertilizer materials

The organic fertilizer used in this study wasvermi-compost produced from the combination of soybean straw and cattle manure in the previous experiment which out ranked the other types of vermi-composts in its quality (nutrient content composition). According to the laboratory analytical result, the major plant nutrients contained in this compost are 1.98% Total N, 1.39% Total P, 3.94% Total K, 7.91% Total Ca, 8.7% Total Mg and it had a CN ratio of 16.27.The inorganic fertilizer and rates used were 110 N and 46 P_2O_5 for maize, and 23 P_2O_5 for sesame. Improved varieties of the test crops, (BH-661) for Maize and (Walin) for Sesame were sown with the fertilizers according to the recommended agronomic practices for each crop.

Treatment and experimental design

Twelve treatments consisted of three levels recommended vermi-compost (25 %, 50 %, and 75 %) and 25 %, 50 % and 75 %) levels of recommended NPS and Urea fertilizer were combined with a control and standard checks or 100 % recommended vermi-compost respectively. The experiment was laid out in randomized complete block design (RCBD) with three replications.

RESULT AND DISCUSSION

The grain yield and soil fertility parameters response in different location and test crops showed significant difference. The modification of acidity was possible due to balancing inorganic chemical fertilizers by incorporated nitrogen waste in the process which increase the soil moisture, neutralizing the pH of soil which from strongly acidic to moderately acidic rated by Takalgn 1991, considering organic carbon, CN ratio, organic matter and increase availability of phosphorus, improvement in the fertility status of the soil due to organic vermi-compost nutrient and inorganic fertilizers, similar trend was obtained by (Geetha, S., 2004). The highestOrganic carbon distinctly indicated that leads to deposits of organic matter.Organic matter, content influence the ability of soils retains moisture. TN similar to the others total nitrogen of the soil was increased from pre planting to postharvest soil sample, recorded after crop harvested regardless of treatment and seasonal variations.

The application of vermi-compost integrated with inorganic fertilizers has significantly influenced total biomass, grain yield and soil fertility status.(Shiferaw B., et al 2018 and Acta fytotechn, zootechn, 2014) reported similar result where the application of vermi-compost positively impacted the height and stock of Maize at growth stages. From each observation higher grain yield was obtained from treatment 7 that received 50% (2.32 tons per hectare) of recommend vermi-compost and 75 % of NPS and Urea fertilizers.Yield obtained from Maize across location (7299 kg ha^{-1} (Table 1) and (701 kg ha^{-1})from Sesame with significant difference in total bio mass weight and grain yield (Table 3).

The mean change in soil chemical properties for soil pH (1:2.5) H_2o ranges from 5.28 to 5.91, % OC from 2.89 to 5.24, % OM from 5 to 9.03, % TN from 0.25 to 0.45 and pH (1:2.5) H_2o from 4.46 to 5.12 OC from 0.93 to 2.37, % OM from 1.6 to 4.09, % TN from 0.08 to 0.16 for Sesame and Maize test crop respectively.

Available P before planting and at harvest for maize at two sites is compared. The highest available p is recorded in treatments 3 and 6due to the ability of vermi-compost access soluble phosphorus in soils high in soil, while the lowest available P is recorded in treatment 8 and 12which is received the highest inorganic fertilizers and used as standard check, agree with reported of (Temedo, T. and Mitiku, W. 2017).In sesame, significant difference was observed in most parameters measured such as branch number, plant height, biomass and grain yield. From each observation higher significant grain yield was obtained from treatment 6 (50 %), (2.32 tons per hectare) vermi-compost +50 % of inorganic fertilizer). Means rain fall (mm), Maximum and Minimum Temperature (0^c), the total amount of rain fall (mm) in 2018 and 2019 during cropping season vary amount of rain fall impact on mean grain yield (Table 2 and 4).

Economic Analysis

The dominance analysis indicated all treatments were not dominated in Maize and for Sesame in Treatments 5,11,10,4,3 and 8 were dominated; treatments 2, 12, 7, 9 and 6 were lower variable cost with higher net benefit (Table 5). Based on the dominance analysis all treatments were potential options for maize and treatments 2, 12, 7, 9 and 6 were potential options for Sesame (Table 6), depending on partial budget analysis, treatment 7 (62,364.2 ETB. per hectare) for maize and treatment 6 (17, 814.1ETB. ha^{-1}) for sesame Showed the highest net benefit.

Table 1: Maize, Ls-means of Yield production parameters influenced by integrated organic vermi compost and Inorganic fertilizers.

Treatments	Mad	Plh	Tbiow	Cobn	Cobw	Gry
T1	165.03	246.695e	13.108 e	54.333 e	10.108c	4709.3 c
T2	164.03	70.783bdc	19.433dc	63.833dc	13.125ba	6114.7ba
T3	164.03	70.898bdc	24.100 a	63.583dc	14.633ba	6817.4ba
T4	161.53	265.923bdc	23.708ba	2.833a	14.958ba	6968.8ba
T5	163.00	257.233ed	19.875bdc	63.333dc	12.850bac	5986.6bac
T6	161.00	276.475bac	21.842bac	63.917dc	14.858ba	6922.2ba
T7	162.70	264.925bdc	23.99a	68.167bdac	15.667a	7298.8a
T8	162.53	270.483bdc	23.450bac	65.333bdc	12.833bac	5978.8bac
T9	161.53	280.525ba	22.092bac	68.667bac	14.950ba	6964.9ba
T10	162.67	289.197 a	23.142bac	71.3ba	15.425a	7186.2a
T11	164.67	260.750edc	17.458d	62.500d	12.292bc	5726.5bc
T12	162.67	271.403bdc	23.108bac	68.833bac	14.917ba	6949.4bc
Means	162.92	268.7743	21.27569	65.55556	13.88472	6468.647
CV%	8.3349	7.411404	24.38915	11.37919	24.38915	25.72094
LSD	10.971	16.089	4.191	6.025	2.8844	1343.8

Mad= Maturity day, Plh=plant height, Tbiow=total biomass weight, Cobn=cob number, cobw=cob weight, Gry= Grain yield.

Table 2: Maize Mean yield of years and Location

	Mad	Plh	Tbiow	Cobn	Cobw	Gry
Yearone	168.333	287.176	24.3111	71.042	14.1917	6611.6
Year two	157.625	250.372	18.2403	60.069	13.5778	6325.6
LSD(0.05%)	1.97838*	6.5682ns	1.711ns	4597ns	1.1776*	548.6*
Location one	166.000	286.05	27.3792	67.875	18.4403	8591.0
Location two	159.958	251.496	15.1722	63.236	9.3292	4346.3
LSD(0.05%)	4.479ns	6.5682ns	1.711ns	2.4597*	1.1776ns	548.6ns

Table 3: Sesame Ls-means of Yield production parameters influenced by integrated organic vermi-compost and Inorganic fertilizers.

Treatments	Stc	Plh	Brn	Pn	Tbiow	Gry
T1	157.83	109.06bac	4.73ba	44.72a	2.98 b	0.283bac
T2	158.00	109.18bac	4.36bac	45.84a	2.48b	0.325bac
T3	155.33	102.31c	4.26bac	44.12a	3.31BA	0.255bc
T4	156.83	107.83bac	4.46bac	52.99a	3.30ba	0.248bc
T5	157.50	111.12ba	4.23bc	45.87a	3.90ba	0.213 c
T6	154.50	106.69bac	4.76ba	54.97a	4.61a	0.448a
T7	152.66	106.57bac	4.23bc	52.70a	3.61ba	0.36bac
T8	157.50	109.56bac	4.03bc	45.66a	3.83ba	0.30bac
T9	159.16	111.67a	5.23 a	52.08a	4.01ba	0.410ba
T10	157.00	104.36bac	4.10bc	49.10a	3.58ba	0.250bc
T11	156.83	103.75bc	3.73 c	46.99a	2.88 b	0.253bc
T12	155.50	109.99ac	4.53bac	58.60a	3.28ba	0.365bac
Cv%	3.44	6.25	19.35	25.26	38.78	47.11
LSD(0.05)	6.2315	7.7861	0.9822	14.614	1.5612	0.1688

Stc=stand count, Plh=plant height, Brn=branch number, Pn=pod number, Tbiow=total bio mass weight, Gry=Grain yield.

Table 4: Yield of Sesame mean years

	Stc	Plh	Brn	Pn	Tbm	Gry
Year one	157.917	108.833	4.4889	56.506	5.6556	0.38111
Year two	155.194	106.524	4.2944	42.443	1.3139	0.23917
LSD0.05%)	2.544ns	3.1787ns	0.401ns	5.9661*	0.6374*	0.0689*

Table 5: Economic (partial budget and dominance Analysis) integrate vermi-compost and inorganic fertilizers rates on Maize production

Treatments	Av. Yield	Adj. yield	GB (Eth.birr)	TCTV (Eth.birr)	NB (Eth.birr)	MRR (%)
T1	4709.30	4238.37	42383.70	0.00	42383.70	
T11	5726.50	5153.85	51538.50	2300.00	49238.50	7.21
T8	5978.80	5380.92	53809.20	2450.00	51359.20	12.58
T5	5986.60	5387.94	53879.40	1875.00	52004.40	9.10
T2	6114.70	5503.23	55032.30	1300.00	53732.30	8.73
T3	6817.40	6135.66	61356.60	2025.00	59331.60	7.72
T9	6964.90	6268.41	62684.10	3175.00	59509.10	11.24

T12	6949.40	6254.46	62544.60	2900.00	59644.60	17.34
T6	6922.20	6229.98	62299.80	2600.00	59699.80	10.61
T4	6968.80	6271.92	62719.20	2750.00	59969.20	0.88
T10	7186.20	6467.58	64675.80	3900.00	60775.80	1.75
T7	7298.80	6568.92	65689.20	3325.00	62364.20	3.68

Key: Av. Yield=Average yield kg/ha, Adj. yield=Adjusted yield 10%field Kg/ha, GB=Gross Benefit, TCTV=total cost that varies, NB=Net benefit, MRR=marginal rate of return

Table 6: Economic (partial budget and dominance Analysis) integrate vermi-compost and inorganic fertilizers rates on Sesame production

Treatments	Av. yield	Adj. yield	GB(Eth. Birr)	TCTV (Eth. birr)	NB (Eth.birr)	MRR (%)
T2	507.81	457.03	13710.94	549.89	13161	2.197
T12	570.31	513.28	15398.44	2199.6	13198.9	-47.9
T7	575.51	517.96	15538.92	1480.4	14058.5	-9.87
T9	640.62	576.56	17296.88	1269	16027.8	11.01
T6	700.51	630.46	18913.92	1099.8	17814.1	25.05

Av. Yield=Average yield kg/ha, Adj. yield=Adjusted yield 10%field Kg/ha, GB=Gross Benefit, TCTV=total cost that varies, NB=Net benefit, MRR=marginal rate of return

CONCLUSION AND RECOMMENDATION

A decline in the levels of soil properties such as soil organic carbon, pH, cation exchange capacity (CEC), and plant nutrients or increment of the level of toxicity are causing significant productivity decline in crop productivity. Despite of the potential ofland productivity and could decrease due tosustainable cultivation of repeated application of inorganic fertilizer .This study declared to maintains soil fertility through vermi-composting rates of organic materials integrated with inorganic fertilizers (NPS and Urea) indicated in the soil fertility may of the area, Bako and Wayu-tuka districts . The highest net benefit (62364.2 ETB per hectare), (17814.1ETB per hectare)was obtained from treatment 7 and 6 for maize and Sesame respectively with acceptable marginal rate of return. Therefore integration vermi-compost with inorganic fertilizers is unselected option for Maize and Sesame producers and maintains sustainability fertility of soil.

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Verification of Soil Test Based Crop Response Phosphorous Calibration Study for Teff (Eragrostis tef (Zucc.) Trotter) Production in Guduru District, Oromia Regional State, Ethiopia

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ABSTRACT

Verification of soil test based crop response phosphorous calibration study for teff (Eragrostis tef (zucc.) Trotter) production in Guduru District was conducted on farmer's field during 2019/20 main cropping season. The trial was conducted on eight farmers' field across the district. The aim of the study was to verify phosphorus (P) critical value on recommendations of P fertilizer rate for teff production in the area and to compare P recommended rate with farmers practice. The treatments were soil test-based phosphorus fertilizer rate recommendation (RR), No Phosphorus fertilizer/ Control (C) and Farmers practice (FP). All treatments were replicated three times. Phosphorus critical level and Phosphorus requirement factor for teff production in the district were 6 ppm and 17.33 kg/ha; respectively.Economical optimum rate of N (46 kg/ha) was applied. Representative soil samples of verification sites were collected before planting to analyze its selected chemical properties. Soil acidity of the verification sites that have a pH of less than 5.5 were amended with lime application. The soil test results of verification sites indicated that the soil reaction pH (H_2O) were strongly acidic ranged from 4.67 to 5.1 and available P ranges from very low to medium (1.4 to 11.8). The results from the experimental crop revealed that the average grain yield of all verification sites in the district fall in the range of 6.17 to 12.08 qt/ha. The effects of treatments were highly and significantly ($p \leq 0.01$) influenced both grain and biomass yield of teff. The highest (12.08 q ha^{-1}) and the lowest (6.17 q ha^{-1}) grain yield of teff were recorded at the soil test based phosphorus fertilizer rate (RR) and no Phosphorus fertilizer (C) application; respectively. Similarly, economic analysis using partial budget analysis indicated that soil test based phosphorus fertilizer rate (RR) was economically optimal for production of teff in Guduru District. Therefore; soil test based phosphorus fertilizer rate recommendation was chosen and verified as economically feasible for teff production in the study district and also led to the maximum yields.

Key words: Guduru, Phosphorus, Recommendation, Teff, Verification

INTRODUCTION

In Ethiopian agriculture, teff is the most widely grown crops for the purposes of both consumption and income generation. It is one of the most important and widely grown cereal crops in Ethiopia, with annual land coverage of about 3.01 million hectares (CSA, 2016). The high lands of Oromia Regional State are an ideal place for teff production in Ethiopia. However, productivity of the crop is becoming too low. There are several factors that hampered teff production in the region especially in the study district. Among others, land

holdings, unwillingness of farmers to accept new improved teff varieties, inappropriate management practices and soil degradation leading to low soil fertility are the most important factors that limit teff production potential (Abdenna et al., 2014). Land holdings in Ethiopia are small because of land fragmentation due to an increased population pressure (Bacha et al., 2001).Based on Habtamu et al., 2000 suggestion, extra use of nitrogen and phosphorus (NP) for teff grain yield production was not economical because of its genetic potential and an alarming increase of fertilizer cost from year to year.

Unless land is intensively and more productively used, it is unlikely to provide enough food for consumption and sale. Land productivity could improve if soil fertility were improved. To overcome the soil fertility problem, farmers in western Oromia use mainly chemical fertilizers and manures for crop production. For instance, in the mid-altitude areas like Bako, more than 80% of the farmers use chemical fertilizers (Abdissa, 2001). These chemical fertilizers are becoming expensive and out of the capacity of small scale farmers.

Soil test based fertilizer recommendations that can give farmers a service leading to better and more economic use of fertilizers and better soil management practices for increasing agricultural production are necessary. The use of fertilizers without first testing the soil is like taking medicine without consulting a physician. Taye et al. (2002), has observed that encouraging result from the model calibration trial undertaken at Hetosa district of Arsi Zone, and forwarded the importance of undertaking similar trial across Ethiopia. Soil test based phosphorus calibration study on teff (Eragrostis teff (Zucc.) Trotter) production in Guduru district was conducted in 2000/2001 cropping season.To have confidential on technology dissemination to end users, the economic visibility and acceptance of the technology, Nekemte soil research center decided to verify it at the same area where P critical value recommendations of P fertilizer rate for teff production was made and to compare P recommended rate with farmers practice.

MATERIALS AND METHODS

Description of the study area

The trial was conducted on farmer's field in Guduru District in Horo Guduru Wollega Zone of Oromia Regional State, Ethiopia. Guduru is situated at latitude: $9^0$16'55" N to $10^0$02'31" N; Longitude: $37^0$12'42" E to $37^0$42'45" E and an altitude ranging from 878 – 2448 m above sea level in Horo Guduru Wollega zone of the Oromia regional state, Ethiopia. The terrain is generally undulating to rolling plains. The mean monthly rainfall ranges from 10.43 mm to 344.7 mm, and mean monthly temperature is 16.11^0C to 19.11^oC. The major soil types are generally described as Nitisols (FAO, 2014). The district falls under SA_2, tepid to cool semi arid mid high lands, agro-ecological zones classification of Ethiopia.

Site selection for the experiment

Guduru district was selected for the implementation of the trial due to its potentiality for teff production and to have confidential on the technology of soil test based phosphorus calibration study done previously in the study District. The specific experimental site was selected from best performing farmers in teff production and willingness to provide land for the experimental purpose. Accordingly, composite soil samples were collected from different

farmers' field of the study district by using zigzag method. Since Olsen method is most widely used for P extraction under both acidic and basic pHranges, available phosphorus was determined by using Olsen et al. (1954) method. Six (6) farmers' fields below and two (2) farmers' fields above critical phosphorus concentration were selected for the trial. Totally, the trial was conducted on eight (8) farmers' field in the district.

Experimental procedure, design and treatments

The verification activity was conducted on farmers' fields in Guduru district in 2019/20 main cropping season. The teff variety called "Guduru" was used for the trial. Seed were sown by broadcasting and the rate was 15 kg/ha. Phosphorus recommendation rate was calculated as P fertilizer to be applied = (Critical P conc.- initial P values) × P requirement factor. whereas Pc= 6 ppm, and Pf = 17.33) with determined optimum N (46 kg) that were found during the calibration study), Farmer practice and control (without fertilizer).

The test based phosphorus fertilizer rate recommendation (RR) was compared with farmers practice (100 kg DAP and100 kg Urea) and without phosphorus fertilizer application (control). The treatments were replicated three times. Economical optimum rate of N (46 kg/ha) was applied. Nitrogen was split-applied (1/2 at planting and the remaining about three weeks after planting). The entire phosphorus rate was applied at sowing. The experimental design was simple arrangement. Plot size was 10 m x 10 m, and there was 1mbetween blocks and 0.5 m between plots.

Data collection and analysis

During field trial most important data of pre planting soil properties and agronomic parameters were collected. Such parameters were soil reaction, available phosphorus, exchangeable acidity, grain yield and biomass yield. The collected agronomic data were analyzed using SAS software version 9.0 (2004). Mean separation was done by LSD at 5% significant level. Following procedures described in CIMMYT (1988), economic analysis was performed to investigate the economic feasibility of the treatments. During economic analysis, grain yield obtained from each treatment were adjusted down by 10% in order to narrow the possible yield gap that may happen due to difference in field management. The average prices of relevant inputs and grain yields required to do the partial budget analyses were collected from different sources at harvesting season.

RESULTS AND DISCUSSIONS

Selected soil properties of experimental site

Soil reaction (pH): The result revealed that the soil reaction pH (1:2.5 soil to H_2O) of the experimental sites before planting ranged from 4.67 to 5.1 (table 1). Based on acidity classification established by FAO (2006) the soil acidity of experimental sites ranged from very strongly acidic to strongly acidic which is not suitable for the growth of most crops. Optimum pH for many plant species to be 5.5 to 6.8 (Amare et al., 2005). Soil pH values below these will affect its growth and yield. Soil pH result clearly indicated that the value was below the described range. For optimum teff production, the soil pH should be adjusted to the desired range through management intervention.

Available phosphorus: Soil test result of the verification sites before planting indicated that available phosphorus level of verification sites before planting ranged from 1.4 to 11.8 ppm (Table 1). Two verification sites were above critical level (>6) while the rest sites were below. According to Cottenie (1980) available phosphorus rating, phosphorus level of six verification sites were fall in very low (<5 ppm) rating while the two rest sites were in low to medium (5 to 17). Dawit et al. (2002) reported that availability of P in most soils of Ethiopia decline by the impacts of fixation as a result of low pH.

Exchangeable acidity (EA): The soil analysis results showed that the concentration of exchangeable acidity of verification sites before planting were ranged from 0.78 to 3.35 cmol (+) kg^{-1}.Thus, according to Daryl and Buchholz (1983) rating, the exchangeable acidity of soil of the verification sites were very low (< 4.5 cmol (+) kg^{-1}) (Table 1).

Table 7.Selected soil chemical properties analysis result before planting teff in Guduru District

Sites	pH (H_2O)	Available phosphorus (ppm)	Exchangeable acidity (cmol(+)/Kg)
1	4.89	2.8	1.4
2	5.1	1.4	0.78
3	4.97	4.8	1.56
4	4.95	1.5	2.17
5	5.08	11.8	0.9
6	4.75	4.3	2.24
7	4.67	4.2	3.35
8	4.78	6.1	1.68

Yields of teff as influenced by the treatments

Treatment influence on mean grain and biomass yield of the experimental crop were statistically and highly significant ($p \leq 0.01$) as presented in table 2 below. The maximum mean grain yield (1208.13 kg/ha) was recorded with application of soil test based recommended phosphorus rate. While, the minimum (617.53 kg/ha) was recorded without Phosphorus fertilizer application. Soil test based phosphorus fertilizer application gave the grain yield advantage of 314.1 and 690 kg/ha as compared to without phosphorus fertilizer application and blanket recommendation (farmers practice); respectively.

Table 8.Treatments effect on grain yield and biomass yield of teff

Treatment	Grain Yield (kg/ha)	Biomass (kg/ha)
RR	1208.13a	10675.0a
FP	894.03b	8945.8b
C	617.53c	6514.6c
Significance	***	***
LSD (5%)	112.82	1346.4
CV (%)	6.23	7.73

Partial Budget Analysis

To estimate the economic feasibly of the treatments, partial budget analysis using the actual unit prices during the harvesting season (2019/20) was investigated. The result of economic analysis indicated that soil test based phosphorus fertilizer rates was economically optimal for

production of teff in Guduru district (see table 3 below) with gaining a net benefit of three thousands three hundred and forty eight Ethiopian birr (3348.4EB).

Table 9.Economic analysis for teff production in study district.

	URE(qt/h)	DAP(qt/h)	AGY(qt/h)	GFB(ETB/h)	FC(birr/h)	TSC(birr/h)	HBC(birr/h)	TVC(birr/h)	NB(birr/h)	MRR(%)
C	1.00	0	5.2	18113.5	1488.5	517.5	258.8	2264.8	1584.8	
FP	0.41	1.5	7.9	27791.1	2810.8	794.0	397.0	4001.9	2378.2	457.11
RR	0.05	2.44	11.1	38784.6	3639.5	11081	554.1	5301.7	3348.9	745.78

While Trt = Treatment; qt = Quintal; h = Hectare; ETB = Ethiopian birr; C = Control (without Pfertilizers);FP= Farmers practiced fertilizer rate; RR =Soil test based Fertilizer rate;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.

CONCLUSION AND RECOMMENDATION

Economic analysis of the verification trial of soil test based crop response phosphorous calibration study for teff production in Guduru District showed that the maximum net income was obtained from soil test based Phosphorus fertilizer rates with greater than the acceptable minimum rate of return (>100%). Economically optimum nitrogen rate (46 kg/ha) and soil test based phosphorus recommended rate was significantly increased both grain and biomass yield of teff in the study district. Accordingly, soil test based recommended fertilizer rate application increased mean grain and biomass yield by 35.13 and 19.33%; respectively compared to blanket fertilizer application. Based on the results, the soil test based phosphorus recommendation was chosen and verified as economically feasible and led to the maximum yields of the experimental crop in the study district. Therefore, demonstrating and scaling up of the technology for popularization should be followed up.

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Verification of Soil Test Based Crop Response Phosphorous Calibration Study for Bread Wheat (Triticum Aestivum L.) Production in Horo District, Oromia Regional State, Ethiopia

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ABSTRACT

On-farm verification trial of soil test based crop response phosphorous calibration study fo+=r bread wheat production was conducted in 2019/20 main cropping season in the Horo District of the Horo Guduru Wollega Zone. The trial was initiated to verify phosphorus critical level and requirement factor for bread wheat production in Horo District. The treatments were the control (without phosphorus fertilizer), farmers practice (blanket recommendation), and soil test based recommended phosphorus fertilizer rate (RR). The trial was conducted on six farmers' field across the district. Plot size was 10m * 10m. Soil data before planting and yield data were collected throughout the trial. Soil reaction pH (H2O) of all the sites ranged from 4.73 to 5.42 and available P ranges from 1.4 to 12.6ppm. Soil acidity of the experimental sites were amended with lime.Bread wheat grain and biomass yield (kg/ha) were high and significantly ($p \leq 0.01$) affected by different fertilizer rates used as treatments. The highest grain yield (2875 kg/ha) was resulted with soil test based phosphorus fertilizer rate recommendation. Economically optimum N (46 kg/ha), critical level phosphorus (10 ppm) and phosphorus requirement factor (11.03 kg/ha) for bread wheat production in the district were gained and recommended during the calibration study. It was significantly higher than the grain yield gained from the farmers' practice (2119.4 kg/ha) and control/without phosphorus fertilizer (1647.2 kg/ha).Similarly soil test based phosphorus fertilizer rate recommendation was economically optimum and feasible for bread wheat production in the district.

Key words: Bread wheat, Horo, Phosphorus Fertilizer, Recommendation

INTRODUCTION

Wheat with production area of about 1.66 million hectares is one of the most important cereal food crops cultivated in Ethiopia, ranking fourth after teff (Eragrostis tef), maize (Zea mays) and sorghum (Sorghum bicolor) in area coverage (CSA, 2016). Traditionally, wheat grains are used to prepare household bread, beverage and pancake. It is also processed in factories to produce flour for commercial production of bread for consumers in cities and towns. Despite, the population of Ethiopia is currently growing at a faster rate (Cohen, 2006) and demands also proportional for agricultural products.

On the other hand, growth in food production is not in equal footings with population pressure. Strengthening food production capability of the country by wisely exploiting its existing human and natural resources is critical option to avert the existing situation. However, soil fertility depletion and soil quality decline are the main constraints affecting the yield and sustainability of crop production in Ethiopia (Haile et al., 2009). The annual per-hectare net loss of nutrients is estimated to be at least 40 kg N, 6.6 kg P and 33.2 kg K

(Scoones and Toulmin, 1999). The identification of the proper fertilizer mix is beneficial at the macro-economic level by improving the efficiency of fertilizer procurement and resource allocation. It is generally understood that crop response to fertilizer inevitably declines, if nutrient applications are continually unbalanced. But, if harvested nutrients are replaced, intensive agricultural systems can be sustained indefinitely, provided that measures are taken to halt soil erosion and to minimize detrimental changes in soil pH.

In Ethiopia, century-long, low-input agricultural production systems and poor agronomic management practices, limited awareness of communities and absence of proper land-use policies have aggravated soil fertility degradation (Sishaw and Tegegne ,2016). Phosphorous is the most yield limiting of soil-supplied elements, and soil P tends to decline when soils are used for agriculture (David and David, 2012). Studies have demonstrated that Nitisol areas in Ethiopia are marginally to severely deficient in P (Bekele et al., 1996, Regassa and Agegnehu, 2011). 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 (Bekele et al., 2002, Zeleke et al., 2010). 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.

Soil tests are designed to help farmers predict the available nutrient status of their soils. Once the existing nutrient levels are established, producers can use the data to best manage what nutrients are applied, decide the application rate and make decisions concerning the profitability of their operations (Agegnehu, and Lakew, 2013). However, local assessments for the soil P critical levels and soil P requirement factors even for the major crops of the country are negligible. Currently, soil fertility research improvement is agreed with respect to site specific fertilizer recommendation in the country (EthioSIS, 2015).

Previously, soil test crop response based phosphorus calibration on bread wheat study was carried out in Horro district and the critical phosphorus value has to be verified to approve the acceptance of the technology at farmers' level. Therefore, this project must address the need for reliable soil nutrient calibration/ correlation data and verify the economic profitability of the technology comparing with farmers practice and verify the critical levels of P calibrated previously.

MATERIALS AND METHODS

Description of the study area

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

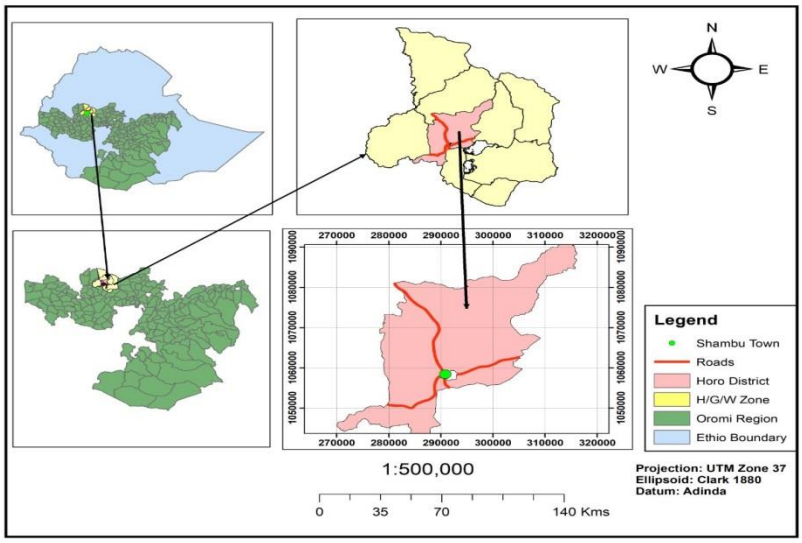

Figure 1.Location map of Horo District, Oromia, Ethiopia.

Experimental design and procedures

The study was conducted on farmers' fields across the District. Six farmers were selected purposively based on their willing, wealthy and initial soil P-value. Improved wheat variety Dendea was used at 150 kg/ha seeds rate with 20 cm inter row spacing were sown. Phosphorus fertilization rate was given according to the formula developed, P (kg/ha) = (P critical – P initial)*Prf. This recommendation was compared with farmers practice (blanket recommendation) and control. Urea and DAP were used as the source of N and P, respectively. For verification purpose the experiment was laid out in randomized complete block design that was replicated over farmers. The treatment considered were calculated P (Rate of P fertilizer to beapplied= (Critical P conc. - initial P values)*P requirement factor whereas Pc= 10 ppm, and Pf= 11.02) with determined optimum N (46 kg), Farmer practice /blanket recommendation (100 kg DAP and100 kg Urea) and control (without fertilizer). Nitrogen was applied in the form of urea in two splits (1/2 at planting and 1/2 at mid-stage).Plot size was 10 m x 10 m and there was 1m between blocks and 0.5m between plots.

Data Collection

Composite soil samples were collected at a depth of 20 cm from each selected farmers' field to determine pH (H_2O) using a pH meter with glass electrode (Barauah and Barthakulh, 1997) and available P using Olsen et al. (1954) method. The grain data and biomass yield of the crops were collected. Grain yield and biomass yield recorded on the plot bases were converted to kg ha^{-1} for statistical analysis.

Economic analysis

Partial budget analysis was done to determine economic feasibility of recommended fertilizer P for bread wheat production around the study areas following procedures described in CIMMYT (1988). The mean grain and biomass yield data of wheat were employed in the analyses. Furthermore, the grain and biomass 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.

Data management and analysis

Data were subject to analysis of variance (General Linear Model (GLM) procedure) using SAS software (SAS Institute, 2004) to test treatments effect on crop growth and yield parameters. Means of treatment effects were separated using the Duncan's Multiple Range Test (DMRT) comparison at $p \leq 0.05$.

Result and Discussion

Soil pH and available phosphorus

The soil reaction of the experimental sites before planting ranged from 4.73-5.42 (table 1). Accordingly, the soils were strongly to extremely acidic in reaction (Tekalign, 1991). According to Roy et al. (2006), 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 (Mokwunye et al., 1996). 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 (Frossard et al., 2000).

The maximum and minimum values of available P were 37.88 and 2.31 ppm, respectively (table 1). Available phosphorus of most samples fall under low category according to the critical level set by EthioSIS (Karltun et al., 2013). Generally, the available P status of the soils in the study area are low, even below the critical level indicating that soil P infertility is among the factors that are highly limiting the productivity of the soils. This shows the need for external application of phosphorus fertilizer sources for good crop growth and yield.

Table 1: Initial available soil phosphorus and soil pH

Sites	Soil pH (H_2O)	Available P (ppm)
Site 1	4.73	7.04
Site 2	5.31	2.31
Site 3	5.42	7.29
Site 4	5.09	37.88
Site 5	5.4	19.25
Site 6	5.27	6.98

Biomass and grain yield of bread wheat

The analysis of variance showed that the recorded biomass yield of bread was significantly affected ($p<0.001$) only by the application of soil test crop response based phosphorus fertilizer application. The highest mean grain yield (2875 kg/ha) was recorded with the soil test crop response based fertilizer recommendation treatment (table 1) which was significantly higher than the farmer practice (2119.4 kg/ha). The results of this study are consistent with findings of Dejene et al. (2020) who reported that the highest grain yield was recorded under application of soil p calibration.

Table 2: Mean grain and biomass yield (kg/ha) of bread wheat as influenced by different fertilizer application at Horo district

Treatments	Grain Yield (kg/ha)	Biomass (kg/ha)
RR	2875.0[a]	8330.6[a]
FP	2119.4[b]	6625.0[b]
C	1647.2[b]	6036.1[b]
Significance	***	***
LSD (5%)	536.03	1543.4
CV	12.12	1.04

RR: Recommended rate; FP: Farmers practice/blanket recommendation; C: Control

Economic Analysis

The results of partial budget analyses data of S fertilizers across two soils are summarized in table 3. Accordingly, all treatments produced higher and positive net benefit (NB) relative to the control treatment in both sites, indicating that feasibility of fertilizer application for wheat production in the study area.

The marginal rate of return of the non-dominated treatments in table 3 shows that 149 kg /ha of soil test crop response based P fertilizer (RR) treatments provided a positive marginal rate of return of 3501.6. According to CIMMYT (1988), on the farm-economic analysis of major cereals training reported that MRR that range from 50% to 100% was the minimum recommended rate in most agricultural production and it is better when the MRR was >100 %. Treatments that receive recommended rate of fertilizer was received 3501.6 which indicates that by investing one birr on these treatments, there was high rate of returns which was 35.02 birr benefit without including costs that not vary among treatments.

The marginal rate of return (MRR) was found to be 3501.6% for soil test based fertilizer rate and 1970.7% for farmer practice (table 3). The economic analysis showed that the highest net income (27649.3ETB) was obtained from soil test based recommended treatments. So, those treatments that receive recommended fertilizer record the highest MRR acceptance range and so, farmers use this soil test crop response based fertilizer application than other treatments which is cost effective and economically feasible.

Table 3: Partial budget analysis for verification of bread wheat at Horo District

Treatments	UREA(qt/ha)	DAP(Qt/ha)	GY(Qt/ha)	AGY(Qt/ha)	GFB(ETB/ha)	FC(birr/ha)	TSC(birr/ha)	HBC(birr/ha)	TVC(birr/ha)	NB(birr/ha)	MRR(%)
C	1	0.00	16.472	15.5	18566.4	2804.6	1547.2	773.6	5125.4	13441.0	
FP	0.6087	1.00	21.194	20.2	24232.8	2369.9	2019.4	1009.7	5399.0	18833.8	1970.7
RR	0.4158	1.49	28.75	27.8	33300.0	1488.3	2775.0	1387.5	5650.8	27649.3	3501.6

Where:qt = Quintal; ha = Hectare; GY = Grain yield;AGY = Adjusted Grain Yield;GFB = Gross field benefit ETB = Ethiopian birr;FC = Fertilizer cost; TSC = Total Service cost; HBC = Harvesting and bagging cost; TVC =Total variable cost; NB = Net benefit;MRR = Marginal rate of return; C = Control (without Pfertilizers);FP= Farmers practiced fertilizer rate and RR =Soil test based Fertilizer rate;FC = Fertilizer cost; and.

CONCLUSION AND RECOMMENDATION

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. Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P fertilizer rate to their fields regardless of soil fertility differences. Based on the results of this study, it is generally concluded that, soil test crop response based fertilizer application (P application) gave consistently high grain yield of bread wheat the study area showing that the soil of the study area is deficient in P content.

Since by applying recommended rate of P and optimum urea fertilizer application rate, yield of bread wheat could be increased by 36 % over the blanket fertilizer recommendation of DAP and urea. The implication was that application of fertilizer based on site specific soil test crop response based is useful to attain the demand of bread wheat for the current population growth by boosting yield by more than 50%. Result of economic analysis also showed that recommended rate of fertilizer with site specific recommendation is ideal to obtain higher yield in the study area.

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

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ABSTRACT

Periodic assessment of soil fertility status and plant nutrients requirement of a given area has vital role in enhancing crop production on sustainable basis. In view of this, a study was conducted in Chora district on farmers' fields in 2018 and 2019 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 standard 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, 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 almost all the maize characters tested. The shortest (96.2) mean days to 50% tasseling was obtained from 100% Pc from NPS fertilizer, whereas the longest (103.3) days was recorded for the unfertilized plot. The maximum mean biomass yield (29.0 t ha^{-1}) was recorded for 100% Pc from DAP and grain yield of 6.7 t ha^{-1} was recorded from NPS fertilizer, respectively. Whereas, the lowest mean grain yield (0.7 t ha^{-1}) were recorded for the treatment with no fertilizer. Economic analysis for nutrient management indicated that the highest net benefit of 19914.00ETB ha^{-1} with an acceptable MRR of 244% 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 Chora 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

Soil fertility and plant nutrition are the two closely related subjects that emphasize the forms and availability of nutrients in soils, their movement to and their uptake by roots, and the utilization of nutrients within plants (Stewart etal, 2005). Moreover, periodic assessment of important soil properties and their responses to changes in land management is necessary in order to improve and maintain the fertility and productivity of soils (Wakene and Heluf, 2004).Without maintaining soil fertility, achieving sustainable agricultural production is difficult to feed increasing population. The secret of ensuring food security for the ever increasing world population is strongly linked to the productivity of soils (Vlek, 1990).

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 etal., 2001, Matano etal, 2015). Moreover, the shortage of land for production of food crops has eliminated the practice of fallowing and crop rotation. According to (FAO,2001) soil fertility management on small farms in the tropics has become a major issue, as a result of continued land degradation and rapid population growth. Furthermore, shortage of grasslands (grazing areas) has forced the farmers to remove crop residues for animal feed. Since the study 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 fertility and availability of nutrients. (Mokwunye,1996) also stated that cultivated weathered soils commonly suffer from multiple nutrient deficiencies, and nutrient balances are generally negative. The loss of soil fertility from continual nutrient mining by crop removal without adequate replenishment, combined with imbalanced plant nutrition practices, has posed a serious threat to agricultural production (FAO, 2006). Unless something is done to restore soil fertility first, other efforts to increase crop production would end up with little success (Quinenes, 1992).

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) Plant nutrient deficiency is one of the foremost problems hamper the development of an economically successful agriculture (Fageria and Baligar, 2005).

Over the past 40 years, soil fertility management in Ethiopia focused on the application ofNP fertilizers. Moreover, trials carried out in many localities across the country for about nine years also recommend different rates of NP fertilizers. However, yield levels obtained by small scale farmers remained stagnant despite the availability of improved varieties and NP fertilizers even in high maize growing potential areas of western Oromia (Benti, 1993) . One of the main causes for this discrepancy is the low use of external inputs. in accordance to crop and soil types (Ho, 1992). Higgs et al. (2002) is pointed out that some 30 to 50% of the rise in world food production since the 1950s attributed to utilization of fertilizers.

Understanding the plant nutrients requirement of an area could help to implement demand-driven soil fertility management practices. On the other hand, 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 Chora District; and recommended Phosphorus critical level and correction factor **(*Dagne and Abdulmalik, 2017*).** 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 rateand 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 Chora district, Western Oromia.

MATERIALS AND METHOD

Description of the Study Area

A study was conducted in Chora district on twelve farmers' fields in 2018 and 2019 main cropping seasons. Chora district is located at 08°13'33.7"to 08°33'55.0"N and 035 °59'59.7"to 036 °15'15.8"E with altitude ranging from 1000 to 2060 masl (Fig 1). The 18 years weather information at nearby study area (Ethiopian Metrology Agency Bedele District Branch) indicated that a uni-modal rainfall pattern with average annual rain fall of 1945 mm. The rainy season covers April to October and the maximum rainfall is received in the months of June, July and August. The minimum and maximum annual air temperatures are 12.9 and 25.8.0°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)

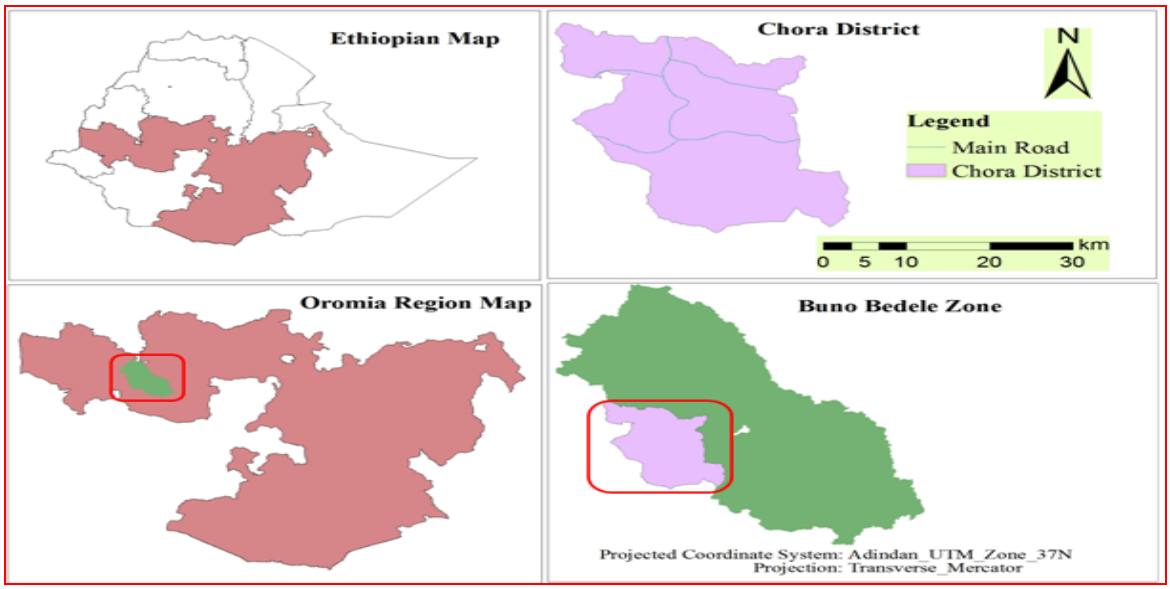


Figure 1. Map of the Study Area(Chora district)

Soil Sampling and Analysis

Composite surface soil samples (0-20) cm depth was 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.

Treatments, Experimental Design and Procedures

The treatments consisted of five (0, 25, 50, 75 and 100 %) P critical levels (Pc) calculated fromNPS fertilizer and one previously recommended P critical level (100% Pc) calculated from DAP was included ,which was used as check, that means the total number of treatment were six. The experiment was laid out in RCBD with three replications. The gross plot size was $12m^2$ (3m x4m)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 appliedaccording 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. RecommendedN determined during Phosphorus calibration; (92 kg N ha^{-1}) for the District for maize were used. The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times., and treated with lime for soilpHless than 5.5, and the amount of lime needed per hectare was calculated based on the formula LR = Ex.acidity*1.5*10 kun ha^{-1}.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.

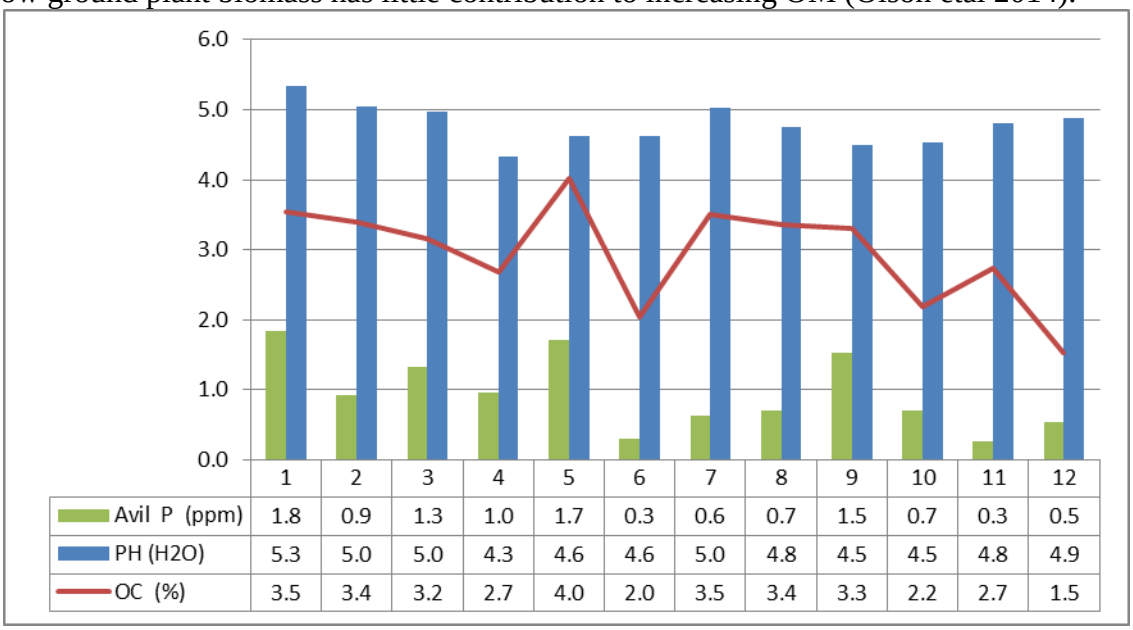
Finally, days to 50% tasseling, biomass and grain yields,thousand kernel weight were collected. Data on plant basis was recorded from the three central rows out of the five rows per plot. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD..

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).

RESULTS AND DISCUSSION

Soil pH, Available Phosphorus and Organic Carbon Status Before Planting in Chora District

The pH (H_2O) of surface soil (0 - 20cm) was ranged from (4.3 to 5.3) (Fig 2). Accordingly, the soils were strongly acidic in reaction. The available phosphorus (P) extracted with Olsen method were ranged from (0.3 to 1.8 ppm) (Fig 2). Thus, the present study showed that the available P contents at the surface soil were very low. The low contents of available P observed in the soil of the study areas 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 ofP sources application. The Organic Carbon (OC) content of the soil ranged from (1.5 to 4.0 %) (Fig 2), which is grouped under low range (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).



	1	2	3	4	5	6	7	8	9	10	11	12
Avil P (ppm)	1.8	0.9	1.3	1.0	1.7	0.3	0.6	0.7	1.5	0.7	0.3	0.5
PH (H2O)	5.3	5.0	5.0	4.3	4.6	4.6	5.0	4.8	4.5	4.5	4.8	4.9
OC (%)	3.5	3.4	3.2	2.7	4.0	2.0	3.5	3.4	3.3	2.2	2.7	1.5

Figure 2. Soil pH, Available Phosphorus and Organic Carbon status before planting in Chora District

Soil CEC, Exchangeable Acidity and Textural Class Status Before Planting in Chora District

The CEC values were low to moderate in the study area (Table 1).The lowest and highest CEC values ranged from (11.6 to 19.5 cmol(+)/kg soil).The observed CEC values of the soils generally showed similar trend withthat of soil OC. This implies that CEC was more influenced by OM than clay content. The results of the present study agreed with similar studies conducted elsewhere (Taye etal, 2003). Theexchangeable acidity content of the soil ranged from 0.1 to 1.4 meq/100 gsoil).The soil textural class was clay.

Table1. Soil CEC, Exchangeable acidity and Textural class status before planting in Chora district

Sites	CEC (cmol(+)/kg soil)	Ex. acidity meq/100 gsoil)	Textural class
1	17.6	0.1	clay
2	16.2	0.2	clay
3	16.9	0.5	clay
4	14.7	0.8	clay
5	11.6	0.3	clay
6	19.5	1.0	Clay
7	12.7	0.3	Clay
8	16.9	0.5	Clay
9	14.0	0.7	clay
10	18.4	1.4	Clay
11	15.9	0.6	Clay
12	16.4	0.3	Clay

Mean Days to Tassling of Maize (BH 661) Under Different NPS Fertilizer Rates in Chora District in 2018 and 2019 Cropping Seasons

The significantly shortest mean days to tasling (96.2 days) was recorded for 100% Pc from NPS, where as the longest (103.3 days) was obtained from unfertilized plot. This indicated that Physiological maturity of maize was influenced by NPS fertilizer. This may be due to 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 S in plants (Wilkinson et al., 2000).

Table 2:Mean days to tassling of maize (BH 661) under different NPS fertilizer rates in Chora Districtin 2018 and 2019 cropping seasons

Treatments	**Days to tassling (days)**
Without fertilizer	103.3[a]
25%Pc from NPS +Rec N	98.6[b]
50%Pc from NPS +Rec N	97.7[bc]
75%Pc from NPS +Rec N	96.9[bc]
100% Pc from NPS + Rec N	96.2[c]
100% Pc from DAP+ Rec N	96.7[bc]
Mean	98.3
CV (%)	4.8
LSD	2.2

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 Biomass and Grain Yields of Maize (BH 661) Under Different NPS Fertilizer Rates in Chora District in 2018 and 2019 Cropping Seasons

The result of combined analysis showed that mean above ground dry biomass and grain 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 DAP fertilizers (Table 3). All applied NPS fertilizer rates yielded significantly more than the treatment without fertilizer. The highest above ground dry biomass yield (29.0 t ha^{-1}) and grain yield (6.7 t ha^{-1}) were obtained from 100% Pc from DAP and NPS, respectively. 100% Pc from NPS increased maize biomass and grain yield by 29% and 26% over 75% Pc from NPS fertilizer rate, respectively. This increment in grain yield with the NPS fertilizer which contained Sulfur(S) is an indicator of positive interaction of sulfur and nitrogen. 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 S in plants (Wilkinson et al., 2000).Moreover, the current study indicated that, low soil fertility status 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. Kelsa etal, (1992)also indicated that low soil fertility is among the greatest constraints to maize production in Ethiopia.

Table 3:Mean biomass and grain yields of maize (BH 661) under different NPS fertilizer rates in Chora District in 2018 and 2019 cropping seasons

Treatments	**Biomass yield (t ha^{-1})**	**Grain yield (t ha^{-1})**
Without fertilizer	5.7^{d}	0.7^{e}
25%Pc from NPS +Rec N	15.6^{c}	3.6^{d}
50%Pc from NPS +Rec N	19.4^{b}	4.7^{c}
75%Pc from NPS +Rec N	21.7^{b}	5.3^{b}
100% Pc from NPS + Rec N	28.1^{a}	6.7^{a}
100% Pc from DAP+ Rec N	29.0^{a}	6.4^{a}
Mean	19.9	4.6
CV (%)	20.9	26.7
LSD	2.5	0.5

Mean followed by the same letters in each column are not significantly different at $P\leq 5\%$.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 in Chora District in 2018 and 2019 Cropping Seasons

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 (450.7 g) and lowest (203.7 g) mean thousand kernel weight were recorded for the treatment with 100% Pc from DAP, and no fertilizer application, respectively. However, 100% Pc from DAP and NPS were statistically at par. 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 Chora District in 2018 and 2019 cropping seasons

Treatments	**TKW (g)**
Without fertilizer	203.7[c]
25%Pc from NPS +Rec N	359.2[b]
50%Pc from NPS +Rec N	385.6[b]
75%Pc from NPS +Rec N	408.5[ab]
100% Pc from NPS + Rec N	444.3[a]
100% Pc from DAP+ Rec N	450.7[a]
Mean	375.3
CV (%)	19.0
LSD	

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, 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 19914.00 ETB $ha^{-1}$with an acceptable marginal rate of return (MRR) of 244% , were achieved from use of 100% Pc from NPS. The minimum net benefit was obtained from the treatments with no fertilizer. So, application of100% Pc from NPS fertilizer for maize is agronomicaly and economically feasible.

Table 5: Partial budget analysis for NPS fertilizer rates on maize in ChoraDistrict

Treatments	Av. GY(t ha^{-1})	Adj.GY(t ha^{-1})	TVC(ETB)	Gross benefit(ETB)	Net benefit(ETB)	D.A	MRR(%)
Without fertilizer	0.7	0.6	2260.00	3600.00	1340.00		-
25%Pc from NPS +Rec N	3.6	3.2	10482.50	19200.00	8717.50		0.90
50%Pc from NPS +Rec N	4.7	4.2	12557.00	25200.00	12643.00		1.89
75%Pc from NPS +Rec N	5.3	4.8	13991.50	28800.00	14808.50		1.51
100% Pc from NPS + Rec N	6.7	6.0	16086.00	36000.00	19914.00		2.44
100% Pc from DAP+ Rec N	6.4	5.8	16765.00	34800.00	18035.00	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

Rational fertilizer promotions and recommendations based on actual limiting nutrients for a given crop is not only revealed to supply adequate plant nutrients but also helped to understand the long-term ecological and economic benefits of the studied crop. 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 andacceptable 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 study100% Pc from NPS is agronomically and economically feasible for maize and hence recommended for the end users in Chora district. To 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 application can help to rebuild the soil conditions to increase crop productivity. Further researches have to be continued to recommend fertilizer types and rate for the major crops grown in this region.

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Evaluation and Selection of different physical soil and water conservation techniques for early mature sorghum root zone moisture retention at Harari regional state, Erer research station

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ABSTRACT

The experiment was conducted at Babille district, during 2018 and 2019 main cropping season at Erer Research Station. Erer research sub site is located latitude of 09° 10' 41.5" north and longitude of 042° 15' 27.3".The objectives of the experiments were to evaluate and select best methods of root zone moisture retention and soil conservation techniques suited for early mature sorghum .The treatments of experiments were,Control (no soil and water conservation measures), open ended tied ridge, level soil bund, contour furrow, closed ended tied ridge, Broad bed, Semi-circular and mulch respectively. The design of the experiment was RCBD with three replication. Genstats 18th editions was used for data Analysis. Statistically there is highly significant variation among the treatments interms of all parameters at 5% significance level across three planting years. First year, the highest plant height was obtained from the treatment with Broad bed followed by closed ended tied ridge. On other hand, the lowest plant height was recorded from the treatments with soil bund followed by control (no conservation structure). This is because of no more top fertile soil disturbance during first year. During the second and third planting year, the highest, plant height (132.86cm) and the longest panicle diameter (6.5) was recorded, from the treatments with open ended tied ridge, followed by soil bund and contour furrow respectively. That was because of soil and water conservation (swc) structures design and the extra moisture harvested in those structure than rest treatments. The highest grain yield was obtained from the mulch followed by open ended tied ridge treatment during first year. This is because of no and slight top soil disturbance during the construction stage. During the third year, the maximum grain yield was obtained from contour furrow followed by open ended tied ridge (2130.9 and 2000) kg ha^{-1}) respectively. The lowest grain yield was obtained from no conservation measures followed by mulching (1125 and 1232.1 kg ha^{-1}). The most probable reason for this variation could be due to the amount of the moisture harvested in the root zone of sorghum because of conservation structure. So contour furrow and open ended tied ridges are suitable swc measures for the area.

Key words: swc- physicalsoil and water conservation, sorghum, moisture.

INTRODUCTION

Agriculture is the main economic activity in sub-Saharan Africa (SSA) supporting over 67% of the population, out of which 60% depends on rain fed agricultural practices; generating 30-40% of the country's Gross Domestic Product (Rockström, 2002). However, rainfall is poorly distributed in these countries (Ngigi, 2003). High losses occur due to high surface runoff during high intensity rains, poor crop rooting conditions, past and present soil erosion and evaporation losses from soil, and crop canopy in particular during pre-planting and early crop

stages (Rockström, 2003).Uncontrolled runoff can cause damaging flash floods; severe erosion; increased water turbidity. It has been estimated that, a sixth of the world's land area, nearly 2 billion hectares, is now degraded as a result of overgrazing and poor farming practices. Water resources for agricultural purposes are getting scarce, and there are hardly any land reserves to be brought into production to widen the agricultural base. By 2025, close to three billion people in 48 countries will be affected by critical water shortage for all or part of the year. Water is the most limiting factor for agricultural production in these regions and the low annual rainfall is often a major reason for food insecurity. Poor yields together with a large population growth have often led to severe food shortages. To improve rural livelihood there is a big need for improved farming methods and increased yields.

Generally the soil cannot absorb the amount of water which falls in such a short time, causing intense surface runoff. This climatic factors means that it is important to use the limited amount of rainfall as efficiently as possible. By increasing soil water content supply and retention, crop yields can be improved significantly, and successful crop production can be made possible even in areas of very limited production potential (Yitebitu, 2004).

Increasing water availability for crop production can be achieved by irrigation, but due to the lack of available water resources this is not often an option in arid regions of Ethiopian dry lands. A more realistic option is to try and utilize rainfall amounts as efficiently as possible for crops. In the arid, regions where access to irrigation and insufficient rainfall is prevailing tomeet the water demands of crops, water can be harvested in order to increase the available water for crops. Water harvesting and soil moisture retention are cheap and simple options for increasing soil moisture. Water harvesting makes use of surface runoff for productive purposes, while soil moisture retention aims at preventing runoff and keeping rainwater as much as possible in place where it falls (FAO, 2001). In-situ water harvesting techniques such as furrow ridges, tied ridges and contour ridges improve soil moisture stored within the root zone, improve the agronomic components and produce higher grain yields (Mikias et al.2018).

Tied ridges or basins are a variation of the ridge and furrow system in which cross-ties are constructed at intervals across the furrows. The cross ties retain rainwater by restricting lateral flow of the accumulated runoff and so allow longer time for infiltration. By constructing the cross ties lower than the ridges, excess accumulated runoff can drain away. Contour ridges are, small earthen banks, with a furrow (ridges) on the higher side which collects runoff from the catchment area between the ridges. The catchment area is left uncultivated and clear of vegetation to maximize runoff. Crops can be planted on the sides of the furrow and on the ridges. Plants with high water requirements, such as beans and peas are usually planted on the higher side of the furrow, and cereal crops such as maize and millet are usually planted on the ridges. Sorghum (Sorghum bicolor) is an essential to diets of poor people in the semi-arid tropics where droughts cause frequent failures of other crops. It is one of the most important cereal crops of the tropics grown extensively over wider areas with elevation range from 1400 to 2100 meters above sea level (m.a.s.l). Its ability to adapt to adverse environmental conditions has made sorghum a popular crop worldwide. It is the major source of energy and protein for millions of people living in semi-arid tropical Africa and Asia. It remains to be the

primary source of food in Ethiopia where poor harvest due to drought is common (Kidane, 1982). It is a major food crop grown in both Eastern and western Hararghe.

Basic bottle neck moisture stress is the major hazards that affect the livelihood. Moisture stress affects crops in the livelihood zone every year either due to inadequate rainfall (in terms of total volume) or due to irregular distribution of showers during the growing period. Disruptions in the amount and regular pattern of rainfall significantly affect crop production. Rainy season lasts for about one and a half months and a long rainy season that lasts for more than two months. Even though, the rainfall pattern is not easily predictable and has shown yearly fluctuations. Due to the rainfall pattern, Babile districtis considered as food insecure. Though the area is moderately productive for agriculture, soil degradation, erratic rainfall and farmland fragmentation contribute to lowered productivity in the area. Therefore to combat the hazard and food insecurity, the best way is enforcing existing rain drop harvesting technique like in-suit and ex-suit water harvesting and soil conservation by incorporating improved sorghum variety is uncompressible solution.Consequently, the Evaluation and Selection of different physical soil and water conservation techniques for early mature sorghum root zone moisture retention at Harari regional state, Erer research station was initiated with the objectives of evaluate and select best methods of root zone moisture retention and soil conservation techniques suited for early mature sorghum and compare effects of selected soil and water conservation techniques on yield and yield components early maturing sorghum.

MATERIAL AND METHODS

Description of Study area

The experiment was conducted at Babille district, Erer research station for three consecutive growing years of 2017, 2018 and 2019. The agro-climatic condition of the area is semi-arid, Arid. Erer research sub site is geographically locatedat latitude of 09° 10' 41.5" (N) and longitude of 042° 15' 27.3" east, and the area is in the vicinity of extreme lowlands in the range of altitude of 1200 – 1300m. The area is also characterized by very short rainy season of 3 to 4 months (single quarter of the year), with all its intermittent condition and erratic distribution.Even though, the rainfall pattern is not easily predictable and has shown yearly fluctuations. Due to the rainfall pattern, the woredais considered food insecure. The annual maximum and minimum temperatures are 26 and 20^{0}C, respectively, and the mean annual temperature was 24°C. The soil
is clay loam in texture and medium in organic matter content and high in exchangeable potassium

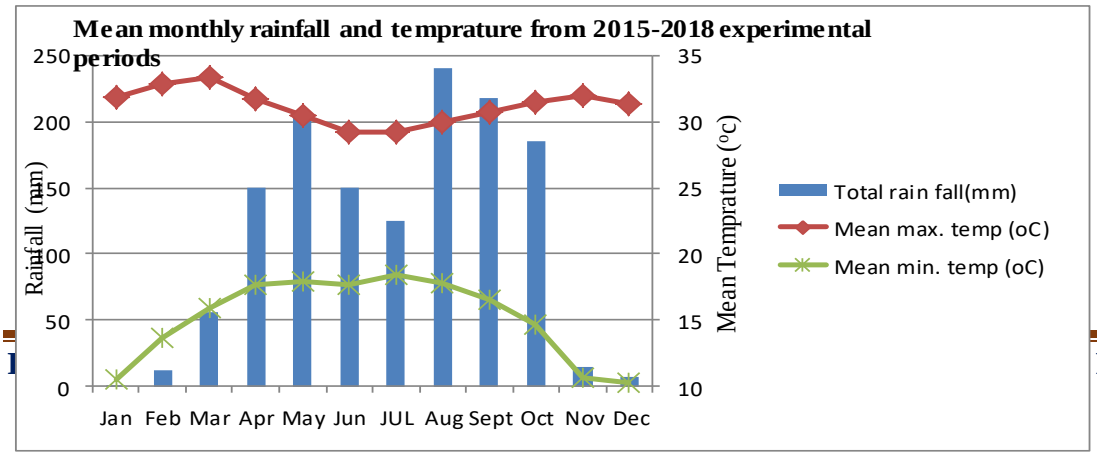

Figure 1. Mean monthly rainfall and temperature during experimental period of Erer, based on 2017-2019 meteorological data at Fadis Agricultural Research Center.

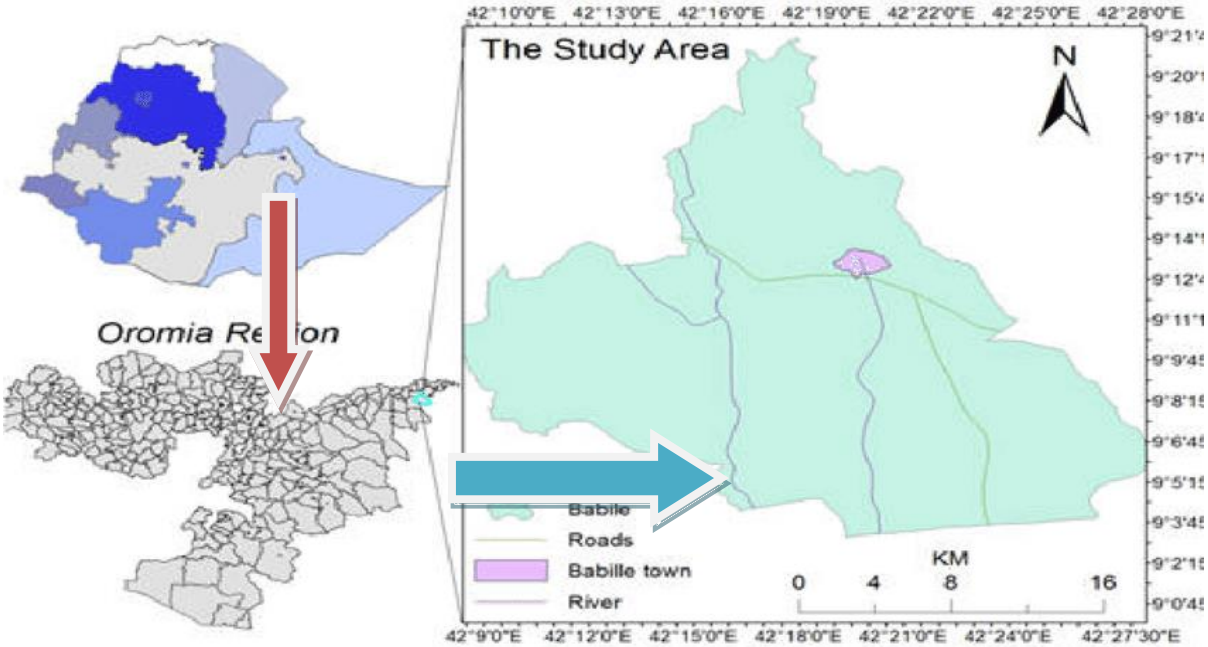

Figure 2.Map representing the study area (Babille District).

Experimental Design and Treatments.

The experimental design was laid out in Randomized Complete Block Design (RCBD) with three replication. The improved and early mature Melkam sorghum variety was used as a test crop. Sorghum was planted on the area of plot size 10m x 9m (90m^2) at spacing of 75cm by 30cm. Distance between plot and block were 1m and 2m, respectively. The experiment consisted of eight treatments, seven type of soil and water conservation structure on which the sorghum crop was planted and control (without conservation structure). Test treatments are open ended tied ridge, soil bund, contour ridge, closed ended tied ridge, Broad bed and furrow, Semi-circular, mulching and control. Those physical soil and water structures were constructed based on (Critchley et al, 1991) manual and Ethiopia soil and water conservation guideline with some modification to fit the soil, slope and site of the experiment. Data Collection, Soil Sampling and Statistical Data Analysis. Treatment effect was determined using plant height, panicle length, above ground biomass and grain yield. Composite soil sample was collected from (0-20 spots) before planting in zigzag movement with the sampling depth of 0-20cm, Soil sample after harvest was collected from every plot (at 5 spots /auger points) and analyzed for soil physio-chemical properties. Soil moisture content also recorded at planting time as well as at different growth stage of sorghum.

Data Analysis

Analysis of variance was performed using the GLM procedure of SAS Statistical Software Version 9.1. Effects were considered significant in all statistical calculations when the P-value was< 0.05. Means were separated using Least Significant Difference (LSD) test.

RESULT AND DISCUSSION

Soil Analysis

Table 1. Soil physic- chemical properties of Erer

P(H_2O)	E.C in mmhos/cm	MCF	%TN	%C	P (ppm)	Exch. K (cmol(+)/kg soil)	Exch. Na(cmol(+)/kg soil)	CEC (meq/100g) soil)	Sand %	Clay %	Silt %	Classification
7.83	2.746	1.111	0.070	1.66	1.98	0.852	0.700	14.443	38	46	16	Sandy clay

The soil of Erer is sandy clay in distribution and known by its salinity nature (table 1). The EC of the sample was 2.746mmhos/cm which was in salinity range. The organic matter which was 2.8, total nitrogen and available p (ppm) were very low when compared with the standard.

Table 2. Effect of Soil and Water conservation structure on Growth Parameter of Sorghum

		Plant height (cm)			**Panicle length (cm)**		
S N	Treatments	Year 2017	Year 2018	Year 2019	Year 2017	Year 2018	Year 2019
1	Control	125.9^{b}	100.3^{bc}	97.467^{d}	17.47^{ab}	16.33^{bc}	16.33^{d}
2	Open ended	137.5^{ab}	118.6^{ab}	125.067^{ab}	16.27^{b}	18.73^{ab}	21.267^{ab}
3	Soil bund	132.8^{ab}	130.7^{a}	121.8^{abc}	16.27^{b}	20.53^{a}	20.4^{abc}
4	Contour ridge	136.2^{ab}	102.9^{bc}	132.867^{a}	18.27^{ab}	20.2^{a}	22.133^{a}
5	Closed ended	149.2^{ab}	112.7^{abc}	110.6^{bcd}	18.93^{ab}	21.53^{a}	18.667^{bcd}
6	Broad bed& furrow	153.7^{a}	101.7^{bc}	$116,8^{abc}$	19.67^{a}	15.87^{bc}	19^{bcd}
7	Semi-circular	143.7^{ab}	108.9^{abc}	122.867^{ab}	19.6^{a}	18.93^{ab}	19.4^{abc}
8	Mulching	139.6^{ab}	96.1^{c}	103.2^{cd}	18.93^{ab}	14.93^{c}	18^{cd}
	LSD	22.45	22.05	19.011	2.69	3.485	2.96
	CV(%)	9.2	11.6	9.33	8.6	10.8	8.71

Plant height

The effect of physical soil and water conservation structure showed that there was high significance difference on sorghum plant height at of 5% significance level the during three growing season. In 2017 the highest plant height (153.7 cm) was recorded from the treatments with broad bed & furrow, this was in statistically parity with the rest treatments except control, while the lowest plant height (125.9 cm) was recorded from control treatment. Ramesh and Rathika (2009) that taller sorghum was observed on the ridges and furrow while the lowest height on the flat land. In 2018 the highest plant height (130.7 cm) was recorded from treatment with soil bund, but this was in statistically parity with the rest of treatment except treatment with broad bed & furrow, mulching and control, while the lowest plant height (96.1 cm) was recorded from treatment with mulching. In 2019 the highest plant height

(132.8 cm) was recorded from the treatment with contour ridge, this was in statistical parity with the rest of treatment except treatment with closed ended tied ridge, mulching and control, while the lowest plant height (97.467 cm) was recorded from the control treatment. The result of the current study was in agreement with the finding that indicated a significant effect of the conservation practices in increasing the plant height of the crop at different stage and conservation structures wer significantly ($p<0.05$)increasing all the agronomic data during the dry season (Mikiasetal ,2018). The hypothesis behind this finding is that the extra moisture conserved during the dry season due to the conservation structure can prominently contribute for better uptake of nutrients by the plant for facilitating the photosynthesis, fertilization of flowers, seed setting, protein synthesis, and nitrogen metabolism activities within thep lants tissues, which would in turn improve the physical stand and yield of crops (Mudalagiriyappe BK et al, 2012, Patil, 2003).

Panicle Length

The effect of physical soil and water conservation structure showed that there was high significance difference on sorghum panicle length at 5% significance level during three growing season. In 2017 the highest plant panicle length (19.67 cm) was recorded from the treatments with broad bed & furrow, but this was in statistically parity with the rest of treatments except treatment with open ended tied ridge and soil bund, while the lowest panicle length (16.27 cm) was recorded from treatment with open ended tied ridge and soil bund. In 2018 the highest panicle length (21.53 cm) was recorded from treatment with closed ended tied ridge, this was in statistically parity with the rest treatments except treatment with broad bed & furrow, mulching and control, while the lowest panicle length (14.93 cm) was recorded from treatment with mulching. In 2019 the highest panicle length (22.133 cm) was recorded from treatment with contour ridge, this was in statistical parity with the rest treatment except treatment with Broad bed & furrow, closed ended tied ridge, mulching and control, while the lowest plant height (16.33cm) was recorded from control treatment. This observation is similar to the study by (Ramesh, et al,2009) observed that there was significant sorghum growth parameter(plant height, panicle length) in the conservation structure of rain water through land configuration methods such as compartmental bunding, ridges and tide ridging.

Table 3. Effect of soil and water conservation structure on yield and yield components of sorghum

		Biomass in kg/ha		**Yield in kg/ha**		
S N	Treatments	Year 2018	Year 2019	Year 2017	Year 2018	Year 2019
1	Control	2500^{e}	3667^{e}	707.3^{bc}	697.8^{c}	1125^{c}
2	Open ended	6805.6^{ab}	9981^{ab}	1090.7^{a}	1244.3^{ab}	2000^{ab}
3	Soil bund	5757.6^{b}	8444^{bc}	557.3^{c}	874.8^{bc}	1398.8^{bc}
4	Contour furrow	7941.9^{a}	11648^{a}	695.7^{bc}	1324.9^{a}	2130.9^{a}
5	Closed ended	5517.7^{bc}	8093^{bc}	683.7^{bc}	856.3^{bc}	1375^{bc}
6	Broad bed	6224.7^{b}	9130^{b}	935.7^{ab}	875.6^{bc}	1404.8^{bc}
7	Semi-circular	4457.1^{dc}	6537^{cd}	869.7^{ab}	843.7^{c}	1351.2^{c}
8	Mulching	3055.6^{de}	4481^{de}	1097.3^{a}	768.1^{c}	1232.1^{c}
	LSD	1692.1	2481.7	311.2	391.7	628.1
	CV (%)	18.29	18.3	21.4	23.9	23.9

Biomass

The effect of physical soil and water conservation structure showed that there is highly significance difference on sorghum biomass at significance level of 5% during three growing season. In 2018 the highest biomass (7941.9 kg/ha) was recorded from the treatments with contour furrow, this was in statistically parity with open ended tied ridge treatments, while the lowest biomass (2500 kg/ha) was recorded from control treatment. In 2019 the highest biomass (11648 kg/ha) was recorded from treatment with contour ridge, this was in statistically parity with open ended tied ridge treatments, while the lowest biomass (3667 kg/ha) was recorded from control treatment.Ridges have been found to be very efficient in storing the rain water, which has resulted in substantial grain yield and biomass increase in some of the major dry land crops such as sorghum, maize, wheat, and mungbeans in Ethiopia (Georgis and Takele 2000). Similarly reported that contour ridge and tied ridges are increase dry biomass and yield of sorghum due to improved and stored soil moisture within the root zone karraretal (2012)

Grain Yield.

The effect of physical soil and water conservation structure showed that there is high significance difference on sorghum grain yield at significance level of 5% during three growing season. In 2017 the highest grain yield (1097.3 kg/ha) was recorded from the treatments with mulching (due to undisturbed top soil and increase soil moisture), this was in statistically parity with the rest treatments except contour ridge, closed ended tied ridge, soil bund and control, while the lowest plant height (557.3) was recorded from treatment with soil bund (Table 4). This have conformity with finding reported that different agricultural water conservation methods(mulching, ridges, supplementary irrigation…) saved limited water and improved grain yield per hectare in drought prone agro ecological zone (Uwizeyimana. D et al, 2018). In 2018 and 2019 the highest grain yield (1324.9kg/ha and 2130.9kg/ha respectively) was obtained from treatment with contour ridge, this was in statistically parity only with the open ended tied ridge treatments, while the lowest grain yield (697.8 kg/ha and 1125 kg/ha) was obtained from control (table 3). This was in line of agreement with in situ soil water conservation techniques such as contour ridge and tied ridges improved soil moisture stored within the root zone as compared to the control, resulting in higher grain yield of sorghumKarrar, et al, (2012). Similarly, reported that contour ridges and other tied ridges has resulted in above 130% higher in grain yield compared to flatbed planting (control) and also under ridges the average grain yield ranged from 50 to over 100 percent when compared with traditional practice (Mikias et al, 2018).

Table 4: Effect of different insitu conservation measures on economic sorghum productivity.

Treatments	Yield kg/ha	TR(ETB/ha)	TVC(ETB/ha)	TFC(ETB/ha)	TC(ETB/ha)	NI(ETB/ha)	B/C
No conservation)	1125	12,375	**1125**	2680	**3805**	**8,570**	2.2
Open ended	2000	22,000	**1350**	2680	**4030**	**17,970**	4.5
Soil bund	1398.8	15,386.8	**1350**	2680	**4030**	**11,356**	2.8
Contour Furrow	2130.9	23,439.9	**1350**	2680	**4030**	**19,409.9**	4.8
Closed E	1375	15,125	**1800**	2680	4480	**10,645**	2.6
Broad B	1404.8	15,452.8	**1125**	2680	**3805**	**11,647.8**	3
Semi cercular	1351.2	14,863.2	**1125**	2680	**3805**	**11,058.2**	2.9

Mulch	1232.1	13,553.1	**1125**	2680	**3805**	**9748.1**	2.5

Key* where, TR=total revenue, TVC =total variable cost, TC =total fixed cost, TC=total cost, NI= net income and B/C benefit cost ratio

Data concerning economic comparison was presented in table 3. The detail evaluation of the economic analysis of conservation treatments showed that, the direct impact of moisture and soil saving in generating net income (NI) was very high for a hectare of land per season which means very high value from hectare. Maximum total cost (ETB) was obtained by control treatment whereas the minimum variable cost (ETB) was obtained by semicircular structure. Benefit cost ratio (BCR) of each treatment was computed as the ratio of NI earned to the TC expended. Accordingly, maximum BCR (4.8) were obtained by contour furrow conservation measure. However, the lower BCR was recorded by no any conservation measure and mulching respectively. This implies that, minimum yield were obtained by those treatments and they were not economically more profitable. From this economic analysis, contour furrow was the most economically viable treatment with high BCR and optimum net benefit followed by open ended tied ridges (19,409.9 ETB and17,970) respectively. Therefore, farmers in the study area were benefited when they apply contour furrow and open ended tied ridges, rather than absolute control (no conservation measures). Generally the experiment with contour forrow and open ended tied ridges treatments were economically profitable for farmers.

CONCLUSION

Introduction of physical soil and water conservation structure in moisture stress area improve the soil moisture at the rooting zone due to improved soil infiltration and cached runoff at time of the rain fall which increased the crop stand, biomass and grain yield of early maturing sorghum in the study area. Contour furrow, open ended tied ridges, and broad bed were significantly increase the plant height, panicle length, above ground biomass and grain yield of sorghum and reduced soil loss. This is due to extra moisture stored in the soil and root zone of the crop at dry season due to the conservation(because of used design) which prominently contribute for better uptake of nutrients by the plant, which would in turn improve the physical stand and yield of crops.

Physical soil and water conservation practices are absolutely necessary in agricultural operations for successful sorghum production and improve productivity in such Erer site of moisture stressed area. Moreover Contour furrow and open ended tied ridges are promising physical structure in the study area at improving the biomass of sorghum crop and grain yield due to improved soil moisture in the soil and root zone. Generally, it is necessary more or repeated research for validity and conformity to consider and quantify the soil loss and soil moisture at different growing stage of crop as well as to determine its adoptability analysis. Farmers in the study area were benefited when they apply contour furrow and open ended tied ridges, rather than absolute control (no conservation measures). Farmers in the study area can be benefited or obtain (17,759.9 ETB) and (16320 ETB) when they apply contour furrow and open ended tied ridges respectively, rather than absolute control (no conservation measures).Generally the experiment with contour furrow and open ended tied ridges treatments were economically profitable for farmers.

RECOMMENDATION

Farmers of Babile District should use appropriate soil and water conservation measures during the crop production season. Farmers of Erer should practice or use contour furrow and open ended tied ridgeson sandy clay loam soil texture as physical soil and water conservation structure respectively. Office of agriculture and other NGO's should create awareness for farmers on use of appropriate soil and water conservation measures which could fit with the physical properties of the soil. Farmers in the study area can be benefited or obtain (17,759.9 ETB) and (16320 ETB) when they apply contour furrow and open ended tied ridges respectively, rather than absolute control (no conservation measures).

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Evaluation of Balanced Fertilizer Types on Yield and Yield Components of Sorghum and Validation of Soil Fertility Map Based Fertilizer Recommendation.

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ABSTRACT

Sorghum has tremendous uses for the Ethiopian farmer and no part of this plant is ignored. However, the productivity of sorghum is low. In Harari region, the average productivity of 22.22 Quintal ha^{-1} which is even below the national average yield of 27.26 Quintal ha^{-1} mainly constrained by soil nutrient deficiencies. Soil fertility depletion in agricultural land is the fundamental biophysical root cause of declining per capita food production. So balanced fertilizer amended with enough amount of Nitrogen and phosphorous on sorghum gave the highest yield, nutritional content and economic return. Soil fertility map of Ethiopia was conducted during 2016 by ATA (Agricultural transformation Agency) .So this fertility map should be validated. Therefore, a field experiment was conducted during 2018 and 2019 main cropping season at Kile PA, Sofi woreda of Harari Regional state under rain-fed condition on balanced fertilizer types. The objectives of the experiment was to evaluate sorghum crop response to different balanced fertilizer types and validate soil fertility map based fertilizer recommendation. And to identify effects of different balanced fertilizer on yield and yield components of sorghum crop.The experiment was laid out in randomized complete block design with three replications. The treatments of this experiment were: control without any fertilizer (no fertilizer applied), NPS, NPSB, NPSZn, NPSZnB, DAP and Urea. The result shows significant difference among the treatments ($P<0.05$).Analysis of variance was performed using the GLM procedure of SAS Statistical Software Version 9.1.And partial budget analysis was conducted based on CIMMYT procedure (CIMMYT, 1988).Out of five balanced fertilizer types applied, NPSzn balanced fertilizer type shows the highest significant difference ($P<0.05$). The highest result of both sorghum grain yield and yield components was obtained from treatments that receive NPSzn fertilizer (52qu/ha) and the lowest grain and biomass yield was obtained from control with no fertilizer (25.48quntal/ha) followed by DAP and urea. Next to grain yield, biomass yield of sorghum is very important parameter that should be considered for the sake of animal feed in the Harari region (kile PA). So, the treatments that receive NPSZn balanced fertilizer shows the highest biomass yield (11.666t/ha).Thus why NPSZn fertilizer is valid for kile PA. Partial budget analysis was conducted and treatments with NPSZn balanced fertilizer was economically profitable for farmers. Mean that, farmers can obtain39,134 Ethiopian birr/ha byapplying NPSZn balanced fertilizer**,** over the control (with no fertilizer) 17186 Ethiopian birr/ha and the rest treatments.

Key Words: Balanced Fertilizer, unbalancedfertilizer, Soil Fertility, Sorghum, Harari.

INTRODUCTION

Sorghum (sorghum bicolor l.) Belonging to the family panacea, it is produced in many countries of the world and the fifth major cereal crop in the world in terms of tonnage after maize, wheat, rice and barley (fao, 2012). It is the third most important cereal crop in Ethiopia and forth in southern region in terms of area of production (csa, 2018). In Ethiopia, it is adapted to a wide range of environments, and hence can be produced in the high lands, medium altitude and low lands. Sorghum is widely produced more than any other crops in the areas where there is moisture stress (moa, 2010). It is a staple food crop on which the lives of millions of poor Ethiopians depend. It has tremendous uses for the Ethiopian farmer and no part of this plant is ignored (adugna, 2007). Sorghum is used in various ways in our country; the grain is used for human foods such as injera, bread, porridge, nifro, infant food, syrup, and local beverage known as "tella" and "arekie." And also, the leaf and stalk are used for animal feed, and further, the stalks are used for the construction of houses and fences and as fuel wood.

However, the productivity(both grain and biomass yield) of sorghum is low; in harari region, the average productivity of 22.22 quintal ha^{-1} which is even below the national average yield and productivity of 27.26 quintal ha^{-1} (csa, 2016; csa, 2018).soil fertility decline is the main issue in african agriculture in general and in Ethiopia in particular. In Ethiopia, large number of population is hardly satisfied by reliable production, instead a decline in their crop yield is letting them to suffer from poverty and malnutrition. Studies indicated that in some parts of Ethiopia farmer suffer from lack of what to eat particularly in months starting from june up to september (abera, 2003). Ethiopian soils have been subjected to severe degradation caused by natural and man-made factors (ifdc, 2015). Low soil fertility and shortage of moisture is the major constraints in the reduction of growth and productivity of sorghum (gebreyesus, 2012).the rate of soil fertility decline depends on soil erosion, nutrient removal in harvests, the rate at which nutrients are returned to the soil through the use of both inorganic fertilizer and organic manures, and the rate of mineralization of soil mineral and organic matter nutrients (kaizziet al., 2017).

Since its start in the early 1970's, fertilizer use in Ethiopia has focused mainly on the use and application of nitrogen and phosphorous fertilizers in the form of urea and dap for almost all crops. Such unbalanced (phosphorus and urea alone, even though the soil may require micro nutrients like boron, zink etc.) Application of plant nutrients may aggravate the depletion of other important nutrient elements in soils (fayeraet al., 2014). The appropriate use of nitrogen and phosphorous fertilizer for sorghum production could make an important contribution to optimize profit through increasing production and productivity of sorghum in areas, where there is low practice of using improved technologies such as optimum level of fertilizer (abebeet al., 2016). Not only phosphorus and nitrogen in form of dap and urea, application of potassium, sulfur and zinc in different parts of the country sharply increase yield which leads the country started using fertilizers which can supply the deficient nutrients and will continue to use in the form of blends /balanced (ifdc, 2015).

Application of balanced fertilizer based on the actual limitation of nutrients in the soil is very crucial to increase production and productivity of crops. Balanced fertilizer amended with enough amount of nitrogen and phosphorous on sorghum gave the highest yield, nutritional content and economic return (gebrekorkoset al., 2017). Moreover, application of macronutrients in combination with micronutrient increased sorghum yield and concomitantly improved n, p and k uptake and its nutrient use efficiency of sorghum varieties (redaiet al., 2018).Now a day, agricultural transformation agency (ata), has been conducted soil fertility survey and display it on the map. And also recommend different balanced fertilizer based on their map which is blanket recommendation. Thus why, those balanced fertilizer has to be checked and validated before going for calibration. And also, increasing yields through the application of nitrogen and phosphorus alone can deplete other nutrients. Therefore, information on production practices to optimize the grain yield and quality of sorghum by applying the appropriate type of balanced fertilizer is important to sorghum production in Ethiopia in general and kile PA specifically. Hence. The objective of this study was to evaluate the effects of different balanced fertilizers in smallholder sorghum crop based farming systems in sofi district,kilel PAof Harar regional state. Hence. The objective of this study was to evaluate the effects of balanced fertilizers and application rate in smallholder sorghum crop based farming systems in kile pa, harari regional state.

MATERIAL AND METHODS

Study Area Description

The study was conducted during 2018 and 2019 main cropping season in Kile kebele Sofi woreda of Harari Regional state. Soil of study area was sandy clay loam. The annual average rainfall of the woreda ranges between to mm. The minimum and maximum annual temperature of 26 and 20^0C>respectively. Rainfall of the woreda is bimodal, small rains start in March to April interrupted by drought whereas; the second rain starts at July and ends at October with very big variations in distributions and amount. The study area has diversity of climate, soil, and land forms. The topography of the woreda includes mountains, hills, uplands and lowland plains. The altitude ranges 1200 - 1300 meter above sea level.

Experimental Design and Treatments

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replication of each treatments. There was three block in the experimental field .Totally there were18 plots occupied by six treatments, since each treatment was replicated three times.. The space between block was 1.5m and space between plots was 0.5m.The experimental site was ploughed and harrowed before sowing. The improved and moisture stress resistant Melkam sorghum variety was used for the experiment. Plot size was 3m x 4m. Furrow rows were made manually in spacing of 75 cm apart and sorghum seed was drilled manually and thinned by 20cm spacing between plants. Those fertilizer treatments were differing in their nutrient composition. For example NPS differ from NPSzn by their nutrient composition (chemical formula), NPS consists, Nitrogen, phosphorous and sulfur in one pack (19 N – 38 P2O5 +7S) and NPSzn (17.7 N – 35.3 P2O5 + 6.5S + 2.5 Zn) contains, Nitrogen, phosphorous, sulfur and Zink nutrients in one pack and NPSB (18. 1 N – 36.1 P2O5 + 6.7S + 0.71B).

The experiment consisting of six treatments
Treatments;
T1- control (no fertilizer)
T_2, 100 kg/ha NPS
T_3, 100kg/ha NPSB
T_4 100 kg/ha NPSZn
T_5 100 kg/ha NPSZn B
T6 100 kg/ha DAP & 60 kg/ha Urea.

Data Collection and Soil Sampling.
Treatment effects were determined by collecting plant height, panicle length, panicle diameter above ground biomass, and grain yield datas. Plant height was measured using meter tape (since malkam sorghum variety was short in height and simple to measure plantheight, it was low land variety. Composite soil sample was collected from (0-20 cm) depth by diagonal rule orzigzag method with the sampling depth of (0-20) cm, Soil sample after harvest were collected from every plot (from 5 spots /auger points) and analyzed for soil physico-chemical properties.

Data Analysis.
Analysis of variance was performed using the GLM procedure of SAS Statistical Software Version 9.1. Means were separated using Least Significant Difference (LSD) test.Response

Economic Analysis for balanced fertilizer
The dominance analysis procedure, which was used to select potentially profitable treatments, a dominance analysis is thus carried out by first listing the treatments in order of increasing costs that vary. Any treatment that has net benefits that are less than or equal to those of a treatment with lower costs that vary is dominated. The selected treatments by using this technique were referred to as dominated treatments. For each pair of ranked un dominated treatments, a percentage marginal rate of return (% MRR) was calculated. The percent MRR between any pair of dominated treatments denoted the return per unit of investment in crop management practices expressed as percentage. The MRR (%) was calculated as follows (CIMMYT, 1988). For a treatment to be considered a worthwhile option to farmers, the marginal rate of return (MRR) needed to be at least 100%. Thus, the minimum acceptable rate of return was considered to be 100%.Partial budget analysis was used for economic balanced fertilizer analysis by considering the general relationship between the types of balanced fertilizer and sorghum yield per hectare of land. Total revenue, total variable cost, total fixed cost, total cost, net income and benefit cost ratio, of each treatment were analyzed by partial budget analysis based on CIMMYT procedure (CIMMYT, 1988). The data used for economic analysis were fixed cost and variable cost.

Assessmentwas undertaken to take the price of sorghum at local market. Based on the assessment done 1kg of sorghum was 11ETB at time at field level. For calculation of labour cost the price of human labor was 75ETB at the field. Net income (NI) in ETB/ha, generated from sorghum crop, was computed by subtracting the total cost (TC) in ETB/ha from the total return (TR) in ETB/ha obtained from sorghum sale (Kuboja and Temu, 2013).

$$NI = TR - TVC$$

TC is the sum of FC and VC. Fixed costs (FC) are those that do not vary between fertilizer treatments, i.e. sorghum seeds, fertilizer, land rent and. Variable costs, on the other hand, are those that do vary between fertilizer treatments, i.e. fertilizer and labor. Benefit cost ratio (BCR) of each treatment was computed as the ratio of NI earned to the TC expended.
BCR= NI/TC

RESULT AND DISCUSSION

Soil Analysis

Table 1. Physico-chemical soil properties of the study area.

Lab result	TN (%)	OM (%)	PH	Av. P(ppm)	Av. K(ppm)	Na	Particle distribution (%)			
							Sand	silt	clay	Textural class
Before	0.045	1.68	7.46	2.39	1.008	0.219	36	46	18	
After	0.078	2.62	6.83	3.39	0.976	0.483	Sandy clay loam			

Key*TN=total nitrogen, OM=organic matter, PH= pH (H_2O) 1:2.5 g soil, Avp Available Phosphorus Ppm, Av.K= Available potassium in ppm and Na= sodium.

The textural class of the experimental soil was found to be sandy clay loam with the pH of 6.83-7.46, which is slightly alkaline and it is a preferred range for most crops (Table 1). Total nitrogen content was 0.045-0.078%, which is within the range of very low levels (0.02-0.5%) for tropical soils. The organic matter content of the soil was 1.68-2.62%, which is within a range of low (0.5-2%) for Ethiopian soils as per criteria developed by Murphy (1968). The available P content of the experimental soil was 2.39-3.39ppm that lies in a range of deficiency (< 20-40mg/kg) for most crops (Landon, 1991). And available K (ppm) was very limiting when compared to the standard (Murphy (1968).

Table 2.Yield And Yield Components Of Sorghum As Influenced By Different Balanced Fertilizer Type.

Control(no fertilizer)	147^{b}	27^{c}	5.47^{c}	6944^{c}	2548^{c}
100 NPS kg/ha	153.8^{a}	29.6^{ab}	6.33^{b}	6389^{c}	3822.2^{abc}
100 NPSB kg/ha	152.87^{ab}	29.07^{ab}	6.33^{b}	8750^{abc}	3844.4^{abc}
100 NPSZn kg/ha	156.6^{a}	29.73^{ab}	7.27^{a}	11666^{a}	5200^{a}
100 NPSZnB kg/ha	155.93^{a}	30.33^{a}	6.93^{a}	10869^{ab}	4546.2^{ab}
100 DAP + 60 UREA kg/ha	151.8^{ab}	28.73^{ab}	6.8^{ab}	$8055b^{c}$	3238.9^{bc}
LSD	6.77	1.28	0.55	3538.5	1465.9
CV (%)	2.43	2.42	4.67	21.16	20.84

Key* PH = plant height (cm), PL = panicle length (cm), Panicle diameter (cm) Biomass kg/ha Gy = grain yield (kg ha^{-1}), * = h significant at P<0.05.

Plant Height

Statistically there was highly significant difference among the treatment at 5%. Level of confidence. The highest plant height (156.6 cm) was recorded from treatment which receives 100 $kgha^{-1}$of NPSzn, but this was in statistical parity with rest treatments except control treatment.and the lowest plant height (147 cm) was measured from the control treatment. This is because of soil macro and micro nutrients deficiency at kile PA's. Especially Zink and sulfur were the most deficient nutrients there. This finding is in agreement with the report of

Gebrekirkoset al (2017) that plant height increases with increment of fertilizer application from nil to balanced fertilizer type including NPSzn. Furthermore, Redaiet al., 2018 reported that application of NPSzn gives the highest plant height over the absolute control treatment. In addition to this, it can be suggested the application of optimum fertilizer nutrients increased the plant growth and biomass and the increased amounts of nutrient increases the production of sorghum (Bayuet al., 2006).

Panicle Length (kg/ha):

The longest panicle length (30.33cm) was recorded from treatment that receives 120 Kg ha^{-1} NPSzn, but this was in statistical parity with the rest treatment except control while the lowest panicle length (27 cm) was recorded from the control treatment. The result was in conformity with the finding reported that tallest panicle length was recorded from the plot treated by blend fertilizer and the shortest panicle length was recorded from the control (Redaiet al., 2018). The current result was agree with increasing trend in blended fertilizer and amended with N and P in case of (NPSZn) fertilizer shows a corresponding increment of panicle length as compared with the nil fertilizers (Gebrekorkos et al., 2017). The current finding was disagree with finding reported that panicle length of sorghum did not give significantly different response under fertilized and unfertilized conditions (Sibhatuet al., 2017).

Biomass (kg/ha):

Biomass yield is an important output as farmers are also interested in it for animal feed and use as fuel wood in addition to grain yield. The highest above ground biomass (11666 $kgha^{-1}$) was recorded from the treatment that receives 100 $kgha^{-1}$NPSZn and followed by NPSZnB; whereas the lowest above ground biomass (6389 $kgha^{-1}$) was measured from treatments which receive 100 $kgha^{-1}$NPS this was in statistical parity with control and treatments that receive 100 kg/ha DAP and 60 kg/ha Urea . The result is in line with the finding of Gebrekorkos et al., 2017 reported that the highest biomass yield of sorghum was obtained from the application of blended fertilizer amended with NPSZn which was statistically at parity with the application of balanced fertilizer NPSZn. In contrary, the lowest above ground biomass was obtained from the nil fertilizer plots. Similar finding was reported by Berhaneet al., 2015as application of high nitrogen level results in high amount of biomass yield in sorghum. The current finding was agree with the report plots treated by blend fertilizer gives highest biomass yield over the control plot as the lowest biomass yield was obtained (Redaiet al., 2018).

Grain Yield (kg/ha)

The highest grain yield (5200 $kgha^{-1}$) was recorded from the treatment that receives 100$kgha^{-1}$ NPSZn followed by NPSZnB. This is because of soil macro and micro nutrients deficiency at kile PA's is compensated by balanced fertilizer. Especially Zn and sulfur were the most deficient nutrients (ATA, 2016). Whereas the lowest grain yield (2548 $kgha^{-1}$) was measured from control treatment (Table 2). The current finding was agree with finding reported as the plots treated by NPSZn fertilizer gives highest grain yield as that of NPKSZn and the lowest grain yield of sorghum was recorded from control(Redaiet al., 2018). Similarly, Gebrekorkos et al., (2017) reported that the maximum grain yield was obtained from the balanced fertilizer types NPSZn, while the lowest yield was obtained in unfertilized plots. Additionally, the finding reported that increasing application of fertilizer nutrients such as N, P, K and Zn

increases the grain yield and biomass weight of sorghum significantly (Regessa, 2005). Additionally, the result was agreed with the finding reported as sorghum yield increase with increase in the rate of nitrogen and application of blended fertilizer to the optimum rate (Kasaye, 2018).

Economic Analysis

The economic evaluation and comprising partial budget analysis with dominance, and marginal rate of return was carried out. To estimate economic parameters, the yield of sorghum was valued based on average market price collected from the local markets during two consecutive years of production. The average cost of urea, NPS, NPSB, NPSZn, NPSZnB, and DAP 9.6 and birr per kg respectively. A wage rate of 75 birr a man per day was considered. Some of the concepts used in the partial budget analysis are gross field benefit (GFB), total variable cost (TVC), TFCand thenet benefit (NB) CIMMYT, 1988.

Table: 3 financial analysis for different balanced fertilizers.

T1,Control(no fertilizer)	2548	22932	4246	1500	5746	17186	2.9
T2,NPS	3822.2	34399.	6166	1500	7666	26733	3.5
T3,NPSB	3844.4	34599.6	6166	1500	7666	26933.6	3.5
T4,NPSzn	5200	46800	6166	1500	7666	39134	5.1
T5,NPSZnB	4546.2	40915.8	6166	1500	7666	33249.9	4.3
T6, DAP and Urea.	3238.9	29150.1	6166	1500	7666	21484.1	2.83

KEY TR=total revenue, TVC=total variable cost, TFC=total fixed cost, NI= net income and B/C = benefit cost ratio.*

Effect of balanced fertilizer on Economic sorghum Productivity

Data concerning to economic comparison was presented in Table 3. The detail evaluation of the economic analysis of fertilizer treatments was shows that, as a result, the direct impact of balanced fertilizer (NPSZn) in generating NI was very high for a hectare of land per season which means good value from hectare than absolute control. Maximum total cost (7666ETB) was obtained by NPSZnB treatment whereas the minimum variable cost (5746ETB) was obtained by T1 (control). Benefit cost ratio (BCR) of each treatment was computed as the ratio of NI earned to the TC expended. Accordingly, maximum BCR (5.1) were obtained by T4 means that treatment which receives NPSZn fertilizer. However, the lower BCR was recorded by T1 and T8. This implies that even though maximum yield was obtained by those treatments they were economically not more attractive. From this economic analysis the application, T4 (NPSZn)) was the most economically attractive treatment with high BCR and optimum net benefit.

The marginal rate of return above 100% is high and acceptable to farmers (CIMMYT, 1988).With the acceptable marginal rate of return (MRR), NPSZn application was produced the highest net benefits and marginal rate of return as compared to absolute control and DAP and Urea. Therefore, farmers in the study area were benefited when they apply NPSZn rather than absolute control and the experiment with NPSZn and NPSZnB treatments are economically viable.

CONCLUSION

The results of the study shows significant difference among the treatments ($p<0.05$), out of five fertilizer types applied, NPSzn balanced fertilizer type shows the highest significant difference. The highest plant height (156.6 cm) was recorded from treatment which receives 100 $Kgha^{-1}$NPSZn. Biomass yield is an important output as farmers are also interested in it for animal feed and use as fuel wood in addition to grain yield. The highest above ground biomass (11666 $kgha^{-1}$) was recorded from the treatment that receives 100 $kgha^{-1}$NPSZn and followed by NPSZnB; whereas the lowest above ground biomass (6389 $kgha^{-1}$) was measured from treatments which receive 100 $kgha^{-1}$NPS.Therfore, to get the highest, above ground biomass, farmers should apply NPSZn fertilizer. The highest grain yield (5200 $kgha^{-1}$) was recorded from the treatment that receives 100$kgha^{-1}$ NPSZn followed by NPSZnB.whereas the lowest grain yield (2548 $kgha^{-1}$) was measured from control treatment (table 2). Using soil test based recommended balanced fertilizer type is economically profitable. The ATA recommendation of NPSZn for kile PA, of Harari regional state is valid for a given specific location.

RECOMMENDATION

Farmers should use fertilizer during the sowing season. Farmers of kile PA, should purchase and use NPSZn balanced fertilizer and urea only. Not only inorganic fertilizer, farmers better to apply organic manures to alleviate their soil from low organic matter and soil salinity. Research extension, Office of agriculture and natural resource and other NGO's should create awareness for farmers on fertilizer application and which balanced fertilizer to be used.

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Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Bread Wheat in Chora District, Western Oromia

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ABSTRACT

Adequate plant nutrient management is among the most important factors in sustaining crop production and productivity. An experiment was conducted in Chora district on farmers' fields, in 2018 and 2019 to determine NPS fertilizer rate based on calibrated phosphorus for bread wheat. 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 standard 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, 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 almost all the agronomic data of bread wheat recorded. However, it showed no significant difference on bread wheat days to heading. The maximum mean biomass yield (15.2 t ha^{-1}) and grain yield (5.2 t ha^{-1}) were recorded for 100% Pc from NPS fertilizer, whereas the lowest mean grain yield (0.4 t ha^{-1}) was recorded for the treatment without fertilizer. Economic analysis for nutrient management indicated that the highest net benefit of 35400.00ETB $ha^{-1}$with an acceptable MRR of 404% was achieved from use of 100% Pc from NPS. Hence application of 100% Pc from NPS fertilizer is agronomically and economically feasible for bread wheat and recommended for the end users in Chora 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: Bread Wheat, Nitrogen, NPS rate, Phosphorus, P-critical level

INTRODUCTION

Plant nutrient deficiency is one of the foremost problems hamper the development of an economically successful agriculture (Fageria and Baligar, 2005). 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 etal., 2001, Matano etal, 2015). Moreover, the shortage of land for production of food crops has eliminated the practice of fallowing and crop rotation. According to (FAO,2001) soil fertility management on small farms in the tropics has become a major issue, as a result of continued land degradation and rapid population growth. Furthermore, shortage of grasslands (grazing areas) has forced the farmers to remove crop residues for animal feed. Since the study 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 fertility and availability of nutrients. (Mokwunye,1996) also stated that cultivated

weathered soils commonly suffer from multiple nutrient deficiencies, and nutrient balances are generally negative. The loss of soil fertility from continual nutrient mining by crop removal without adequate replenishment, combined with imbalanced plant nutrition practices, has posed a serious threat to agricultural production (FAO, 2006). Unless something is done to restore soil fertility first, other efforts to increase crop production would end up with little success (Quinenes, 1992).

In Ethiopia, low soil fertility is one of the factors limiting the yield of crops, including wheat. Mbah (2006) indicated that soil fertility is a major overriding constraint that affects all aspects of crop production. 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 (Wassie et al., 2010; Wassie and Shiferaw, 2011) and resulted in stagnant crop production.. The results of several studies conducted on the status of P in Ethiopian soils (Tekalign and Haque, 1987) indicated that most of the soils studied require addition of P fertilizer for profitable crop growth.

On the other hand, 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 bread wheat using DAP fertilizer in Chora district; and recommended Phosphorus critical level and correction factor (Dagne and Abdulmalik ,2017). 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 rateand response of the newly introduced NPS fertilizer was not adjusted to the previously calibrated phosphorus using DAP fertilizer for bread wheat. Therefore, the objective of this study was to determine NPS fertilizer rate based on calibrated phosphorus for bread wheat in Chora district, Western Oromia.

MATERIALS AND METHOD

Description of the Study Area

An experiment was conducted in Chora district on twelve farmers' fields in 2018 and 2019 main cropping seasons. Chora district is located at 08°13’33.7”to 08°33’55.0”N and 035 ^{o}59’59.7” to 036 ^{o}15’15.8” E with altitude ranging from1000 to 2060 masl (Fig 1). 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 season covers April to October and the maximum rainfall is received in the months of June, July and August. The minimum and maximumannual 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)

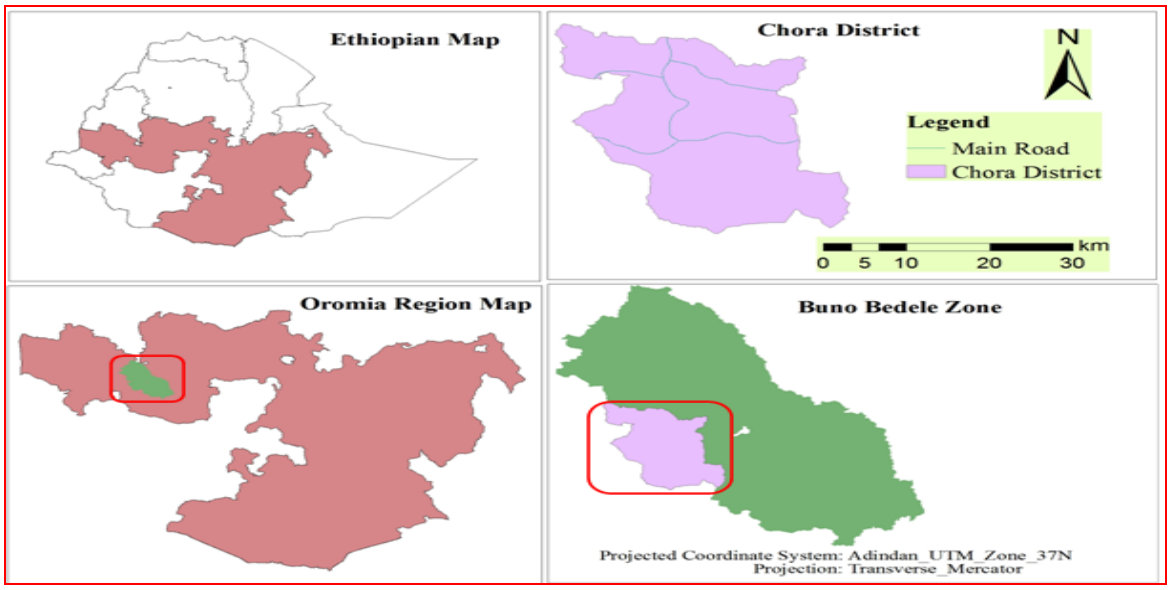

Figure 1. Map of the Study Area(Chora district)

Soil Sampling and Analysis

Composite surface soil samples (0-20) cm depth was 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.

Treatments, Experimental Design and Procedures

The treatments consisted of five (0, 25, 50, 75 and 100 %) P critical levels (Pc) calculated fromNPS fertilizer and one previously recommended P critical level (100% Pc) calculated from DAP was included ,which was used as check, that means the total number of treatment were six. The experiment was laid out in RCBD with three replications. The gross plot size was $12m^2$ (3m x4m) with seed rate of $150kgha^{-1}$**.** Bread wheat variety(liban) which is high yielder as compared to other improved bread wheat varieties in the study areas was used as a test crop, Phosphorus rate was calculated and appliedaccording 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. RecommendedN determined during Phosphorus calibration; (138 kg N ha^{-1}) for the district for bread wheat were used. The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times, and treated with lime for soilpHless than 5.5, and the amount of lime needed per hectare was calculated based on the formula LR = Ex.acidity*1.5*10 kun ha^{-1}.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% heading, biomass and grain yield were collected. Data on plant basis was recorded fromnet 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 trashing were estimated by assessing the current local market prices. The price of NPS (1548.87ETB 100 kg-^{1}), DAP (1997.00ETB 100 kg-^{1}), UREA (1394.00ETB 100 kg-^{1}), daily labors (35 ETB per one person day based on governments' current scale in the study area) and the cost of bread wheat trashing (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. Bread wheat yield was valued at an average field price of ETB 10.00 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, bread wheat grain yields obtained from each experimental plot were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price that farmers receive for the sale of the crop. The net benefit and the marginal rate of return (MRR) were also calculated as per standard manual ((CIMMYT, 1988).

RESULTS AND DISCUSSION

Soil pH, Available Phosphorus and Organic Carbon Status Before Planting in Chora District

Laboratory analysis of surface soil pH, available phosphorus and Organic Carbon status before planting were indicated on(Fig 2).The pH (H_2O) of soil ranged from (4.3 to 5.4). Accordingly, the soils were strongly acidic in reaction. The available phosphorus (P) extracted with Olsen method were ranged from (0.6 to 3.0 ppm. Thus, the present study showed that the available P contents at the surface soil were very low. The low contents of available P observed in the soil of the study areas 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 ofP sources application. The Organic Carbon content of the soil ranged from (2.2 to 4.4 %), which is grouped under low range (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).

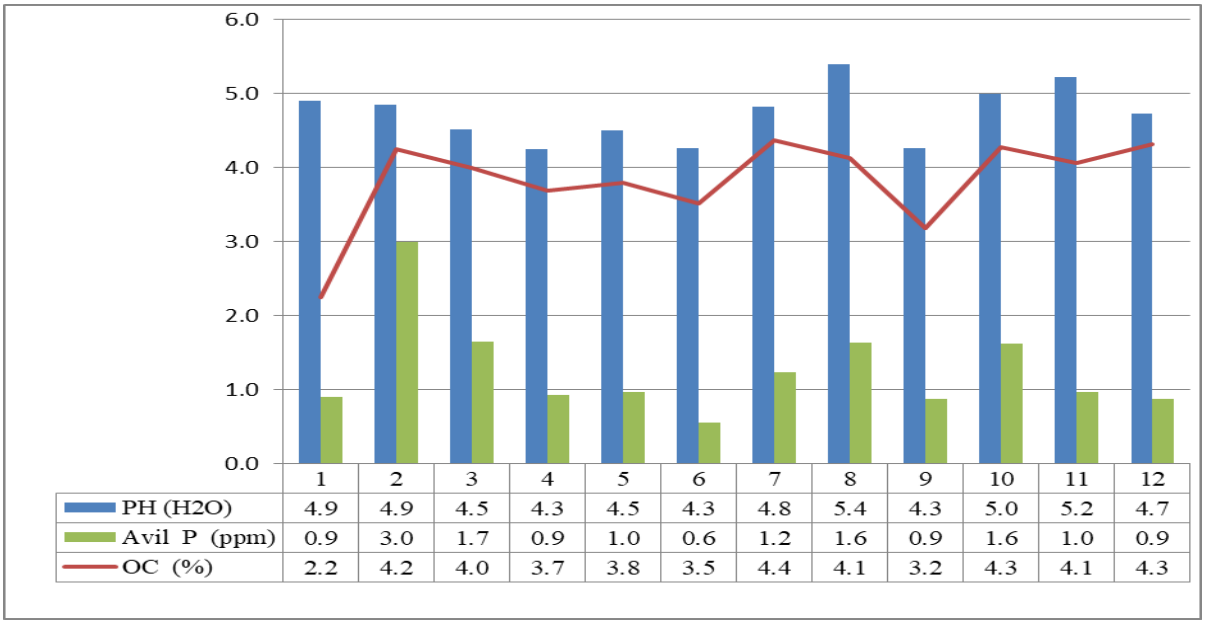

Figure 1. Soil pH, Available Phosphorus and Organic Carbon status before planting in Chora District

Soil CEC, Exchangeable Acidity and Textural Class Status Before Planting in Chora District

The soilCEC values were ranged from low to moderate (11.9 to 17.5 cmol(+)/kg soil) in the study area (Table 1). The observed CEC values of the soils generally showed similar trend withthat of soil OC. This implies that CEC was more influenced by OM than clay content. The results of the present study agreed with similar studies conducted elsewhere (Taye etal, 2003). Theexchangeable acidity content of the soil was ranged from 0.2 to 2.1 meq/100 gsoil),while the soil textural class was clay

Table1. Soil CEC, exchangeable acidity and textural class status before planting in Chora district

Sites	CEC (cmol(+)/kg soil)	Ex. acidity meq/100 gsoil)	Textural class
1	16.1	0.4	clay
2	13.2	0.2	clay
3	13.1	0.7	clay
4	14.3	2.0	clay
5	12.9	1.2	clay
6	11.9	0.4	clay
7	16.9	0.9	Clay
8	16.5	1.0	Clay
9	17.5	2.1	Clay
10	16.0	0.9	Clay
11	15.5	0.9	Clay
12	17.0	0.3	Clay

Mean Days to Heading of Bread Wheat under Different NPS Fertilizer Rates in Chora District in 2018 and 2019 Cropping Seasons

The result of combined analysis showed that mean days to heading of bread wheat were non significantly differences ($P \leq 0.05$) amongNPS fertilizer rates and DAP fertilizer (Table 2).This indicated that Physiological maturity of bread wheat was not influenced by NPS fertilizer rates. The highest (67.1) and lowest (66.2) days to heading were recorded from un fertilized plot and 75% Pc from NPS fertilizer, respectively.

Table 2:Mean days to heading of bread wheatunder different NPS fertilizer rates in Chora districtin 2018 and 2019 cropping seasons

Treatments	**Days to heading (days)**
Without fertilizer	67.1[a]
25%Pc from NPS +Rec N	67.0[a]
50%Pc from NPS +Rec N	66.6[a]
75%Pc from NPS +Rec N	66.2[a]
100% Pc from NPS + Rec N	66.4[a]
100% Pc from DAP+ Rec N	66.8[a]
Mean	4.4
CV (%)	66.6
LSD	ns

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

Mean Biomass and Grain Yields of Bread Wheat Under Different NPS Fertilizer Rates in Chora District in 2018 and 2019 Cropping Seasons

Biomass and grain yield data were indicated in (Table3**).** The result of combined analysis showed that mean above ground dry biomass and grain yields of bread wheat 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 DAP. All applied NPS fertilizer rates yielded significantly more than the treatment without fertilizer. The highest above ground dry biomass and grain yields (15.2 t ha^{-1}) and (5.2 t ha^{-1}, respectively) were obtained from 100% Pc from NPS fertilizer. Calculated 100% Pc from NPS increased bread wheat biomass and grain yields by 45% and 27% over 75% Pc from NPS fertilizer rate, respectively. This increment in grain yield with the NPS fertilizer is an indicator of positive interaction of sulfur and nitrogen. 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 S in plants (Wilkinson et al., 2000).

Table 3:Mean biomass and grain yields of bread wheatunder different NPS fertilizer rates in Chora district in 2018 and 2019 cropping seasons

Treatments	**Biomass yield ($t\ ha^{-1}$)**	**Grain yield ($t\ ha^{-1}$)**
Without fertilizer	4.7^{d}	0.4^{e}
25%Pc from NPS +Rec N	8.1^{c}	2.0^{d}
50%Pc from NPS +Rec N	10.7^{b}	3.4^{c}
75%Pc from NPS +Rec N	10.5^{b}	4.1^{b}
100% Pc from NPS + Rec N	15.2^{a}	5.2^{a}
100% Pc from DAP+ Rec N	14.8^{a}	5.1^{a}
Mean	10.7	3.4
CV (%)	26.9	27.8
LSD	1.9	0.6

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

Effects of NPS Fertilizer Rates on Economic Feasibility of Bread Wheat Production

The results of economic analysis for nutrient management are indicated in (Table 4). The highest net benefit of 35400.00 ETB $ha^{-1}$with an acceptable marginal rate of return (MRR) of 404% , were achieved from use of 100% Pc from NPS fertilizer. The minimum net benefit was obtained from the treatments with no fertilizer . Therefore, application of100% Pc from NPS fertilizer for bread wheat is agronomically and economically feasible.

Table 4: Partial budget analysis for NPS fertilizer rates on bread wheatin ChoraDistrict

Treatments	Av. GY($t\ ha^{-1}$)	Adj. GY($t\ ha^{-1}$)	TVC(ETB)	Gross benefit (ETB)	Net benefit (ETB)	D.A	MRR(%)
Without fertilizer	0.4	0.3	2040.00	3000.00	960 .00		-
25%Pc from NPS +Rec N	2.0	1.8	10756.50	18000.00	9243.50		1.49
50%Pc from NPS +Rec N	3.4	3.1	13071.00	31000 .00	20929.00		2.24
75%Pc from NPS +Rec N	4.1	3.7	14615.50	37000.00	26384.50		1.36
100% Pc from NPS + Rec N	5.2	4.7	16600.00	47000.00	35400.00		4.04
100% Pc from DAP+ Rec N	5.1	4.6	17389.00	46000.00	33611.00	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

Sustaining soil fertility in intensive cropping systems for higher yields of better quality can be achieved through application of balanced external inputs or fertilizers. Accordingly, all the studied NPS fertilizer effects on bread wheat yield and yield components showed that NPS fertilizer would be promising to grow bread wheat in the study area. Analysis of variance

indicated that the shortest mean days to 50% heading, the maximum mean biomass and grain yieldswere recorded for 100% Pc from NPS fertilizer, whereas the longest mean days to 50% heading, the lowest mean biomass and grain yields were recorded for the treatment without fertilizer. Application of 100% Pc from NPS fertilizer had the highest net benefit with an acceptable MRR. Bread wheat productivity for the newly introduced NPS fertilizer was high; which indicated that bread wheat productivity in the study sites was reduced due to high demand for external nutrient inputs. In conclusion, application of 100% Pc from NPS fertilizer is agronomically and economically feasible for bread wheat and hence recommended for the end users in Chora 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 the major crops grown in this region.

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

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ABSTRACT

Verification of soil test crop response based phosphorous recommendation for bread wheat was conducted in Gechi district, Western Oromia in 2019. The aims of the study was to verify the recommended nitrogen fertilizer (92 kg N ha^{-1}), determined P-critical level (2.5ppm) and P- correction factor (46.06) of Phosphorus recommendation for bread wheat in Gechi district during soil test crop response based phosphorus calibration study. The treatments consisted of control (without fertilizer) (T1), farmers' practices (blanket recommendation) (T2)) and soil test crop response based phosphorus recommendation (STCRBPR) (T3). The treatments were simply arranged side wise and replicated over farmers. The results of the study revealed that the analyzed surface soils were strongly acidic, 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 bread wheat biomass and grain yields. The maximum mean biomass yield (16.5 t ha^{-1}) and grain yield (5.8 t ha^{-1}) were recorded for STCRBPR. Whereas the lowest mean grain yield (1.1 t ha^{-1}) was recorded for the treatment without fertilizer. Economic analysis for nutrient management indicated that the highest net benefits of 34501.00 ETB $ha^{-1}$with MRR of 256% were achieved by the application of STCRBPR. Hence fertilizer application of STCRBPR is agronomically and economically feasible for bread wheat and recommended for the end users in Gechi district. The result also showed that the soils of the study areas were poor in chemical nutrient contents (soil fertility) hence, integrated soil fertility management practices can improve the current situation.

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

INTRODUCTION

Soil is a critically important natural resource. Hence, efficient management of which is vital for economic growth and development. African soil nutrient balances are often negative due tolow level of fertilizer inputs, and soil nutrient depletion that 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. 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 (Wassie et al., 2010;

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 wheat. It may be caused as a result of removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residue from farmland, and lack of proper crop rotation program (Tamirie, 1982). The results of several studies conducted on the status of P in Ethiopian soils (Tekalign and Haque, 1987) indicated that most of the soils studied require addition of P fertilizer for profitable crop growth.

The demand for fertilization is evident, as growers around the world have already recognized the return, which can be realized from added plant nutrients. Estimated essential plant nutrients loss in Africa was approximately 50 kg $ha^{-1}year^{-1}$(Janssen et al., 1995). So 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 (Stewartn et al., 2005). Moreover, using chemical fertilizers that bring more than 100% extra yield is inevitable in most cases (Kelsa et al., 1992). This implies that using chemical fertilizer plays significant role in increasing food production to meet the demand of the growing world population.

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 Gechi district for bread wheat for three years. Thus formula comprises phosphorus critical level (2.5 ppm) and phosphorus requirement factor (46.06) were determined based on initial P value in the soil. Even though nitrogen fertilizer, critical phosphorus level and phosphorus correction factor were determined during calibration study, further verification trial was needed to have confidence on the significances ofdetermined 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-correction factor as well as N-fertilizer on bread wheat in Gechi district..

MATERIALS AND METHOD

Description of the Study Area

Verification of soil test crop response based phosphorous recommendation for bread wheat was conducted in Gechi district on twelve farmers' fields in 2019 cropping season. Gechi district is located at 08°24’40.0”to 08°25’12.0”N and 036 ^{o}25’61.0” to 036 ^{o}33’20.0” E with altitude ranging from 1013 to 2390 masl (Fig 1). The 18 years weather information at nearby study area (Ethiopian Meterology 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 maximumannual 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)

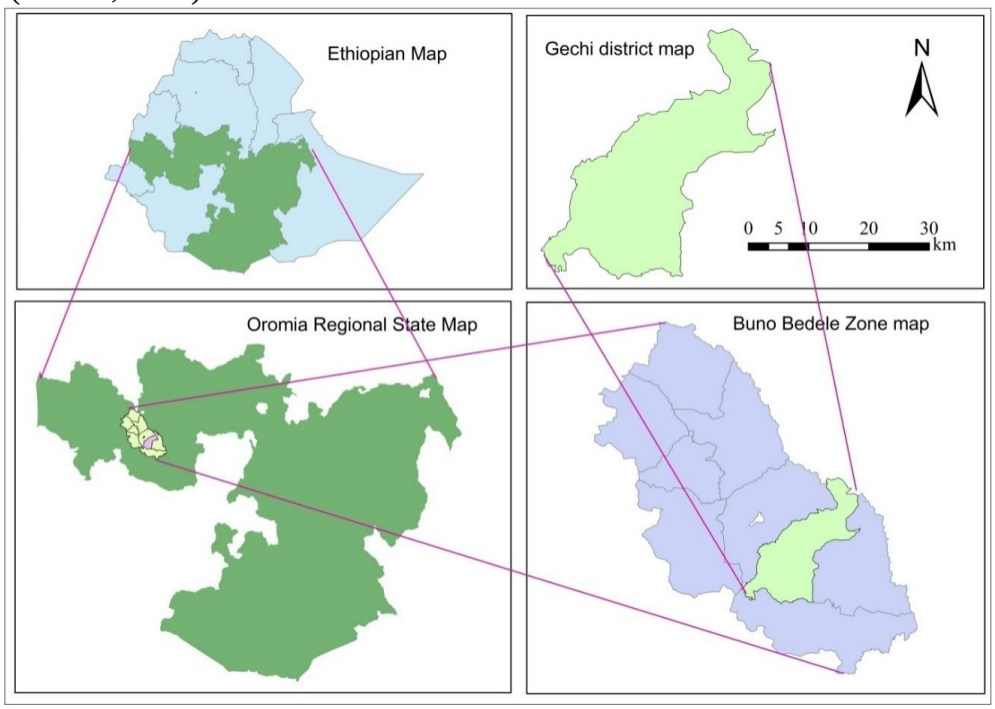

Figure 1. Map of the Study Area(Gechi district)

Soil Sampling and Analysis

Composite surface soil samples (0-20) cm depth was 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.

Treatments, Experimental Design and Procedures

The treatments consisted of control(without fertilizer) (T1), farmers' practices (blanket recommendation) (T2)) and soil test crop response based phosphorus recommendation (STCRBPR) (T3).). The treatments were simply arranged side wise and replicated over farmers. The growth plot size was 10m by 10m for eachplot. Bread wheat variety(liban) which is high yielder as compared to other improved bread wheat varieties in the study areas was used as a test crop with seed rate of 150kgha^{-1} . Phosphorus rate was calculated and appliedaccording 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. RecommendedN determined during Phosphorus calibration; (92 kg N ha^{-1}) for the District for bread wheat were used for soil test. whereas, 100kgha^{-1} DAP and UREA for each were used for farmer's practices. The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times., and treated with lime for soilpHless than 5.5, and the amount of lime needed per hectare was calculated based on the formula LR =

Ex.acidity*1.5*10 kun ha^{-1}.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, biomass and grain yields data were collected fromnet 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 (1997.00ETB 100 kg-^{1}), UREA (1394.00ETB 100 kg-^{1}), daily labors (35 ETB per one person day based on governments' current scale in the study area) and the cost of bread wheat 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 was recorded to calculate daily labor required for one hectare. One person per day was estimated based on eight working hours per day. Bread wheat yield was valued at an average field price of 10.00 ETB $kg^{-1,}$. However, other non-varied costs were not included since all agronomic managements were equally and uniformly applied to each experimental plot. Before calculating gross revenue, bread wheat grain yields obtained from each experimental plot were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price that farmers receive for the sale of the crop. The net benefit and the marginal rate of return (MRR) were also calculated as per standard manual (CIMMYT, 1988).

RESULTS AND DISCUSSION

Soil pH, Available Phosphorus and Organic Carbon Status before Planting in Gechi District

The pH (H_2O) of the soil samples collected before planting were ranged from 4.4 to 5.0(Fig 2).Accordingly, the soils were strongly acidic in reaction (FAO, 2008. Hence, this soil pH affects bread wheat production which is less than its requirement proposed (FAO, 2006). Available Phosphorus (Olsen method) was ranged from 0.4 to 1.3ppm (Fig 2). The available P contents of the soil samples were very low (Olsen et al., 1954). The low contents of available P observed in the soil of the study areas are in agreement with the results reported by Yihenew, (2002);Dagne, (2016) that stated as, the Ethiopian agricultural soils particularly the Nitisols and other acid soils have low available P content due to their inherently low P content, high P fixation capacity, crop harvest and soil erosion. The Organic Carbon content of the soil ranged from (1.9 to 4.5 %). 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).

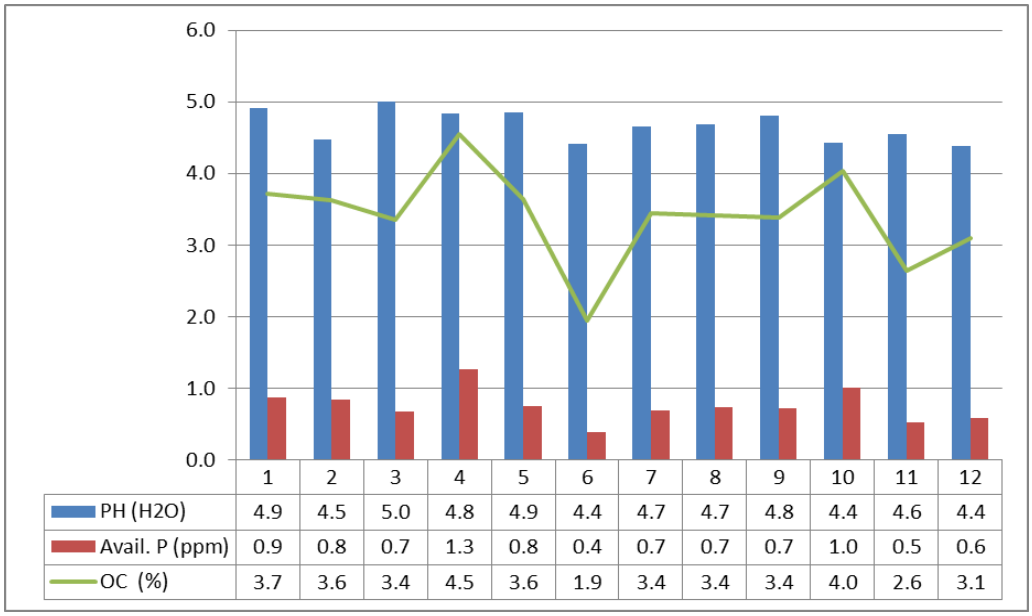

Figure1. Soil pH, Available Phosphorus and Organic Carbon status before planting in Gechi District

Soil CEC, Exchangeable Acidity and Textural Class Status before Planting in Gechi District

The CEC values were low to moderate in the study area (Table 1).The CEC values of soil in the study area ranged from (15.2 to 19.3 cmol(+)/kg soil). The observed CEC values of the soils generally showed similar trend withthat of soil OC. This implies that CEC was more influenced by OM than clay content. The results of the present study agreed with similar studies conducted elsewhere (Taye etal, 2003). Theexchangeable acidity content of the soil ranged from 0.3 to 2.1 meq/100 gsoil),while the textural class was clay

Table1. CEC, exchangeable acidity and textural class status of the soil before planting in Gechi district

Sites	CEC (cmol(+)/kg soil)	Ex. acidity meq/100 gsoil)	Textural class
1	15.9	2.1	clay
2	18.8	1.0	clay
3	19.3	2.0	clay
4	15.6	1.1	clay
5	17.2	0.3	clay
6	16.3	1.9	clay
7	18.8	0.9	Clay
8	19.0	0.5	Clay
9	18.8	0.7	Clay
10	15.2	1.1	Clay
11	15.9	1.1	Clay
12	17.1	2.0	Clay

Mean Biomass and Grain Yields of Bread Wheat in Gechi District in 2019 Cropping Season

There were significant differences ($P \leq 0.05$) amongtreatments in bread wheat biomass and grain yields. The maximum mean biomass yield (16.5 t ha^{-1}) and grain yield (5.8t ha^{-1}) were recorded from the application of STCRBPR (soil test crop response based phosphorus recommendation), whereas the lowest, was recorded from the control plot (Table 2). STCRBPR highly increased bread wheat biomass and grain yields over farmers' practices fertilizer application,. This indicated that farmers' practices fertilizer application, which is adoptedby farmers' is unbalanced fertilization in the district. Ethiopian farmers use inadequate nutrient inputs, inappropriate quality and inefficient combinations of fertilizers, which in the end prove to be lack of soil fertility restoring inputs and unbalanced nutrient using (Palm et al, 1997). Nutrient mining due to sub optimal fertilizer use coupled with unbalanced fertilizer use favored the emergence of multi nutrient deficiency in Ethiopian soils (Wassie et al., 2010; Wassie and Shiferaw, 2011) and resulted in stagnant crop production.

Table.2: Mean biomass and grain yields of bread wheat in Gechi district in 2019 cropping season

Treatments	**Biomass yield (t ha^{-1})**	**Grain yield (t ha^{-1})**
Control	2.8^{c}	1.1^{c}
Farmers' Practices	9.9 b	2.7^{b}
STCRBPR	16.5^{a}	5.8^{a}
Mean	9.7	3.2
CV(%)	31.5	25.1
LSD	2.6	0.7

Mean followed by the same letters in each column are not significantly different at $P \leq 5\%$, LSD = Least Significant Difference, CV = Coefficient of Variation, STCRBPR= soil test crop response based Phosphorus Recommendation

Partial Budget Analysis on Economic Feasibility of Bread Wheat Production

The results of economic analysis for nutrient management are indicated in (Table 3). The highest net benefit of 34501 00ETB $ha^{-1}$with an acceptable marginal rate of return (MRR) of 256% , were achieved from use of STCRBPR. The minimum net benefit was obtained from the treatments with no fertilizer. Therefore, application ofSTCRBPR for bread wheat is agronomicaly and economically feasible.

Table 3. Partial budget analysis for verification of STCRBPR for bread wheatin Gechi district

Treatments	Av. GY(t ha^{-1})	Adj. GY(t ha^{-}	TVC(ETB)	Gross benefit (ETB)	Net benefit (ETB)	D.A	MRR(%)
Control	1.1	1.0	2700	10000	7300		
Farmers' practices	2.7	2.4	9631	24000	14369		100
STCRBPR	5.8	5.2	17499	52000	34501		256

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 BasedPhosphorus Recommendation

CONCLUSION AND RECOMMENDATION

Fertilization needs to be rationally used in order to avoid undesirable effects on the sustainability of agricultural production system.Accordingly, verified P-critical level , P correction factorand N fertilizer signified the economic benefit of recommended soil test crop response based calibrated phosphorus for improved bread wheat in the study area. The results of the study revealed that the maximum mean biomass yield (16.5 t ha^{-1}), grain yield (5.8 t ha^{-1}) were recorded for STCRBPR, whereas the lowest were recorded for the treatment without fertilizer. STCRBPR highly increased bread wheat biomass and grain yields over farmers' practices fertilizer application, which indicated that bread wheat productivity in the study sites was reduced due to high demand for external nutrient inputs. Application of STCRBPR had the highest net benefit with an acceptable MRR. Therefore, application of STCRBPR is agronomically and economically feasible for bread wheat and hence, determined P-critical level (2.5 ppm), P- correction factor (46.06) andnitrogen fertilizer (92 kg N ha^{-1}) are recommended for bread wheat in Gechi district. To 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.

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Effects of pigeon pea (Cajuns Cajan) intercropping on sorghum crop production and soil fertility level in case of Harari regional state and DDA (Erer research on station).

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ABSTRACT

The study was conducted during 2019 main cropping season at Erer research station and Dire Dawa, Awale district Adada2 PA.Globally pigeon pea (Cajanus Cajan (L.) Millsp) is the fifth most important pulse crop mainly grown in the developing countries by resource-poor farmers in drought prone areas and on degraded soils. It is a multipurpose leguminous crop that can provide food, forage, fuel wood and fodder for the small-scale farmer in subsistence agriculture (Egbe, 2005).Pigeon pea is a deep-rooted and drought tolerant grain legume that adds substantial amount of organic matter to the soil (Egbe, 2005) and has the ability to fix up to 235 kg N/ha (Peoples et al., 1995). At Dire Dawa and Harari regional state, farmers didn't accept drought tolerant sorghum variety, because of small harvests of total biomass. Thus why, pigeon pea sorghum intercropping can solve the problem of low availability of forage and low soil fertility in this low land area. The treatments of the experiments were, Sole sorghum (malkam) variety, Sorghum + Accession 16520, Sorghum + Accession 16527, sorghum +Accession 16528, pigeon pea Accession 16520, Pigeon pea Accession 16527and Accession 16528 respectively. The design of the experiment was, RCBD with three replication. The experiment shows significant difference statistically, in terms of plant height, panicle length, and panicle diameter at 5 %(table 1). The highest plant height was obtained from the treatment with sorghum intercropped with pigeon pea accession 16527(tsegab variety). The result that obtained was statistically not significant interms of grain yield ($p < 0.01$) among treatments (both sole and intercropped one). In (Table 1) was indicated that intercropping of pigeon pea Accessions had no negative significant effect on grain yields of sorghum. The maximum grain yields were obtained from T3 (sorghumX16527 pigeon pea accession); (2894) kg ha^{-1}), followed byT2 (16527pegeon pea accession) (2856) kg ha^{-1} respectively. The minimum grain yield obtained from sole sorghum (2339 kg ha^{-1}) .The most probable reason for this variation could be due to leguminous nature of pigeon pea accessions that add nitrogen nutrients to the soil and affect sorghum positively. When observed graphically, there is mean yield difference. Both land equivalent ratio and relative total yield was calculated and the obtained result is about 1.22. So this intercropped experiment is advantageous. Partial budget analysis was conducted and the experiment is economically viable.

Key words: Accessions, pigeon pea, soil fertility

INTRODUCTION

Globally pigeon pea (Cajanus Cajan (L.) Millsp) is the fifth most important pulse crop mainly grown in the developing countries by resource-poor farmers in drought prone areas and on degraded soils. It is a multipurpose leguminous crop that can provide food, forage, fuel wood and fodder for the small-scale farmer in subsistence agriculture (Egbe, 2005).Pigeon pea is a deep-rooted and drought tolerant grain legume that adds substantial amount of organic matter to the soil (Egbe,2005) and has the ability to fix up to 235 kg N/ha (Peoples et al., 1995) and produces more N per unit area from plant biomass than many other legumes. The effects of intercropping on soil fertility vary with management practice.. In a situation in which the farmer uses little or no fertilizer and the soil is very low in organic matter, the issue of transfer of N from legume to cereal assumes great importance. Two types of beneficial effects have generally been reported: higher N content and/or higher grain yield of the intercropped cereal in comparison with the cereal alone without any added N.Nitrogen is an essential plant nutrient. It is the nutrient that is most commonly deficient in Ethiopian soils, contributing to reduced yields of crops in the country. Pigeon pea is a drought-tolerant leguminous crop with vast potentials for cultivation for food, feed, fuel wood and as soil-ameliorant (Egbe, 2005; 2007). (Odeny, 2007).Egbe (2005, 2007) had documented that pigeon pea fixe approximately between 37.52 – 164.82 kg/ha under intercropping with sorghum. It has also been reported that long duration pigeon pea is one legume which has considerable potential to improve soil fertility when grown as an intercrop (Hardy, 1998).

Biological nitrogen fixation has become very important not only because of its reduction of energy costs but also in seeking more sustainable way of crop production (Montanez, 2000).Also, the benefits of improving legume N fixation include reduced reliance on soil N, leading to more sustainable agricultural systems and reduced requirements for fertilizer N, enhanced residual benefits to subsequent crops, and increased legume crop yields (Herridge et al., 2004). The main goal of this study is to enhance soil nutrients through sustainable way, improve soil fertility and the productivity of the intercropping systems with consequent enhancement of food security of the region. Not only for nitrogen fixing but also Cajuns cajan can be used as forage in Dire Dawa administration and Harari regional state. In this area, farmers didn't accept drought tolerant malkam sorghum variety even though it is very promising crop for the area, because of it's small harvests of total biomass. Thus why, this system/ practice can compensate/ solve the problem of low availability of forage for livestock in this low land area. For this sake, this activity is designed with the following objectives. To quantify amount of soil nutrient (N) obtained deuto intercropping of Cajuns Cajuns, To improve soil fertility and increase production and productivity of the crop and land respectively and To identify economic feasibility of Cajuns cajan intercropping arrangement and recommend the best economic and sustainable intercropping arrangement.

MATERIAL AND METHODS

Description of Study area

The agro-climatic condition of the area is semi-arid, arid. The annual maximum and minimum temperatures are 26 and 20^0C, respectively. There is a short rainy season that lasts for about one and a half months and a long rainy season that lasts for more than two months.

Even though, the rainfall pattern is not easily predictable and has shown yearly fluctuations. Due to the rainfall pattern, the woreda is considered food insecure. Though the area is moderately productive for agriculture, soil degradation, erratic rainfall and farmland fragmentation contribute to lowered productivity in the area. The woreda suffers from a food deficit every year.

The experiment was conducted at Babille district, Erer research station. Erer research sub site is located latitude of 09° 10' 41.5" north and longitude of 042° 15' 27.3" east, and the area is in the vicinity of extreme lowlands in the range of altitude of 1200 - 1300 meter above sea level. The area characterized by very short rainy season of 3 to 4 months (single quarter of the year), with alits intermittent condition and erratic distribution. The mean annual temperature was 24°C the soil is clay loam in texture and medium in organic matter content and high in exchangeable potassium.

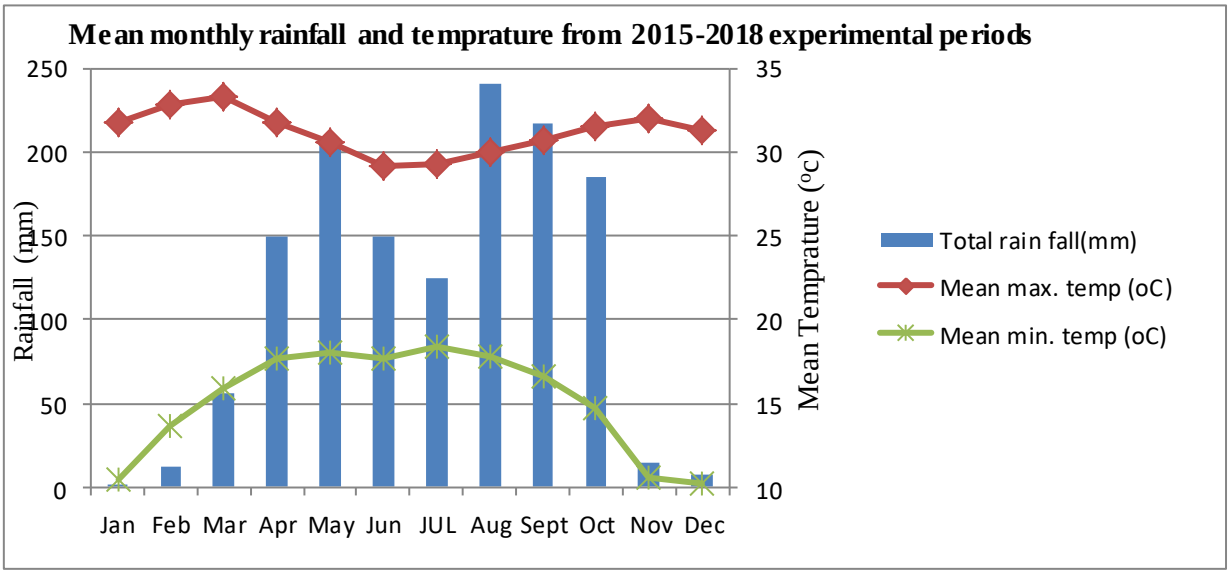
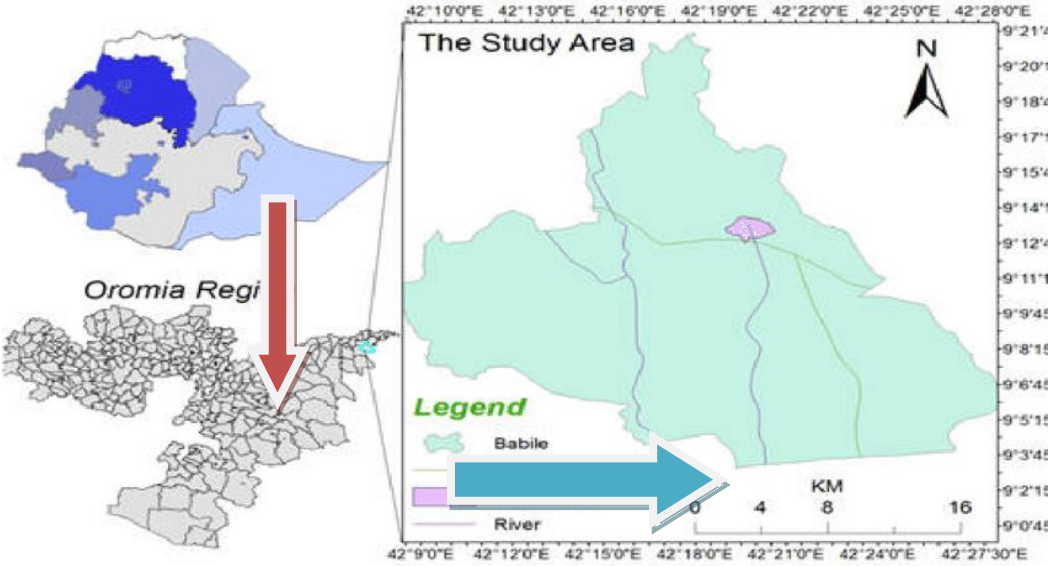


Figure 1.Mean monthly rainfall and temperature during experimental period of Erer, based on 2015-2018 meteorological data at Fadis Agricultural Research Center.



Figure

Fig 2. Map representing the study area (Babille district)

Experiment: Pigeon pea/sorghum Intercropping.
Treatments
T1. Sole sorghum (Bran / malkam variety)
T2. Sorghum +pigeon pea (Accession 16520)
T3. Sorghum intercropped with pigeon pea (Accession 16527)
T4 sorghum intercropped with pigeon pea (Accession 16528)
T5 pigeon pea 16520
T6. Pigeon pea (Accession 16527)
T7. (Accession 16528).

The experiment was laid out in randomized complete block design with three replications. Cropping systems at two levels [sole cropping (pigeon pea, sorghum) and intercropping (pigeon pea + sorghum, malkam variety) was constitute the main plot treatments. The sorghum varieties was the early maturing malkam variety. The gross plot was comprise of 3 ridges and 4 m long (12 m^2), while the net plot was made up of the middle ridge (4 m^2). Pigeon pea was planted at a spacing of 1 m x 0.5m with three seeds per hole and later thinned to two plants/stand (66,666 plants /ha),while the sorghum was planted at a spacing of 0.75 m x 0.25 m with three seeds per hole and later thinned to one plants/stand (40,000 plants/ha). The same population of pigeon pea and sorghum was maintained in both intercrop and sole crop treatments. Intercropping will have a 1:1 (pigeon pea: sorghum) row proportion. In the intercrop treatments, both pigeon pea and sorghum will be planted on the same ridge. Pigeon pea will occupy the crest of the ridge, while sorghum will be planted on the side. All plots will receive a basal application of 100 kg of NPS.

Data Analysis

The collected Data was analyzed using GENSTAT Release 18th, following standard analysis of variance procedures and least significant difference (LSD) test at 5% probability level was used to compare the treatment means.

Result and Discussion

Table 1.Effects peageon pea intercropping on yield and yield components at Erer.

No	Treatments	Plant height in m	Panicle length(cm)	Panicle diameter(cm)	BiomassYkg /ha_	Grain yield kg/ha
1	T1	100.2b	23b	5.467b	9806	2339
2	T2	120.4a	24.67ab	6.467a	11141	2856
3	**T3**	**123.1a**	**27.07a**	**6.533a**	**11412**	**2894**
4	T4	114.2ab	24.07b	6.2a	12638	2667
l.s.d.		15.81	2.698	0.6889	3814.1	962.8
cv%		6.9	5.5	5.6	17	17.9

Plant height, panicle length and panicle diameter

The experiment shows significant difference in terms of plant height, panicle length, and panicle diameter at 5%. The highest plant height was obtained at the treatment, sorghum intercropped with pigeon pea accession 16527(tsegab variety).

Grain yield (kg/ha)

The result that obtained was statistically not significant in terms of grain yield ($p < 0.01$) among treatments (both sole and intercropped one). In (Table 1) was indicated that intercropping of pigeon pea Accessions had no negative significant effect on grain yields of sorghum. The maximum grain yields were obtained from T3 (sorghumX16527 pigeon pea accession); (2894) kg ha^{-1}), followed byT2 (16527pegeon pea accession) (2856) kg ha^{-1} respectively. The minimum grain yield obtained from T1 (2339 kg ha^{-1}). The most probable reason for this variation could be due to leguminous nature of pigeon pea accessions that add nitrogen nutrients to the soil and affect sorghum positively. However, sorghum grain yield was not affected negatively by intercropping statistically due to compatible crops and not an interspecific competition among sorghum and pigeon pea . This result not agreed with result that was reported by Berhane (2016) intercropping of sorghum-cowpea was reduced the grain yield of sorghum; intercropped with 100% sole cowpea plant density and further, cropping system sole sorghum exceeded by 43.54% of the intercropped sorghum yield. The result variation was might be the density, environmental factors and season statistically, there is no significant difference among the treatment in terms of grain yield. But there is variation when observed, in mean using graphs.

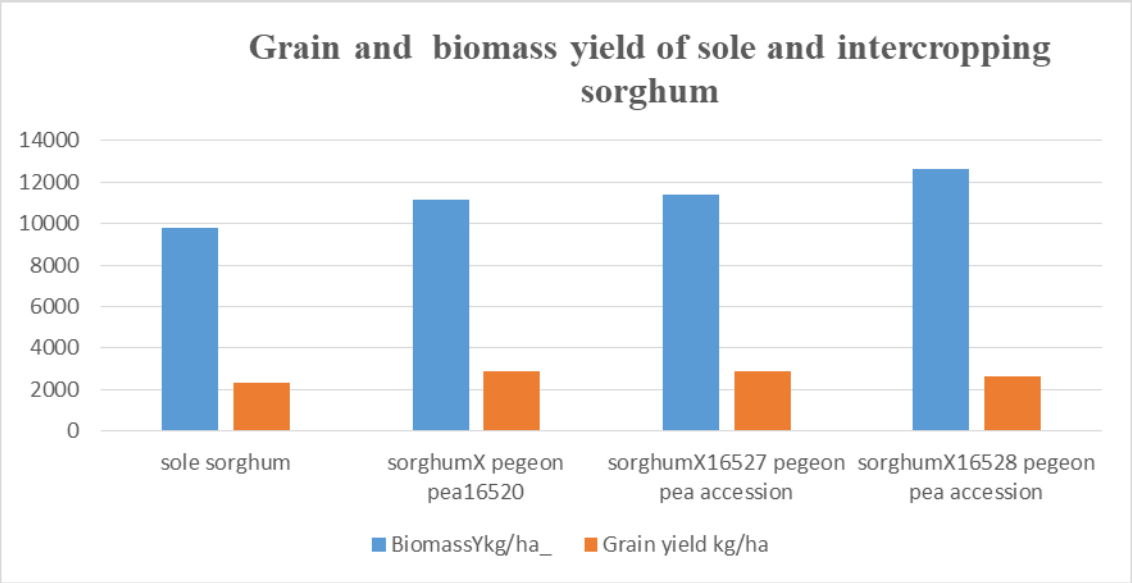


Fig 1. Graphical comparison of both grain and biomass yield of sole and intercropped sorghum.

Land equivalent ration

Land equivalent ratio was greater than 1 which was (1.22) thus why this intercropped experiment is advantageous.

$$LER = (Yab/Yaa) + (Yba/Ybb).$$

Where Yaa and Ybb were yields as sole crops of sorghum and
Yab and Yba were yields as intercrops of sorghum and pigeon pea. Land equivalent coefficient (LEC), is a measure of interaction concerned with the Strength of relationship was collected calculated thus,

LEC = Lax L.b Where, La= LER of main crop and Lb. which was 0.5
= LER of intercrop (Adetiloye et al., 1983).For a two-crop mixture the minimum expected productivity coefficient (PC) is 25%, i.e. a yield advantage was obtained because LEC value exceeds 0.25. Total plant biomass was used to calculate both LER and LEC.

Relative Yield Total (RYT): it was used for intercropping using the equation of RYG= DMYGL/ DMYGG and RYL = DMYLG / DMYLL, Where: DMYGG was dry matter yield of sorghum (G) as a sole crop, DMYLL was dry matter yield of legume (L) as a sole crop, DMYGL the dry matter yields of sorghum/pigeon pea intercropping.

CONCLUSION AND RECOMMENDATION

Globally pigeon pea (Cajanus Cajan (L.) Millsp) is the fifth most important pulse crop mainly grown in the developing countries by resource-poor farmers in drought prone areas and on degraded soils. It is a multipurpose leguminous crop that can provide food, forage, fuel wood and fodder for the small-scale farmer in subsistence agriculture (Egbe, 2005).

The design of the experiment was, RCBD with three replication. The experiment shows significant difference statistically, in terms of plant height, panicle length, and panicle diameter at 5 %(table 1). The highest plant height was obtained from the treatment with

sorghum intercropped with pigeon pea accession 16527(tsegab variety). The result that obtained was statistically not significant interms of grain yield ($p < 0.01$) among treatments (both sole and intercropped one). In (Table 1) was indicated that intercropping of pigeon pea Accessions (variety) had no negative significant effect on grain yields of sorghum. The maximum grain yields were obtained from T3 (sorghumX16527 or pigeon pea tsegab variety); (2894) kg ha^{-1}), followed byT2 (16527pegeon pea accession) (2856) kg ha^{-1} respectively. The minimum grain yield obtained from sole sorghum (2339 kg ha^{-1}).

RECOMMENDATION

Farmers of dry lands in general Erer PA specifically should use , sorghum pigeon pea intercropping system than sole sorghum. Farmers can be benefitted when they apply intercropping system than producing sorghum alone or mono cropping. Research extension, Office of agriculture and natural resource and other NGO's should create awareness for farmers on sorghum intercropping with pigeon pea tsegab variety.

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Integrated Effects of Vermi-Compost and NPS Fertilizer Rates on Soil Chemical Properties and Maize Production in Bedele District, Western Oromia

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ABSTRACT

Integrated plant nutrient management is the application of inorganic fertilizer in combination with organic fertilizer to maintain soil fertility and balance nutrient supply in order to boost up the crop yield per unit area. A study was conducted in Bedele district on farmers' fields to find out the combined effects of vermi-compost(organic fertilizer) and NPS (inorganic fertilizer) rates on soil chemical properties and maize production. The treatments consisted of three levels of vermi-compost (0, 1.5 and 3 t ha^{-1}) and three levels of NPS fertilizer (0, 100 and 200 kg ha^{-1}). The experiment was laid out in RCBD design in factorial combination with three replications. Laboratory analysis results of composite soil samples collected before sowing showed deficiency in soil chemical properties. However, analysis of variance of postharvest composite soil samples collected from each plot indicated significant differences on soilavailable P, OC, TN and CEC while, soil pH and exchangeable acidity showed positive increment as compared to initial one. The analysis of variance among the treatments showed significant differences ($P \leq 0.05$) on almost all the maize agronomic data tested. The highest and lowest maize grain yield (7932.1 kg ha^{-1})and (1944.4 kg ha^{-1}were obtained from thetreatment combination of 3 t ha^{1} vermi-compost with 200 kg ha^{-1} NPS and 92 kg ha^{-1} N, and control plot, respectively. However this combination was statically at par with the treatment combination of 1.5 t ha^{1} vermi-compost with 200 kg ha^{-1} NPS and 92 kg ha^{-1} N, which gave maize grain yield (7577.2 kg ha^{-1}). Therefore, the present study showed that combined fertilization of vermi-compost and NPS fertilizer enhanced maize productivity and soil fertility status in the study area; indicated that maize productivity in the study sites were reduced due to high demand for external nutrient inputs. Hence combined fertilization of 1.5 t ha^{1} vermi-compost with 200 kg ha^{-1}NPS and 92 kg ha^{-1} N could improve maize productivity and soil chemical properties, andrecommended for the study area (Bedele district) and similar agro-ecology. 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.

Keywords: Cation exchange capacity, Soil Organic Carbon, soil pH, Total Nitrogen, Vermi-compost

INTRODUCTION

The loss of soil fertility from continual nutrient mining by crop removal without adequate replenishment, combined with imbalanced plant nutrition practices, has posed a serious threat to agricultural production (FAO, 2006). Continuous cultivation of soils for many years without replenishing the nutrients mined has negatively affected fertility and availability of nutrients. (Mokwunye,1996) also stated that cultivated weathered soils commonly suffer from

multiple nutrient deficiencies, and nutrient balances are generally negative. 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 etal., 2001, Matano etal, 2015). Moreover, the shortage of land for production of food crops has eliminated the practice of fallowing and crop rotation. Furthermore, shortage of grasslands (grazing areas) has forced the farmers to remove crop residues for animal feed. These lead to agricultural soil degradation with detrimental effects on the physical, chemical and biological properties of soils (Rivero etal, 2004)

Soil fertility and functioning must be restored to provide sustainable farming systems. As alternative, solutions for increasing soil organic matter have been proposed. (Bationo et al. 1998; Badiane et al.2000) recommended regular inputs of organic amendments to soil while other authors advocated the use of improved fallows to restore organic matter to soil (Dominguez, 2004; Arancon and Edwards, 2005). These agricultural management methods are known to enhance the stock of soil carbon (Ndegwa and Thompson, 2001). It is well established that organic matter plays a central role in maintaining key soil functions and is an essential determinant of soil fertility and resistance to erosion. Several authors have found that organic inputs increase soil microbial biomass (Walkley and Black, 1934; Tognetti etal, 2005) and enzyme activities (Masto etal, 2006; Koné et al, 2012) and enhance microbial activity (Hungria et al, 2009). The application of organic amendments can, therefore, affect the activity, structure, diversity and function of soil microorganisms, which play a key role in soil processes to a greater extent.

Vermi-compost is the recently organic fertilizer in supplementing chemical fertilizers for sustainable development of agriculture (Gupta, 2003). It is produced through the interaction between earthworm and microorganism by the breakdown of organic wastes. It is a stabilized, finely-divided peat-like material with a low C: N ratio and high water holding capacity that constitute a source of plant nutrition which is released gradually through mineralization whenever the plant needs it (Mathivanan et al., 2012).It is a material that characterized by high porosity, aeration, drainage, water holding capacity and microbial activity (Atiyeh et al., 2000). Vermi-compost can influence the growth and productivity of plants significantly (Edward, 1998). It increases soil organic carbon, nitrates, phosphates, exchangeable calcium and some other nutrients for plants (Orozco et al., 1996). It increases soil Cation Exchange Capacity (CEC) and crop yield (Marinari et al., 2000). The available nutrient status of soil was greatly enhanced by the application of vermi-compost as an organic source (Prabha et al., 2007). Vermi-compost enhanced phosphorous concentration and uptake in soil, increasing the solubilisation of phosphorous either by microorganism activation with excretion of organic acids likes citric, glutamic, tartaric, succinic, lactic, oxalic, malic and fumaric (Sainz et al., 1998). It can improve physical, chemical and biological and processes of soil which have their bearings on plant's growth.(Goutam et al, 2011).

On the other hand, inorganic fertilizers overcome soilfertility problems and responsible for increasing large partof worlds 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). 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). This implies that using chemical fertilizer plays significant role in increasing food production to meet the demand of the growing world population. Similarly, Vermi-compost is increasingly considered in agriculture as a promising alternative to chemical fertilizers. However, the effects of vermi-compost either alone or integrated with chemical fertilizers, on the crop productivity is not yet fully understood. Therefore, integrated plant nutrients management can lessen this problem and can be suitable for any farming system and socio-economic conditions (Lamps, 2000). Integrated plant nutrient management is the application of inorganic fertilizer in combination with organic fertilizer to maintain soil fertility and to balance nutrient supply in order to boost up the crop yield per unit area (Aulakh et al., 2008; Mahajan et al., 2008; Roberts, 2010).

Moreover, Ethiopia has realized that agricultural soils commonly suffer from multiple nutrient deficiencies, and nutrient balances are generally negative, and an effort has been made to increase soil fertility status; among which vermi-compost (organic fertilizer) is one of it. Similarly vermi-worms are distributed to local farmers' and they started producing vermi-compost.However, in the study area there is no information on the combined use of vermi-compost and chemical fertilizer for maize production. Therefore, the objective of the study was to find out the combined effects of vermi-compost (organic fertilizer) and NPS (inorganic fertilizer) rates on soil chemical properties and maize production in Bedele district.

MATERIALS AND METHOD

Description of the Study Area

The study was conducted on three farmers' fields inBedele district of Buno Bedele zone in 2019 main cropping season. Bedele district is located at 08°14’28.6”to 08°37’52.8”N and 036 ^{o}13’22.0” to 036 ^{o}35’09.1” E (Fig 1). The 18 years weather information at nearby study area (Ethiopian Metrology Agency Bedele District Branch) indicated that a uni-modal rainfall pattern with average annual rain fall of 1945 mm. The rainy season covers April to October and the maximum rainfall is received in the months of June, July and August. The minimum and maximumannual 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)

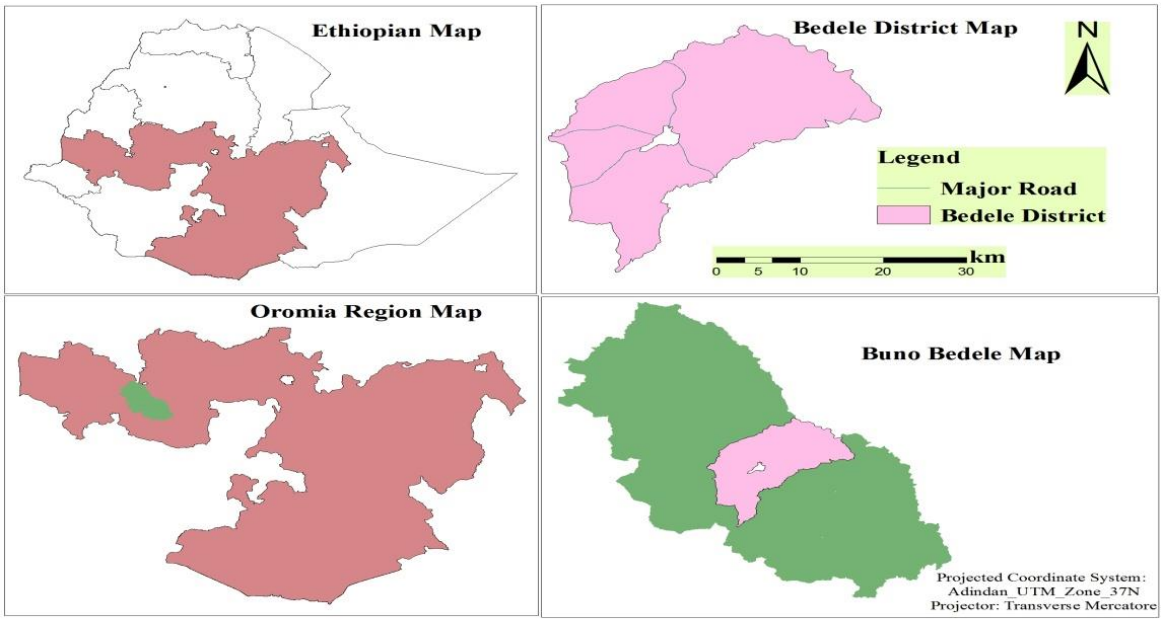

Figure 1. Map of the Study Area(Bedele district)

Soil Sampling and Analysis

Composite surface soil samples (0-20) cm depth was collected from each experimental sites before sowing and intensive soil samples were collected from each experimental plot after harvest to analyze soil pH (H_2O), exchangeable acidity, available P (Olsen), (OC %), (TN %), and CEC. The collected soil samples were prepared and analyzed following standard laboratory procedures at soil analysis laboratory of, Bedele Agricultural Research Center.

Treatments, Experimental Design and Procedures

The treatments consisted of three levels of vermi-compost (0, 1.5 and 3 t ha^{-1}) and three levels of NPS fertilizer (0, 100 and 200 kg ha^{-1}) were arranged in randomized complete block design (RCBD) in a factorial combination with three replications. The total number of treatment were nine. The gross plot size was 12m^2 (3m x 4m)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 in the District, that was planted in rows with spacing of 80 cm between rows and 25 cm among plants within a row. 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 soilpHless than 5.5, and the amount of lime needed per hectare was calculated based on the formula LR = Ex.acidity*1.5*10 kun ha^{-1}.Full dose of vermi-compost and 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 and grain yields were collected 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.

RESULTS AND DISCUSSION

Effects of Vermi-Compost and NPS Fertilizer Rates on Soil pH, Exchangeable Acidity, Available P, OC, TN, and CEC Status After Maize Harvest.

Post-harvest soil pH, exchangeable acidity, available P, OC , TN, and CEC are presented in (Table 1.). The results indicate that there was no significant ($P < 0.05$) difference in soil pH and exchangeable acidity among the different vermi-compost and NPS fertilizer rates. The treatments were statistically similar, however, the greatest positive pH changes (5.20) from the initial pH of 4.90 were recorded with the vermi-compost treatment at 3 tha^{-1} and no NPS fertilizer. The lowest negative pH changes from the initial soil pH were recorded with the control treatment which gave pH values of 4.91.Whereas, exchangeable acidity decreased (improved) from 0.95 to 0.27 at 1.5 t ha^{-1} vermi-compost and 100$kgha^{-1}$NPS fertilizer. The status of soil pH and exchangeable acidity was improved in this study that indicated addition of lime to the experimental sites and Vermi-compost treatments were effective in increasing soil pH, which realized that soil pH is considered a master variable in soils as it controls many chemical processes that take place. It specifically affects plant nutrient availability by controlling the chemical forms of the nutrients.

The results also indicate that there were significant ($P < 0.05$) difference in soil available P, OC , TN, and CEC. The status of soil available P after harvest was greatly enhanced as compared to initial P before sowing (Table 1), indicated that Vermi-compost enhanced phosphorous concentration and uptake in soil, increasing the solubilisation of phosphorous either by microorganism activation with excretion of organic acids likes citric, glutamic, tartaric, succinic, lactic, oxalic, malic and fumaric (Sainz et al., 1998). Plants only absorb approximately 20–30% of P in applied fertilizers each year (Syers et al. 2008). In general a small proportion of applied P is immediately taken up by the plants and the remaining P accumulates in the soil, which is potentially available for uptake by crops in subsequent years. Vermi-compost increases soil organic carbon, nitrates, phosphates, exchangeable calcium and some other nutrients for plants (Orozco et al., 1996). Vermi-compostincreases soil Cation Exchange Capacity (CEC) and crop yield (Marinari et al., 2000).Cation exchange capacity is highly correlated with organic carbon (OC) content of the soil,which is in turn, is affected by different soil management practices such as intensive cultivation, fertilization, and changes in land use (Gao and Chang, 1996). Cation exchange capacity increases with increasing soil OM (Saikh et al., 1998).It is strongly affected by the nature and amount of mineral and organic colloids present in the soil. Thus, CEC measurements are commonly made as part of the overall assessment of the potential fertility of a soil, and possible response to fertilizer application (Landon, 1991).In conclusion the available nutrient status of soil was greatly enhanced by the application of vermi-compost as an organic source (Prabha et al., 2007).

Table1. Effects of vermi-compost and NPS fertilizer rates on soil chemical properties after maize harvest

Treatments		Soil properties					
V. Com (ton/ha)	NPS (kg/ha)	pH (H2O)	Ex.acid meq/100gsoil)	Pav (ppm)	OC %	TN %	CEC (cmol(+) /kg soil)
0	0	4.91^{a}	0.40^{a}	2.00^{bc}	3.02^{c}	0.26^{c}	12.33^{bc}
1.5	0	5.00^{a}	0.40^{a}	3.20^{a}	3.53^{bc}	0.30^{bc}	15.96^{ab}
3	0	5.20^{a}	0.30^{a}	2.13^{abc}	3.36^{c}	0.26^{c}	17.46^{a}
0	100	5.17^{a}	0.30^{a}	3.00^{ab}	3.06^{c}	0.26^{c}	14.53^{abc}
1.5	100	5.17^{a}	0.27^{a}	2.01^{bc}	3.30^{c}	0.30^{bc}	14.46^{abc}
3	100	5.13^{a}	0.40^{a}	2.00^{bc}	4.13^{ab}	0.36^{ab}	14.70^{ab}
0	200	5.10^{a}	0.37^{a}	2.87^{abc}	3.26^{c}	0.30^{bc}	17.03^{a}
1.5	200	5.13^{a}	0.40^{a}	2.40^{abc}	3.66^{bc}	0.33^{abc}	12.50^{bc}
3	200	5.17^{a}	0.33^{a}	1.80^{c}	4.60^{a}	0.40^{a}	10.76^{c}
Mean		5.11	0.35	2.38	3.54	0.31	14.41
CV (%)		2.36	44.9	27.36	11.13	14.17	15.35
LSD		ns	ns	1.12	0.68	0.07	3.83
Initial (before sowing)		4.90	0.95	1.82	3.12	0.25	14.20

Where, means followed by the same letters in each column are not significantly different at (P≤0.05), V.com= Vermi-compost, CV= Coefficient of Variation, LSD= Least Significant Difference,Pav.=Available Phosphorus, OC=Organic Carbon, TN= Total Nitrogen, ppm=Part per million, Ex.acid= Exchangeable acidity, CEC = Cation Exchange Capacity, Ca= Calcium, t= ton,

Mean Days to Tassling of Maize (BH 661) Under the Efect of Vermi-Compost and NPS Fertilizer Rates

The analysis of variance for days to tassling revealed significant variation due to main effect ofNPS fertilizer rates. However, application of vermi-compost rates did not show significant effect on days to tassling (Table 2) .Vermi-compost can influence the growth and productivity of plants (Edward, 1998). Concerning interaction effect of vermi-compost and NPS, the highestdays to tasslingof 92.3 days was obtained with the un fertilized treatment, whereas the lowest (88.2 days) was obtained with the combination of 1.5 t ha^{-1} vermi-compost and 200 kg ha^{-1} NPS (Table 2).

Table 2.Mean days to tassling of maize (BH 661) under the effect of vermi-compost and NPS fertilizer rates.

	VC (t ha^{-1})			
NPS (kg ha^{-1})	0	1,5	3	Mean
		Days to tassling (days)		
0	92.3^{a}	91.5^{ab}	91.6^{ab}	91.8^{a}
100	89.8^{abc}	89.2^{bc}	89.0^{bc}	89.4^{b}
200	89.4^{bc}	88.2^{c}	89.2^{c}	88.9^{b}
Mean	90.6^{a}	89.7^{a}	89.9^{a}	
CV(%)	3.3			
LSDforNPS	1.6			
LSD for VC	1.6			
LSDforNPS * VC	2.7			

Where, means followed by the same letters are not significantly different at (P≤0.05), VC =vermi-compost, t=ton, ha=hectare, NPS= (nitrogen, phosphorus, sulfur), kg=kilogram, DH = days to headings, CV= Coefficient of variation, LSD= Least significant differences.

Mean Biomass Yield of Maize Under the Effect of Vermi-Compost and NPS Fertilizer Rates

Biomass yieldwas significantly ($P \leq 0.05$) affected both by the main effects and the interaction between these factors (Table 3)**.**This might be due to adequate quantities and balanced proportions of plant nutrients in vermi-compost supplied to the crop as per its need during the growth period resulting in favorable increase in yield attributing characters (Devi et al., 2011) The effect of NPS fertilization on maize biomass yield was found to be significant (Table 3).The biomass yield was increased consistently with NPS rates where the maximum biomass yield (23366.8 kg ha^{-1}) was obtained from the application of the highest NPS rate (200 kg ha^{-1} NPS) followed by 16386.3 kg ha^{-1} which was obtained from 100 kg ha^{-1} NPS and the minimum (9940.8 kg ha^{-1}) was from the control plot (Table 3)

Generally, biomass yieldincreased with increasing application rates of both vermi-compost and NPS fertilizer and decreased with the application of the minimum rates of these nutrient sources. Vermi-compost can influence the growth and productivity of plants significantly (Edward, 1998). Moreover, the interaction effect of these factors also revealed that the combinations of higher rates of both the organic and inorganic nutrient sources gave significantly higher biomass yield of maize**.** This indicated that, vermi-compost plays a major role in improving growth and yield of different field crops, vegetables, flowers and fruits (Lekshmanaswamy, 2014).

Table 3.Mean biomass yield of maize under the effect of vermi-compost and NPS fertilizer rates.

	VC (t ha^{-1})			
NPS	0	1,5	3	Mean
(kg ha^{-1})		Bio mass yield(kg ha^{-1})		
0	7261^{e}	10664^{d}	11898^{d}	9940.8^{c}
100	16435^{c}	15756^{c}	16968^{c}	16386.3^{b}
200	20957^{b}	22840^{b}	26304^{a}	23366.8^{a}
Mean	14884.3^{b}	16419.8^{b}	18389.9^{a}	
CV(%)	21.2			
LSDforNPS	1910.7			
LSD for VC	1910.7			
LSDforNPS * VC	3309.5			

Where, means followed by the same letters are not significantly different at ($P \leq 0.05$), VC =vermi-compost, t=ton, ha=hectare, NPS= (nitrogen, phosphorus, sulfur), kg=kilogram, DH = days to headings, CV= Coefficient of variation, LSD= Least significant differences.

Mean Grain Yield of Maize Under the Effect of Vermi-Compost and NPS Fertilizer Rates

Table 4 presents the means of maize grain yield as influenced by different rates of NPS and vermi-compost application. The analysis of variance indicated significant ($P<0.05$) grain yield differences due to the application of vermi-compost, NPS and their interactions. Vermi-compost is the recently organic fertilizer in supplementing chemical fertilizers for sustainable

development of agriculture (Gupta, 2003).Increasing NPS levels from 0 to 200 kg ha^{-1} NPS showed linear and consistent yield increment. The average maize grain yield for the NPS treatments ranged from 2649.2 to 7443.4 kg ha^{-1} NPS with a yield increment of 26 to 74% over the control treatment, respectively. Increasing vermi-compost rate. didn't show significant grainyield differences except for control(Table 4).

Concerning the interaction effect of vermi-compost and NPS, the highest grain yield of 7932.1 kg ha^{-1} was obtained with the combination of 3 t ha^{-1} vermi-compost and 200 kg ha^{-1}, NPS however statically at par with 1.5 t ha^{-1} vermi-compost and 200 kg ha^{-1} NPS. The lowest (1944.4 kg ha^{-1}) was obtained with the un fertilized treatment (Table 4).The highest yield for the interaction effect could be due tovermi-compost promotes better root growth, nutrient absorption and improves nutrient status of soil, both macro-nutrients and micro-nutrients (Lazcanoand Dominguez, J. ,2010). The growth and nutrient status of crops have revealed a positive effect on plant nutrition, photosynthesis, chlorophyll content and nutrient content of different plant components namely roots, shoots and fruits (Theunissen et al. 2010). In conclusion Vermi-compost is the recently organic fertilizer in supplementing chemical fertilizers for sustainable development of agriculture.

Table 4. Mean grain yield of maize under the effect of vermi-compost and NPS fertilizer rates..

	VC (t ha^{-1})			
NPS	0	1,5	3	Mean
(kg ha^{-1})		Grain yield(kg ha^{-1})		
0	1944.4^{e}	2762.3^{de}	3240.7^{d}	2649.2^{c}
100	4753.1^{c}	5108.0^{c}	5416.7^{c}	5092.6^{b}
200	6821.0^{b}	7577.2^{ab}	7932.1^{a}	7443.4^{a}
Mean	4506.2^{b}	5149.2^{a}	5529.8^{a}	
CV(%)	21.4			
LSDforNPS	587.8			
LSD for VC	587.8			
LSDforNPS * VC	1018.2			

Where, means followed by the same letters are not significantly different at ($P \leq 0.05$), VC =vermi-compost, t=ton, ha=hectare, NPS= (nitrogen, phosphorus, sulfur), kg=kilogram, DH = days to headings, CV= Coefficient of variation, LSD= Least significant differences

CONCLUSION AND RECOMMENDATION

Integrated nutrient management for crop production requires that quantitative information on all nutrient sources be made available. Organic fertilizers maintains soil health, improves soil nutrient exchange and it typically mineralized within only a few cropping seasons to obtain a sustainable and stable increase in yield while, the inorganicfertilizer is the immediate source for crop. One test to evaluate the effects of organic nutrient sources on soil fertility is obviously to measure yields over the long-term, because it takes years for the yield to consistently reflect improved soil fertility status. This presumably has been reflected on the soil parameters in the current study. Laboratoryanalysis results of soil samples collected before sowing showed deficiency in soil chemical properties. However, postharvest soil samples indicated that significantly difference and positive increment on soil fertility status

tested.. The analysis of variance among the treatments showed significant differences on maize characters tested. Accordingly, combined fertilization of vermi-compost and NPS fertilizer enhanced soil fertility status and 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 combined fertilization of 1.5 t ha^{1} vermi-compost with 200 kg NPS ha^{-1} fertilizer and 92 kg N ha^{-1} are recommended for maize production to the study area (Bedele district) and similar agro-ecology. 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 rate, time and method of combined application of vermi-compost and NPS fertilizer for major crops grown in this region.

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Integrated Effects of Vermi-Compost and NPS Fertilizer Rates on Soil Chemical Properties and Bread Wheat Production in Gechi District, Western Oromia

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ABSTRACT

Information on soil fertility status and crop response to different soil fertility management is very important to come up with sustainable crop production. A study was conducted in Gechi district on farmers' fields to find out the combined effects of vermi-compost (organic fertilizer) and NPS (inorganic fertilizer) rates on soil chemical properties and bread wheat production. The treatments consisted of three levels of vermi-compost (0, 1.5 and 3 t ha^{-1}) and three levels of NPS fertilizer (0, 100 and 200 kg ha^{-1}). The experiment was laid out in RCBD design in factorial combination with three replications, laboratory analysis results of composite soil samples collected before sowing showed deficiency in soil chemical properties. However, analysis of variance of postharvest composite soil samples collected from each plot indicated significant differences on soil pH, available P, OC, TN and CEC while, soil exchangeable acidity showed positive increment as compared to initial one. The analysis of variance among the treatments showed significant differences ($P \leq 0.05$) on almost all the bread wheat characters tested. The highest and lowest bread wheat grain yield (5722.2 kg ha^{-1}) and (750.0 kg ha^{-1}were obtained from thetreatment combination of 3 t ha^{1} vermi-compost with 200 kg ha^{-1} NPS and 92 kg ha^{-1} N, and control plot, respectively. Therefore, the present study showed that combined fertilization of vermi-compost and NPS fertilizer enhanced bread wheat productivity and soil fertility status in the study area; indicated that bread wheat productivity in the study sites were reduced due to high demand for external nutrient inputs. Hence combined fertilization of 3 t ha^{1} vermi-compost with 200 kg ha^{-1}NPS and 92 kg ha^{-1} N could improve crop productivity and soil chemical properties, andrecommended for the study area (Gechi district) and similar agro-ecology. 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.

Keywords: Cation exchange capacity, Soil organic carbon, soil pH, Total Nitrogen, Vermi-compost

INTRODUCTION

In Ethiopia, low soil fertility is one of the factors limiting the yield of crops, including wheat. Mbah (2006) indicated that soil fertility is a major overriding constraint that affects all aspects of crop production. 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). 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 etal., 2001, Matano etal, 2015). Moreover, the shortage of land for production of food crops has eliminated the practice of fallowing and crop rotation.. Furthermore, shortage of grasslands (grazing areas) has forced the farmers to remove crop residues for animal feed, which have led to a decrease in soil organic matter, a depletion of soil nutrients.

Soil fertility and functioning must be restored to provide sustainable farming systems.As alternative, solutions for increasing soil organic matter have been proposed. (Bationo et al. 1998; Badiane et al.2000) recommended regular inputs of organic amendments to soil. Long-term fertilization had a significant effect on soil organic Carbon, total Nitrogen content, total Phosphorus and pH. The highest values of soil organic Carbon, total Nitrogen content and total Phosphorus were recorded in soils amended with organic manure (Chu et al. 2007;Liu et al. 2010). Organic matter is an imperative indicator of soil fertility (Rahman et al., 2007) by improves soil structure, nutrient exchange and maintains soil physical conditions (Becker et al., 1995; Ayoub, 1990). It also reduces the level of carbon dioxide in the atmosphere that contributes positively to climate change (Anon et al., 2003).

Vermi-compost is the recently organic fertilizer in supplementing chemical fertilizers for sustainable development of agriculture (Gupta, 2003). It is a material that characterized by high porosity, aeration, drainage, water holding capacity and microbial activity (Atiyeh et al., 2000).It increase soil organic carbon, nitrates, phosphates, exchangeable calcium and some other nutrients for plants (Orozco et al., 1996). It can improve physical, chemical and biological processes of soil which have their bearings on plant’s growth. Goutam et al. 2011). Use of organic fertilizers improves soil structure, nutrient exchange, and maintains soil health and has raised interest in organic farming (Khan et al., 2010). Other studies indicated that organic fertilizer typically mineralized within only a few cropping seasons to obtain a sustainable and stable increase in yield (Molina et al., 2014).

On the other hand, inorganic fertilizers overcome soilfertility problems and responsible for increasing large partof 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). 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). This implies that using chemical fertilizer plays significant role in increasing food production to meet the demand of the growing world population. Similarly, Vermi-compost is increasingly considered in agriculture as a promising alternative to chemical fertilizers. However, the effects of vermicompost either alone or integrated with chemical fertilizers, on the crop productivity is not yet fully understood.

Integrated plant nutrients management can lessen this problem and can be suitable for any farming system and socio-economic conditions (Lamps, 2000). Integrated plant nutrient management is the application of inorganic fertilizer in combination with organic fertilizer to maintain soil fertility and to balance nutrient supply in order to boost up the crop yield per

unit area (Aulakh et al., 2008; Mahajan et al., 2008; Roberts, 2010). However, in the study area; there is no information on the combined use of vermi-compost and chemical fertilizer for bread wheat production. Therefore, the objective of the study was to find out the effects of vermi-compost (organic fertilizer) and NPS (inorganic fertilizer) rates on soil chemical properties, bread wheat yield and yield components in Gechi district.

MATERIALS AND METHOD

Description of the Study Areas

The study was conducted on three farmers' fields inGechi district of Buno Bedele zone in 2019 main cropping season, Gechi district is located at 08°24’40.0”to 08°25’12.0”N and 036 ^{o}25’61.0” to 036 ^{o}33’20.0” E with altitude ranging from 1013 to 2390 masl (Fig 1). 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 season covers April to October and the maximum rainfall is received in the months of June, July and August. The minimum and maximumannual 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)

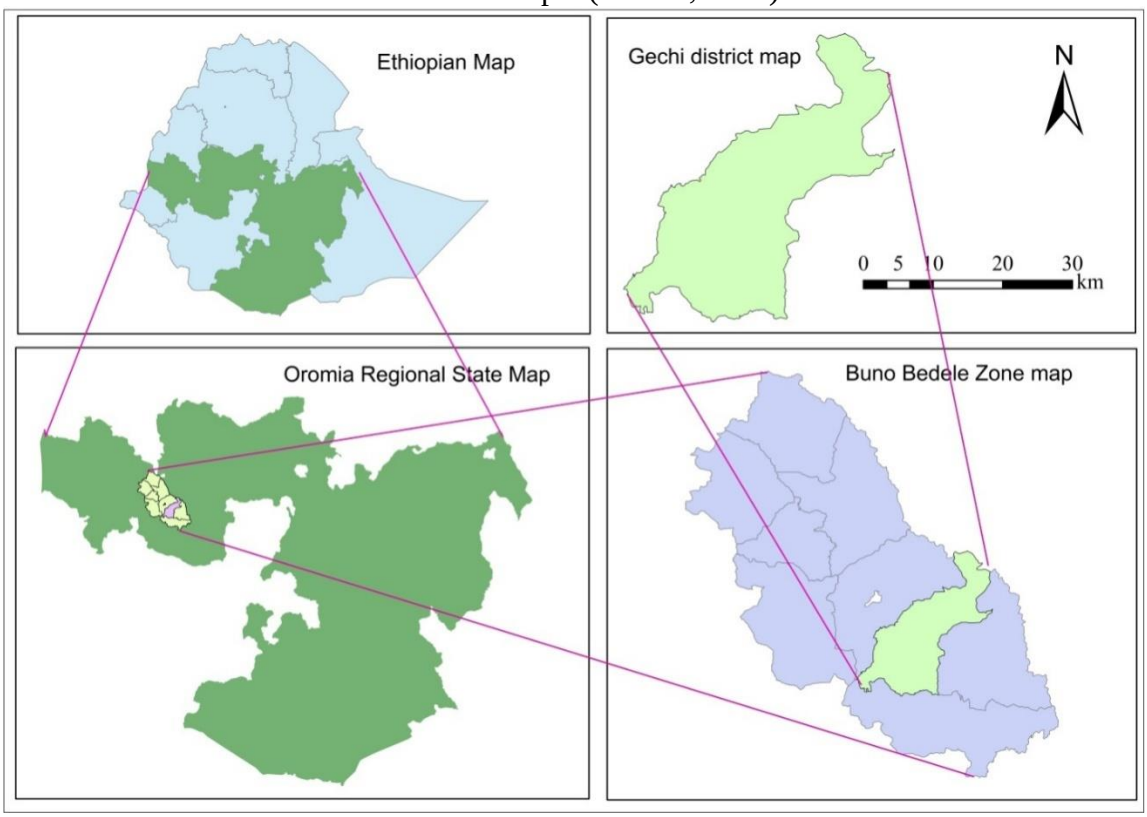

Figure 1. Map of the Study Area(Gechi district)

Soil Sampling and Analysis

Composite surface soil samples (0-20) cm depth was collected from each experimental sites before sowing and intensive soil samples were collected from each experimental plot after harvest to analyze soil pH (H_2O), exchangeable acidity, available P (Olsen), (OC %), (TN %), and CEC. The collected soil samples were prepared and analyzed following standard laboratory procedures at soil analysis laboratory of Bedele Agricultural Research Center.

Treatments, Experimental Design and Procedures

The treatments consisted of three levels of vermi-compost (0, 1.5 and 3 t ha^{-1}) and three levels of NPS fertilizer (0, 100 and 200 kg ha^{-1}) were arranged in randomized complete block design (RCBD) in a factorial combination with three replications. The total number of treatment were nine. The gross plot size was $12m^2$ (3m x 4m). Liban bread wheat varietywhich is high yielder as compared to other improved bread wheat varieties in the study areas was used as a test crop with seed rate 150 $kgha^{-1}$ 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 soilpHless than 5.5, and the amount of lime needed per hectare was calculated based on the formula LR = Ex.acidity*1.5*10 kun ha^{-1}.Full dose of vermi-compost and 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% heading, biomass and grain yields data were collected.. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD..

RESULTS AND DISCUSSION

Effects of Vermi-Compost and NPS Fertilizer Rates on Soil Chemical Properties After Bread Wheat Harvest

Postharvest soil pH, exchangeable acidity, available P, OC, TN and CEC are presented in (Table 1). The results indicate that there were no significant ($P < 0.05$) difference in soil pH and exchangeable acidity among the different treatments. The treatments were statistically similar, however, the greatest positive pH (5.10) changes from initial pH of 4.88 were recorded at the treatments combination of 3.0 tha^{-1} vermi-compostand no NPS fertilizer,. The lowest negative pH changes from the initial soil pH were recorded with the control treatment which gave pH values of 4.85**.** Whereas, exchangeable acidity decreased (improved) from 1.05 to 0.47 at 1.5 tha^{-1} vermi-compost and 100$kgha^{-1}$NPS fertilizer. The status of soil pH and exchangeable acidity was improved in this study which indicated that addition of lime to the experimental sites and Vermi-compost treatments were effective in increasing soil pH, which realized that soil pH is considered a master variable in soils as it controls many chemical processes that take place. It specifically affects plant nutrient availability by controlling the chemical forms of the nutrients.

The results also indicate that there were significant ($P < 0.05$) difference in soil available P, OC , TN, and CEC. The status of soil available P after harvest was greatly enhanced as compared to initial P before sowing (Table1),indicated that Vermi-compost enhanced phosphorous concentration and uptake in soil, increasing the solubilisation of phosphorous either by microorganism activation with excretion of organic acids likes citric, glutamic, tartaric, succinic, lactic, oxalic, malic and fumaric (Sainz et al., 1998). Plants only absorb approximately 20–30% of P in applied fertilizers each year (Syers et al. 2008). In general a small proportion of applied P is immediately taken up by the plants and the remaining P accumulates in the soil, which is potentially available for uptake by crops in subsequent years. Vermi-compost increases soil organic carbon, nitrates, phosphates, exchangeable calcium and some other nutrients for plants (Orozco et al., 1996). Vermi-compostincreases soil Cation Exchange Capacity (CEC) and crop yield (Marinari et al., 2000).Cation exchange capacity is highly correlated with organic carbon (OC) content of the soil,which is in turn, is affected by different soil management practices such as intensive cultivation, fertilization, and changes in land use (Gao and Chang, 1996). Cation exchange capacity increases with increasing soil OM (Saikh et al., 1998).It is strongly affected by the nature and amount of mineral and organic colloids present in the soil. Thus, CEC measurements are commonly made as part of the overall assessment of the potential fertility of a soil, and possible response to fertilizer application (Landon, 1991).In conclusion the available nutrient status of soil was greatly enhanced by the application of vermi-compost as an organic source (Prabha et al., 2007).

Table 1. Effects of vermi-compost and NPS fertilizer rates on soil chemical properties after bread wheat harvest

Treatments		Soil properties					
V. Com (tha^{-1})	NPS (kg/ha^{-1})	pH (H2O)	Ex.acid meq/100gsoil)	Pav (ppm)	OC %	TN %	CEC (cmol(+) /kg soil)
0	0	4.85^{b}	0.60^{a}	0.67^{b}	3.20^{d}	0.30^{b}	10.10^{c}
1.5	0	4.90^{ab}	0.60^{a}	0.53^{b}	3.53^{d}	0.30^{b}	12.36^{abc}
3	0	5.10^{a}	0.57^{a}	0.90^{ab}	4.16^{bc}	0.36^{a}	12.96^{abc}
0	100	5.00^{ab}	0.57^{a}	1.03^{ab}	3.56^{d}	0.30^{b}	11.96^{abc}
1.5	100	5.00^{ab}	0.47^{a}	1.07^{ab}	4.13^{bc}	0.40^{a}	11.76^{bc}
3	100	5.00^{ab}	0.50^{a}	1.17^{ab}	4.56^{ab}	0.40^{a}	14.00^{ab}
0	200	4.87^{b}	0.53^{a}	1.10^{ab}	4.10^{c}	0.36^{a}	13.76^{ab}
1.5	200	4.87^{b}	0.53^{a}	1.50^{a}	4.50^{abc}	0.40^{a}	13.80^{ab}
3	200	4.87^{b}	0.60^{a}	0.73^{b}	4.86^{a}	0.40^{a}	14.93^{a}
Mean		4.94	0.55	0.97	4.07	0.35	12.85
CV (%)		2.61	30.63	43.46	6.19	7.80	13.74
LSD		0.22	Ns	0.72	0.43	0.04	3.05
Initial (before sowing)		4.88	1.05	0.92	3.91	0.29	11.98

Where, means followed by the same letters in each column are not significantly different at ($P \leq 0.05$), V.com= Vermi-compost, CV= Coefficient of Variation, LSD= Least Significant Difference,Pav.=Available Phosphorus, OC=Organic Carbon, TN= Total Nitrogen, ppm=Part per million, Ex.acid= Exchangeable acidity,CEC = Cation Exchange Capacity, Ca= Calcium, t= ton,

Mean Days to Heading of Bread Wheat (Liban) Under the Effect of Vermi-Compost and NPS Fertilizer Rates

The analysis of variance indicated that days to heading was significantly ($P<0.05$) affected due to the application of NPS, vermi-compost and their interactions (Table 2).increasing the levels of vermi-compost elongated days to heading of bread wheat. Vermi-compost can influence the growth and productivity of plants significantly (Edward, 1998). Concerning. the interaction effect of NPS and vermi-compost, the highestdays to heading of 67.4 days was obtained with the un fertilized treatment, whereas the lowest 60.0 days) was obtained from 200 kg NPS ha^{-1}without vermi-compost application (Table 2).

Table 2.Mean days to heading of bread wheat (liban) under the effect of vermi-compost and NPS fertilizer rates.

	VC (t ha^{-1})			
NPS	0	1,5	3	Mean
(kg ha^{-1})		Days to heading (days)		
0	67.4^{b}	67.0^{b}	69.0^{a}	67.8^{a}
100	62.1^{d}	64.6^{c}	64.8^{c}	63.9^{b}
200	60.0^{e}	64.6^{c}	65.1^{c}	63.3^{b}
Mean	63.2^{c}	65.4^{b}	66.3^{a}	
CV(%)	2.3			
LSDforNPS	0.8			
LSD for VC	0.8			
LSDforNPS * VC	1.4			

Where, means followed by the same letters are not significantly different ($P\leq0.05$), VC =vermi-compost, t=ton, ha=hectare, NPS= (nitrogen, phosphorus, sulfur), kg=kilogram, DH = days to headings, CV= Coefficient of variation, LSD= Least significant differences.

Mean Biomass Yield of Bread Wheat under the Effect of Vermi-Compost and NPS Fertilizer Rates

The effect of NPS fertilization on bread wheat biomass yield was significant. However, application of vermi-compost rates did not show significant effect on bread wheat biomass yield (Table 3) Biomass yield was increased with NPS rates where the maximum biomass yield (14416.7 kg ha^{-1}) was obtained from the application of the highest NPS rate (200 kg NPS ha^{-1}) andthe minimum (8148.1 kg ha^{-1}) was from un fertilized one (Table 3). Moreover, the interaction effect of these factors also revealed that the combinations of (200 kg NPS ha^{-1}) and (1.5 t ha^{-1}) vermi-compost gave significantly higher biomass yield of bread wheat (Table 3) This indicated that, vermi-compost plays a major role in improving growth and yield of different field crops, vegetables, flowers and fruits (Lekshmanaswamy, 2014).

Table 3.Mean biomass yield of bread wheat under the effect of vermi-compost and NPS fertilizer rates.

		VC (t ha^{-1})		
NPS	0	1,5	3	Mean
(kg ha^{-1})		Biomass yield(kg ha^{-1})		
0	6889.0^{d}	7667.0^{cd}	9889.0^{bc}	8148.1^{b}
100	12358.0^{ab}	12278.0^{ab}	14194.0^{a}	12943.5^{a}
200	14222.0^{a}	14944.0^{a}	14083.0^{a}	14416.7^{a}
Mean	11156.5^{a}	11629.6^{a}	12722.2^{a}	
CV(%)	24.9			
LSDforNPS	1601.2			
LSD for VC	1601.2			
LSDforNPS * VC	2773.4			

Where, means followed by the same letters are not significantly different (P≤0.05), VC =vermi-compost, t=ton, ha=hectare, NPS= (nitrogen, phosphorus, sulfur), kg=kilogram, DH = days to headings, CV= Coefficient of variation, LSD= Least significant differences.

Mean Grain Yield of Bread Wheat Under the Effect of Vermi-Compost and NPS Fertilizer Rates

Table 4 presents the means of bread wheat grain yield as influenced by different rates of NPS and vermi-compost application. The analysis of variance indicated significant (P<0.05) grain yield differences due to the application of NPS, vermi-compost and their interactions. Vermi-compost is the recently organic fertilizer in supplementing chemical fertilizers for sustainable development of agriculture (Gupta, 2003).Increasing NPS and vermi-compost levels showed linear and consistent yield increment. Increasing vermi-compost rate from 1.5 to 3 tha^{-1} increased grain yield with a yield increment of 20 to 35 % over the control treatment, respectively (Table 4). Concerning the interaction effect of NPS and vermi-compost, the highest grain yield of 5722.2 kg ha^{-1} was obtained with the combination of 200 kg NPS ha^{-1}and 3 t ha^{-1} vermi-compost, whereas the lowest (750.0kg ha^{-1}) was obtained with the un fertilized treatment (Table 4).The highest yield for the interaction effect could be due to vermi-compost promotes better root growth, nutrient absorption and improves nutrient status of soil, both macro-nutrients and micro-nutrients (Lazcano and Dominguez ,2010). The growth and nutrient status of crops have revealed a positive effect on plant nutrition, photosynthesis, chlorophyll content and nutrient content of different plant components namely roots, shoots and fruits (Theunissen et al. 2010). In conclusion Vermi-compost is the recently organic fertilizer in supplementing chemical fertilizers for sustainable development of agriculture.

Table 4. Mean grain yield of bread wheat under the effect of vermi-compost and NPS fertilizer rates..

		VC (t ha^{-1})		
NPS	0	1,5	3	Mean
(kg ha^{-1})		Grain yield(kg ha^{-1})		
0	750.0^{g}	1055.6^{g}	1527.8^{f}	1111.1^{c}
100	2722.2^{e}	3361.1^{d}	3694.4^{d}	3259.3^{b}
200	4611.1^{c}	5277.8^{b}	5722.2^{a}	5203.7^{a}
Mean	2694.4^{c}	3231.5^{b}	3648.1^{a}	
CV(%)	13.2			
LSDforNPS	228.9			
LSD for VC	228.9			
LSDforNPS * VC	396.5			

Where, means followed by the same letters are not significantly different (P≤0.05), VC =vermi-compost, t=ton, ha=hectare, NPS= (nitrogen, phosphorus, sulfur), kg=kilogram, DH = days to headings, CV= Coefficient of variation, LSD= Least significant differences

CONCLUSION AND RECOMMENDATION

The manner in which soils are managed has a major impact on agricultural productivity and its sustainability. Moreover, optimum productivity of any cropping system depends on adequate supply of plant nutrients. Laboratory analysis results of soil samples collected before sowing showed deficiency in soil chemical properties. However, postharvest soil samples indicated that significant differences and positive increment with soil fertility status tested. Moreover, application of limeto the experimental sites was effective in increasing soil pH, which realized that soil pH is considered a master variable in soils as it controls many chemical processes that take place. It specifically affects plant nutrient availability by controlling the chemical forms of the nutrients. The analysis of variance among the treatments showed significant differences on bread wheat characters tested. The maximum mean grain yield (5722.2 kg ha^{-1}) were recorded for the combined fertilization of 3 t ha^{-1}vermi-compost and 200 kg ha^{-1}NPS fertilizer, whereas the lowest was recorded for nil fertilized plot. Accordingly, all the studied effects of vermi-compost and NPS fertilizer rates enhanced soil fertility status and bread wheat productivity in the study area; which indicated that bread wheat 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 combined fertilization of 3 t ha $^{-1}$ vermi-compost, 200 kg ha^{-1}NPS fertilizer and 92 kg N ha^{-1} are enhanced soil nutrient availability and bread wheat productivity, and recommended for the end users in Gechi district and similar agro-ecology.. 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 rate, time and method of combined application of vermi-compost and NPS fertilizer for major crops grown in this region.

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Effect of Lime and Vermicompost on Grain Yield of Maize, Acid Soil Reclamation and Soil Fertility Amelioration under Maize/pigeon pea intercropping on Acid soils of Western Oromia, Ethiopia

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ABSTRACT

Soil acidity in cultivated land is more aggravated by harvesting and residue removal of crops with high grain yield. The experiment consisted of three levels of lime (No lime, 79% $CaCO_3$ and 100% $CaCo_3$) and three levels of vermicompost (no vermicompost, 23N equivalent vermicompost +87N and 46N equivalent vermicompos+64N) were laid out in RCBD, factorial arrangement under maize/pigeon pea intercropping plus sole maize under recommended NP and control treatments. The experiment was conducted on acidic soils of Bako Agricultural Research Center, Gute and Bonaya Boshe sub-centers during 2018 and 2019 main cropping seasons with the objectives to identify the influence of lime and integrated use of organic/inorganic fertilizers under maize/pigeon pea intercropping on yield of maize, soil acidity reclamation and soil fertility amelioration. Lime was applied at the rate of exchangeable acidity based a month before planting while vermicompost was applied during maize planting. Both maize and pigeon pea were planted simultaneously and crop residues were soil incorporated after harvest and before planting. Maize grain yield was significantly influenced by the main effect of vermicompost during 2018 and 2019 and was significantly influenced by the main effect of lime during 2019 at all locations. Maize grain yield was also affected by the interaction of lime by vermicompost at Bako during 2019 main cropping season. The highest maize grain yield, 8931 kg ha^{-1} was obtained by the application of 100 kg ha^{-1} $CaCO_3$ and 46N equivalent vermicompost+46N followed by application of 100 kg ha^{-1} $CaCO_3$ and 23N equivalent vermicompost +87N. Furthermore, lime and vermicompost associated with maize/pigeon intercropping reduced soil acidity, increased TN, OC and AVP of the soil.

Key words: Acid soil, Lime, Maize, Pigeon pea, Vermicompost

INTRODUCTION

Soil acidity is influenced by organic matter decay, harvest of high yielding crops, acid forming inorganic sources of fertilizers, excessive rainfall, climate and land management practices (Belinda, 2000). The effect of aluminum below pH of 4.8 reduces root growth while manganese disrupts growth and photosynthesis. Activities of nitrogen fixing bacteria will be reduced; Zn and Cu could be toxic to plants and microorganisms. Consequently, availability of macronutrients is limited in strongly acidic soils (Yost, 2000). Aluminum toxicity interferes with phosphorus activities like normal growth, maturity, photosynthesis, respiration and cell enlargement in plants. Phosphorus deficiency affects tillering, root development, phenology, reduces quality of grain and decreases disease resistance (Tisdale et al., 2002). Crops grown in such soils, extend their roots down to the sub soil and spreading the lateral

roots at the surface, are exposed to various concentrations of P and Al at different depths in the soil profile (Iqbal, 2012).

Ethiopian Nitosols and other acid soils are reported to have low P contents not only due to the inherent low available P but due to the high P fixation capacity of the soils (Yihenew, 2002). The highest concentrations of available P were recorded on the surface soil of intensively cultivated soils of research sites compared to the soils of farmers' field and virgin land (Wakene and Heluf, 2003), presumably due to the continuous application of inorganic P fertilizers. Study by Tesfaye et al., (2015) reported that 85% of sampled soils of central highlands of West Shewa (Jeldu, Cheliya, Tikur Inchini, Jibat, Welmera and Ejere) were strongly acidic and 70% were P deficient. Besides P deficiency and unavailability in acidic soils, Ca and Mg are among important base cations removed by crops, lost by leaching and replaced by H^+ and these bases are carried away by drainage water. High and torrential rains also cause acidity while the more water moving down the soil, the faster is the leaching process (Abreha, 2013).

No other single chemical soil characteristic is more important in determining the chemical environment of soil nutrients than the pH. Lime is truly a foundation for much of humid region agriculture. Knowing how pH is controlled and how it influences the supply and availability of essential plant nutrients as well as toxic elements is essential for the conservation and sustainable management of soils throughout the world (Brady and Weil, 1999). No matter how it is expensive, to improve the condition on acid farmlands, intensive-abundant liming and controlled-efficient subsurface drainage of the tillage has been recommended because liming of top soil does not reduce acidity which drives from below the tillage layer (Kannen et al., 2012). The authors with similar opinion addressed that more than single reclamation is required for complex soil acidification. Use of lime, application of organic fertilizers, and crop rotation in the cultivated lands may alleviate P fixation and low crop productivity problems (Achalu, 2012). Report by Chandrasekaran et al., (2010) also emphasized on application of manures, sewage sludge, and/or green manure and conservation tillage, crop residue management, compost, vermicompost and poultry compost enhances the availability of P and other nutrients. Proper residue management retains Mg and Ca whereby the rate of decomposition of crop residue is high in pearl millet/pigeon pea intercropping and assessment by Crusciol et al., (2013) reported higher contents of macronutrients in pearl millet/pigeon pea intercropping compared to the sole cropping system of both crops. Residue management increased soil pH from 4.6 to 5.5 whereby maize residue management also increased plant height by 52 cm and grain yield by 57% compared to the control (Mbah and Nneji, 2011).

In addition to inherent parent materials, cropping system and land management, soils of humid regions are more prone to acidity due to torrential rains which have mean rainfall that exceeds evapo-transpiration. High termite abundance in the region affects crop growth and feed on crop residues that contained base nutrients like Ca and Mg. Unavailability of these base cations, unavailability/deficiency of P associated with soil erosion and down ward movement of water enhances soil acidity in the region. Lime experiments with maize elsewhere in the world is focusing on identification of acid tolerant varieties and reclamation with lime. Research in Ethiopia considered single technology (liming) for multiple causes of

soil acidity in maze based monocropping system of Western Ethiopia. However, recent works by Shiferaw and Zerihun (2019) recommended maize/pigeon pea intercropping at reduced chemical N for multiple advantages like increased yields, OC, TN and reduced soil acidity. Maize/pigeon pea intercropping had better influence on soil acidity reduction if integrated with lime and organic fertilizers but this cropping system alone could not raise soil pH of strongly acid soils to the desired level. Current $CaCO_3$ content of applied lime is not yet considered and consequently might have underestimated or overestimated the recommendation.

MATERIALS AND METHODS

An experiment consisting of three levels of lime (No lime, 79 % $CaCO_3$ and 100% $CaCO_3$) and 3 levels of vermicompost (no vermicompost, 23N- equivalent vermicompost + 87 kg ha^{-1} N and 46 N- equivalent vermicompost + 64 kg ha^{-1} N) were laid out in RCBD, factorial arrangement of 3 × 3 plus a plot with 110 N and 100 NPS kg ha^{-1} and a control plot. All the treatments except a control received 100 kg ha^{-1} NPS. The experiment was conducted at Bako agricultural research center, Gute and Bonaya Boshe sub-centers on acid soils with pH of 4.94, 4.43 and 5.15, respectively during 2018 and 2019 main cropping seasons.

During the initial year of the experiment, composite soil samples were collected from the experimental sites before planting, while during the first and second year soil samples from each experimental plot were collected after harvest at the depth of 0-20 cm. The samples were air dried grinded and sieved at particle size of less than 2mm. Soil pH was determined using pH meter 1:2.5 soil: water; Available P was determined using Bray II method; Total nitrogen was determined using Kjeldhai method while Walkley-Black method was used to obtain OC.
NPS fertilizer was applied at the rate of 100 kg ha^{-1} while vermicompost was 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). Maize variety BH 661 was planted at spacing of 75 cm between rows and 30 cm between plants on a plot area of 19.125 m^2 (3.75m ×5.1m) and perennial pigeon pea was intercropped between rows of maize at spacing of 50 cm between plants. Maize was also planted receiving recommended N P_2O_5 and without fertilizers. Plots with lime and vermicompost were intercropped with pigeon pea between rows of maize at the spacing of 50cm between plants. Pigeon pea branches were removed while leaving 2 upper one during the first year and cut back to 30cm during second year. Removed branches were chopped and incorporated into the respective plots. Maize residue other than the control plot was also chopped and incorporated to the respective plots.

Data

Maize grain yield was weighed and adjusted to 12.5% moisture standard. Soil sample was collected from each site and analyzed for soil pH, Total N, AVP and OC before planting. Soil samples were also collected after crop harvest from each plot and were analyzed for similar chemical characteristics during 2018 and 2019 main cropping seasons.

Statistical analysis

Data were analyzed using SAS version 9.1 (SAS, 2002) computer software and were subjected to ANOVA to determine significant differences among factors and their

interactions. Means were separated using LSD test. For all analyzed parameters, $P<0.05$ were interpreted as statistically significant.

RESULTS AND DISCUSSIONS

Maize grain yield

Maize grain yield was not affected by the main effect of lime application during 2018 main cropping season at all locations. However, it was significantly influenced by application of lime during 2019 at all locations. At Bako, the highest maize grain yield, 8362 kg ha^{-1} which was not significantly different from application of lime with 79% $CaCO_3$ was obtained by application of l00% $CaCO_3$. Similarly, during 2019, application of lime under maze/pigeon pea intercropping increased maize grain yield by 16.65% and 23.23% at Gute and Boshe sites, respectively compared to sole maize without lime application (Table 1). On the other hand, application of lime under maize/pigeon pea intercropping produced mean maize grain yield advantage of 10.77%, 15.79 and 6.77%, over maize grown sole at Bako, Gute and Boshe, respectively.

The main effect of vermicompost significantly influenced maize grain yield at all locations during 2018 and 2019 main cropping seasons. The highest maize grain yield at Bako during 2018 was 9660 kg ha^{-1}, obtained by application of vermicompost at the rate of 46N-equivalents + 64 N under maize/pigeon pea intercropping and followed by application of the same rate at Gute. Maize mean grain yield over all locations by application of 46 N-equivalent vermicompost +64N produced yield advantages of 2.71%, 17.21% and 45.90%, compared to application of 23 N equivalent vermicompost + 87 N, no vermicompost and control treatments, respectively (Table 1). Similar result by Esmaeil et al., (2015) identified 5 tons vermicompost with 75% N produced the highest maize grain yield compared to combinations of 10 tons vermicompost with 50% N.

Maize grain yield was affected by the interaction of lime by vermicompost at Bako during 2019. Indeed, the highest maize grain yield, 8931 kg ha^{-1} was obtained by the application of 100 kg ha^{-1} $CaCO_3$ and 46N -equivalent vermicompost +64N followed by application of 100 kg ha^{-1} $CaCO_3$ and 23N- equivalent vermicompost. Moreover, application of 100 kg ha^{-1} $CaCO_3$ and 46N- equivalent vermicompost+64N under maize/pigeon pea intercropping produced maize grain yield advantage of 17.61% over maize grain yield obtained by sole maize applied only recommended inorganic fertilizer (110N) but without lime (Table 2). This could be attributed to integrated use of lime, vermicompost and maize/pigeon pea intercropping which reduced soil acidity, facilitate normal stem and root growth and increased biomass that favored better yield production. The result obtained in this study agreed with the findings of Maria and Peter, (2014) who reported the yields were most positively influenced by vermicompost application with ammonium nitrate and dolomite.

Table 1. Maize grain yield as affected by the main effects of lime and vermicompost under maize/pigeon pea intercropping at BARC, Gute and Boshe during 2018 and 2019 main cropping seasons

	BARC		GUTE		BOSHE	
Factor	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
L0+Maize/Pigeon pea	8447	7333	6662	5697	7900	5222
L1 +Maize/Pigeon pea	8753	8350	6523	6792	8178	7472
L2 +Maize/Pigeon pea	8869	8362	6948	6835	7936	6802
LSD (5%)	NS	437.13	NS	815.48	NS	618.29
Sole maize +110N	7483	7151	5701	5424	7175	6059
Control	6607	6447	3609	1754	5142	1922
V0+Maize/Pigeon pea	7616	7619	5774	6219	7060	6179
V1+Maize/Pigeon pea	8794	8112	6939	7058	8420	6497
V2 +Maize/Pigeon pea	9660	8315	7421	6048	8535	7120
LSD (5%)	469	437.13	961	815.48	374	688.98
CV %	9.42	5.50	14.46	12.78	7.14	10.54

Table 2. Maize grain yield as affected by the interaction of lime by vermicompost under maize/pigeon pea intercropping at Bako during 2019 main cropping season

Factor	**V0 (No vermicompost)**	**V1 (23 N equivalent)**	**V2 (46 N equivalent)**
L0 (No lime)	7358	7212	7429
L1 (79% $CaCO_3$)	8119	8349	8583
L2 (100% $CaCO_3$)	7380	8775	8931
LSD (5%)		482	
CV %		5.50	

Soil reaction

At Bako, during 2019 main cropping season, soil pH was increased from 4.94 to 5.05 in maize/pigeon pea intercropping without lime but remained unchanged during 2018 whereby soil pH in sole maize also remained unchanged during both cropping seasons. However, soil pH for maize pigeon/pea intercropping but without lime and vermicompost was reduced below the initial pH. Maize/pigeon pea intercropping+79% $CaCO_3$ and maize/pigeon pea+100% $CaCO_3$ increased soil pH to 5.1 and 5.2 during 2018 and 2019, respectively (Fig. 1a). At Bilo Boshe, initial soil pH of 5.15 remained unchanged rather showed decreasing tendency in sole maize without lime.

However, high soil pH ranging between 5.5 and 5.8 were recorded for maize/pigeon pea intercropping with lime (Fig. 1b). Low initial pH at Gute (4.43) was unchanged in control plots and in sole maize applied N at rate of 110 kg ha^{-1} rather increased to 4.7 (2018) and 5.1 (2019) in maize/pigeon pea intercropping without lime. Moreover, maize/pigeon pea intercropping +79% $CaCO_3$ and maize/pigeon pea+100% $CaCO_3$ increased soil pH during both cropping seasons. Tremendous soil pH increase were recorded during 2019 from maize/pigeon pea+100% $CaCO_3$+vermicompost and maize/pigeon pea+79% $CaCO_3$+ vermicompost (Fig. 1c). Obviously, Lime, Vermicompost and maize/pigeon pea intercropping increase sources of Ca and Mg for plants and permit improved water penetration for acid soil whereby decreases H^+ concentration and reduces soil acidity. The result obtained from the

current study is in agreement with the works of Tamado and Mitiku (2017) that indicated increased level of application of vermicompost caused a corresponding increase in soil pH.

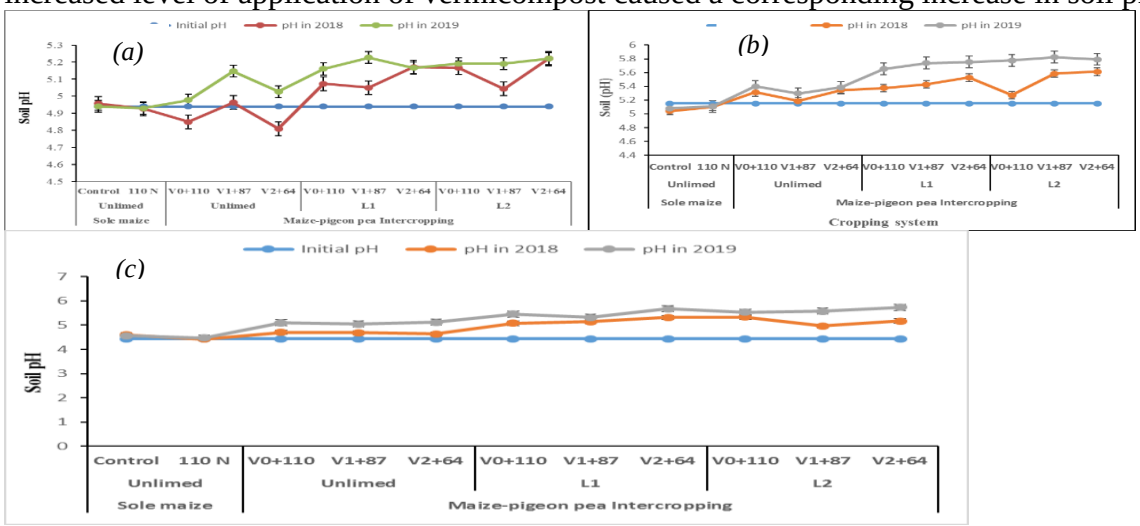

Fig 1. Soil pH as influenced by lime, vermicompost and maize/pigeon pea intercropping at Bako (a), Boshe (b) and Gute (c) during 2018 and 2019 main cropping seasons

Soil chemical properties

At Bako, AVP decreased below the initial level in a control and a plot where sole maize is grown without lime and vermicompost. It increased from 11.2 to 16.11 (2018) and 19.79 (2019) in maize/pigeon pea+ 79% $CaCO_3$ +vermicompost whereby an increase in maize/pigeon pea+ 100% $CaCO_3$ +vermicompost was to 17.48 and 21.83 during 2018 and 2019 main cropping seasons, respectively (Fig. 2a). At Bilo Boshe, it remained unchanged in control and sole maize without lime and without vermicompost. Available P is increased from 12.4 to 15.56 (2018) and 17.63 (2019) in maize/pigeon pea+ 79% $CaCO_3$+vermicompost and increased to 16.18 (2018) and 17.84 (2019) in maize/pigeon pea+100% $CaCO_3$+vermicompost (Fig. 2b). At Gute, AVP increased from 9.4 to 11.92 (2018) and 14.48 (2019) in maize/pigeon pea+79% $CaCO_3$+ vermicompost and increased to 13.33 (2018) and 15.4 (2019) in maize/pigeon pea+100% $CaCO_3$ +vermicompost (Fig. 2c). Similar work by Abdissa et al., (2018) confirmed that highest AVP was obtained by application of 60 kg ha^{-1} chemical P + 2 tons ha^{-1} lime + 7.5 tons ha^{-1} vermicompost.

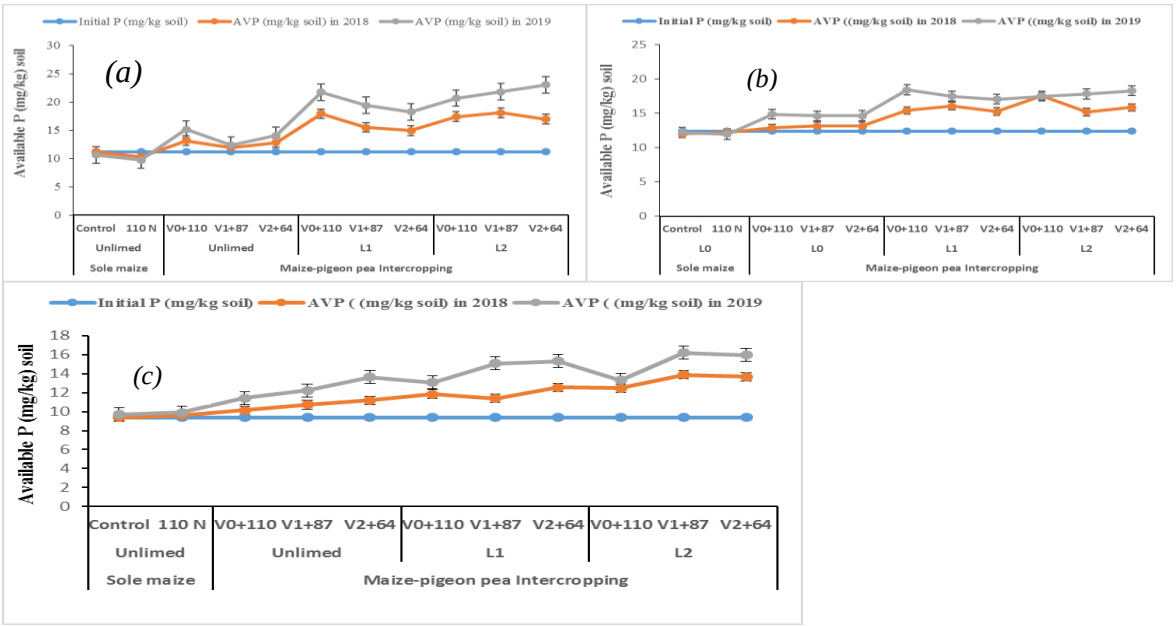

Fig 2. Available P as influenced by lime. Vermicompost and maize/pigeon pea intercropping at Bako (a), Boshe (b) and Gute (3) during 2018 and 2019 main cropping seasons At Bako, the highest OC was recorded from limed and vermicompost applied maize/pigeon pea intercropping. The increase was high, 3.02 in maize pigeon/pea + 46N- equivalent vermicompost +64N during 2019 and followed by 2.81 in maize pigeon/pea + 23N equivalent- vermicompost +87N during 2018 (Fig. 3a). At Bilo Boshe, the highest OC was obtained by maize/pigeon pea +liming and application of vermicompost during 2019 (Fig. 3b). The increasing trend during 2019 at Gute was also similar to Bako with similar cropping systems and organic/inorganic fertilizer combinations (Fig. 3c). Earlier work by Shiferaw and Zerihun (2019) identified soil incorporated pigeon pea branches in maize/pigeon pea intercropping increased effective rainfall use and consequently increased OC and total nitrogen.

The highest N increase at Bako was obtained by maize/pigeon pea intercropping + 46N - equivalent +64 kg ha^{-1} N during 2019 and 2018 main cropping seasons. Total Nitrogen remained unchanged or showed low unit increase in both sole and maize/pigeon pea intercropping but without vermicompost during 2018 (Fig. 4a). Total nitrogen increase trend at Boshe was also similar to Bako. The highest Total Nitrogen was obtained by maize/pigeon pea intercropping+46N equivalent vermicompost and 64 kg ha^{-1} N+100% $CaCO_3$ during 2019 (Fig.4b). Total nitrogen was reduced below initial value in sole maize without vermicompost and a control plots at Gute during both cropping seasons. It showed high total nitrogen increase in maize/pigeon pea intercropping+ vermicompost (Fig.4c), could be attributed to the slow release of N from vermicompost. The work by Tamado and Mitiku (2017) justified the application of 5 t ha^{-1} FYM in combination with 75% inorganic N and P increased the OC and consequently increased total nitrogen.

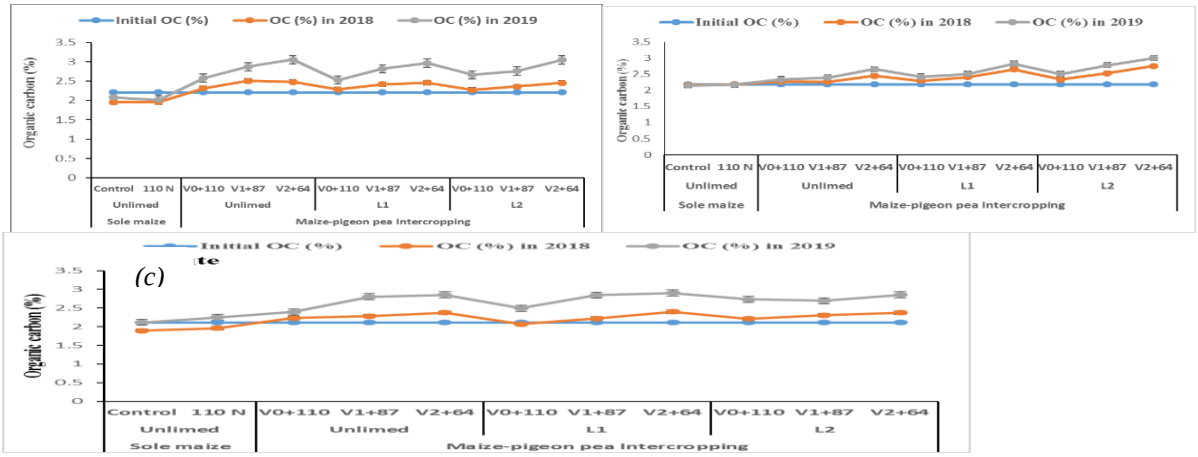

Fig. 3. OC as influenced by maize/pigeon pea intercropping, lime and vermicompost at Bako, Bilo Boshe and Gute during 2018 and 2019 main cropping seasons

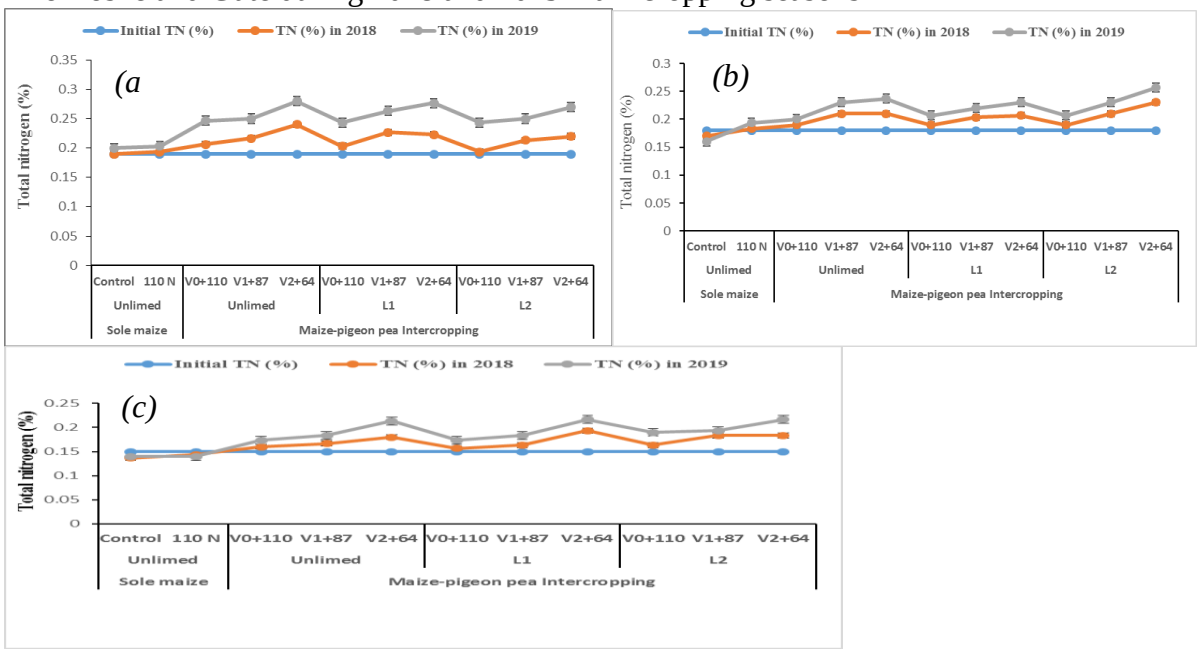

Fig 4. Total N as influenced by maize/pigeon pea intercropping, lime and vermicompost at Bako (a), Bilo Boshe (b) and Gute (c) during 2018 and 2019 main cropping seasons

CONCLUSIONS

The single mitigation approach for multiple threats to soil fertility might end up with solving the particular threat and requires more time and resources for the other ones. In acid soils with low fertility status, integrated use of soil acidity reclamation (liming), soil fertility amelioration (integrated use of organic/inorganic fertilizers) and cereal/legume intercropping resulted in maize yield increase, reduction of soil acidity and increased soil organic matter, soil available P and total nitrogen. Considering the results obtained, it is suggested to apply integrated use of lime, vermicompost and maize/pigeon pea intercropping in acidic and infertile soils of sub-humid areas of western Ethiopia.

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Verification of Phosphorus Critical Level for Bread Wheat (Triticum aestivum L.) in Kofole District of West Arsi Zone, Oromia, Ethiopia

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ABSTRACT

Verification of phosphorus critical level for bread wheat was conducted in Kofole District in 2019 cropping season with the objectives to verify phosphorus critical (Pc) level and determined during soil test crop response based phosphorus fertilizer calibration and to create awareness on soil test crop response based fertilizer recommendation. A Composite soil samples at the depth of 0-20 cm in zigzag method were collected from 10 farmers' fields for Eutric Vertisols. Likewise, soil samples analyses were made to identify available P in the level of the required phosphorus in the select crop fields for actual experiment. The treatments included (1) soil test based phosphorus calibration result; (2) farmers' practice in the area which was assessed from the surrounding farmers' and (3) no fertilizer application (control) and each treatment was planted on 10*10m experimental plot & the design was randomized complete block design replicated over farmers. Bread wheat, Ogolcho variety, was used with seed rate of 150 kg $ha^{-1}$and other cultural practices such as weed and rust management were used from which had been recommended for the area. The partial budget analysis showed that the highest net income (71630.48 ETB) was from soil test based recommended and the lowest net benefit (44378.55 Birr ha^{-1}) was obtained from control treatment with marginal rate of return (653.38%) which is greater than the minimum rate of return (MRR) 100%. The result showed that the average grain yield of 4745 kg ha^{-1} was obtained from the application of soil test based phosphorus calibration (Pc and Pf) followed by blanket recommendation (3853 kg ha^{-1}) and 2778 kg ha^{-1} for the control treatment. The recommended N rate, 69 kg N ha^{-1} with soil test based phosphorus critical level gave 58.54% grain yield advantage over the control. In general, soil test and crop response based fertilizer recommendation for crops increases crop yields through application of adequate nutrient rates for the identified soil nutrient deficiencies in specific locations.

Key-words: Verification, Farmer, Concentration, Application and Calibration

INTRODUCTION

Bread wheat (Triticum aestivum L.) is one of the most important cereal crops globally and is a main food for about one third of the world's population (Hussain et al., 2002). Wheat took up 13.73% (1,747,939.31 hectares) of the grain crop area. Likewise, cereals contributed 87.97% (about 277,638,380.98 quintals) of the grain production and the wheat 15.33% (48,380,740.91 quintals) of the grain production (CSA, 2019). Moreover, wheat production in the country is adversely affected by low soil fertility and suboptimal use of mineral fertilizers in addition to diseases, weeds, erratic rainfall distribution in lower altitude zones, and water-logging in the Vertisols areas (Amanuel et al., 2002).

Phosphorous is the most yield limiting of soil-supplied elements, and soil P tends to decline when soils are used for agriculture (David and David, 2012). Additionally, the nutrient deficiencies identified in this study could be due to either inherently low availability of these nutrients in the soils or as a consequence of continuous intensive cropping without applying fertilizer or manure containing these nutrients (Hailu et al., 2015). Similarly, the blanket recommendations that are presently in use all over the country were issued several years ago, which may not be suitable for the current production systems. Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P rate to their fields regardless of soil fertility differences (Gete et al., 2010).

Phosphorus calibration is a means of establishing a relationship between a given soil test value and the yield response from adding nutrient to the soil as fertilizer. So that it provides information how much nutrient should be applied at a particular soil test value to optimize crop growth without excessive waste and confirm the validity of current P recommendations (Getachew et al., 2013). Likewise, they enable to revise fertilizer recommendations for an area based on soil and crop type, pH and soil moisture content at time of planting. Soil tests are designed to help farmers predict the available nutrient status of their soils. Once the existing nutrient levels are established, producers can use the data to best manage what nutrients are applied, decide the application rate and make decisions concerning the profitability of their operations (Girma et al., 2016). Hence, calibrations are specific for each crop type and they may also differ by soil type, climate, and the crop variety. Generally, soil test based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops. Therefore, optimum return from the investment on input and minimum environmental pollution are the two major issues to be addressed while prescribing soil test based nutrient recommendations (Singh et al., 2010).

Therefore, to alleviate this problem Batu Soil Research Center undertaken soil test crop response based fertilizer calibration Kofole District on bread wheat and determined optimum nitrogen to be applied, P critical and P-requirement factors. But to ensure confidence in recommendations, these determined values should be verified for grain yield and economic benefit as compared to blanket recommendation and control. Therefore, the objectives of this verification were to verify phosphorus critical (Pc) level determined during soil test crop response based P fertilizer calibration, and to create awareness on soil test crop response based fertilizer recommendation.

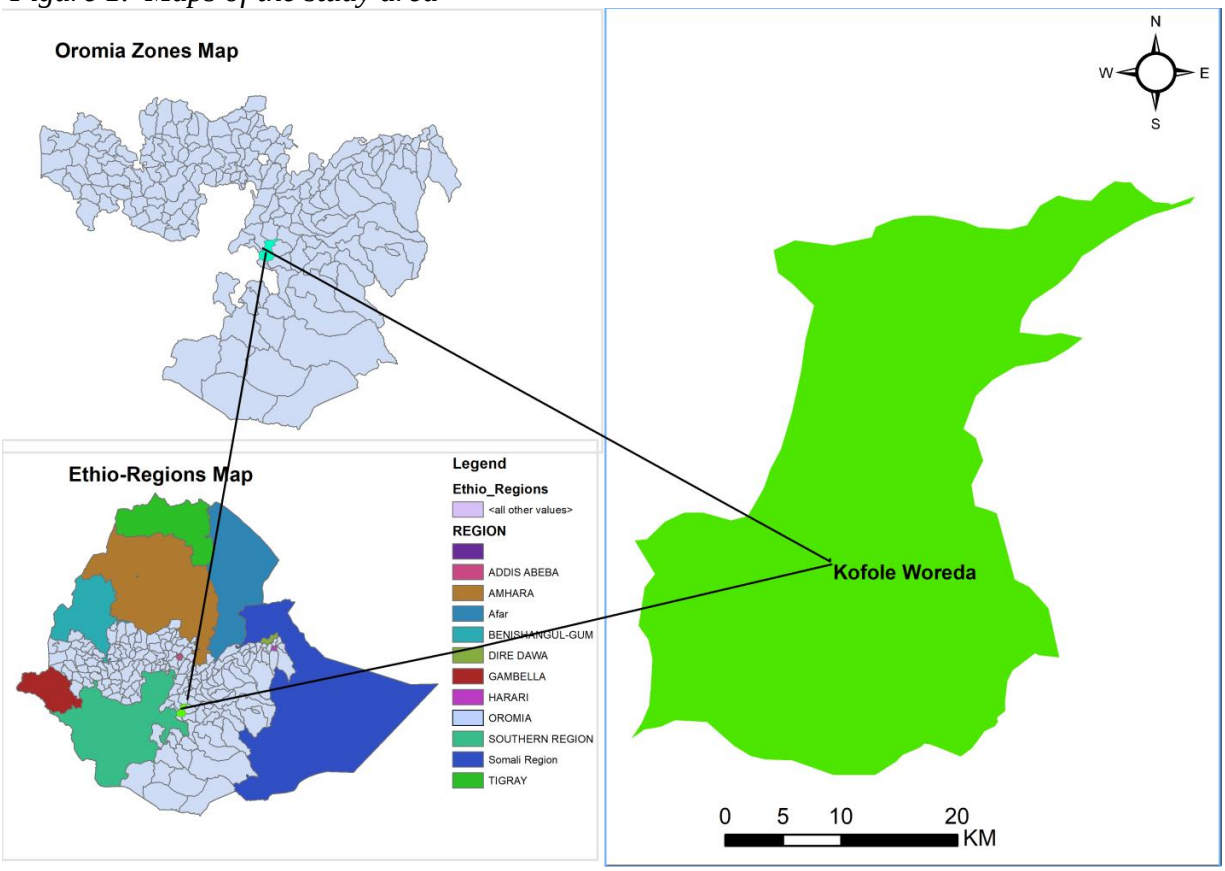
MATERIALS AND METHODS

Description of the Study Area

Phosphorus critical level Verification for bread wheat was conducted on farmers' fields in 2019 main cropping seasons in Kofole District, West Arsi Zone, in the central highlands of Ethiopia. Bread wheat is grown mainly by subsistence farmers. Geographically, the study area is located at 06^0 50' to 07^0 09' N and $38^0$38' to $39^0$04' E and at an altitude of 2620 m above sea level. It is located at a distance of about 280 km Southeast of Addis Ababa. The area is characterized by high altitude in the humid temperate climatic zones. According to National Ethiopia Meteorology agency Station records the experimental field was under continuous

cereal production for long time. The long-term (1998-2019) mean total annual rainfall was 1036 mm with mean maximum and minimum temperatures of 19.64 and 7.53^{o}C, respectively. The environment is seasonally humid and major soil type of the trial sites was Eutric Vertisols.

Figure 1. Maps of the study area



Experimental design and treatments

For verification, first selection of the sites was done and 10 composite soil samples were collected at the depth of 0-20 cm in zigzag method from ten farmers' fields for Eutric Vertisols. Moreover, available phosphorus was determined by extraction with 0.5 M $NaHCO_3$ according to the methods of Olsen et al. (1954). Among ten (10) farmers, six (6) were selected for actual experiment based on initial phosphorus concentration categories below critical P-concentration for Kofole District. Therefore phosphorus fertilizer requirement was calculated from the formula:

Phosphorus fertilizer rate = (pc-pi)*pf;

Where, **Pc**- critical phosphorus concentration which was determined from the calibration study (**19 ppm**),

Pi-Initial available P obtained from laboratory analysis from each farmers' fields and

Pf- phosphorus requirement factor derived from the calibration experiment **(3.30).**

Verification of phosphorus critical level was done with three treatments (1) soil test crop response based P criticl level; (2) farmers' practice in the area (blanket recommendation) and (3) control (no fertilizer application). It was conducted on 10*10m plot for each treatment

with 20 cm row spacing. The experiment was laid out in randomized complete block design and replicated over farmers' fields. The fields were prepared by the local ox plow and after bund application of fertilizer; it was incorporated by the local plow during sowing. Urea split application was used, and top dressing of urea and incorporating it with soil was done 25-30 days after sowing and all cultural practices with recommended production practices were used. Weeds were controlled by Pallas. Yellow rust was controlled by spraying fungicide (Reoxido) at the rate of 0.5 Liter ha^{-1} immediately at the appearance of the symptom of the disease.

Data collection and analysis

Agronomic data collected were plant height, biomass yield, grains per spike, spike length, 1000 kernel weight (TKW) and grain yield. Generally all data were properly managed and subjected to the analysis of variance using the SAS computer package version 9.0 (SAS Institute, 2002) statistical software.

Cost–benefit analysis

The partial budget, dominance and marginal analyses were done for both farmer practice and soil test based values using CIMMYT (1988)**.** Total variable cost was cost incurred due to application of P fertilizer (separately for soil test based P criticl level result and farmers' fertilizer rate) with the assumption that the rest of the costs incurred were the same for all treatments. The discarded and selected treatments using this technique were referred to as dominated and un-dominated treatments, respectively.

RESULTS AND DISCUSSION

Soil available phosphorus

The available P content of the soil was ranged from very low to medium according to Cottenie (1980) with the value ranged from 2.64 to 12.68 ppm. Therefore, the soil of the study area needs application of phosphorus containing fertilizers and phosphorus fertilizer requirement was calculated from the formula: Phosphorus fertilizer rate = (pc-pi)*pf for crop production.

Table 1. Available soil phosphorous status before planting in Kofole District, West Arsi Zone

Sites	Site code	Available soil phosphorus (mg kg^{-1} soil)
1	F1	5.08
2	F2	9.44
3	F3	2.64
4	F4	8.20
5	F5	8.16
6	F6	9.04
7	F7	6.28
8	F8	2.96
9	F9	12.68
10	F10	7.56
Average Initial P		**7.24**

Grain yield

Analysis of variance revealed that grain yield of bread wheat was highly significantly increased with application of soil test crop response based fertilizer recommendation, which gave 19.67 Qt.ha^{-1} yield advantages over the control treatment and 8.92 Qt ha^{-1} over farmer practices with grain yield increment (Table 2). The optimum N rate was 69 kg N ha^{-1} which influenced high yields of bread wheat in the district. Accordingly soil test crop response based fertilizer recommendation rate-influenced grain yield; biomass and mean highest grain yield was 47.45 Qt. ha^{-1}, 58.54% grain yield and 57.09% straw yield advantages over the control. Therefore the yield increment due to the soil test based phosphorus fertilizer recommendation rate (STBR) was supported by farmers positively. Accordingly, different stakeholders should work and harmonize on the transfer of the technology and additionally further effort should be made to disseminate to farmers or end users. Generally this study was in line with Kefyalew et al. (2017) mean comparison of verification experiment with revealed that mean grain yield of the calibrated phosphorus (critical concentration) treatment showed 320 & 877 kg for bread wheat yield increment over blanket recommendation and control plot, respectively.

Table 2.Effect of verification of phosphorus critical level on yield and yield components of bread wheat in Kofole District, West Arsi Zone

Treatments	Plant height (cm)	Spike length (cm)	Grains per spike (No.)	Biomass yield (ton/ha)	Grain yield (Qt/ha)	TKW (gm.)
Control	75.20^{b}	5.92^{c}	24.80^{b}	7.81^{b}	27.78^{b}	38.73
PC	102.68^{a}	8.10^{a}	35.80^{a}	13.68^{a}	47.45^{a}	41.97
FP	93.92^{a}	7.24^{b}	36.08^{a}	11.95^{a}	38.53^{a}	41.94
LSD(0.05)	11.22	0.76	6.69	3.22	10.52	NS
CV (%)	8.99	7.81	15.07	21.00	20.12	11.01

Means followed by the same letter with in the same column of the respective treatments are not significantly different ($P \leq 0.05$) according to fishier Test, PC= Phosphorus Critical, FP= Farmer practices, CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant.

Economic analysis

The partial budget analysis (CIMMYT, 1988) was employed to calculate the marginal rate of return (MRR) to investigate the economic benefit of treatments. Based on actual unit prices during the year 2019 harvesting season (personal observation) farm gate price of 15 ETB per kg of wheat, bread wheat seed price 13.80 Birr per kg, & of Phosphorus from NPS (12.78 Birr per kg) & Nitrogen from Urea (10.4 Birr per kg) were used to calculate variable cost. The Marginal Rate of Return (MRR) was 653.38% for soil test based fertilizer rate and farmer practice was dominated soil test based fertilizer rate as indicated in Table 3. The economic analysis showed that the highest net income (71630.48 ETB) was obtained from soil test based recommended treatment was greater than the minimum rate of return (MRR) 100% (Table 3). Generally, this study in line with Dejene et al. (2020) the economic analysis showed that the highest net income (51284 ETB) was obtained from soil test based recommended treatments with marginal rate of return (857.27%).

Table 3. Partial budget analysis for verification of phosphorus critical level for bread wheat in Kofole District, West Arsi Zone

Treatments	GY (Qt ha^{-1})	AGY (Qt ha^{-1})	GFB (ETBha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
Control	27.78	25.00	44378.55	0	44378.55	0
Pc	47.45	42.70	75801.38	4170.90	71630.48	653.38
Fp	38.53	34.68	61551.68	4887.48	56664.20	D

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, grain yield, AGY, adjusted grain yield.

CONCLUSION AND RECOMMENDATIONS

Verification of phosphorus critical level with farmer practices and control on the selected farmers' fields was encouraging indicator of use of soil test crop response based fertilizer recommendation for bread wheat. Accordingly, verifying phosphorus critical level influences grain and biomass yield. The highest grain yield was 47.45 Qt. ha^{-1} of 58.54% grain yield and 57.09% straw yield advantage over the control. The economic analysis showed that the highest net income (71630.48 ETB) was obtained from soil test based recommended fertilizer application with marginal rate of return (653.38%). Therefore farmers had positive responses on soil test based phosphorus fertilizer recommendation. Further effort should be made to disseminate the soil test based phosphorus fertilizer recommendation. Generally different stakeholders should work and harmonize on the transfer of the technology to farmers or end users.

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Nutrient Quality Assessment of Vermicompost Prepared from Different Raw Materials in Lume District of East Shewa Zone, Oromia, Ethiopia

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ABSTRACT

Hygienic disposal of organic wastes by vermicomposting is an environmentally sound and economically viable technology resulting in the production of organic fertilizer. Hence, the experiment was carried out in Lume District under small shade to determine the effect of varying feeding materials of vermin-worms on some selected nutrient quality of vermi-compost during 2019 cropping season. Feeding materials were (i) paunch manure alone, (2) cattle manure alone, (iii) paunch manure with wheat straw, (iv) cattle manure with wheat straw and (v) paunch manure with cattle manure and wheat straw, these were used and mixed in 8:4:1 ratio. The experiment was laid out in a randomized complete design with three replications. Shallow wood boxes with a dimension of 0.4m height, 0.6m width and 1m length were constructed for vermicompost production and vermi-worms maintaining. The bedding materials were mixed in. Then 11kg of partially digested bedding material was weighed into the boxes and 300 numbers of red worms (Eisenia fetida) were introduced in to each treatment. The analysis of variance revealed that feeding materials of vermin-worms had a highly significant ($p<0.01$) influence on all tested parameters of vermin-compost except pH, electrical conductivity and organic carbon. The results indicated that the highest sodium content (38.8 mg/kg), total nitrogen (3.03%), carbon to nitrogen ratio (10.31%), available phosphorus (1523mg/kg) and cation exchange capacity (69.08%) of vermin-compost were recorded by feeding cattle paunch manure alone. On the other hand, the highest value of potassium (25.63 mg/kg), available potassium (988.0 mg/kg) and magnesium (988.0 mg/kg) were resulted by mixed feeding materials of cattle manure and wheat straw. However, it was the only highest value (56.17 mg/kg) of calcium which was recorded from feeding of cattle manure alone. Generally, from this study results it is possible to conclude and recommend that among the substrate used for the experiment the highest values of total nitrogen and the highest values almost all tested parameters were recorded by cattle paunch manure. Therefore, cattle paunch manure is suitable for vermin-worms to decompose and produce a quality of vermin-compost and recommended for farmers and slaughterhouse industries around Lume District to be used as feeding materials of vermin-worms and produce organic fertilizer for crop production and make environmentally friendly disposal.

Keywords: *Cattle paunch manure, Eisenia fetida, Quality of vermicompost, Vermicomposting*

INTRODUCTION

Vermicomposting is an easy way to make a positive environmental impact by reducing the amount of organic waste that finds its way into landfills, incinerators, and sometimes the ocean. It can be classified as an innovative and alternative technology that represents a technology that is environmentally sound and relatively new technology (Latifah, et al., 2009). The use of vermin-compost over the years helps in building up the soil's physical, chemical and biological properties restoring its natural fertility. In the age of rapidly increasing waste, vermicomposting offers sustainable, eco-friendly and affordable techniques for waste management (Sandeep et al., 2017).

Vermi-compost use is an 'environmentally friendly, protective and restorative' process as it diverts wastes from ending up in landfills and also reduces the emission of greenhouse gases due to the very small amount of energy used in its production process(Korkmaz, 2018). Vermin-compost gives twofold benefits-producing good quality organic fertilizer and reducing the volume of organic waste by converting it into bioactive rich soil fertilizer conditioner. Similarly, vermin-composting contains major and minor nutrients in plant-available forms, enzymes, vitamins, and hormones that stimulate plant growth (Manaig, 2016).

The nutritional quality of vermin-compost is determined primarily by the type of the substrate (raw materials) and species of earthworms used for composting (Manaig, 2016). There are more than 3000 species of earthworms in the soil, but the best types of earthworms for vermicomposting are Epigaeic species (litter dwellers, live in the organic horizon) such as Eisenia fetida and Eudrilus eugeniae (Manaig, 2016). These worms have been recognized as the worm species that can eat as much as half of its weight daily. They work efficiently in breaking down and decaying natural remains and turning these scraps into high-quality organic compost. Given the optimum conditions of temperature (20 -35 °C) and moisture (60-80%), about 5 kg of worms (numbering approximately 10,000) can vermiprocess 1 ton of organic wastes into vermin-compost in just 60 days and the process becomes faster with time(Manaig, 2016).

Moreover, Eisenia fetida specie is resistant to temperature and moisture fluctuations. It is characterized by rapid growth rate, early sexual maturity; remain active throughout the year, high feeding capacity (rapid casting) and extensive reproductive capabilities. For this reality, it has been extensively used for vermicomposting of different plant residues, animal manures, and city refuse and sewage sludge (Anil et al., 2018).

In Ethiopia increasing human population, uncontrolled urbanization and waste disposal cause serious quality degradation of surface waters. Now a day's water pollution from the disposal of industrial wastewater is becoming an environmental concern in Mojo, Addis Ababa and its vicinity areas. There are many slaughterhouses (like Luna, Organic, Halal, Mojo Modern and Mojo town slaughterhouse) in Mojo Twon and they generates huge amounts of manures as waste which contain significant plant nutrients and organic matters. These activities result to generate large amounts of wastewater along with other by-products and dispose of the effluents directly into streams and rivers without any form of treatment. These effluents may cause pollution over the rivers and also create other environmental stresses in the down

streams and nearby residential areas. Consequently, human beings and other animals that might use these contaminated rivers can highly expose to various types of health problems (Abrha et al., 2015).

The disposal of ever-increasing amounts of organic wastes is becoming a serious problem. The hygienic disposal of organic wastes by composting is an environmentally sound and economically viable technology resulting in the production of organic fertilizer which is a basic and valuable input in organic farming (Thiruneela and Subbulakshmi, 20 15). Paunch manure is the partially digested feed material of rumen contents of beef at slaughterhouse and it has similar characteristics to livestock manure and an ideal material for composting through vermi-worm(Ron et. al, 2004). Composting paunch manure has benefits of agricultural sustainability and a safe way of disposing or use to create a healthy environment (Ron et. al, 2004). However, no studies have been undertaken in the study area on the nutrient quality of vermin-compost prepared from different materials. Based on the above-mentioned facts, this experiment was carried out designed to study the quality and nutrient content of cattle paunch manure vermin-compost processed by Eisenia fetida in Lume District.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Tade FTC, Lume District, East Shewa Zone of Oromia located at 73 kilometers far from Finfine (Addis Ababa) to the East. Geographically Lume District is located between 8^0 24’300” to 8^0 49’30” North and 39^0 01'00" to 39^0 17'00" East with total area coverage 67514.73 hectares. The Elevation ranges from 1590 to 2512 meters above sea level, whereas the average elevation is 1909 meters above sea level.

Experimental Design and treatments

The treatments were composted by red worms (Eisenia fetida) and consisted of five feeding materials (paunch manure alone, cattle manure alone, paunch manure with wheat straw, cattle manure with wheat straw, and paunch manure with cattle manure + wheat straw) each mixed at a ratio of 8:4:1 respectively. The experiment was laid out in a randomized complete design (CRD) with three replications. The shallow boxes were constructed with dimensions of 0.4m height, 0.6m width and 1m length from wood. Then 11kg of partially digested bedding material was weighed into the boxes and 300 numbers of red worms (Eisenia fetida) were introduced in to each treatment.

The vermiculture was constructed for vermicompost production and multiplication of warms. The size of vermiculture was 5m x 5m depending on the number of boxes. The roof of vermiculture was covered by greenhouse plastics to protect worms from sunlight and rainfall. Similarly, its walls covered by mesh wire to protect birds and other animal attacks. In the vermiculture, beds were constructed and all the boxes were set on the beds, and ash was applied under the wall of the vermiculture and legs of the beds to protect worms from small ants and insects. The details of the treatments are shown in Table 1.

Table 1:- The bedding material used in the experiment

No.	Treatments	Abbreviations
1	Paunch manure alone	PM
2	Cattle manure alone	CM
3	Paunch manure + Wheat straw	PM-WS
4	Cattle manure + Wheat straw	CM-WS
5	Paunch manure + Cattle manure + Wheat straw	PM-CM-WS

Vermicompost preparation

Composting is an excellent option for reducing environmental threats and preparing a natural, beneficial soil additive. Vermi-compost was produced using pit methods (sized 0.4m*0.6m*1m wood box) under the shade to protect worms from sunlight and rain. The roof of the shade was covered by greenhouse plastics and its wall covered by mesh wire to protect birds and other animal attacks. Cattle paunch manure was collected from Luna Export Slaughter House PLC, vermiwarms(Eisenia Fetida) and fresh animal dung obtained from Adami Tulu Agricultural Research Center and wheat straw from farmers around the site. The wheat straw was chopped to a smaller size to make favorable to worm action and to provide more surface area per volume, which facilitates microbial activities as well as moisture availability.

Then the raw materials (cattle paunch manure, animal manure, and chopped wheat straw) were mixed in 8:4:1 ratio (Ron et. al, 2004) and water was sprayed to the mixture to moist enough and make ready for worms. The mixtures were left with moisture for 30 days to degrade into smaller particles(partial digestion) to make it palatable for the worms. Then after one month 11 kg of a substrate (a mixture of pre decomposed bedding material and food source) was taken into the box and 300 number of worms (Eisenia fetida) were introduced and sprayed with water to moisten it (Anteneh et al., 2016). At the starting, the moisture of the substrates was determined and water was sprayed every three to five days or whenever drying was observed to maintain moisture at approximately 60-80% and temperature till the entire set up is moist, but not wet. Because less water kills the worms and too much water chases them away.

Vermi-compost sample collection and preparation

At the end of the experiment (60 days), watering the vermin-compost was stoped for 5 days and the worms were made to move down to the heap of the compost and gathered at the bottom of the heap. Then the vermin-compost was easily removed from the upper. Lastly, the worms were taken from the bottom by hand and the vermin-compost was gently removed and transferred to another box.

The harvested vermin-compost was then mixed thoroughly and for aggregates, due to moisture, it was allowed to air dry for one day. Then the air-dried weight of vermin-compost was determined and allowed to pass through 2mm stainless sieve. Then approximately 1 kg of the composite sample of all treatments was taken in polythene bags and brought to the laboratory for their nutrient (pH, EC, CEC, K, Na, Ca, Mg, OC, TN, Av. P, Av. K, and C: N) quality analysis. All the data were recorded by replication.

Vermicompost analysis

The collected vermi-compost samples were brought to the laboratory and test for necessary parameters (moisture, pH, EC, CEC, K^+, Na^+, Ca^{+2}, Mg^{+2}, OC, TN, Av. P, Av. K and C: N). The moisture content of the vermin-compost samples were measured gravimetrically. The pH and EC (H_2O;1:5) of vermin-compost samples were measured by a digital pH meter and conductivity meter, respectively. The total nitrogen was estimated (Kjeldahl, 1993), available P (Olsen et al., 1954) and K content (flame photometer). The CEC and exchangeable bases (K^+, Na^+, Ca^{+2}, and Mg^{+2}) of the samples were also analyzed using Ammonium acetate extraction method. The C: N ratio was calculated from the measured values of C (%) and N (%).

RESULTS AND DISCUSSION

The analysis of variance indicated that pH, Electrical conductivity, and organic carbon were not significantly ($p < 0.05$) affected by different feeding materials of vermiworm (Table 2).

Table 2:- pH, electrical conductivity and organic carbon as influenced by different feeding materials of vermin-worms.

Treatment	pH	EC(mS/cm)	OC (%)
PM	7.78	8.5	9.62
CM	7.61	10.76	8.42
PM-WS	7.78	7.97	9.99
CM-WS	7.88	10.73	8.49
PM-CM-WS	7.63	11.83	8.45
LSD(0.05)	NS	NS	NS
CV(%)	4.6	19.4	11.9

Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher protected LSD test; PM =Paunch manure alone, CM =Cattle manure alone, PM-WS =Paunch manure + Wheat straw,CM-WS=Cattle manure + Wheat straw, PM-CM-WS =Paunch manure + Cattle manure + Wheat straw, CV =Coefficient of variation, LSD = Least Significant differences, NS = not

Table 3:- Nutrient contents of vermin-compost as influenced by different feeding materials of vermin worm

Treatment	Moisture (%)	TN (%)	C:N	Av. P g/kg	Av. K mg/kg	CEC meq/ 100gm	K^+ meq/ 100gm	Na^+ meq/ 100gm	Ca^{+2} meq/ 100gm	Mg^{+2} meq/ 100
PM	77.28^a	3.030^a	10.31^d	1523^a	597.7^c	69.08^a	14.78^c	38.80^a	8.41^d	597.7^c
CM	65.67^c	2.013^b	14.38^c	1329^c	927.8^a	51.49^c	22.92^{ab}	4.14^c	56.17^a	927.8^a
PM-WS	79.18^a	1.580^c	16.26^b	1226^d	682.3^b	61.76^{ab}	15.96^c	32.58^{ab}	12.61^d	682.3^b
CM-WS	69.71^b	1.507^c	17.51^a	1023^e	988.0^a	57.14^{bc}	25.63^a	4.40^c	47.53^b	988.0^a
PM-CM-WS	76.10^a	2.077^b	14.34^c	1408^b	933.0^a	65.94^{ab}	22.64^b	29.35^b	28.13^c	933.0^a
LSD(0.05)	3.926	0.255	1.189	9.92	81.16	9.91	2.9251	7.90	7.71	4.060
CV(%)	2.8	6.6	4.3	0.4	5.2	8.6	7.6	19.2	13.4	25.7

Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher protected LSD test; PM =Paunch manure alone, CM =Cattle manure alone, PM-WS =Paunch manure + Wheat straw,CM-WS=Cattle manure + Wheat straw, PM-CM-WS =Paunch manure + Cattle manure + Wheat straw, CV =Coefficient of variation, LSD = Least Significant differences, NS = not significant

Moisture content

The analysis of variance showed that moisture contents of vermin-compost were highly significantly ($p < 0.01$) influenced by different composting materials of vermin-worms. As indicated in Table 3, the highest (79.18%) moisture content was recorded by feeding material of cattle paunch materials with wheat straw. However, this result was not statistically different from the result of cattle paunch manure as well as paunch manure + cattle manure + wheat straw. That means optimum moisture content for the growth of Eisenia fetida becomes faster and optimum at around 76% moisture content of vermin-compost.

In agreement with this result, Kiyasudeen et al., (2016) reported that moisture content of vermin-composts should be between 75% and 90 % during processing. Similarly, Liang et al., (2003) reported the moisture content of 60-70% was proved to have maximal microbial activity, while 50% moisture content was the minimal requirement for a rapid rise in microbial activity. However, Swati and Reddy, 2009 reported that optimum moisture content for the growth of Eisenia fetida earthworms was 85% in organic waste management.

Total nitrogen

The analysis of variance indicated that total nitrogen was highly significantly ($p < 0.01$) influenced by variation in feeding materials of vermin-worms (Table 3). As the result indicated that the highest total N content (3.03%) was recorded by feeding of cattle paunch manure alone, while the lowest value of (1.507%) was recorded by mixed feeding ratio cattle manure with wheat straw.

This result is in line with the result of Tadele, et al., (2018) who reported the range of 3.04% to 4.26% of total nitrogen in vermin-compost prepared from different organic materials. Similarly, the result is consistent with the result of Manaig, (2016) who recorded total nitrogen ranges from 0.86-3.87%. Moreover, similar results by Ron et al., (2004) who reported that total nitrogen of vermin-compost prepared from paunch manure and dry animal manure ranged 2.74-2.57(%).

According to Tadele et al., (2018) the variation of total nitrogen content among the treatments might attribute to the type of substrates and their content of nitrogen. It was also reported that the enhancement of nitrogen in vermin-compost was probably due to mineralization of the organic matter containing proteins and conversion of ammonium-nitrogen into nitrate (Sandeep et al., 2017). However, the nitrogen content of vermin-composts varies from country to country and substrate to substrates; the standard total nitrogen content of compost will normally range from 1.5-3.5 % (Katheem et al., 2016). In addition, Kefyalew and Tilahun, (2018) reported that a compost had fertilizing capabilities and for it to be used in agriculture the total nitrogen content had to be over 1%.

Carbon to nitrogen ratio (C: N)

The analysis of variance indicated that the C: N ratio was highly significantly ($p < 0.01$) influenced by variation in feeding materials of vermin-worms (Table 3). As the result indicated that the lowest (10.31%) was from feeding of cattle paunch manure alone. While the highest value of (17.51%) was recorded by mixed feeding ratio cattle manure with wheat

straw. This result is consistent with the result of Tadele et al. (2018) who reported that C: N ratio < 20 indicated advance in organic matter stabilization and reflects a satisfactory degree of maturity of organic wastes. Moreover, the result is concurrent with the result of Ron et al., (2004) and Tadele, et al., (2018) who reported that the C: N ratio of vermin-compost prepared from different organic materials ranged between 13% to 16% and 7% to 9.13% respectively.
The C: N ratio is one of the most widely used indicators of vermin-compost maturation, decreased sharply during the vermin-compost process. According to Jayanta et al., (2015) higher nitrogen levels and lowers C: N ratio in vermin-compost could be attributed to alteration of microbial nutrient spectrum in earthworm casts due to the increased presence of nitrogen-fixing microbes which in turn enhance total nitrogen concentration in vermin-compost. Similarly, Katheem et al., (2016) reported that the C: N ratios much higher than this may indicate the presence of bioavailable carbon and therefore material that is not completely stabilized.

Available phosphorus

The analysis of variance indicated that available phosphorus was highly significantly ($p < 0.01$) influenced by variation in feeding materials of vermin-worms (Table 3). As the result indicated that the highest (1523 mg/kg) was from feeding of cattle paunch manure alone. While the lowest value of (1023 mg/kg) was recorded by feeding of cattle manure with wheat straw. This result is agreed with the finding of Jayanta et al., (2015) and Zarei et al., (2011) that reported that available phosphorus in vermin-compost ranged1300-1600 mg/kg and 1056-1643 mg/kg, respectively.

According to the report of Muzafer, and Pinky, (2017) the content of available phosphorus in vermin-compost was based on raw material used for composting and management of the process, the uptake of bacteria, fungi and other microorganisms by the earthworms, excretion and decomposition by the earthworms and microorganisms might be the reason of releasing and increasing the content of phosphorus in the vermin-compost.

Available Potassium

The analysis of variance indicated that available potassium was highly significantly ($p < 0.01$) influenced by variation in feeding materials of vermin-worms (Table 3). The result indicated that the highest available K (25.63 mg/kg) was resulted from feeding of cattle manure with wheat straw. The lowest value (14.78 mg/kg) was recorded by feeding paunch manure alone.

Cation exchange capacity

The analysis of variance indicated that cation exchange capacity was highly significantly ($p < 0.01$) influenced by variation in feeding materials of vermin-worms (Table 3). The highest CEC (69.08 meq/100gm) was from feeding of cattle paunch manure alone. The lowest value of (51.49 meq/100 gm) was recorded by mixed feeding ratio cattle manure. This result was similar to the finding of Tadele et al. (2018) who reported that CEC in vermin-compost ranged from 57-68.70 mg/kg.

Exchangeable bases

The analysis of variance indicated that all exchangeable bases (K^+, Na^+, Ca^{+2}, Mg^{+2}) were highly significantly ($p < 0.01$) influenced by different feeding materials of vermin-compost. As indicated in Table 3, the highest exchangeable potassium (25.63 meq/100 gm), and exchangeable magnesium (988 meq/100 gm) were recorded by feeding mixed cattle manure with wheat straw. Similarly, the highest exchangeable sodium (38.80 meq/100 gm) and exchangeable calcium (56.17 meq/100 gm) were recorded by feeding paunch manure alone and cattle manure, respectively. Except for the lowest value (8.41 meq/100 gm) of exchangeable sodium which was recorded by cattle manure alone, all the lowest values of exchangeable potassium (14.78 meq/100 gm), exchangeable calcium (8.41 meq/100 gm) and exchangeable Magnesium (597.7 meq/100 gm) were recorded by feeding materials of cattle paunch manure alone.

CONCLUSION AND RECOMMENDATION

The disposal of ever-increasing amounts of organic wastes is becoming a serious problem. Therefore, the hygienic disposal of organic wastes by composting through vermin-worm is an environmentally sound and economically viable technology resulting in the production of organic fertilizer which is a basic and valuable input in organic farming.

The results of composting experiment showed that the highest total nitrogen (3.03%), the lowest Carbon to nitrogen ratio (10.31%), the highest available phosphorus(1523 mg/kg), the highest cation exchange capacity(69.08 meq/100gm), and the highest sodium content (38.80 mg/kg) were recorded by feeding material of cattle paunch manure alone. However, the highest available potassium (988 mg/kg), the highest potassium (25.63 mg/kg), and the highest magnesium (988 mg/kg) were recorded by mixed feeding materials of cattle manure with wheat straw. Also the highest calcium (56.17 mg/kg) and the highest moisture content (79.18 %) of vermin-comost were recorded by feeding materials of cattle manure and paunch manure with wheat straw, respectively.

From the results of this experiment it can be conclude that almost all of the highest values of tested parameters of vermin-compost were recorded by feeding materials of cattle paunch manure alone. Besides the highest values of total nitrogen was recorded by this substrate. Therefore, cattle paunch manure alone is suitable for vermin-worms to decompose and produce quality vermin-compost and recommended for farmers and slaughterhouse industries around Lume District to be used as feeding materials of vermin-worms and produce organic fertilizer for crop production and make environmentally friendly disposal.

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Restoration and Rehabilitation of Degraded Land: The case of Termite Management Technologies in Diga District, Wollega, Oromia, Ethiopia

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ABSTRACT

Land degradation is a pervasive and systemic phenomenon. It is a global problem, adversely affecting the livelihoods and food security of billions of people. Combating land degradation and restoring degraded land is an urgent and a priority to protect the biodiversity and ecosystem services vital to all life on Earth and to ensure human well-being in general. Majority of the Kebele in Diga district was highly degraded, infested by termite and thus left bared throughout the year. The present land restoration and rehabilitation demonstration activity was aimed to restore vegetation cover, soil loss and most biodiversity components thereby re-initiating livelihood activities on the mostly degraded land located in Mada Jalala kebele. We used different restoration technologies, such as enclosing the area from livestock and human interference, planting different termite tolerant tree/shrub species, manual plowing of the compacted soil structures, sowing exotic grass species, soil and water conservation practices such as filling with grass and other vegetation types into the gully erosion path ways. About 9 hectares of degraded area was covered. Planting of 7 termite tolerant tree/shrub species (including Chomo grass) was made and on average about 90% are survived to date. Initial and intermediate soil sample analysis and biodiversity data were collected and analyzed. From the initial data of biodiversity analysis, species richness for plants were only 7, while for birds and other wildlife was zero prior to the implementation. The intermediate biodiversity assessment data shows that species richness of vegetation (grass and plants) becomes 70, of which 85.7% are naturally regenerated. About 7 birds' species and 6 other wildlife species have been also restored in to the area. From satellite image analysis, vegetation coverage of the study site increased from 22.22% in 2016 to 83.33% in 2019. This achievement is a clue for practicing similar restoration and rehabilitation in Diga district in particular; termite damaged and degraded lands of the western Oromia in general.

Key words: *biodiversity, degraded lands, rehabilitation, restoration*

INTRODUCTION

Land degradation is a pervasive and systemic phenomenon which is a global problem, adversely affecting the livelihoods and food security of billions of people. Combating land degradation and restoring degraded land is an urgent and a priority to protect the biodiversity and ecosystem services vital to all life on Earth and to ensure human well-being in general. About 46% is currently being used for agriculture and forestry; almost 7% is considered urban, peri-urban or modified by human infrastructure from the total area of ice-free land on earth which is estimated as much as 13 billion hectares (Hooke et al. 2012). Estimates indicate that up to 25% of all land is currently highly degraded, 36% is slightly or moderately degraded while only 10% is improving (FAO 2011). In the last two centuries, humans have

converted or modified 70% of the world's grasslands, 50% of the savannah, 45% of the temperate deciduous forest, and 27% of the tropical forest biome primarily for farming and grazing activities (FAO 2018). In twenty years (1985-2005), the world's croplands and pastures expanded by 154 million hectares (Ray et al. 2012). Agriculture is estimated to be the proximate driver for approximately 80% of deforestation worldwide, (Kissinger and Desy 2012) resulting in a dramatic loss of water, carbon and other regulating services. Given the current trends in land degradation, and under a business-as-usual scenario, deforestation and other forms of ecosystem conversion are likely to continue in order to meet the projected increases in demand for food, energy and water in the next decades. Agricultural practices and socio-ecological benefits are strongly interrelated, which might also affect the ecosystem services of different farming systems. Especially, land area used for agricultural production or for other purposes, such as nature conservation, presents a tradeoff to society in terms of ecosystem services provided. Agricultural lands provide food, feed, and fiber and, increasingly, biofuels, while natural ecosystems provide other important ecosystem services (Duguma et al. 2019).

As far as Africa is one of the most vulnerable continents to degradation in the world, over 700 million ha of its land has already degraded, and degradation still occurs at an alarming rate of 3% annually. Nearly 3 million hectares of forests are lost and sixty five percent (65%) of the land is affected by degradation every year and an estimated 3 percent of GDP is lost annually from soil and nutrient depletion on cropland (FAO 2018). This places forest loss and land degradation among the key challenges facing Sub-Saharan Africa (SSA). This offers tremendous opportunity for restoration.

FAO has been deliberately reporting that land degradation and desertification greatly impair the livelihoods and food security of farmers and pastoralists in Ethiopia's dry lands. It is estimated that 92 000 hectares of forest, woodlands and 2 billion metric tons of fertile soil are lost every year. Improper land use, poor land management practices, population pressure, overgrazing and deforestation are among the main causes of land degradation in Ethiopia. Moreover, climate change is exacerbating its impact on rural communities. In 2016, the country faced the worst drought in fifty years that affected more than 10 million people (FAO 2018). In general UN tried to display how different life forms suffer and an approach how they should be conserved on land in the below figure (fig. 1).

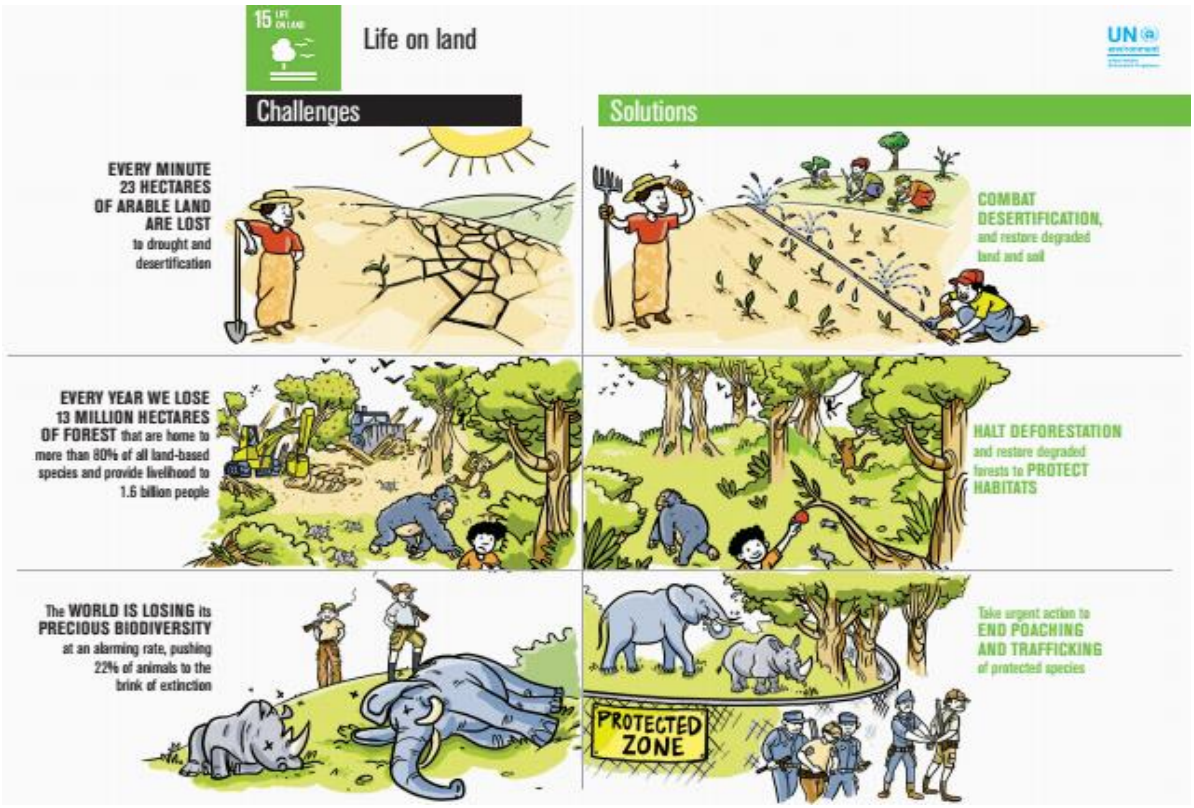

Figure 1: A joined-up approach to delivering the global goals for sustainable development, FAO. 2018.

Accordingly, African leaders responded to the urgent global wakeup call at COP21, with a collective pledge to restore 100 million ha of degraded land by 2030 (FAO 2018). Although some articles discusses that over the last 20 years, the scale of restoration of degraded land through soil and land conservation and tree planting in Ethiopia is noteworthy, there are still tremendous land degradation continues in most parts of the country in general, and specifically in western parts of Ethiopia. During our different ADPLAC meetings, surveys, trainings and professional observations in western parts of Oromia, we recognized that the land degradation impact is becoming major issue of the natural resources sectors and initiated for the current project in Mada Jalala Kebele.

Therefore, this project planned and undertakes restoration and rehabilitation of land degradation which can simultaneously contribute to climate change, biodiversity and sustainable development objectives. Specifically, majority of Kebeles in the Diga district were highly degraded, infested by termite and thus left bared throughout the year. The present land restoration and rehabilitation demonstration activity was aimed and implemented restoration of the vegetation cover, soil loss and most biodiversity components thereby re-initiating livelihood activities on the mostly degraded land located in Mada Jalala kebele.

MATERIALS AND METHODS

Description of the study area

The project was implemented in Mada Jalala Kebele of Diga district. Diga district is located in East Wellegga, Oromiya, Ethiopia (fig. 2). Its agroecology consists about 48.6% mid

altitude and the rest 51.4% is low-land, and its altitude ranges from 1200-2220m asl. It is geographically located between coordinates of 8° 56' 0" North, 36° 35' 0" East. It has been getting annual rainfall ranging from 1200-2100mm, and its temperature ranges from 18-32C^{o} (Diga district agricultural office, 2020).

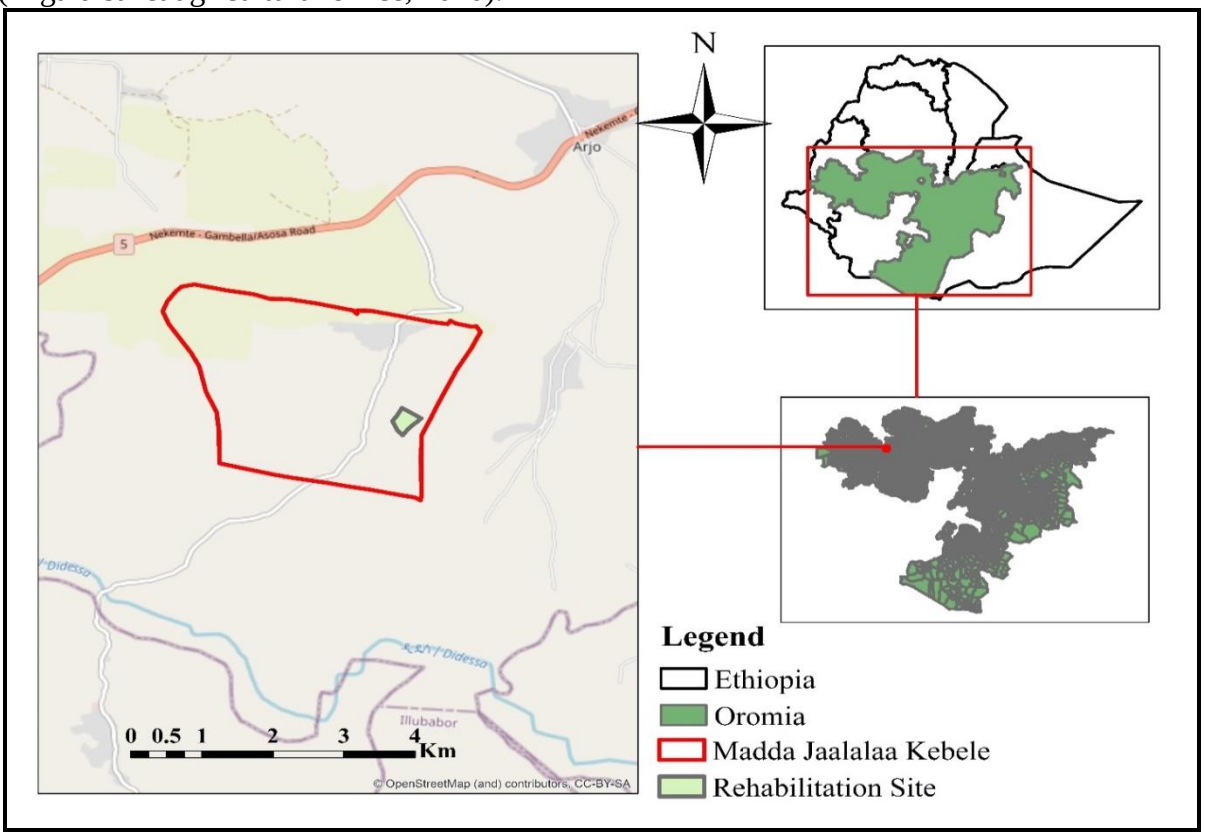

Fig. 2. Description of study site

Rehabilitation and Restoration Methodologies Used

Natural Regeneration (Area closuring)

This involves deliberately managing the land to enhance and accelerate the natural processes of ecological succession in order to re-establish a healthy and resilient forest ecosystem (Blay et al. 2004; ITTO 2005). Accordingly, this method was used to protect the area from livestock and human interferences. About 10 hectares of the rehabilitating area were enclosed and guards were employed for night and day protection. Informal and illegal human paths (roads) were closed and shifted to corners from inside of the area.

Enrichment Planting (Planting different termite tolerant tree/shrub species)

It is defined as the planting of valuable species in degraded forests without the elimination of valuable individuals already present. The technique is suitable for the restoration of over exploited primary and secondary forests as it can increase total tree volume and the economic value of forests (Blay et al. 2004). Based on this valuable method, since the area was under termite damage and left bare from any vegetation cover, planting different exotic tree species which will tolerate the termite infest was mainly used. By planting different exotic tree/shrub species, different indigenous tree/shrub species will be regenerated. Tree/shrub planting was

made systematically using purposive spacing. Accordingly, tree species were planted using 1m within each plant and 10-20 meters away within rows.
Additionally, covering the bared and eroded top soil of the area was very important thereby helping for natural regeneration of local grasses from soil seed bank. Accordingly, we used to sow signal grass (Brachiaria decumbens) or which is locally known as chomo grass in to the area. Sowing exotic grass will help natural regeneration of indigenous grass species more for competition.

Assisted Natural Regeneration
It is used to accelerate regeneration by assisting the natural processes and it involves cutting or pressing down the weeds around existing naturally occurring seedlings, protecting the site from fire and inter-planting with desired species if necessary (ITTO 2005). Due to high degradation and leaching of the soil structures of the area, the porosity and simplicity of the land for plantation and grass sowing was impossible. Therefore, we used manual plowing (hoe and oxen plowing) to make it easy for planting and sowing management.

Soil and water conservation practices such as filling with grass and other vegetation types into the gully erosion path ways.

To control gully erosion and extra soil loss we have also made soil and water conservation structures and filling with grass and other vegetation coverage in to the gully erosion path ways were achieved here.

Data Collection Methods

Soil data
Composite (initial) soil sample was taken before taking actions of restoration activities. After implementation of the restoration activities, we have been also collected soil samples once a year.

Survival count and species selection
Planted trees/shrubs species were being counted for survival data. The result of survival data contributed to select any tree/shrub species which is termite and soil infertility tolerant to be planted in the degraded area.

Vegetation cover change
Vegetation cover of the area was from the main purpose to change because there was very limited and only 22% of the total area was covered by grass and weedy species before restoration actions in 2016. This vegetation coverage was found at edges of the area. Therefore, bringing change and remarking its data was very important, and we used different satellite images and analyze them by GIS tools.

Biodiversity data
Biodiversity of naturally regenerated and planted tree, shrubs, grass and bushy species were systematically collected from 10*10m plotted areas containing a total of 34 plots, where the plots' length and width were laid 50m apart from each other. From each plot all vegetation

forms including grasses and weeds were collected and recorded by their local or common names. Birds and other wild animals restored in to the area were also recorded based on day to day follow-up of the guards and causal workers.

Data Analysis

Soil data

Soil data were analyzed in laboratory and epecially, its acidity was carefully observed for more soil conservation actions.

Survival data

Survival ratio of planted trees/shrubs species was computed by dividing numbers of survived count to planted amount, and then multiplying it by 100%.

Vegetation cover change

Analysis of vegetation cover change was made from downloaded satellite images by using GIS tools (tab. 1; fig. 3).

Table. 1: Descriptions of Land cover classes

No.	Land cover types	Description
1	Vegetation	All vegetation's including grasses (both green and dried)
2	Non-vegetation	Bare lands, degraded lands (have no any vegetation coverage)

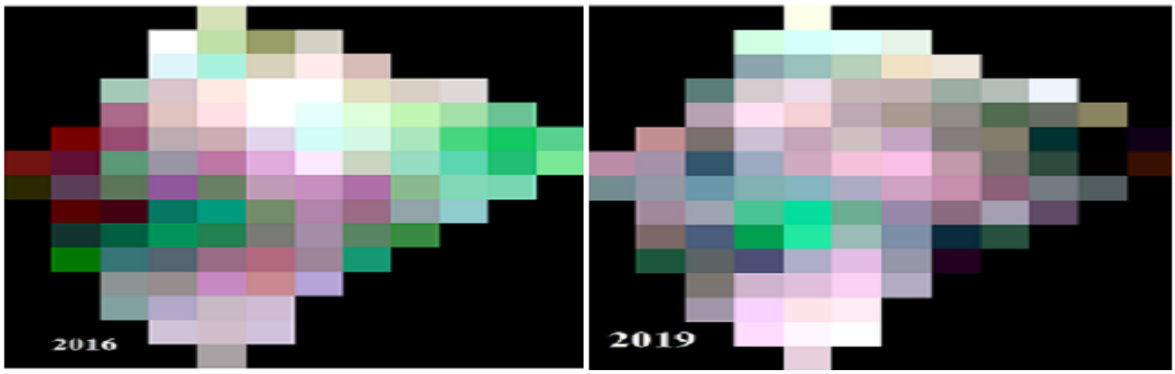

Fig. 3. Identified Regions of Interests of 2016 and 2019 images

Biodiversity data analysis

Level of species diversity and their distribution in the restoration area was identified. For now species compositions (richness (S)) was simply counted for plants, birds and other wild animals. This was based on 34 plots from the restoration area, and a total number of species was identified, categorized and registered. The birds' species were identified and categorized by their color and size. Wild animals hosted in the area were counted, and other reptiles and insects were not addressed.

RESULTS AND DISCUSSION

Planting and Survival

The result of this project includes only the 3 consecutive planting years (2017-2019), and we achieved planting of about 45,000 tree seedlings on the 10 hectares of degraded area, while

sowing of different grasses and shrubs like tephrosia were additional activities to enhance the natural regeneration. Grevillea robusta, Melia azedrach, Croton macrostachyus, Shinus mole, Cordia africana, Moringa olifera, Moringa stenopetala and Tephrosia candida were among the tree and shrub species planted for the restoration purpose. Selection of termite moisture stress tolerant species was made after the first year survival count. Accordingly, Grevillea robusta (91% survived), Tephrosia candida (98% survived), Melia azedrach (86% survived), Croton macrostachyus (84.5% survived) and Cordia africana (84% survived) were selected for more expansion in to the area.

This successful survival of the planted tree and shrub species disagrees with Verma et al. 1999 and Blay et al. 2004 which indicate that past reforestation and afforestation programs in the degraded areas have often been unsuccessful with no or very low survival of the planted trees. They reason out factors such as unavailability or low availability of propagules, low soil nutrient availability, absence of fungal and/or bacterial root symbiosis or unsuitability of the microhabitats for plant establishment in general and seasonal drought. We realized the reason of our disagreed result from the above studies may be due to the integrated and multidisciplinary restoration actions and successful approaches we made. Integration of soil protection, biodiversity conservation, vegetation cover increment and enhancing natural regeneration of vegetation types were the best methods we implemented. Brachiaria decumbens (Chomo grass) has been also sown on very degraded and bare areas. The below figure shows procedures gone through during the restoration activities (fig. 4).

Fig. 4. Some procedures and current status of Diga restoration site

Soil

Composite soil test indicates that the soil was extremely acidic of PH 4.3. After a year its nalysis shows that it comes to very strongly acidic of PH 4.52. This acidity levels were classified as a PH of 'extremely acidic' soil ranges from 3.5 – 4.4, and 'very strongly acidic' soil ranges from 4.5 -5.0 as far as it is sated in the manual of U.S. Department of Agriculture (Kellogg, C.E. 1993). Compacted and eroded soil was very common in the area before the restoration. After the three years of implementation, the soils become soften, and especially top soil is becoming stored due to erosion control of grasses, planted trees/shrubs and some conservation structures (fig. 5).

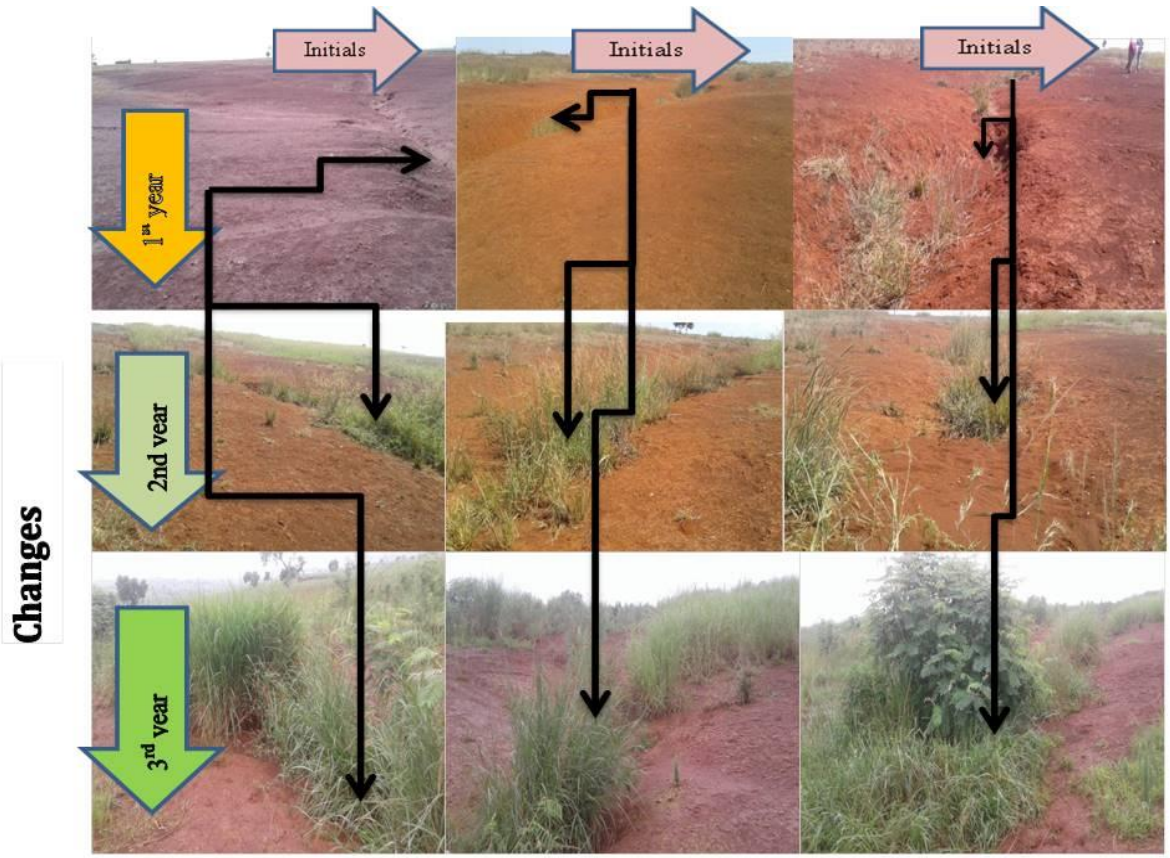

Fig. 5. Pictures demonstrate how erosion controlled and being covered with grasses and shrubs

From the above pictures we can observe that there were so many changes come after the implementation of restoration activities.

Biodiversity

From the initial data of biodiversity analysis, species richness for plants were only 7, while for birds and other wildlife was zero prior to the implementation. This result was in line with Verma et al. 1999 and Blay et al. 2004; studies, which indicate that severely degraded lands are typically characterized by heavily eroded or nutrient deficient soils, hydrological instability, reduced primary productivity and low biological diversity. The intermediate biodiversity assessment data shows that species richness of vegetation (grass and plants) becomes 70, of which 85.7% are naturally regenerated. About 7 birds' species and 6 other wildlife species have been also restored in to the area (tab. 2). This result also agrees with Emiru 2002; Kidane 2002; Tesfaye 2002 and Tefera et al. 2003 studies which put that it has become a common phenomenon to observe increase of plant as well as animal biodiversity with time after the establishment of area closures and restoration activities.

Table:2. Species diversity after restoration

Local name	Scientific name	Family name
Ada	Guizotia scabra	Compositae/Asteraceae
Alihanqa	unidentified	Compositae/Asteraceae
Anano	unidentified	unidentified
Arama Bira	unidentified	unidentified
Asangira	Datura stramonium	Solanaceae
Bakkanniisa	Croton macrostachyus	Euphorblaceae
Biiqqaa	Combretum molle	Combretaceae
Bitimo	unidentified	unidentified
Came	unidentified	unidentified
Ceka	Calpurnia aurea	Fabaceae/Leguminosae
Cita Bicu	Digitaria abyssinica	Poaceae/Gramineae
Cita Saro	Digitaria velutina	Poaceae/Gramineae
Cita Simbira	Eragrostis cilianensis	Poaceae/Gramineae
Como	Brachiaria decumbens	Poaceae/Gramineae
Como uumamaa/Chafe	Brachiaria eruciformis	Poaceae/Gramineae
Coqorsa/Sardo/Sardu	Cynodon nlemfuensis	Poaceae/Gramineae
Dafura	Pennisetum polystachion	Poaceae/Gramineae
Damakase Gurati	unidentified	unidentified
Dargu/Mata jabo/Kontoma	Hypoestesforskaolii	Acanthaceae
Dhadha'o	Echinocloa colona	Poaceae/Gramineae
Dhoboroka	unidentified	unidentified
Ebicha	Vernonia amygdalina	Compositae/Asteraceae
Garagara	Eleusine indica	Poaceae/Gramineae
Gravillea	Gravillea robusta	Proteaceae
Gura Hantuta	unidentified	unidentified
Hamaresa	unidentified	unidentified
Harata mana	unidentified	unidentified
Hiddi Hola	unidentified	unidentified
Ifte	unidentified	unidentified
Incini	unidentified	unidentified
Jajaba	unidentified	unidentified
Jajabo/Muruyyii	Loudetia simplex	Poaceae/Gramineae
Kalala	unidentified	unidentified
Lilu	Piliostigma thonningii	Fabaceae/Leguminosae
Mango	Mangifera indica	Anacardiaceae
Maraga	unidentified	unidentified
Maxxane	Galium spurium	Rubiaceae
Migira	unidentified	unidentified
Mishinga	Sorghum bicolor L.	Poaceae
Muka tasbi	unidentified	unidentified
Mutaa bokkolluu	unidentified	unidentified
Nimi	Melia azedarach	Meliaceae
Nyata Arba	Elephant grass (Pennisetum purpureum	Poaceae
Qaxaxu/Maxaxa	unidentified	unidentified
Qobo	Jatropha curcas	Euphorbiaceae
Qubo/Gambela	unidentified	unidentified
Qumuxu	unidentified	unidentified
Qunce salixa	unidentified	unidentified
Quni/Giranxa	Cyperus esculentus	Cyperaceae

Local name	Scientific name	Family name
Riga Adi/Karaba	Sida rhombifolia	Malvaceae
Riga dima	unidentified	unidentified
Riga Farda	unidentified	unidentified
Rodesi/Bajjii Adii	Pennisetum clandestinum	Poaceae/Gramineae
Sanbaleta callaa/Sanbaleta qal'aa	Hyparrhenia anthistrioides	Poaceae/Gramineae
Sanbaleta furdaa/ Daggala/ Sanbaleta obbaa	unidentified	Poaceae/Gramineae
Sartu Hola	Portulaca oleracea	Portulacaceae
Shufe	Digitaria ternata	Poaceae/Gramineae
Soyoma	Vernonia thomsoniana	Compositae/Asteraceae
Tefrosia	Tephrosia candida	Fabaceae/Leguminosae
Toma Simbiro	unidentified	unidentified
Uddun taa'i	unidentified	unidentified
Unknown	unidentified	unidentified
Wacara	unidentified	unidentified
Waddeessa	Cordia africana	Boraginaceae
Walgabis/holgabis	Launaea intybacea	Compositae/Asteraceae
Warake	unidentified	unidentified
Xayisar	unidentified	unidentified
Xiye	Bidens pilosa	Compositae/Asteraceae
Xosno	unidentified	unidentified
Zayituna	Psidium guajava	Myrtaceae

3.4. Vegetation Cover Change

From satellite image analysis (fig. 6), vegetation coverage of the study site increased from 22.22% in 2016 to 83.33% in 2019 (tab. 3).

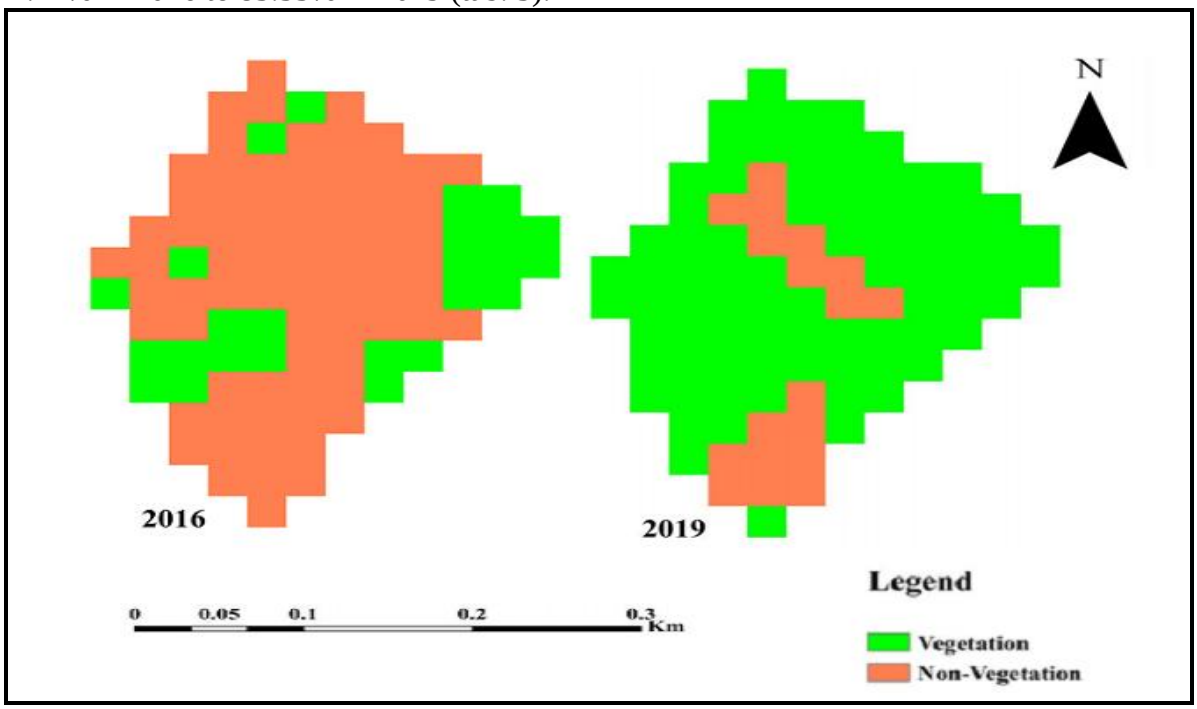

Fig. 6. Classified images of 2016 and 2019

The overall classification accuracy for over the period of 2016 and 2019 was 95% and 96.97% with kappa coefficient of 92.26% and 89.11%, respectively (tab. 3). This result is in agreement with Fitzgerald and Lees (1994) argued that, the values of kappa coefficient (K) ranges between 0 (no agreement) and 1 (complete agreement). These values are poor agreement when K < 0.4 (40%), good agreement when K values ranges between (0.4 or 40% ≤ K ≤ 0.75 or 75%) and excellent agreement when K > 0.75 (75%).

Table 3. Producer's and User's accuracies classification by year (in percent)

Land cover classes	2016		2019	
	Prod.	User's	Prod.	User's
Vegetation	93.33	87.50	100.00	96.43
Non-vegetation	96.30	96.30	83.33	100.00
Overall accuracy (%)	**95.00**		**96.97**	
Kappa coefficient (%)	**92.26**		**89.11**	

Table 4. Area coverage and percentage statics of land cover class from 2016-2019

Land cover classes	2016		2019	
	Area (ha)	%	Area (ha)	%
Vegetation	2.22	22.22	8.33	83.33
Non-vegetation	7.78	77.78	1.67	16.67
Total	**10.00**	**100.00**	**10.00**	**100.00**

Source: computed from the classified Landsat 2016 and 2019 images.
N.B: Percentage of area coverage = (Area of the year/total area)*100

In 2016, vegetation class category accounts 22.22% and non-vegetation accounts 77.78%, while in 2019; vegetation and non-vegetation class accounts about 83.33% and 16.67%, respectively (tab. 4). Between the periods of 2016 and 2019 (tab. 5), vegetation showed maximum changes. It increased to 6.11ha (mean rate of 2.04ha/yr) while the non-vegetation decreased with -6.11ha (mean rate of -2.04ha/yr).

Table 5. Extent of land cover classes change in 2016 and 2019 years image data

Land cover classes	2019		2016		Change (ha)	Average rate of change (ha)
	Area (ha)	%	Area (ha)	%		
Vegetation	8.33	83.33	2.22	22.22	6.11	2.04
Non-vegetation	1.67	16.67	7.78	77.78	-6.11	-2.04
Total	**10.00**	**100.00**	**10.00**	**100.00**		

N.B: Change = (Area of the final year- Area of initial year), Average rate of change = change/number of year interval

This indicates that, vegetation cover has been dramatically increased; whereas covered by non-vegetation were declined over the study durations. Report done by Payn et al. (2015) expressed that, the reasons for contributing net increases in vegetation includes reduced pressure on forests (vegetation) as a result of economic growth, declining rural populations or improved agricultural productivity and effective policies aimed at expanding forest area/protecting the degraded area (FAO 2016). One study done in western Ethiopian highland stated that, for some periods of the year, small portion of the farmland was converted into vegetation's due to some forest reestablishment including rehabilitations and restorations (Feyissa 2015). In the study area, land cover class patterns showed an increment of vegetation class and shrinkage of non-vegetation cover. This is caused due to protections of human and animal's interference, plantations of multipurpose exotic tree/shrubs species, grass species as well as some regenerations of tree/shrub and grass species.

CONCLUSION AND RECOMMENDATIONS

Restoration and rehabilitations of degraded lands need integration of different techniques and also commitment and involvement of different disciples. The technologies we have been implemented in order to restore the ecosystem and the ways we follow to understand how it worked before it was modified or degraded, and then the procedures we use to realize our understanding to reassemble it and reinstate the degraded area were very tremendous and challenging. However, we have realized and achieved, first, how to enhance the translation of recent advances in our understanding of ecosystem and landscape dynamics into the conceptual and practical frameworks for restoration. Second, how to promote the development of an ability to correctly diagnose ecosystem damage, identify restoration thresholds, and develop corrective methodologies that aim to overcome such thresholds. The third key achievement was that we could determine that the results were the realistic goals for restoration which are based on the ecological realities of today and how these will change in the future, given on-going changes in climate and land use systems. Finally, we realized how successful synthetic approaches draw together the ecological and social aspects of the issues surrounding restoration and the setting of restoration goals. Beside this all, termite damage to the plants and top soils is being reduced through time, and its clue indicates that our challenging procedures were successful. Therefore, the soil improvement change, biodiversity

conservation gained, vegetation cover changes and overall changes we achieved in the restoration activities enhance our objectives of overcoming termite risks in the degraded environment. From this achievement we recommend that: 1. to eradicate extreme poverty or to generate additional income and employment we must look to healthy and productive land. Since land is a very necessary source for every livelihood, we should firstly conserve land reverse its productivity. The land use sectors in general and of the Diga district in specific, with its high concentration of poor people will offer some of the most significant opportunities for green growth and prosperity if and only if conservation made to it. Therefore, preventing further land degradation must be a high priority if we are to make a transition to a more sustainable development and community's livelihood, which is strongly reflected in Sustainable Development Goal 15 which states: "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

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AGRICULTURAL ENGINEERING RESEARCH

Modification of Engine powered Single Disc Coffee Pulper to Double Disc and Evaluation its performance

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ABSTRACT

An engine powered single disc coffee pulping machine was modified in to double disc machine with an objective increases the capacity of single disc and value add for coffee. The machine was developed in Jimma agricultural Engineering research center and its performances were evaluated in local woredas. The evaluated performances of the machine were; pulping capacity, percentage of mechanical damage, pulping efficiency and none pulped losses of the coffee. Results of the evaluations indicated, maximum pulping capacity, minimum percentage of mechanical damage, pulping efficiency and minimum none pulped losses of; 983.33 kg hr-1 at 7 kg/min feed rate and 208 rpm, 1.28 % at 7 kg/min and 92 rpm, 97.10 % at 9 kg/min and 208 rpm and 1.87 % at 9 kg/min and 208 rpm, respectively of double disc while 173.06kg/hr capacity and 95.5% pulping efficiency of the single disc. The performance of this machine is based on the adjustment of the machine (the clearance between discs and guide) especially mechanical damage, pulping efficiency and none pulping loss. Therefore, we recommended that coffee producing farmers and organizations can use this machine to increase their coffee products pulping capacity and efficiency, save time of pulping, minimize losses and maintain quality of their coffee bean.

Keywords: Coffee pulper, Double disc, engine powered, Parchment, Performance, evaluation,

INTRODUCTION

Coffee is the world's favorite beverage and most traded commodity (Barbosa et al., 2014). Ethiopia is the center of origin for highland coffea (Coffea arabica L), which is one of the most valuable cash crops in the country. It represents the major agricultural export crop, providing 20–25% of the foreign exchange earnings (ECFF, 2015). The coffee sector contributes about 4–5% to the country's Gross Domestic Product (GDP) and creates hundreds of thousands of local job opportunities (EBI, 2014).Ethiopia is the center of origin for Coffee Arabica and possesses a diverse genetic base for this Arabica coffee with considerable heterogeneity (Minten et al., 2014). Jimma Zone is one of coffee growing zones in the Oromia Regional State, Samuel et al., (2018) found that the share of coffee income from total income in coffee producing districts of Jimma zone is 77%. On other hands, share of land allocated to coffee crop in these areas is more than 69%. This shows that coffee is not only the source of cash and income; but also the means of livelihood for the smallholder farmers of the area.

Coffee berries' pulping, is the first phase of the coffees' post harvest processing, that can be done in to methods called wet and dry pulping.. The wet pulping is the process that can be

done immediately after harvesting. The wet method currently varies depending on the degree of fermentation (P. Palmiro and R. Franca., 2016). Any of the methods employed, which depends on locality, types of coffee and prevailing weather conditions, is followed by hulling which is the removal of hull or parchment to obtain two usual beans from cherry.

Desse (2008) reported that, out of the Jimma's coffee sent to the coffee quality inspection center laboratory. in years 2003 to 2007, more than 60% of dry processed coffee were classified into grade 3 as compared to 80% of wet processed classified into grade 2 and 3. According to the author, the problem of post harvest processing and handling in the area were the causes, for resulted poor quality as a main contributing factor. The poor quality due to post harvest processing and the subsequent drop in earnings had severely affected coffee farmers in woredas like Gomma, Limmu Kossa, and Manna, where coffee provides a larger portion of their annual income. (Kassaye T., et al., 2018) studied that coffee beans sampled from cooperatives had higher quality scores and were classified as specialty 1 (Q1) (33%) or specialty 2 (Q2) (67%). About 78% of coffee beans sampled from private traders fall in grade 3, while 22% of their beans qualified for Q2. Coffee certification, in general, did not add any value to coffee quality. No quality differences were also observed between coffee beans sampled from farmers. Coffee quality differences were observed between coffee processing methods. Due to absence of such technologies the cost of their coffee would be reduced. This force them to sell to local investors who reduce the costs of coffee since the farmers didn't have alternative. Therefore, they require the coffee processing technologies such as single disc coffee pulper and others. Some farmers produce coffee in large scale while others were on small areas. Therefore for those who produce in large scale could need better pulper with high capacity due to wet coffee deteriorate after few days.

MATERIALS AND METHODS

Materials

The materials used for construction of the machine were: - Sheet metal, square pipe, knives, disc, angle iron and wet coffee

The instruments used were:-Stopwatch used to measure time, digital tachometer used to measure rpm of the dics, digital weight balance to measure weight of sample and 5HP engine

Methods

The modified parts of the single disc coffee pulper were adjustment of clearance between knife and the disc were fixed due to it is difficult to adjust during the pulped coffee or non pulped coffee is drawn with coffee husk. Therefore this part was fixed no needed to adjust and the number of disc was increased to increase the capacity of the machine.

Description of the machine and it's working principle

The modified coffee pulp machine was operated by 5HP motor engine and operated by one person. The machine had two discs which attached to one shaft and the opening of the machine between disc and guidance is adjusting according to the size of coffee.

Pulping involves removal of outer red skin, white fleshy pulp, separation of the pulp and wet parchment coffee. This machine did these activities by squeezing the cherries between a pulper guidance and disc.

Data collection and analysis

The experimental was conducted in split plot design having speed of disc as main plots and feeding rate as sub plots with the three levels of disc speeds, the three levels feeding rates and three replication. The collected data were: the broken grain, un-pulp coffee, pulped coffee, feeding rate and rpm of the disc.

Performance evaluation of machine

Pulping capacity

Weight of coffee cherry fed into the pulper per unit of time, expressed in kilogram per hour as stated by Ogunlade et al., 2014

$$pc = \frac{total\ weight\ of\ \ pulped\ coffee}{time\ taken}$$

Pulping efficiency

Ratio of total weight of parchment coffee collected at all outlets to the total coffee cherry to the machine, expressed in percentage PAE standard 221 (2005)

$$pe = \frac{weight\ of\ \ pulped}{weight\ of\ \ total} * 100$$

Un pulped loss

Ratio of the total weight of un-pulped coffee cherry to the total input weight of coffee cherry to the pulper, expressed in percentage PAE standard 221(2005)

$$Up\,(\%) = \frac{weight\ of\ \ unpulped\ coffee}{total\ weight\ of\ \ input\ coffee} * 100$$

Mechanically damaged parchment coffee

Ratio of the total weight of damaged parchment coffee to the total weight of sample, expressed in percentage PAE standard 221 (2005)

$$Md\,(\%) = \frac{weight\ of\ \ damaged\ coffee}{total\ weight\ of\ \ sample} * 100$$

RESULT AND DISCUSSION

Pulping capacity

The maximum pulping capacity of the machine was 983.33kg/hr was obtained at maximum rpm (260) and 7kg/min feed rate. As shown in the table 1, the capacity of the machine is not significantly different among feed rate means. This indicated that the capacity of pulping is based on speed rather than feed rate. According to Adekange et.al (2016) threshing capacity increased with an increased drum speed

Table 10. Pulping capacity of double disc coffee pulper

Feed rate x speed		Speed (rpm) 92	208	260	Speed (rpm)	Mean	Feed (kg/min)	Mean
Feed rate (kg/min)	7	**514.00^{d}**	730.65^{bc}	**983.33^{a}**	92	652.37^{b}	7	742.66a
	8	665.95^{c}	783.57^{bc}	890.47^{ab}	208	754.66^{b}	8	780.00a
	9	777.17^{bc}	749.77^{bc}	865.85^{ab}	260	913.22^{a}	9	797.60a
SE				66.2330		42.1000		38.2400
LSD				0.0191		0.0087		0.3716
CV								10.49

Pulping efficiency

The maximum pulping efficiency of the machine of **97.10%** was recorded at 9kg/min feed rate and 208 rpm of disc where as the minimum pulping efficiency was 94.26% recorded at 92rpm of the disc and 9kg/min feed rate. The pulping efficiency of the machine was varies with increase in disc speed which studied by Adekange et.al (2016). This efficiency was not significantly different among feed rate means.

Table 11. Pulping efficiency of double disc coffee pulper

Feeding rate x speed		Speed (rpm) 92	208	260	Speed (rpm)	Mean	Feed (kg/min)	Mean
Feeding rate (kg/min)	7	95.44^{ab}	95.37^{b}	94.32^{b}	92	94.96^{b}	7	95.04^{a}
	8	95.17^{b}	95.93^{ab}	95.27^{ab}	208	96.13^{a}	8	95.45^{a}
	9	**94.26^{b}**	**97.10^{a}**	95.56^{ab}	260	95.05^{ab}	9	95.64^{a}
SE				0.7011		0.4034		0.4048
LSD				0.0854		0.0766		0.3521
CV								0.90

Un - pulped loss

High un pulped loss of around **4.43%** was obtained at maximum speed of the machine, 260 rpm, and at low feed rate of 7kg/hr and the minimum unpulped loss was **1.87%** which was occurred at 208rpm speed of the machine and at 9kg/hr feed rate. As the physical observation, the maximum un-pulped loss was occurred due to the adjustment between the discs and the guidance parts and also due to the non uniformity of coffee.

Table 12. Un-pulped loss of coffee due to double disc coffee pulper

Feeding rate x speed		Speed (rpm) 92	208	260	Speed (rpm)	Mean	Feed (kg/min)	Mean
Feeding rate (kg/min)	7	3.40^{b}	3.15^{bc}	**4.43^{a}**	92	3.29^{a}	7	3.66^{a}
	8	3.08^{bc}	2.53^{cd}	2.98^{bc}	208	2.52^{b}	8	2.87^{b}
	9	3.40^{b}	**1.87^{d}**	2.53^{cd}	260	3.31^{a}	9	2.60^{b}
SE				0.4263		0.0945		0.2461
LSD				0.0726		0.0017		0.0028
CV								17.17

Mechanically damaged parchment coffee

The minimum broken percentage was 1.28 % obtained at combined effect of 7 kg/min feed rate and 92 rpm of the machine. This percentage of broken was occurred due to the adjustment of clearance between dics and coffee guidance parts and also due to non-uniformity of coffee dimensions. Norris, E.R and G.L.Wall. (1986) studied that, increased concave open area resulted in a decreased kernel damaged.

Table 13. Mechanical damaged of coffee due to pulping by this machine

Feeding rate x speed		Speed (rpm) 92	208	260	Speed (rpm)	Mean	Feed (kg/min)	Mean
Feeding rate (kg/min)	7	**1.28^{c}**	1.40^{abc}	1.56^{abc}	92	1.30^{b}	7	1.42^{a}
	8	1.30^{c}	1.43^{abc}	1.67^{ab}	208	1.47^{ab}	8	1.47^{a}
	9	1.33^{bc}	1.58^{abc}	**1.71^{a}**	260	1.65^{a}	9	1.54^{a}
SE				0.1414		0.0823		0.0816
LSD				0.9384		0.0356		0.3416
CV								11.75

CONCLUSION AND RECOMMENDATION

The modified coffee pulping machine was tested and evaluated which the results were as follow. The maximum pulping efficiency of the machine is 97.10 % at 9 kg/min feed rate and 208 rpm of the machine. The maximum pulping capacity of was about 983.33 kg/hr at 7 kg/min feed rate and 208 rpm of the machine speed. The maximum un-pulping loss of the machine was 1.87 % at 9 kg/min feed rate and 208 rpm of the machine speed. The maximum percentage of breakage was 1.71 % at speed of 260 rpm and feed rate of 9 kg/min. the pulping capacity and the pulping efficiency of the modified engine powered were 468.2% and 1.67% higher than manual operated single disc coffee pulper respectively. In addition to its pulping capacity and efficiency, the machine is so easy to adjust to increase its performance and also simple to transport from one place to another.

It was recommended that due to the results obtained were good the double disc coffee pulper is appropriate for farmers and all who participated on coffee production. But to get good result the users can train on the adjustment of the machine and how to operate.

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Performance Evaluation of Single Axel Tractors on Different Soil Types

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ABSTRACT

Single axel tractor is used as a main source of power and plays a major role in the agriculture sector specially to mechanize agricultural tasks like plowing, harrowing, sowing and transportation. Performance data for tractors and implements under different soil conditions are important to select and efficiently use with matching implements. The study was conducted to evaluate the performance of TY-180A and TY-254A models of two single axel tractors having rated engine power of 18 Hp and 25 Hp respectively with different tillage implements. Considered performance parameters of the tractors were; wheel slippage, draught force, speed of operation, drawbar power, volume of soil disturbed, fuel consumption, effective field capacity, theoretical field capacity, field efficiency, and average width and depth of cut during plowing and harrowing operations. The study was conducted on *three different soil types of sandy loam, loam and clay loam, by using different measuring equipment's, such as Dynamometer. The test results of the effective field capacity, field efficiencies and volume of soil disturbed were; 0.094ha/hr and 0.151ha/hr, 60.26% and 68.33% and 204.92m^3/hr and 382.95m^3/hr for disc plowing and 0.189ha/hr and 0.306ha/hr, 79.17% and 85.30 % and 225m^3/hr and 400.51m^3/hr for harrowing respectively for TY-180A and TY-254A model tractors. In the same order draft force (KN) and drawbar pull (hp) were; 2.758 and 2.697 and 1.91 and 2.25 for disc plowing and2.455 and 2.447and 2.22 and 2.75 for harrowing respectively for TY-180A and TY-254A model tractors. Results indicate that tractor model 25A performed better than the tractor model 18A during both ploughing and harrowing operations with respect to the parameters evaluated.*

Keywords*: Performance evaluation, Single axle Tractor, Tillage*

INTRODUCTION

In order to meet the food demand of the ever-increasing world population, one of the approaches being adopted is the substitution of human and animal power with mechanical power in agricultural production. Farm power is an important element of mechanical power in modern agricultural production system, called agricultural mechanization. The main purpose of the Farm power is to reduce number of labor, the difficulties of farm operation and maximize its production. Agricultural mechanization has been receiving a considerable interest in recent years due to increasing demand for food because of increase in world populations (Hebiel, 2006).

The use of machines for agricultural production has been one of the out-standing developments in the global agriculture during the last century. The results of the application

of farm machinery can be seen in many aspects of human life, a number of workers to be released for other activities in developed countries. The main source of power in agriculture is the tractor which is now available in different sizes and tractor power is utilized both through the driving wheels as traction to provide the drawbar power required for draught implements, and to provide mobile support for attached machines.

The primary purpose of agricultural tractors is to provide drawbar work since drawbar is the most commonly used power outlet of a tractor. Draft, energy and fuel requirements for agricultural implements have been recognized as essential when attempting to correctly match an agricultural implement with tractor power.

Ownership of a tractor and associated items of equipment can involve a substantial investment. Improper choice of size of tractor can be costly because a very small tractor can result in long hours of field work, excessive delays and premature replacement, while a too large tractor can result in excessive operating and overhead costs (Summer and Williams, 2007). The ideal tractor with matching equipment should get the work completed on time at the lowest possible cost.

The performance of tractor depends on the performance of a combination of traction devices and the performance of the tractor drive train. Farm size, availability of labour and custom services, crop selection and cultural practices, such as choice of tillage system, all affect the selection of optimum equipment and, ultimately, the number of tractors necessary to carry out farming operation. The proper operation of these machines is essential for profitable agricultural production.

Adama Agricultural Machinery Industry (METEC) import and assembled a number of single axel mini tractors and distributed to farmers in different parts of the country, including Oromia. However, the research team of this research was request the performance data of the tractors and couldn't obtained from the firm there is no available under local conditions to compare the degree of field efficiency, fuel consumption and effective field capacity aimed at evaluating the performance of the machine.

Therefore, performance data for tractors and implements under different soil conditions are important for farmers, machinery operators and tractor manufacturer's alike (Al-Suhaibani*et al.*, 2010). Accordingly, this project was undertaken to evaluate the performance of two different models of TY-180A and TY-254A single axel tractors in different soil type and field conditions and under identical operating conditions in order to guide farmers in selecting suitable tractor- implement combination under different soil type for cost-effective operations.

MATERIALS AND METHODS

Materials

Experiment site and soil type

The study was carried out at Hexosa Woreda of Arsi zone on three different soil types of sandy loam, loam and clay loam soil during April to July.

Tractors and implements used

(a) Tractors

Two single axle tractors of TY-180 and TY- 254 models were used in the experiments. Their specifications are shown in (Table 1).

Table 1: Specifications of tested tractors

Specification	**Model of TY - Tractors**	
	TY – 180A	TY – 254A
Power output (hp)	18	25
Type of Engine	2-Cylinder	2-Cylinder
Type of Fuel	Diesel	Diesel
Type of Steering System	Mechanical	Mechanical
Type of Injector Pump	In-line injector	In-line injector
Type of Cooling System	Natural aspiration water-cooled	Natural aspiration water-cooled
Country of Manufacture	China	China
Country of Assembled	Ethiopia	Ethiopia
Front Tires (size)	4.00 - 16	6.00 - 12
Rear Tires (size)	8.3 - 24	8.3 - 24

(b) Implements

The implements used for the trials were tractor mounted disc plough with two and three disk blades each is 50 cm in diameter and disc harrow with twelve and fourteen disk blades each is 55cm in diameter respectively TY-180 and TY- 254 model tractors.

(c) Other Equipments

- Measuring tape: - for measuring dimensions and distances, to calculate areas and speeds.
- Wooden poles: - for marking distances during the experiment.
- Stop watch: - to determine the tractor speed and recording time.
- Measuring cylinder: - two-litter capacity graduated cylinder was used to refill the fuel tank for determination of fuel consumption.
- Dynamometer: - dynamometer with 3000kg was used for direct draft measurement.

Methods

Experimental plot preparation

The experimental plot size of 20×40 meters (4800m²) was divided into six plots at each location, as three plots for the replication of each treatment. The plots were separated from each other's by a distance of 1 meter, to avoid the interaction between the plots borders, a space will be left at the ends of the block to be used as head lands during the commencement of the tillage operations.

Measurement of performance parameters

Soil moisture content measurement

Soil samples were taken from the two blocks in each location before application of the treatments, randomly selected places across the field. The samples were taken by core sampler at four depths (0-15, 15-30, 30-45, 45-60 cm). The moisture content was determined directly

using gravimetric sampling technique, in which the weights of wet samples were measured, and then soil samples were dried in an oven at temperature of 105-110 c° for 24 hours. Soil moisture content percentage on weight basis is calculated as follows (Gardner, 1986):

$$m_c = \frac{m_i - m_f}{m_f} \times 100 \qquad (1)$$

Where: - m_c = Moisture Content, Percentage.
m_i= Mass of Sample before drying (kg)
m_f = Mass of Sample after drying (kg).

Bulk Density measurement

The bulk density of the soil was determined from the weight of soil to its volume. It is expressed as the ratio of the mass of dried sample to the total volume of the soil including the particles as well as the pores. The bulk density depends upon various factors *viz.*, soil, texture and organic matter, history of tillage and moisture content.

$$Bulk\,density\,of\,the\,soil\,(g/cm^3) = \frac{Weight\,of\,dry\,soil\,sample\,(g)}{Volume\,of\,the\,core\,sampler\,(cm^3)} \qquad (2)$$

Penetration Resistance Measurement

Penetration resistances measurements were carried out before and after tillage operations, by using hand operated soil test penetrometer [Dynamic cone penetrometer (DCP)]. The cone is then pressed into the soil until it just becomes buried; this initial penetration is recorded as "Blow 0." The operator then raised and released the slide hammer one or more times depending on the strength of the soil. Depth of penetration after each blow and total blows to reach a desired depth can be recorded. This process continues until the desired depth of testing is reached (600 mm for this experiment) (Herrick and Jones, 2002).

Penetration resistance of soil was measured as (Kg/cm²) by calculating the pressure exerted by an 8 kg falling hammer on a base of 50 mm diameter through a number of blows, depending on the strength of soil. The falling hammer exerts (0.408 Kg/cm²) through one blow and the soil resistance to penetration for certain depth was calculated by gathering all blows needed to reach that depth, multiplied by the pressure of one blow (0.408 Kg/cm²).

Operating speed measurement

Outside the long boundary of the test plot, two poles 20 m apart were placed approximately in the middle of the test run. On the opposite side also two poles were placed in a similar position 20 m apart so that all four poles form corners of a rectangle, parallel to one long side of the test plot. The speed was calculated as the ratio of the distance (20 m) to the time taken for the tractor to travel the distance.

Wheel slippage measurement

A mark was made on the tractor drive wheel with colored tapes and the distance the tractor moves forward at every 10 revolutions under no load and the same revolution with load on same surface was measured. Expressed mathematically as (Ahaneku, I.E.,*et al*, 2011):-

$$Travel\,reduction(\%) = \frac{m_2 - m_1}{m_2} \times 100 \quad (3)$$

Where, M_2 = Distance covered at every 10 revolutions of the tractor drive wheel at no load (m)

M_1 = Distance covered at every 10 revolutions of the tractor drive wheel at load (m)

Draft force Measurement

Draft was measured using a dynamometer attached to the front of the tractor, on which the implement was mounted. Another auxiliary tractor was used to pull the implement mounted tractor through the dynamometer shown in figure (2). The auxiliary tractor pulls the implement-mounted tractor with the latter in neutral gear but with the implement in the operating position.. On the same field, the implement was lifted out of the ground and the draft recorded. The difference between the two readings, gives the draft of the implement. This procedure was repeated for each of the tractors evaluated.

Drawbar power

Drawbar power was computed using the relation between draft and speed as follows Ahaneku, I.E.,*et al*, 2011:-

$$Drawbar\,power(hp) = \frac{Draft(kg) \times operatingspeed(m/s)}{75} \quad (4)$$

$$Drawbar\,power(kW) = \frac{Draft\ (kN) \times operatingspeed(km/hr)}{3.6} \quad (5)$$

Fuel consumption measurement

The tractor's fuel consumption for seed bed preparation under each treatment was measured by the standard method, the fuel tank was filled up to top level by keeping the tractor on level land and after completing the operation, the fuel tank was filled up again. The difference of two observations gave the fuel consumed in the concerned operation.

$$F_C = \frac{F_r}{t} \quad (6)$$

Where, Fc = fuel consumption (l /hr)

Fr = re-filled quantity of fuel (1)

t = seeding time (hr)

Field efficiency measurement

The tractor started working the plot and then the time in seconds was recorded using stop watch. This was done for each plot. Time for turns at the end of each distance was recorded. The theoretical, effective field capacities (TFC,EFC) and field efficiency (FE) were calculated as following:-

The theoretical field capacity (TFC):-

$$TFC = \frac{Width\,of\ coverage(m) \times Speed\,of\ travel(km/hr)}{10} \quad \textbf{(7)}$$

The effective field capacity of the machine was expressed as the actual rate at which, it can do work, taking into account such non-productive operations as turning at the ends of the field and stopping to check the performance of a particular equipment. The effective field capacity was determined by the following formula:-

$$E_e = \frac{A}{T_p + T_n} \quad (8)$$

Where: - Ee = Effective field capacity (ha/h)
A = Area covered (ha)
Tp = Productive time (h)
Tn= nonproductive time (h) (Nonproductive time is the time lost for turning and adjustment etc. excluding refueling and machine trouble)

$$FE = \frac{EFC}{TFC} x100 \quad (9)$$

Soil volume disturbed
The soil volume disturbed in m^3/hr was calculated by multiplying the field capacity with the depth of cut (Ahaneku*et al.*, 2011).

$$V = 10000SD \quad (10)$$

Where,V = Soil volume disturbed (m3 /hr)
S = Effective field capacity (ha/hr)
D = Depth of cut (m).

Soil pulverization
Pulverization is the process of breaking of soil into small aggregates resulting from the action of tillage forces. The mean mass diameter (MMD) of the soil aggregates is considered as index of soil pulverization and can be determined by the sieve analysis of the soil sample through a set of standard test sieves (IS: 460-1982). Sieve provides a simple means for measuring the range of clod size and relative amount of soil in each size class. For this the soil sample was passed through a set of sieves and weighing of the soil retained on the largest aperture sieve passed through each sieve and retained on the next sieve and passed through the smallest aperture sieve is done (Mehta *et al*., 1995).

RESULTS AND DISCUSSION

The results of the field experiments of various parameters are presented under the following main heads. All the parameters of the tractor-implement performance were measured and recorded in line with the recommendations of RNAM test codes and procedures for farm machinery technical series (1995).

Physical properties of soil

Bulk density

Average bulk density values as affected by soil depths in the three locations are presented in table (2). All the recorded bulk density values were between 0.90 to 1.80 gm/cm³, which is the range described by Chi *et al*., (1993) for usual agricultural soils. Higher bulk densities are recorded for the location of clay soil than sandy clay and sandy loam soil location, and that is probably referred to the variation in the structural conditions of the soil. In all locations, the bulk density increased with soil depths that the soil strength tends to increase with depth of soil

Table 2: Bulk density (gm/cm³) of the three locations of soil at different soil depth

Soil depths	**Soil type**		
	Sandy loam soil	**Sandy clay soil**	**Clay soil**
0-15	1.28	1.30	1.33
15-30	1.30	1.32	1.34
30-45	1.33	1.34	1.36
45-60	1.34	1.36	1.39
Mean	1.31	1.33	1.35

Soil penetration resistance

Table (3) shows the averages soil resistance to penetration as measured by the dynamic penetrometer for the different soil types through the four depths in the soil location. The result indicated that the soil has its highest strength within the depth (15-30 cm), as shown from the mean values of the penetration resistance of the soil. The higher strength within that layer could be justified due to the finding of Saber and Mrabet (2002) that the highest soil strength is recorded in the upper 30 cm of no-tilled plots compared to deep tilled ones.

Table 3: Soil penetration resistance (Kg/cm²) of the three locations of soil at different soil depth

Soil depths	Soil type		
	Sandy loam soil	**Sandy clay soil**	**Clay soil**
0-15	2.9	3.3	3.9
15-30	8.8	9.6	10.7
30-45	8.6	9.4	10.3
45-60	7.9	8.2	8.3
Mean	7.05	7.6	8.3

Tractors and Implement performance in the three locations of soil type

Wheel slippage

The results presented in table (4) revealed that the average percentage of wheel slippage for all implements used is below the top limit of wheel slippage (20%) Pensson *et al*., (1986). All implements recoded higher wheel slippage in the sandy loam soil than the sandy clay and clay soil that may be due to the soil in that location more firm causing a noticeable motion resistance. This is in agreed with the findings of Belel and Dahab (1997).

Higher slippage values in the three locations are recorded by the disk plough. The disk plough gave the highest slippage value of (16.84%), and this may be the disc plough goes deeper in

the soil than the disk harrowand increased load transfer to the rear drive wheel of tractor. This is in agreement with Riethmuller, (1989) who stated that, all the tested implements for draft requirements showed linear increase in draft with depth and speed. The lowest slippage values at the three locations (sandy loam soil, sandy clay soil, clay soil) were recorded by the disc harrow (12.12%) , (11.09%) and (9.98%) respectively. This is most likely due to its shallower operation depth. While in bigger tractor the slippage was less than the slippage in the small tractor in both implements which may be due to the bigger horse power and the weight of the big tractor make it higher stable

Generally, fluctuations in plowing depth and speed depend on the field condition and operator skill, and the latter is the key factor that might alter values of slippage by determining the depth and speed of plowing. The same statement was given by Igbal*et al*., (1994).

Table 4: Effect of soil type and implement type on wheel slippage of the two tractor types

Implement	**Sandy loam Soil**	**Sandy Clay Soil**	**Clay Soil**	**Mean**
		TY-18A tractor		
Disk plough	16.84	15.75	13.97	15.52
Disk harrow	12.34	11.46	10.68	11.49
Mean	14.59	13.61	12.33	13.51
		TY-25A tractor		
Disk plough	16.14	14.97	13.02	14.71
Disk harrow	12.12	11.09	9.98	10.06
Mean	14.13	13.03	11.50	12.89

Fuel consumption

As shown in table (5), fuel consumption rates in (L/ha) are numerically higher in the location of sandy loam soil than the sandy clay and clay soil location for disk plough and for both tractors, and that probably referred to the higher draft requirements for the implements in the sandy loom soil location. That is in line with Belel and Dahab, (1997) who reported that, as draft increased, wheel slippage and fuel consumption by the tractor increased. Disk plough recorded the highest rate of fuel consumption for all locations. While the disc harrow recorded the lowest rates of fuel consumption at all locations.

Table (5) shows that implement type affect fuel consumption; the disk plough consumed higher fuel than the disk harrow with the same tractor power. However, the largest amount of fuel was consumed with the use of tractor model of TY-18hp for the same area and operation. This indicates that the fuel consumption affected by tractor size and implement type. Generally higher fuel consumptions may be due to small plots sizes, soil condition and usage of tractors.

Table 5: Effect of soil type and implement type on fuel consumption of the two tractor types

Implement	Sandy loam Soil	Sandy Clay Soil	Clay Soil	Mean
		TY-18A tractor		
Disk plough	28.90	28.15	27.98	28.34
Disk harrow	11.70	12.30	13.15	12.38
Mean	20.30	20.23	20.57	20.36
		TY-25A tractor		
Disk plough	20.70	19.80	19.50	20.00
Disk harrow	8.85	9.20	9.65	9.23
Mean	14.78	14.50	14.58	14.62

Effective field capacity

Table (6) showed that the effective field capacity in both implements and in two tractors. Effective field capacity has been reported as major factors in determining the performance of tillage implements (Bukhari et al., 1988). The field capacity of a machine is a function of its width, speed and efficiency of operation. The field performance data regarding these parameters is presented in table 6 respectively for disc plough and disc harrow. Tractor model TY-25A with relatively higher values of width of cut, speed of operation and field efficiency achieved better results for field capacity. This could be explained by the higher travel reduction associated with the TY-18A tractor model during tillage operations which may have resulted from the higher depth of cut attained during operation. This result is in agreement with the findings of Ortiz-Laurel, *et al*. (2006) that travel reduction has effect on field capacity.

Table 6: Some performance parameters of the two tractors on three different soil types with plowing and harrowing operations

Parameter	**Implement type**			
	Disk plough		Disk harrow	
	Tractor Models			
	TY-18A	TY-25A	TY-18A	TY-25A
Speed of operation (km/hr)	1.84	2.21	2.39	2.98
Effective field capacity (ha/hr)	0.094	0.151	0.189	0.306
Draught force (KN)	2.758	2.697	2.455	2.447
Fuel consumption (L/ha)	28.75	20	12.86	9.12
Fuel consumption (L/hr)	2.70	3.02	2.43	2.79
Soil volume disturbed (m^3/hr)	204.92	382.95	225.	400.51
Drawbar Power (hp)	1.91	2.25	2.22	2.75

Draft of implements

Table (6) showed that disc plough require more draft than the disc harrow, which may be due to deeper disc penetration than disc harrow. The smaller tractor (TY-18A) exhibited higher draft force 2.758 and 2.455 KN when compared with that of the larger (TY-25A) tractor 2.697 and 2.447 KN respectively for plowing and harrowing. The results are in agreement with the findings of Bukhari, et al. (1988) and Abubakar et al. (2009) that lighter tractors perform better on soft soils because the driving force increases proportionally with the driving axle load and travelling resistance increases exponentially with tractor weight. As a consequence,

implement draft is less when the tractor is heavy. The results also show that speed of operation and depth of cut affected the draft of the implements. As expected, the drafts recorded during plowing operations were consistently higher than those of harrowing operations, irrespectively of the tractors used. Draft was highest with the TY-18A model than TY-25Amodel tractor. This may be attributable to the higher depth of cut achieved by the tractor during the plowing operations.

Drawbar power

Drawbar power is a function of draft and speed. Table (6) showed that, like draft, tractor model TY-25A gave the highest drawbar power since a large pull and high speed will result in a large drawbar power. In the same manner, tractor model TY-18A gave the lowest drawbar power.

Soil volume disturbed

Soil volume disturbed depends on the effective field capacity and the depth of cut. Table (6) showed that soil volume disturbed observed highest under disc harrow than the disc plough irrespective to tractor size. Though the depth of cut is highest in case of disk plough the results indicated that the depth of cut affected soil volume disturbed positively. The comparative performance of the two tractor models in terms of soil disturbance shows that tractor model TY-25A achieved highest soil disturbance. The results also indicated that higher speed of operation affected soil volume disturbed positively. Thus, tractors operating at higher speed yielded higher disturbed soil volume.

Soil pulverization (MMD)

Singh and Panesar (1991) concluded that the clod mean weight diameter (MWD) has been considered as an index for indirect measurement of soil tilt during seed bed preparation. The clod mean-mass-diameter is an index for indirect measurement of tilth of soil. It has been indicated that soil aggregates of size 12 to 14 mm in the final seedbed were adequate for sowing crops. The observed data for MMD under disk plough and disk harrow for TY-18hp and TY-25hp was (16.85 mm and 18.41 mm) and (10.32mm and 9.95 mm) respectively for disk plough and disk harrow. This result is in agreement with the findings of Singh *et al.* (2002). There is a considerable improvement in soil pulverization with the use of the disk harrow due to the ability of rotating blades to make fine particles by the forward motion of the machine.

Field efficiency

Table (7) showed that the efficiency in both implements and in two tractors affected by soil type. In the clay soil the disk plough and the disk harrow numerically achieved higher field efficiencies 61.18 % and 69% respectively for tractor TY-18A andTY-25A. This result could be explained by the firm soil condition increased the draft and fuel consumption, but gave better efficiency than in loose soil. On the contrary, disc harrow gave the higher field efficiency in the sandy loam soil compared to in the location of sandy clay and clay soil. That probably might be attributed to reduced time losses, and as confirmed by Igbeka, (1986) field efficiencies, which are assessed on time basis, are generally influenced by operator skill in adjusting his operating pattern.

Table 7: Effect of soil type and implement type on field efficiency of the two tractor types

Implement	Sandy loam Soil	Sandy Clay Soil	Clay Soil	Mean
		TY-18A tractor		
Disk plough	59.52	60.08	61.18	60.26
Disk harrow	80.13	79.07	78.32	79.17
Mean	69.83	69.58	69.75	69.72
		TY-25A tractor		
Disk plough	67.86	68.13	69.00	68.33
Disk harrow	86.00	85.03	84.87	85.30
Mean	76.93	76.58	76.94	76.82

CONCLUSION

The results of drawbar pull, drawbar power, slip and forward speed showed that TY-25 tractor relatively performed better. Field performance of the two model tractors indicated that average field capacity, field efficiency and ploughing depth were highest for TY-25 tractor but least for TY-18 model tractor which consumed much higher fuel per unit area than the TY-25 models. Consequently with respect to evaluated drawbar and field performance parameters, the findings of this study indicated that TY-25 model tractor was preferred tractor models.

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Modification and Performance Evaluation of an Improved Teff Thresher

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ABSTRACT

Threshing of cereal crops traditionally or simple tools is a time consuming and a tedious process and leads to high post harvesting loss. The drudgery involved in the manual threshing of the cereal crops has discouraged the mass production and commercialization of the cereal crop and this necessitates the adaptation and evaluation of an engine operated threshing machine. Stationary teff thresher was modified and a prototype of simple machine was constructed to thresh teff. The machine modifications to thresh teff crop was made simple. For purpose of improving threshing capacity different modifications was made on drum size and straw auger was removed. The thresher modified prototype was tested for teff at three levels of cylinder speed (S_1 = 1000 rpm, S_2 = 1100 rpm and S_3 = 1200 rpm) and three different feed rates of the crop (FR_1 = 8 kg/min, FR_2 = 10 kg/min and FR_3 = 12 kg/min). The optimum output capacity of the developed thresher was obtained at a cylinder speed of 1200 rpm and feed rate level of 12 kg/min. The grand mean of threshing efficiency, cleaning efficiency, total grain loss and the output capacity were found 100, 91.96, 1.47 % and 180.26 kg/hr respectively at 35% of grain straw ratio. The analysis of variance carried out showed that both the cylinder speed and feed rate have a significant effects on the cleaning efficiency, total grain loss and throughput capacity whereas, non-significant on threshing efficiency.

Key words: Cleaning Efficiency, grain loss, Threshing Capacity, Threshing Efficiency

INTRODUCTION

Teff originated and has diversified in Ethiopia. Ethiopian farmers grew it for centuries because of its various merits. Otherwise it would not have existed after the introduction of other cereals such as maize, wheat, barley and others. Teff accounts for about two-third of the daily protein intake in the diet of the population (Ethiopian Nutrition Survey, 1995). The demand for teff is increase both at local and global markets. Therefore, an attempt to improve the post-harvest operations more especially threshing aspect, which is highly laborious, would be welcome.

Teff is one of the economical cereal crops in Ethiopia. It is indigenous to the country, and is a fundamental part of the culture, tradition and food security of the people. Teff is gaining international recognition and acceptance, and is a means of foreign currency earning in addition to its values as food crop at home. Currently, teff is grown on approximately 2.80 million hectares of land which is 27% of the land under cereal production (Bekabil*et al.*, 2011). Teff accounts for about a quarter of the total cereal production and is highly

economical food grain in Ethiopia. Approximately, 6 million households grow tef and it is the dominant cereal crop in 30 of the 83 high-potential agricultural woredas (Bekabil*et al.*, 2011).

Threshing of teff can be done traditionally or mechanically. The traditional method of grain separation is laborious, time consuming and uneconomical. This method of threshing consumes more time, compared to mechanical threshing method. Traditional threshing method also causes grain loss. MOA (Ethiopia Ministry of Agriculture) imported, CAAMS (Chinese Academy of Agricultural Mechanization Sciences) teff thresher have good threshing and cleaning efficiency; however it has low output capacity and choking problems. So this and other problems brought about the idea of modifying CAAMS teff thresher by increasing the size of the threshing cylinder and introducing spike tooth type cylinder that would prevent the problem of chocking during the operation and also improve the output capacity.

Thus the development of a more efficient threshing machine for teff, which is the aim of this study, would contribute immensely to the teff processing activities. In addition, such works would continue to aid the process of perfecting teff threshers by researchers and other stake holders. So, there is need to design the thresher with spike tooth type cylinder, blades attaches to the threshing drum so that the straw of the teff are easily slash to prevent chocking. Also, based on the limitations observed in some of the earlier research, this design and fabrication of teff threshing machine hopes to overcome those problems stated above. Thus, this study was carried out to modify an existing teff thresher and evaluate the modified and developed prototype.

MATERIALS AND METHODS

Materials selection for modified machine fabrication

The machine was designed and constructed (fabricated) from locally available materials. The components of the machine were constructed from mild steel materials of various sizes and shapes. These materials were selected based on the strength and rigidity that is required by each component and also on the availability of the material in local market. Mild steel sheet metal of 2mm was selected for the production of the machine components such as fan blades, cylinder, sides and top covers of cylinder housing, blower casing, chaff outlet, feed hopper, and grain delivery chute among others. Medium carbon steel 30mm round bar was selected for the shafts. Different pulleys sizes were selected based on the speed ratio requirement.

Measuring instrument and test materials

A tachometer was used to determine the peripheral speed of the cylinder, while stopwatch was used for elapsed time measurements and electronic balance of sensitivity of 0.01 kilograms was used in weight measurements during the performance evaluation of the machine. For measuring fuel consumption of the engine, a graduated cylinder was used to measuring consumed fuel that refilled during test. The locally available variety of teff commonly called “manya” was used for the evaluation.

Methods

Design improvement consideration

The following factors were put into consideration in the design improvement of the thresher:-

i) Transportability
ii) Availability of power source (10hp diesel engine)
iii) Materials availability in the local market keeping engineering standards and specifications.

Determination of threshing cylinder size

The principal parameters of the threshing drum are the drum length, the drum diameter, number of spike/pegs on the drum and the drum speed. The drum length will be obtained from the following equation as reported by (Kepner*et al*. 1987).

$$q = q_o \times L \times M \quad (1)$$

Where: - L = Drum length (m),
q = Feed rate of thresher (kg/s),
q_o = Permissible feed rate (kg/s) and
M = Number of rows of beaters/pegs.

Determination of the threshing cylinder shaft size

Design of a shaft involves determination of the minimum diameter of the shaft material that can withstand certain loading conditions. The threshing drum shaft may be subjected to torsion, to bending, to axial tension or compression or combination of any or all of these actions. Therefore there is the need to take all of the above into consideration to avoid shaft failure. The diameter of threshing shaft can be calculated according to the theory of maximum shear stress according to (Khurmi and Gupta, 2005).

$$d^3 = \frac{16}{\pi s_s}[(K_b M_b)^2 + (K_t M_t)^2]^{1/2} \quad (2)$$

Where: - d= diameter of the shaft; mm
M_t = Maximum torque (Kg.cm)
M_b = Maximum bending moment (Kg.cm)
K_b = Shock factor for bending moment;
K_t= Shock factor for torsional moment;
S_s= allowable stress for shaft; (MN/m^2)

Working principle

The operation of the thresher is based on the use of beaters (spike tooth) which thresh the crop by impact and the use of centrifugal type of fan which generate a sacking pressure to clean the threshed teff. After assembling, starts and sets the engine to the required speed and operated by one person. Then, feeds the harvested teff crops manually into the machine which flows by gravity into the threshing chamber; the chaff is blown away while clean grains are collected at the grain outlet chute.

Performance evaluation of the machine

Performance parameter of the threshing machine was calculated following the procedure of FAO (1994), as follows:-

Threshing Efficiency (TE)

$$\text{TE}\ (\%) = \frac{Weight of\ threshed grain\ (Kg)}{Total\ weight\ of\ grain\ (Kg)} * 100 \quad (3)$$

Threshing Capacity (TC)

$$\text{TC}\ (\text{Kg/hr}) = \frac{Total\ weight of\ threshed grain\ (Kg)}{Time\ taken\ to\ thresh (hr)} \quad (4)$$

Cleaning Efficiency (CE)

$$\text{CE}\ (\%) = \frac{Weight of\ grain after cleaning\ (Kg)}{weight of\ grain before cleaning\ (Kg)} * 100 \quad (5)$$

Percentage grain losses

Drum losses (DL)

$$\text{DL}\ (\%) = \frac{Weight of\ unthreshed grain\ (Kg)}{Total\ grain\ weight\ (Kg)} * 100 \quad (6)$$

Separation losses (SL)

$$\text{SL}\ (\%) = \frac{Weight of\ grain goes with\ dust (Kg)}{Total\ grain\ weight\ (Kg)} * 100 \quad (7)$$

Fuel Consumption

The fuel consumption was quantified by refill methods. The fuel tank was filled to full capacity before and after the test. Amount of refueling after the test was recorded as fuel consumption for the test. While filling up the tank, careful attention was given to keep the tank horizontal and not to leave empty space in the tank. The fuel consumption was computed as follows:-

$$F_C = \frac{F_r}{t} \quad (8)$$

Where, Fc = fuel consumption (l /hr)
Fr = re-filled quantity of fuel (l)
t = seeding time (hr)

Experimental design and analysis of data

Completely randomized design (CRD) was employed on the treatment factor replicated three times. The data were analyzed statistically using analysis of variance (ANOVA) and least significant difference (LSD) methods were used to assess the effect of the variables, their interactions, their significant differences, and to determine the most appropriate combination of speed and feed rates among the selected ones. The collected data were statistically analyzed with the help of Genstat 15th edition software.

Results and Discussion

CAAMS teff thresher was modified and tested for determination of threshing capacity (TC), threshing efficiency (TE), Cleaning efficiency (CE), grain losses in straw (GLS) and un-threshed grain losses (UGL) at Tiyo districts of Arsi Zone. The data were collected to study

the effect of three different cylinder speeds and feed rates on the machine efficiency and crop recovery.

Effects of cylinder speed and feed rates on threshing efficiency

The threshing efficiency results 100% for all cylinder speed, feed rate and their combinations. The results of the analysis of variance shows that the effect of speeds, feed rates and their interactions were non-significant on threshing efficiency at 5% level of confidence. Nonetheless, it is commonly reported that, most of research reports confirm that an increase in threshing efficiency with increase in the cylinder peripheral speed was expected due to an increase in impact energy and rubbing shear action on the crop (Hussen Abagisa *et al.*, 2016).

Effects of cylinder speed and feed rates on cleaning efficiency

The cleaning efficiency of the machine ranges from 88.28 % to 97.01 % at a cylinder speed of 1000 rpm and 1200 rpm respectively. The minimum cleaning efficiency was obtained at a feed rate of 12 kg/min while the maximum was at 8 kg/min (figure 1). The cleaning efficiency increases with increase in cylinder speed at different feed rates which could be due to the increase in fan speed. As the fan speed increases there was more stream of air flowing across the falling objects thereby blowing off the materials. Hence, a higher cylinder speed with a lower feed rate resulted in higher cleaning efficiency. The results of the analysis of variance shows that the effects of cylinder speeds and feed rates were highly significant on cleaning efficiency at 5% level of confidence while the effects of their interactions were not significant at 5% level . The interaction between the cylinder speed and the feed rates further indicated that the combination of cylinder speed level 1200 rpm and a feed rate level of 8kg/min gives the best cleaning efficiency for the threshing process.

Figure (1) shows that cleaning efficiency has direct relationship with cylinder speed, i.e. with the increase in the cylinder speed the cleaning efficiency increased, and it decreased with the increase in feed rate. The cleaning efficiency was increased with increase in cylinder speed as the threshing cylinder and cleaning system are mounted on the same shaft. Hence, increase in the speed of threshing cylinder increased the materials other than grain separation. On the other hand, the inverse relationship between cleaning efficiency and feed rate was indicated due to the increasing load on the sieve that restricted free movement of grains and undesired materials.

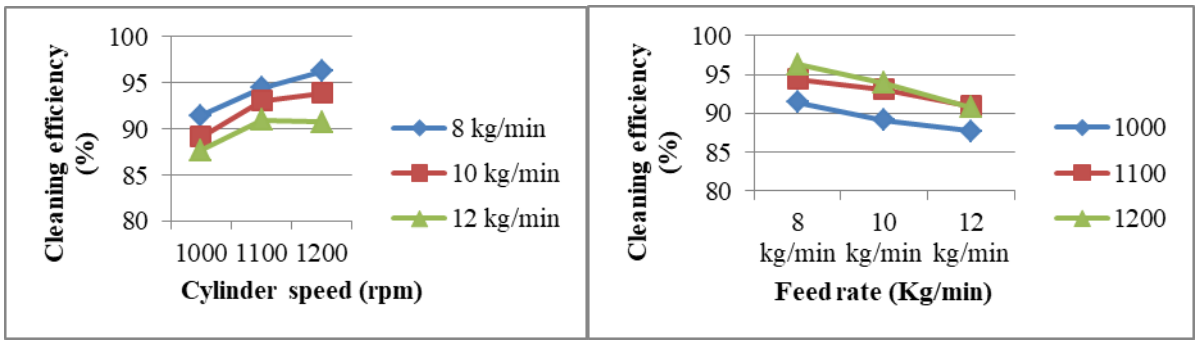

Figure 1: Effect of cylinder speed and feed rate on cleaning efficiency

Effect of cylinder speed and feed rates on output capacity

The output capacity shows that an increasing pattern with the increase in cylinder speed at various feed rates. The throughput capacities of the machine tend to increase with the speed and the level of feed. The higher the feed rate and at an increase in speed, throughput capacity increases. A high throughput capacity of 200.67 kg/hr was obtained at the highest speed of 1200rpm and highest feed rate of 12 Kg/min. The effect of cylinder speeds on the output capacity was highly significant at 5% level and that of feed rates were also highly significant at 5% level and their interactions were not-significant at 5% level.

Figure (2) shows that, throughput capacity increased with cylinder speed and feed rates. The reason for that could be as a result of greater speed of cylinder which made more impact on the threshed materials thereby increasing the rate of grain detachment from the straw.

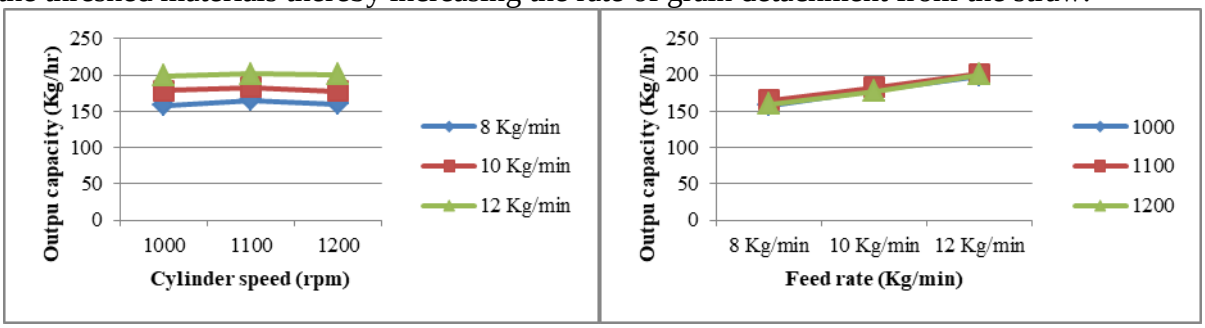

Figure 2 Effect of cylinder speed and feed rate on output capacity

Effect of cylinder speed and feed rates on total grain loss

A maximum total grain loss of 2.22 % was obtained at cylinder speed of 1200rpm with a feed rate of 12kg/min while a minimum of 0.41 % was obtained at the speed of 1000rpm and feed rate of 8kg/min. The total grain losses of the machine increased with the increase in cylinder speed at various feed rates. These were because of the reduction in speed when there were more materials in the threshing chamber resulting in the reduction in the volume of air stream required to blow off the chaffs at the lower speed level. With the little materials in the threshing chamber at higher speed level there were tendency of premature grains to be blown off; being their aerodynamic requirement might have been exceeded. The analysis of variance shows that the effects of cylinder speeds and feed rates were highly significant at 5% level on the total grain losses and their interactions were also highly significant at 5% level. Figure (3) shows that grain separation losses increased in proportion to cylinder speed. This could be due to overloading of the sieve at higher speed which is always associated with increased in quantity of the materials being threshed. This implied that speed increase has positively affected the scatter losses. A similar trend was reported by Sale (2015).

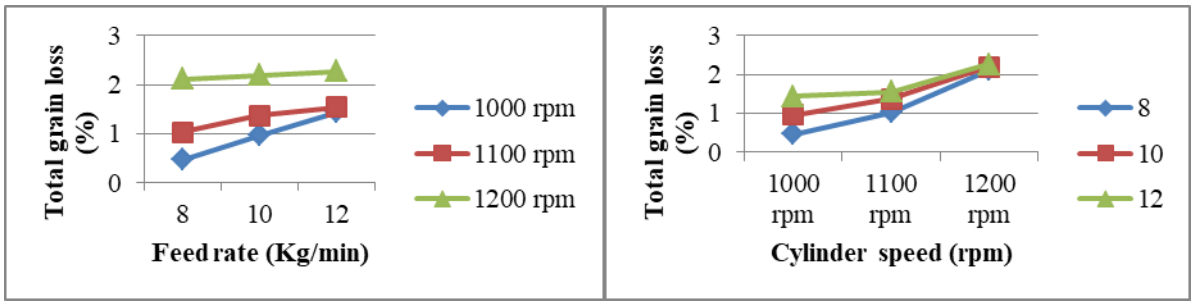

Figure 3 Effect of cylinder speed and feed rate on grain separation losses

Optimum values of independent parameters

The effects of drum speed and feed rate on dependent variables were threshing capacity, cleaning efficiency and threshing efficiency and grain separation losses. To obtain optimum combination of parameters the criteria adopted was that the threshing efficiency should be the maximum, percentage of grain separation losses should be minimum and cleaning efficiency should be the maximum. The threshing efficiency was 100 percent for all treatment combinations; therefore any combination could be selected. Grain separation loss was less than 2 percent for cylinder speed of 1000rpm and 1100 rpm for all feeding rates. Therefore, any combination from these would lead to optimum performance. Amongst combinations selected based on percent of grain separation losses, the separation loss was the minimum at cylinder speed of 1000rpm and crop feed rate of 8 kg/min (0.41%).

Comparison between the existing and the modified thresher

An independent t-test shows that there is a significant difference between the efficiencies of the machines. The comparison between the existing teff CAAMS thresher and the modified thresher using t-test showed that output capacity, cleaning efficiency and total grain loss are significantly different. The means of the threshing efficiency were not statistically significant. This revealed that the performance of the modified teff thresher is superior to that of the old one (Table 1).

Table 1: Comparison between the Existing and the Modified Thresher

Parameters	Mean value				
	Existing thresher	Modified thresher	Alpha	P(T<=t)	Significance
Threshing efficiency (%)	100	100	0.05	-	NS
Cleaning efficiency (%)	97.34	91.96	0.05	-10.318	*
Output capacity (Kg/hr)	111.32	180.26	0.05	21.539	*
Total grain loss (%)	2.51	1.47	0.05	-9.266	*

CONCLUSION AND RECOMMENDATION

Based on identified shortcomings of existing teff thresher, it was modified through redesigning some of the components and reconstructed from locally available materials. The modified teff thresher was tested to determine its performance parameters. All the performance indices showed an increase pattern with an increase in cylinder speed. The best output capacity of the developed thresher was obtained at a speed of 1200rpm at a feed rate

level of 12kg/min. The grand mean of threshing efficiency, cleaning efficiency, total grain loss and the output capacity were found to be 100, 91.96, 1.47% and 180.266kg/hr respectively. It was, also, observed that the straws out let chocking problems are solved. In comparing the modified thresher with the existing CAAMS machine the t-test, results indicated the modified machine's better performances in terms of total grain loss and output capacity, but statistically similar in terms of threshing efficiency as indicated in Table 1. In general, based on the specific objectives, a prototype of teff thresher was designed and constructed with modification on the threshing cylinder, the straw outlet and the feed hopper. The performance evaluation of the improved teff thresher was carried out and from the result it shows that the thresher has a great potential in mechanizing the threshing process of teff.

From the analysis and discussions of the performance result of the test on the modified teff thresher, the following additional activities have recommended for furher improvement of the machine's performances:-

1. On-farm trail of the improved teff thresher should be carried out by the farmers for assessment
2. Further research should be conducted and modified to multi crop thresher and evaluated for different crops.

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Effect of Alternate furrow irrigation with different irrigation intervals on yield, water use efficiency, and economic return of green Cob Maize production at Wayu Tuka and Diga Districts, Western Oromia

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ABSTRACT

Alternate furrow irrigation with proper irrigation intervals could save irrigation water and result in high yield with minimum irrigation water and costs during dry season. Field experiment was conducted at two locations for two consecutive years to investigate the effect of alternate furrow irrigation with irrigation intervals (AFI with normal, reduced and extended irrigation intervals) on yield, water productivity and economic return of maize (Zea *mays* L.) as compared with every-furrow irrigation (EFI, conventional method with normal irrigation interval). Normal irrigation interval is irrigation interval produced by CROPWAT model. Results indicated that highest green cob yield 10733/ha and 10822/ha at Diga and 10044/ha and 10200/ha were obtained from AFI with normal irrigation interval treatment during two consecutive seasons whereas, low number are collected from Farmer practice (FP) treatments. However, highest water productivity (WP) values (3.42kg/m^3, 3.45 kg/m^3,3.55kg/m^3 and 3.30kg/m^3) were observed from AFI with extended irrigation interval at both locations during consecutive growing seasons. Irrigation water saved at Wayu Tuka under AFI_{norm} and $AFI_{extended}$ treatments were approximately 50% and 60% respectively, as compared to the CFI treatment and 43.6 and 55.7% AFI_{norm} and $AFI_{extended}$ treatments respectively at Diga site. However, under $AFI_{extended}$ yield reduction was observed as compared with AFI_{norm}. It could be concluded that Alternate-furrow irrigation with normal irrigation interval can improve crop water productivity without the risk of yield reduction. Therefore, if low cost water is available and excess water delivery to the field does not require any additional expense, then the AFI normal irrigation interval treatment will essentially be the best choice under the study area conditions.

Key words: Alternate Furrow irrigation, green crop yield, Irrigation interval, Water productivity,

INTRODUCTION

Irrigated agriculture is the main solution to produce crop to feed and achieve the different needs for an ever-increasing world population. However, a Growing competition for water from domestic and industrial sectors reduced its availability for irrigation. In this regards irrigation only based on crop water requirement is not an option especially in areas where water resource is limited. Much of an increase in the irrigated area had come because of the expansion of small-scale irrigation in the country. Yet, the existing irrigation development in Ethiopia, as compared to the resources the country has, is negligible. Irrigation water management implies the application of suitable water to crops in right amount at the right time. Salient features of any improved method of irrigation is the controlled application of the

required amount of water at desired time, which leads to minimization of range of variation of the moisture content in the root zone, thus reducing stress on the plants (Monteith ,1990 and Ulsido and Alemu, 2014). Many investigations have been conducted to gain experiences in irrigation of crops to maximize performance, efficiencies and profitability. However, investigation in water saving irrigation still is continued (sleeper *et al.*, 2007).

Satisfying crop water requirements, although it maximizes production from the land unit, does not necessarily maximize the return per unit volume of water (Oweis *et al*., 2000 and Oweis *et al.*, 1998). The target crop maize is the one of the major crop in Ethiopia with is the top crop by the number of farming community engaged and next to teff it is the highest in area coverage in the country (Oweis *et al*., 20000. The study area is at Western Ethipia where crop production in wet season by rain fall and during dry season is unexpected without irrigation. Moreover, it is characterized by having highly variable initial and conditional probability of threshold limit of 30 mm per decade rainfall in the main rainy season (Oweis *et al.*, 1998). To improve crop production to feed the ever-increasing population under limiting water resource condition, strategies that conserve moisture in the soil and efficient irrigation techniques should be identified and practiced. Different works have been done on irrigation water management for maize in different part of the world that revealed that yield and water productivity of maize enhanced through different irrigation water management methods like conventional furrow, alternate furrow and water conservation methods like application of straw and plastic mulching (Mebrahtu, 2017 and Penman 1948).

Application of irrigation water through conventional furrow method that irrigate all the neighbouring furrow in two consecutive irrigation time leads to maximize yield under different crops including maize. However, productivity of irrigation water is maximized through deficit irrigation practice using different techniques like alternate furrow method by irrigating only one of the neighbouring two furrows during the consecutive irrigation time. For example, (Seid Debaeke and Aboudrare, 2004) reported that maximum maize yield was obtained under conventional furrow irrigation with irrigation water application of 100% crop water requirement than the alternate and fixed furrow irrigation method. The same research revealed that with comparable yield penalty, alternate furrow irrigation method maximized water use efficiency of maize. According to (Nasri *et al.*, 2010) that reported alternate partial root-zone irrigation improves water use efficiency of okra plant than the conventional furrow condition under different soil moisture depletion levels. Based on their findings, they concluded that alternate furrow irrigation as a way to save water and maize production relies heavily on repeated irrigation.

Alternate furrow irrigation (AFI) is considered to be one of the most effective tools to minimize water application and irrigation costs and produce a higher crop yield. The AFI method is a way to save irrigation water, improve irrigation efficiency, and increase corn yield (Shayannejad and Moharreri, 2009; Nasri et al., 2010; Rafiee and Shakarami, 2010; Kashiani et al., 2011). Using Alternate furrow irrigation with appropriate irrigation interval can save irrigation water without yield reduction. Little works were done on irrigation interval of Alternate furrow irrigation. Sepaskhah and Khajehabdollahi (2005) found that corn grain yield of AFI at 7-d intervals was lower than every-furrow irrigation (EFI) at 10-d intervals. In addition, Li et al. (2007) found that alternate partial root-zone and fixed partial root-zone irrigation techniques led to a higher reduction of transpiration than photosynthesis

and thus increased corn leaf water use efficiency (WUE). Beside this, Abdel-Maksoud et al. (2002) found that AFI at 14-d intervals seemed to not significantly decrease yield, whereas yield increased under AFI at 7-d intervals as compared with the EFI method. Therefore, in an effort to improving water productivity through Alternate furrow irrigation with appropriate irrigation interval is an interest of the study done on maize crop.

The objective of this research study was to investigate the effects of alternate furrow irrigation with different irrigation intervals on corn yield, irrigation water productivity, and economic return as compared with EFI (conventional method).

MATERIALS AND METHOD

Description of the study area

This experiment was conducted in Dida and Wayu Tuka Districts of western Oromia. The study sites are Lelisa Dimtu from Diga District and Xaxo from Wayu Tuka. Diga and Wayu Tuka districts were located at 338 and 325km from Addis Ababa respectively. The districts has three agro ecologies Dega,weyna and Kola.

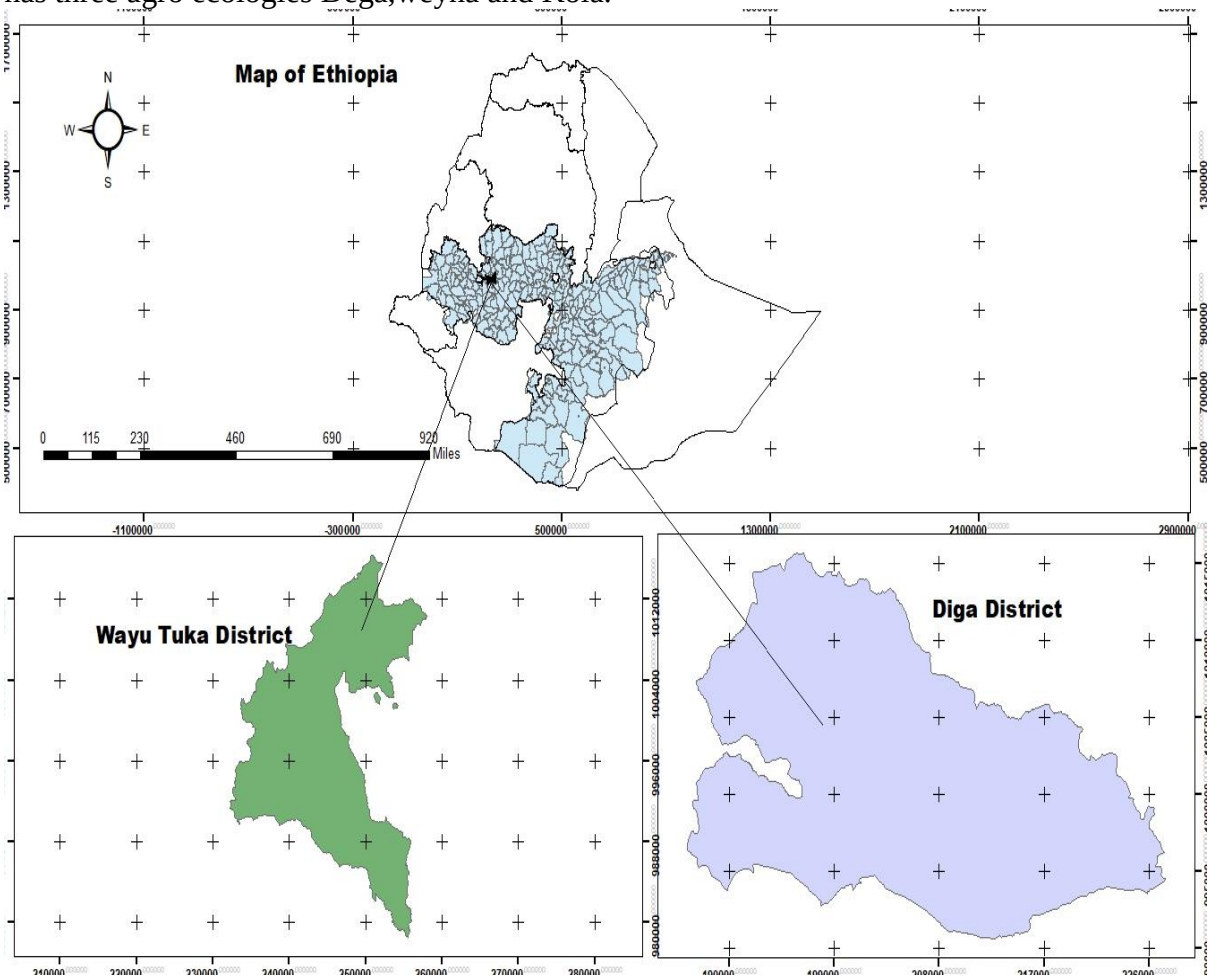

Fig.1. Map of Study area

Treatments and experimental design

Irrigation treatments were: 1, Farmer practice (FP); 2, Conventional irrigation method (EFI), every furrow was irrigated at CROPWAT irrigation interval; 3, Alternate furrow irrigation at CROPWAT irrigation interval (AFI_{norm}); 4, Alternate furrow irrigation at Reduced CROPWAT irrigation interval ($AFI_{reduced}$); and 5, Alternate furrow irrigation at extended CROPWAT irrigation interval ($AFI_{extended}$ The adopted treatments were assessed with randomized complete block design (RCBD) with three replicates. The experimental plot size was $45m^2$ (10m wide × 4.5m long). Each treatment included 7 furrows and 6 planting ridges (rows). Furrow spacing was 0.75 m. Space between plots been 1m and between replication 1.5 m. Space between rows 0.75m and 0.35cm between the plants was used. The experimental plot was pre-irrigated one day before planting. Before the commencement of treatment, two to three common light irrigations was supplied to all plots at two to three days interval to ensure better plant establishment.

Table 1. Treatment set-up

Treatment Code	**Treatment combination**
FP	Farmer practice
EFI	Convectional furrow irrigation (CROPWAT irrigation interval)
AFI_{norm}	Alternate furrow irrigation (CROPWAT irrigation interval)
$AFI_{reduced}$	Alternate furrow irrigation (Reduced CROPWAT irrigation interval)
$AFI_{extended}$	Alternate furrow irrigation (Extended CROPWAT irrigation interval)

Agronomic practices

Agronomic practices maize seeds (BH-546) were planted during 2018/19 and 2019/20 growing seasons at the rate of $25kgha^{-1}$. Two seeds were planted per hole with a plant spacing of 0.35m. All plots were irrigated immediately after planting (planting irrigation). Recommended fertilizer of 100kg/ha NPS and half of 200kg/ha UREA was applied prior to the second pre-treatment irrigation. Thinning was carried out after the second pre-treatment irrigation and the remains half UREA was applied after 35 days of planting. All other agricultural operations, including pesticide and hand weeding, were applied uniformly and simultaneously for all treatments. Experimental treatments were implemented after the second pre-treatment irrigation in both seasons.

Crop water requirement and Irrigation Schedule

The estimate of the water requirement and irrigation scheduling of crops under this study is based on the atmospheric conditions of the environment by using a model. A computer program called "CROPWAT version 8.0" was used to determine reference evapotranspiration, crop water requirements, and irrigation schedule by utilizing metrological data as an input. For estimation of water irrigation requirements, climatic, crop and soil data have been utilized as an input. This calculation has been done by using the FAO Penman-Monteith method (Aallen 1998). In this experiment, the reference evapotranspiration (ETo)

and crop water requirement (ETc) were estimated from long term climatic data collected from Ethiopia Metrological Agency.

Irrigation water was conveyed to the experimental plots through Parshall Flume having appropriate opening diameter of three inch (3") and a length of 2 m. The amount of water for each application was added through Parshall Flume by recording time of water flow through furrows. Time is then recorded with a stopwatch to estimate the amount of water applied to each plot. Furrows subjected to irrigation were close-ended; then, water cannot exceed the edge of the plot because all were closed-ended. The water in the channel was controlled to maintain a constant head to provide an adequate inflow rate during irrigation events with a close ended.

Data Collection

Climatic data

Before the start of the experiment, secondary data such as climatic data of 30 years on rainfall (R.F.) min and max temperature, relative humidity (RH), wind speed (WS) and sunshine hours (SH) were collected from the National meteorological agency. Irrigation efficiency for furrow irrigation, root depth of maize crop, maize crop growth stages and their respective length of period data were also collected from previous records and FAO guidelines.

Soil Physical Properties

Four soil profiles were randomly made in the experimental site to measure soil physical properties. Soil texture was determined using the volumetric method at 0-5, 5-10, 10-15 and 15-20cm depths of the soil profiles. Bulk density was determined by the core method (Blake and Hartage 1986) for each sampling depth. Soil water content was determined from soil samples taken at the same locations using the gravimetric method. The soil basic infiltration rate was determined in the field using double-ring infiltrometer method in two separate sites in the experimental area as described by (Bouwer 1986).

Table 2. Soil physical characteristics of the experimental sites

Sampling Depth	**Wayu Tuka (Lega Xaxo)**			**Diga (Lelisa Dimtu)**		
	Bulk density	Average bulk density g/cm^3	Soil texture	Bulk density	Average bulk density g/cm3	Soil texture
0-5cm	1.32			1.18		
5-10cm	1.34			1.29		
10-15cm	1.36			1.38	1.31	Sandy clay
15-20cm	1.37			1.4		
FC (%)	61.72	1.34	clay	52.6		
PWP (%)	50.18			34.87		

Yield and Yield Components

Yield (green cob) data, were collected from each plot size of 10 *4.5m and extrapolated to a hectare basis. Green Cobs of maize were categorized as small, medium and large based on the size of cobs and data were collected in number and weight basis from each plot at both locations. Stand count data was also collected from all plots at maturity stage.

Water Productivity

Water productivity (WP) Water productivity was determined by dividing grain yield by total applied irrigation water and is expressed as follows (Ali et al., 2007):

$$WP = GY/Wa \quad (1)$$

where GY is grain yield (kg ha^{-1}) and Wa is irrigation applied water (m3 ha^{-1}).

Data Analysis

The collected data was subjected to analysis of variance (ANOVA) and least significant difference (LSD) was used to separate means at $p<0.05$ probability levels of significance.

RESULT AND DISCUSSION

In order to characterize soils of the study site, soil physical and chemical parameters were measured in the field and laboratory. The laboratory results of the average chemical properties of the experimental site were presented in table 3. The result of the soil analysis from the experimental site showed that the top soil surface had bulk densities were of 1.34gm/cm^3 and 1.31gm/cm^3 at Wayu Tuka (Xaxo) and Diga (Lelisa Dimtu) sites respectively. In general, the average soil bulk density (1.31gm/m^3) is below the critical threshold level (1.4g/cm^3) and was suitable for crop root growth. Average moisture content at field capacity of the experimental sites soils were 61.72% and 52.6% at Xao and Lelisa Dimtu sites respectively, and permanent wilting point the sites were 50.18% and 34.87% at Xaxo and Lelisa Dimtu respectively. Soil pH was found to be at slightly acidic value (5.7 averages of all treatments) at both sites for maize and other crops. Therefore, the soils of the study area are normal soils. The weighted average organic matter content of the soil was 5.3 and 5.6% at Xaxo and Lelisa Dimtu respectively.

Table 3. Soil chemical properties characteristics of the experimental sites

Treatments	Wayu Tuka (Lega Xaxo)					Diga (Lelisa Dimtu)				
FP	5.81	3.43	5.92	0.20	16.5	5.86	3.24	5.58	0.18	25.1
CFI	5.64	2.83	4.87	0.14	16.7	5.61	2.91	5.01	0.15	24.7
AFI_{Norm}	5.68	3.24	5.58	0.18	15.6	5.86	3.26	5.61	0.18	19.7
AFI_{Extend}	5.5	3.14	5.41	0.17	12.7	5.64	2.87	4.94	0.15	25.7
AFI_{Redu}	5.84	2.69	4.64	0.13	29.6	5.71	4.04	6.96	0.25	18.1

Depth of applied water

The irrigation events and amount of applied water (Wa) for each treatment at Wayu Tuka district of Lega Xaxo site are shown in Table 4. The AFI_{Redu} (Altenat Furrow irrigation with reduced irrigation interval) treatment was more frequent (11 irrigation events) than CFI and AFI_{Norm} (eight irrigation events) for both seasons. The mean of the two seasons were amounted to 415mm (415m^3ha^{-1}), 346mm (346m^3ha^{-1}), 173mm (173m^3ha^{-1}), 135mm (135m3ha^{-1}) and 208mm (208m^3ha^{-1}) for FP, CFI, $AFI_{Norm,}$ AFI_{Extend} and AFI_{Redu}, respectively.

This indicates that the AFI_{Extend} and AFI_{Norm} alternate furrow irrigation treatments saved water by approximately 60% and 50% (two-season means), respectively, as compared to conventional CFI. Regardless of irrigation intervals, the lowest amount of applied water (Wa) under $AFI_{Norm,}$ treatments as compared with CFI might be due to the great reduction of wetted surface in AFI_{Norm}; almost half of the soil surface is wetted in AFI_{Norm} as compared with CFI. This result supports the outcome obtained by (Awad Abd El-Halim, 2013), who found that AFI methods can supply water in a way that greatly reduces the amount of wetted surface, which leads to less evapotranspiration and less deep percolation.

Table.4. Number of irrigation events and depth of applied water for each irrigation event under different irrigation treatments for both seasons at Wayu Tuka

Irrigation event	Wayu Tuka (Lega Xaxo) Depth of applied water (Wa) (mm)									
	Season 2018/19					Season 2019/20				
1	37.1	30.9	15.4	18.7	11.8	38.9	32.4	16.2	19.6	12.3
2	44.8	37.3	18.6	21.7	9.8	46.9	39.2	19.6	22.7	10.2
3	51	42.5	21.3	21.95	12.7	53.6	44.6	22.3	23.0	13.3
4	51.9	43.3	21.7	22.2	15.5	54.6	45.5	22.7	23.3	16.2
5	52.7	43.9	21.9	25.3	18.7	55.3	46.1	23.0	26.5	19.6
6	53.2	44.3	22.2	22.2	21.3	55.8	46.5	23.3	23.3	22.3
7	53.3	44.4	22.2	-	21.7	55.9	46.6	23.3	-	22.7
8	60.6	50.5	25.3	-	21.9	63.6	53.0	26.5	-	23.0
9	-	-	-	-	22.2	-	-	-	-	23.3
10	-	-	-	-	22.2	-	-	-	-	23.3
11	-	-	-	-	25.3	-	-	-	-	26.5
Total	404.5	337	167	132	203	425	354	177	139	213
Mean	415	346	173	135	208					

The irrigation events and amount of applied water (Wa) for each treatment at Diga district of Lalisa Dimtu site are shown in Table 5. The AFI_{Redu} (Altenat Furrow irrigation with reduced irrigation interval) treatment was more frequent (11 irrigation events) than CFI and AFI_{Norm} (eight irrigation events) for both seasons. Based on the output of the CROPWAT 8 model, the optimum seasonal irrigation requirement in the area for maize was found to be mean of the two seasons were amounted to 471mm (471m^3ha^{-1}), 402mm (402m^3ha^{-1}), 229mm (229m^3ha^{-1}), 178mm (178m3ha^{-1}) and 283mm (283m^3ha^{-1}) for FP, CFI, $AFI_{Norm,}$ AFI_{Extend} and AFI_{Redu}, respectively. This indicates that the AFI_{Extend} and AFI_{Norm} alternate furrow irrigation treatments saved water by approximately 55.7% and 43.6% (two-season means), respectively, as compared to conventional CFI. Amount of water saved under AFI_{Extend} and AFI_{Norm} at Lelisa Dimtu site was relatively low as compared to Lega Xaxo Site. Amount of water applied under alternate furrow irrigation also agrees with the conclusion that says that alternate furrow irrigation is commonly applied as part of a deficit irrigation program because it does not require the application of more than 50–70% of the water used in a conventional furrow irrigation method (Webber et al 2006).

Table.5. Number of irrigation events and depth of applied water for each irrigation event under different irrigation treatments for both seasons at Diga

Irrigation events	Diga (Lelisa Dimtu)									
	Depth of applied water (mm)									
	Season 2018/19					Season 2019/20				
	FP	CFI	AFI_{Norm}	AFI_{Extend}	AFI_{Redu}	FP	CFI	AFI_{Norm}	AFI_{Extend}	AFI_{Redu}
1	43.1	36.9	21.5	24.7	17.8	46.9	40.4	24.2	27.6	20.3
2	50.9	43.3	24.7	27.7	15.8	54.9	47.2	27.6	30.7	18.2
3	57	48.5	27.3	27.9	18.7	61.6	52.6	30.3	31.0	21.3
4	57.9	49.3	27.7	28.2	21.5	62.6	53.3	30.7	31.3	24.2
5	58.7	49.9	27.9	31.3	24.7	63.3	54.1	31.0	34.5	27.6
6	59.2	50.3	28.2	28.2	27.3	63.8	54.5	31.3	31.3	30.3
7	59.3	50.4	28.2		27.7	63.9	54.6	31.3		30.7
8	66.6	56.5	31.3		27.9	71.6	61.0	34.5		31.0
9					28.2					31.3
10					28.2					31.3
11					31.3					34.5
Total	453	385	217	168	269	489	418	241	187	300.8
Mean	471	402	229	178	283					

Yield (Green Cobs) and Stand count

At maturity stage of the crop numbers of cobs were counted for all plots and categorized to three groups (small, medium and large) based on the size of cobs. Based this, Number of cobs categorized as small , medium and large size were collected from each plot was significantly affected by the irrigation treatments and had the same trend in both seasons (Table 6). The highest number of cobs 483 per plot (107333 per hectare) and 487 per plot (108222 per hectare) were recorded from AFI_{Norm} for both seasons respectively followed by AFI_{Redu} at Lelisa Dimtu Site. Numbers of cobs recorded from AFI_{Norm} were higher than for CFI with 9111 to 9333 numbers per hectare in both seasons. Beside this, statistical analysis showed that stand count of maize had not affected by the application of different irrigation systems with different irrigation intervals ($p<0.05$). The lowest number of cobs per plant 438 per plot (97333 per hectare) and 441 per plot (98000 per hectare) were recorded from FP for both seasons respectively at Lelisa Dimtu site. Numbers of cobs AFI_{Extend} were higher than CFI for in both seasons. When comparing CFI and AF_{norm}, the latter increased number of green cobs by approximately 667/ha and 889 in the first and second seasons respectively. Reference

Table.6. Average number of cobs (green cobs) under different irrigation treatments at Lelisa Dimtu during 2018/19 and 2019/20

Treatment	Diga (Lelisa Dimtu)									
	Season 2018/19					Season 2019/20				
	Stand count	Number of cobs per plot			Total number of cobs per ha	Stand count	Number of cobs per plot			Total number of cobs per ha
		small	Medium	Large			small	medium	Large	
FP	160.7a	65c	131.3c	241.7b	97333d	160.7a	65c	132.3c	243.7b	98000d
CFI	162.7a	65.7bc	132.7c	243.7b	98222d	162.7a	65.7c	133.7c	246.7b	98889d
AFI_{Norm}	164.7a	66.7a	146.3a	270a	107333a	164.7a	69.7a	148.3a	275a	108222a
AFI_{Extend}	163.7a	66.3ab	136b	248.7b	100222b	163.7a	67.3b	138b	250.7b	100889c
AFI_{Redu}	162.3a	66.0ab	137.3b	262.7a	103556b	162.3a	67.0b	137.3b	269.7a	104444b
CV	11.6	14.6	11.7	16.8	14.6	12.8	14.6	15.7	13.8	14.6
LSD	5.06	0.91	2.8	8	1867	5.06	1.5	2.8	8	1867

Note: FP; Farmer Practice, CFI; Convectional Furrow Irrigation, AFI_{Norm}; Alternate Furrow irrigation with normal irrigation Interval, AFI_{Exten}; Alternate furrow irrigation with extended irrigation interval, AFI_{Redu}; Alternate furrow irrigation with reduced irrigation interval, CV; Coefficient of Variance and LSD; least significant difference.

Statistical analysis also showed significance influence ($p<0.005$) due to the adoption of both different furrow irrigation methods as well as irrigation intervals on weight of cobs per plot (Table 7). Highest weight of cobs per plot were recorded from AFI_{Norm} 130.2kg per plot (28933 $kgha^{-1}$) and 135.3kg per plot (30067$kgha^{-1}$) for both seasons respectively at Lelisa Dimtu Site respectively. However, the lowest weight of cobs 93kg per plot (20689$kgha^{-1}$) and 97 kg per plot (21578$kgha^{-1}$) were recorded from FP for both seasons respectively.

Table.7. Average Weight cobs (green cobs) under different irrigation treatments at Lelisa Dimtu during 2018/19 and 2019/20

Treatment	Diga (Lelisa Dimtu)							
	Season 2018/19				Season 2019/20			
	Weight cobs per plot(kg)			Total Weight (kg/ha)	Weight cobs per plot (kg)			Total Weight (kg/ha)
	small	medium	large		small	medium	large	
FP	8.7b	12.1c	72.4c	20689d	3.1bc	17.3cd	76.7c	21578d
CFI	8.3b	17.5b	77.6b	22978c	2.7c	21.3bc	83.3b	23844c
AFI_{Norm}	6.0d	34.1a	90.1a	28933a	7.3a	33a	95a	30067a
AFI_{Extend}	7.4c	12.7c	80.6b	22378c	5.0abc	13.3d	86.1b	23200c
AFI_{Redu}	9.5a	21.8b	81.1b	24978b	6.0ab	26b	84.4b	25867b
CV	13.4	15.2	13.8	15.8	12.4	17.6	14.8	16.8
LSD	0.4	4.6	4.9	1422	2.9	5.9	5.9	1489

Note: FP; Farmer Practice, CFI; Convectional Furrow Irrigation, AFI_{Norm}; Alternate Furrow irrigation with normal irrigation Interval, AFI_{Exten}; Alternate furrow irrigation with extended irrigation interval, AFI_{Redu}; Alternate furrow irrigation with reduced irrigation interval, CV; Coefficient of Variance and LSD; least significant difference.

Highly significant ($p<0.005$) difference was observed on number cobs per plot due to different irrigation methods with different irrigation intervals during both the study season at Wayu Tuka (Xaxo site) (Table 8). The higher number of cobs per plot 452 (100444 per

hectare) and 459 (102000 per hectare) were obtained from AFI_{Norm} and statistically superior to other irrigation method during both season. The lower number of cobs per plot 439 (97556 per hectare) and 446 (99111 per hectare) were observed from FP treatment during both season respectively. Application of Alternate furrow irrigation with normal irrigation interval (irrigation interval produced by CROPWAT Model) for maize improved number of cobs than convectional furrow irrigation and other irrigation methods. Beside this, statistical analysis showed that stand count of maize had not affected by the application of different irrigation systems with different irrigation intervals ($p<0.05$). On the other hand, statistically insignificant difference was observed between AFI_{norm} and $AFI_{extended}$ regardingin number of cobs during both seasons (table 8).

This implies at Xaxo Site, under AFI_{norm} and $AFI_{extended}$ treatments similar green cob yield was observed with less amount of water applied for $AFI_{extended}$ during both seasons. When comparing CFI and AF_{norm}, the latter increased number of green cobs by approximately 1555/ha in the first and second seasons. This result shows the same trend as Abd El-Halim [15] reported Shifting irrigation practice from conventional irrigation (CFI) to alternate furrow increased corn yield to 8.9% (0.5 ton/ha).

Table.8. Average number of cobs (green cobs) under different irrigation treatments at Lega Xaxo during 2018/19 and 2019/20

Treatment	**Wayu Tuka (Lega Xaxo)**									
	Season 2018/19					Season 2019/20				
	Stand count	Number of cobs per plot small	Medium	large	Total number of cobs per ha	Stand count	Number of cobs per plot small	medium	Large	Total number of cobs per ha
FP	160.7a	65.0c	132.3c	241.7c	97556c	165.7c	70.0c	138.3c	248.7c	99111c
CFI	161.3a	65.7bc	132.7c	243.3bc	98156c	166.3c	70.7bc	138.7c	250.3bc	99711c
AFI_{Norm}	164.7a	66.7a	136a	249.3a	100444a	169.7a	71.7a	142a	256.3a	102000a
AFI_{Exten}	1643.3a	66.3ab	135a	248a	99933a	1648.3ab	71.3ab	141a	255a	101489a
AFI_{Redu}	161.7a	66ab	133.7b	245b	98822b	166.7bc	71ab	139.7b	252b	100378b
CV	12.3	17.4	15.6	16	11.3	12.4	16.4	10.2	17.4	12.5
LSD	5.76	0.81	0.94	2.3	700	1.8	0.81	0.9	2.3	711

Note: FP; Farmer Practice, CFI; Convectional Furrow Irrigation, AFI_{Norm}; Alternate Furrow irrigation with normal irrigation Interval, AFI_{Exten}; Alternate furrow irrigation with extended irrigation interval, AFI_{Redu}; Alternate furrow irrigation with reduced irrigation interval, CV; Coefficient of Variance and LSD; least significant difference.

The analysis of means and both season data also revealed that different irrigation methods with different irrigation interval on maize had a highly significant ($p<0.05$) influence on weight of cobs per plot (Table 9). Moreover, weight of cobs (green cob) of maize was significantly ($p<0.05$) affected by different types irrigation methods with different irrigation interval at Lega Xaxo site for both seasons. Maximum weight of cobs per plot 126 (28044kgha^{-1}) and 129 (28711kgha^{-1}) were observed from AFI_{Norm} treatment during both season respectively. The maximum weight of cobs obtained from AFI_{Norm} was statistically superior to both treatments which followed Alternate furrow irrigation condition. Moreover, the minimum weight of cobs per plot 89 (19822 kgha-1) and 93 (20711kgha-1) were obtained from FP treatment were statistically inferior to other treatments during both seasons respectively.

Table.9. Average Weight cobs (green cobs) under different irrigation treatments at Lega Xaxo during 2018/19 and 2019/20

Wayu Tuka (Lega Xaxo)								
Season 2018/19					Season 2019/20			
Treatment	Weight cobs per plot			Total Weight (kg/ha)	Weight cobs per plot			Total Weight (kg/ha)
	small	medium	large		small	medium	large	
FP	8ab	13.2b	68d	19822d	8.8b	18.7c	65.7d	20711d
CFI	7.3ab	14.1b	78.3c	22156c	10.7ab	21bc	71.4c	22911c
AFI_{Norm}	7b	26.5a	92.7a	28044a	12.7a	31.2a	85.3a	28711a
AFI_{Exten}	7.4ab	14.53b	74.6c	21444c	10.7ab	21.1bc	68.5cd	22267c
AFI_{Redu}	9.5a	14.5b	84.4b	24089b	10.9ab	23.5b	78.1b	24978b
CV	13.6	14	12	10.7	15.4	13.5	10.5	12.3
LSD	2.2	3.9	4.9	1600	2.9	4.8	4.7	1200

Note: FP; Farmer Practice, CFI; Convectional Furrow Irrigation, AFI_{Norm}; Alternate Furrow irrigation with normal irrigation Interval, AFI_{Exten}; Alternate furrow irrigation with extended irrigation interval, AFI_{Redu}; Alternate furrow irrigation with reduced irrigation interval, CV; Coefficient of Variance and LSD; least significant difference.

Water productivity (WP)

Water productivity was significantly ($p<0.05$) influenced due to application of different irrigation method with different irrigation intervals at Diga (Lelisa Dimtu site) and Wayu Tuka (Xaxo site) for both seasons (Table 10). Results indicated that the water productivity of maize was higher under AFI_{norm} next to $AFI_{extended}$ treatment during both seasons as compared with conventional and other treatments. Maximum water productivity values were 3.42kg/m^3, 3.45 kg/m^3,3.55kg/m^3 and 3.30kg/m^3 observed from $AFI_{extended}$ and statistically superior to AFI_{norm} and other treatments for both seasons respectively. Statistically there was significant difference between Water productivity values of AFI_{norm} and $AFI_{extended}$ at both locations and seasons. However, there was no statistical difference between AFI_{norm} and $AFI_{reduced}$ on water productivity values for both location and seasons. This implies that more amount of water was applied under $AFI_{reduced}$ at both sites than AFI_{norm} produces similar water prodctity values. The minimum water Productivity values were 1.04kg/m^3, 1.05kg/m^3,1.03kg/m^3 and 1.05kg/m^3 s observed at both locations from FP respectively and this was statistically inferior to other treatments (Table 10). These results indicated that $AFI_{extended}$ and AFI_{norm} were appropriate to increase WP because they allow applying less irrigation water for maize production.

The high WP values for AFI could be due to the small amount of applied water for AFI as compared with the EFI treatment. Sepaskhah and Hosseini (2008) reported similar results. In addition, Nouri and Nasab (2011) concluded that the AFI system generally increases crop yield and WP. Clearly, WP depends on total applied water. This finding agrees with results obtained by Ibrahim and Emara (2010), who reported that an adverse relationship was found between the amount of applied irrigation water and WP.

Table.10. Water Productivity of maize crop at Diga and Wayu Tuka sites of both seasons

Treatment	Diga		Wayu Tuka	
	Season 2018/19 WP	Season 2019/20 WP	Season 2018/19 WP	Season 2019/20 WP
FP	1.04d	1.05d	1.03d	1.05d
CFI	1.60c	1.62c	1.69c	1.67c
AFI_{Norm}	2.84b	2.85b	2.46b	2.56b
AFI_{Exten}	3.42a	3.45a	3.55a	3.30a
AFI_{Redu}	2.30b	2.32b	2.09b	2.12b
LSD	0.6	0.6	0.6	0.5
CV	12.4	10.7	14.4	11.4

Note: FP; Farmer Practice, CFI; Convectional Furrow Irrigation, AFI_{Norm}; Alternate Furrow irrigation with normal irrigation Interval, AFI_{Exten}; Alternate furrow irrigation with extended irrigation interval, AFI_{Redu}; Alternate furrow irrigation with reduced irrigation interval, CV; Coefficient of Variance and LSD; least significant difference.

CONCLUSION AND RECOMMENDATION

The effort of this study was to determine the effect of Alternate furrow irrigation with different irrigation interval on maize green cob production by comparing with farmer practice and convectional furrow irrigation. Beside this, maximum number of green cobs and green cob weight were obtained by applying Alternate furrow irrigation with normal irrigation interval throughout the growing season at both locations and during 2018/19 and 2019/20 growing seasons. Crop water productivity (WP) is highest for Alternate furrow irrigation with extended irrigation interval when comparing with Alternate furrow irrigation with normal irrigation interval and other treatments at both study area. Higher water productivity can be obtained by stressing maize crop by extending irrigation interval under alternate furrow irrigation. However, extending irrigation interval under Alternate furrow irrigation showed yield reduction when comparing with applying Alternate furrow irrigation with normal irrigation interval.

Alternate-furrow irrigation with appropriate normal irrigation interval (irrigation interval produced by CROPWAT software) can be used as an efficient method for maize n production during dry season when production depends heavily on irrigation. It could be concluded that Alternate-furrow irrigation with normal irrigation interval can improve crop water productivity without the risk of yield reduction. Generally in all parameters alternative furrow system with full irrigation application has shown the good mean results in contrasts to other treatments under normal irrigation water quality. Therefore, it is recommended that if the cost of available water is not high and excess water delivery to the field does not require any additional expense, then the alternate furrow irrigation with normal irrigation interval will essentially be the best choice under the conditions of the study area.

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Effect of Deficit Irrigation on Water Productivity and Yield of Onion (Allium cepa L) at Dire Dawa, Eastern Ethiopia

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ABSTRACT

The problem of irrigation water scarcity is the major production constraints in the arid and semi-arid areas of Dire Dawa. The objective of this study was to evaluate the effect of deficit irrigation on water productivity and yield of onion crop. The experiment was conducted at Tony farm experimental station of Haramaya University in Dire Dawa under the furrow irrigation system. Seven irrigation treatments were replicated three times in RCBD. In the treatment combination, a full application of irrigation water (100% ETc) was used as a control treatment and Bombay red onion variety was subjected to six deficit level of treatments 90% ETc, 80% ETc, 70% ETc, 60% ETc, and 50% ETc and 40% ETc throughout the growing season. The study revealed that maximum seasonal water demand for onion (423.8 mm) was consumed by control treatment and minimum seasonal water demand was consumed by 40% ETc application level. The study revealed that full application of irrigation water (100% ETc) produces a high number of leaf per plant, plant height, leaf height, and leaf diameter than the others treatment. Maximum yield (38.09 ton/ha) was obtained by non-deficit treatment (T1) while the lowest application level of irrigation water had the lowest yield of 22.23 ton/ha. Maximum WP (12.85 kg/m^3) was obtained by T7 and minimum WP (9.36 kg/m^3) was obtained by T1 (control treatment). Statistically, no significant difference was observed between T4, T5, T6,and T7 in the case of WP. By saving 30% of irrigation water T4 (70% ETc application level) produce optimum WP (11.20kg/m3) than T1, T2 and T3. This implies that WP decreases with increasing application level of irrigation water up to 30% deficit. The result has shown that the minimum yield response factor (ky) was produced by T4 (application of 70% ETc) by saving 30% of irrigation water. The water saved by T4 can irrigate additional land of 0.43 hector which can produce 13.97 tons of additional onion bulb yield. The benefit cost ratio obtained by 70% ETc application of irrigation level was better than other treatments. Even though the net income of control treatment was high the benefit-cost ratio obtained by this treatment was small. Generally, the finding revealed that 70% ETc application level was the best application-level than the other treatment based on water productivity, economic visibility, total yield, and percent of yield reduction and yield response factor.

Keywords: Deficit Irrigation, Furrow Irrigation, Water Productivity, Onion

INTRODUCTION

Water has always been the main factor limiting crop production in much of the world where rainfall is insufficient to meet crop demand. With the ever-increasing competition for finite water resources worldwide and the steadily rising demand for agricultural commodities, the call to improve the efficiency and productivity of water use for crop production to ensure future food security and address the uncertainties associated with climate change has been more urgent (FAO, 2012). Agriculture is one of the main consumers of freshwater resources in the world. It is consuming more than two two-thirds of total withdrawals (Gan et al., 2013). In many parts of the world, irrigation water has been over-exploited and over-used (Chai et

al., 2014), and the freshwater shortage is becoming critical in the arid and semiarid areas of the world.

In the context of improving water productivity, there is a growing interest in deficit irrigation, an irrigation practice whereby water supply is reduced below maximum level and mild stress is allowed with minimal effects on yield (Kirda, 1999). Under conditions of scarce water supply, the application of deficit irrigation (DI) provides greater economic returns than maximizing yields per unit of water. The DI has been considered worldwide as a way of maximizing water productivity by eliminating irrigation that has little impact on yield (Kirda C.et al., 1999).

Onion (Allium cepa L.) is one of the most important horticultural crops worldwide. Many studies have been carried out regarding its water requirements and the effects of DI on its yield (Igbadun et al., 2012; Patel and Rajput, 2013; Tsegaye et al., 2016). Onion has an economically important role in Ethiopia. Onion production also contributes to the commercialization of the rural economy and creates many off-farm jobs (Lemma and Shimeles, 2003; Nikus and Mulugeta, 2010). Onion production in the country is increasing from time to time.

The problem of irrigation water scarcity is the major production constraints in the Dire Dawa (Kibret et al., 2017). Due to a shortage of irrigation water, much of the potential farmland is not cultivated during the dry season and even in the rainy season, rains cannot meet the amount of water required to sustain crop production. Therefore, there is a competition between farmers for the limited irrigation water in the study area. To satisfy many farmers in the area, water productivity should be increased. Deficit irrigation is known to increase water productivity with insignificant or minimum yield reduction.

Even though there is scarcity of irrigation water, farmers of the study area are using the traditional irrigation system by losing much water. If carefully applied, deficit irrigation is found to be alternative method of water saving in irrigated agriculture. Reduced water application can be done in several ways. These techniques were found to be effective in water and labor-saving.

MATERIALS AND METHODS

Description of Study Area

The experiment was conducted at Tony farm experimental station of Haramaya University in Dire Dawa geographically located between $9^0$27' to $9^0$49'N latitude and $41^0$38'to $41^0$40'E longitude and at 1160 m above sea level. Dire Dawa is found at 515 km East of Addis Ababa. It is situated in the semi-arid tropical zone of Eastern Ethiopia. The area experiences a bimodal type of rainfall and the mean annual rainfall is 604mm. The mean annual maximum and minimum temperatures vary from 29^0C to 35.4^0C and 14.5^0C to 22.6^0C, respectively. The Soil textural class of the study area is classified as clay loam soil.

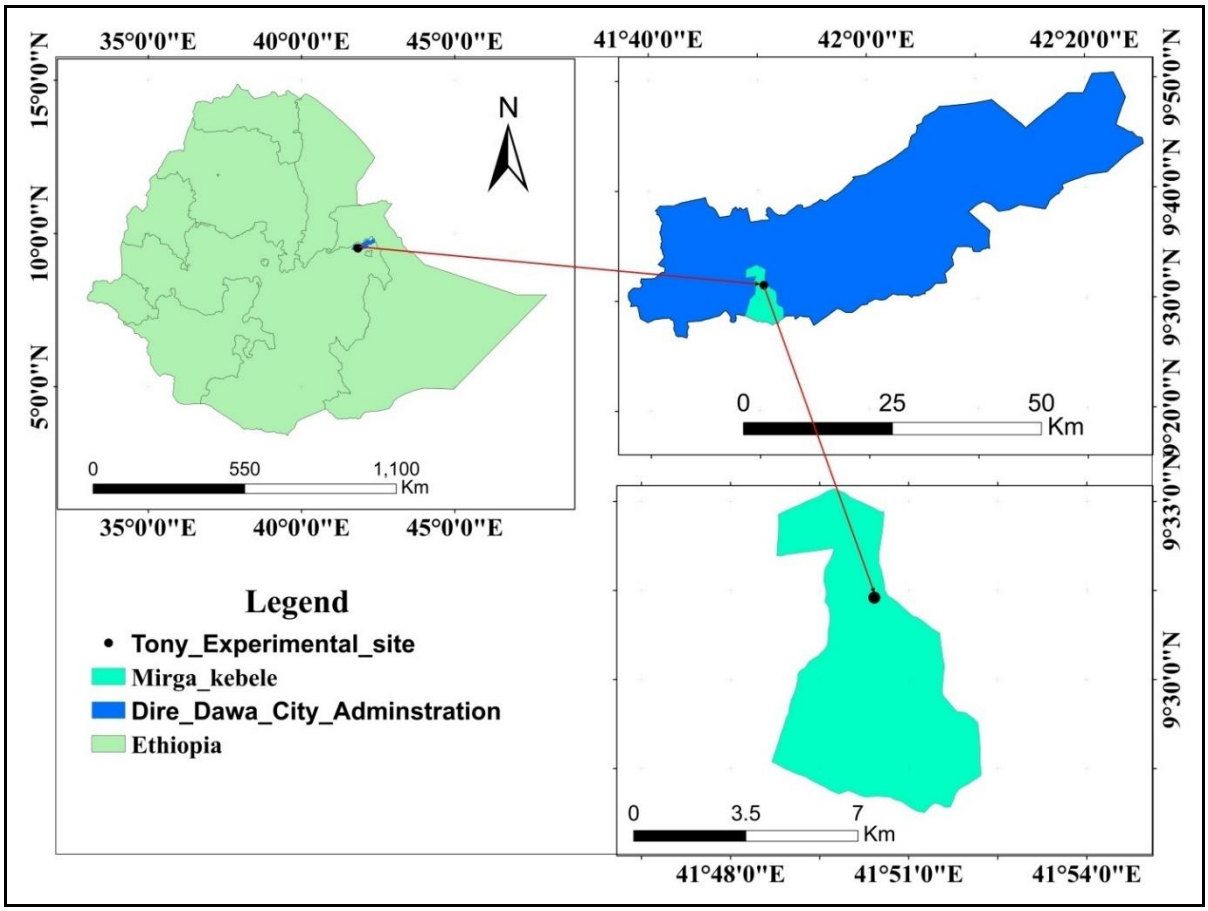

Figure 3: Location Map of the Study Site

Climate of the Study Area

From long term (1988-2018) the two seasons are 'Meher', which occurs in months of July, August, and September, and 'Belg' that occur in March, April, and May. April and August receive the highest of the annual rainfall while December, January, and September receive the less temporal distribution of rainfall (Figure 2). Since there was strong variability in long term climate data collected, the rainfall of the study area was first changed to dependable rainfall (80% probability of exceedance). A simple method of computing dependable rainfall was done by grouping the rainfall data by 10 mm interval and then selecting the high-frequency rainfall (Allen et al, 1998). Since not all dependable rainfall is effective, determination of effective rainfall was computed by the equation:

Peff = 0.6 * P - 10 for precipitation less or equal to 70mm 3.1

Peff = 0.8 * P - 24 for precipitation greater than 70 mm 3.2

Where

Peff – Effective Precipitation (mm)

P- Precipitation (mm)

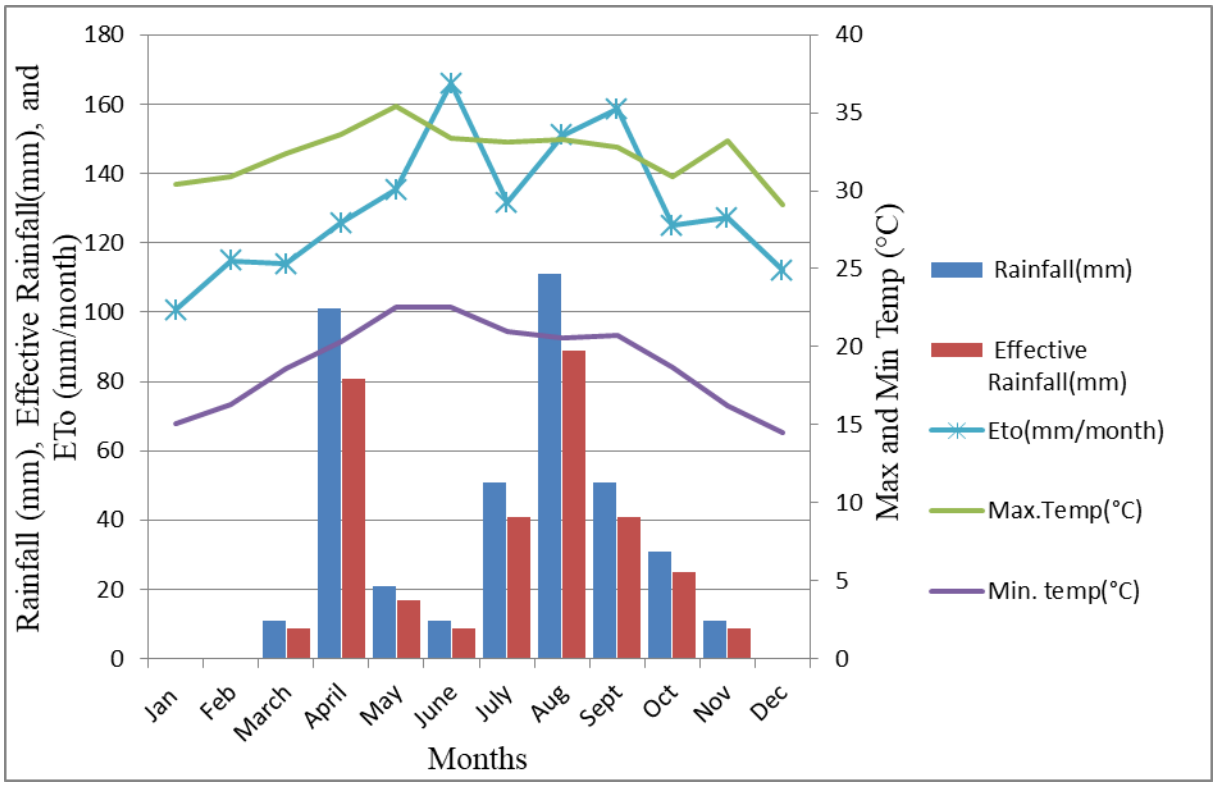

Figure 4: Rainfall, Effective Rainfall, ETo, and Temperature of the study area.

Experimental Design and Treatment

The experiment was laid out in RCBD consisting of seven treatments with three replications. The treatments contain different amounts of irrigation water application levels which are listed in Table 1 below. The experimental field was divided into 21 plots and the size of each plot was 3m * 4m dimension to accommodate five furrows with a spacing of 0.6 m and has 4 m length. Onion is known by two-row plant so transplanting was done row to row spacing 40 cm; space between ridge 20 cm and plant spacing was 10 cm. The buffer zone of plot and replication was 2 m from the water supplying canal and 2 m between plots to eliminate the influence of lateral water movement. For each plot, division box structures were constructed to dissipate the energy of water diverted to the plots. The Experimental treatment combinations are given in Table 1 below.

Table 14: Description of Treatments

Treatment	Treatment Combination
T1	Optimum Irrigation of 100%ETc (Control)
T2	Irrigation Water Application Level of 90%ETc
T3	Irrigation Water Application Level of 80%ETc
T4	Irrigation Water Application Level of 70%ETc
T5	Irrigation Water Application Level of 60%ETc
T6	Irrigation Water Application Level of 50%ETc
T7	Irrigation Water Application Level of 40%ETc

The amount of irrigation water was applied by the furrow irrigation method and measured using Parshall Flume. Out of the experimental field, Parshall Flume was set at 10 m away

from the experimental plot in the main canal. It was set inside a straight and uniform section of the canal. UREA and DAP were the two fertilizers applied equally for each treatment with a rate of 100 kg/ha and 200 kg/ha, respectively (Olani and Fikre, 2010). There were pests and diseases in the areas of the experiment. To protect the experiment both bacticide and pesticide chemicals (Proof, menchozem, and Ridomil Gold) were used according to their rate of application. To achieve the aim of trial onion diseases and pests were controlled.

Soil and water Sampling

Before the start of treatments, soil samples were taken from three spots at random from the diagonal of the experimental field. The samples were taken from four depths (0-15cm, 15-30cm, 30-45cm, and 45-60cm). The soil properties analyzed include bulk density, water retention at field capacity (FC), permanent wilting point (PWP), soil texture, soil PH, organic carbon, and electrical conductivity of the soil. The sample of this irrigation water was taken using a sampling bottle and a proper sampling kit at the pump. The collected irrigation water sample was analyzed for PH and electrical conductivity of water (ECw) in the laboratory.

Determination of Crop Water Requirement of onion

Long term climatic data (1988 -2018) records such as rainfall, maximum and minimum temperature, wind speed, relative humidity, and sunshine hours were collected from Dire Dawa meteorological station for determination of Onion water requirements. Reference evapotranspiration (ETo) of onion was computed using CROPWAT model version 8.0 (FAO, 2009) from Dire Dawa meteorological station.

Evapotranspiration of the crop was determined by multiplying the crop coefficient (Kc) of the crop by the reference evapotranspiration (ETo). The crop coefficient values for respective growth stages were 0.7, 1.05, and 0.95 for the initial, mid and end-stage, respectively (FAO, 1998). Based on the Kc values of the crop and length of each growth stages, crop coefficient was interpolated for development and late season. The length of growth stages of onion crop during the experiment was 20, 30, 40, and 25 days for initial, development, mid-season, and late season, respectively. The graph of interpolated Kc value for development and late-season stage of onion was developed as in Figure 3 below.

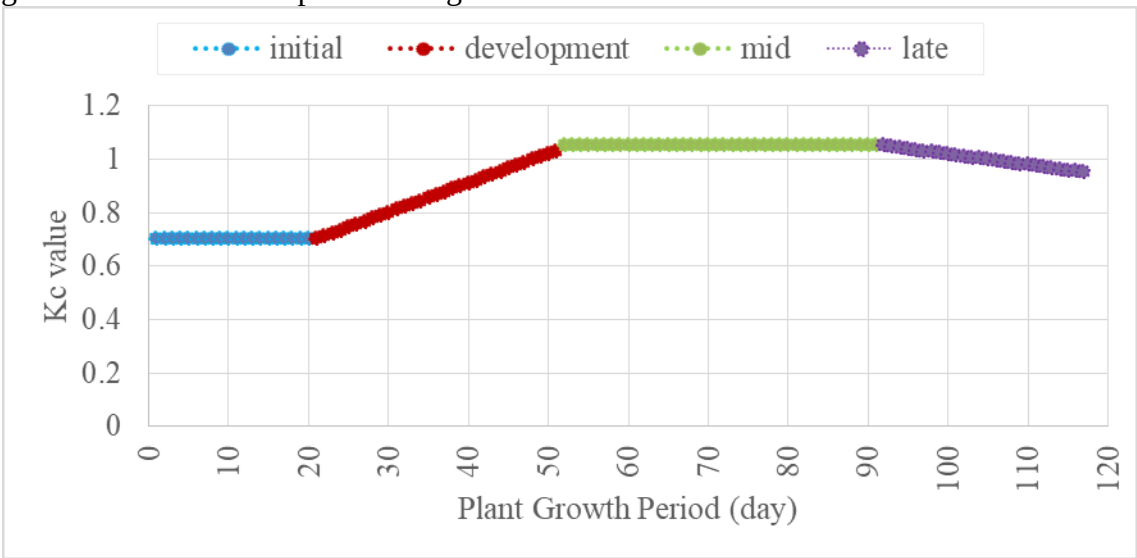

Figure 3: Crop Coefficient for Different Growth Stage of Onion

Determination of Net Irrigation Water Requirement

The net depth of irrigation supplied at any time is obtained from a simplified water balance equation as:

$$In = ETc - Pe \quad 3.3$$

Where; In-Net Irrigation Depth (mm), ETc- The Crop Water Requirement (mm) and Pe -The Effective Rainfall (mm)

Application Efficiency and Gross Irrigation Depth

Field irrigation application efficiency (E_a) is the ratio of water directly available in the crop root zone to water received at the field inlet. It is affected by the rate of supply, infiltration rate of the soil, the storage capacity of the root zone, and land leveling. Furrow irrigation could reach a field application efficiency of 70% when it is properly designed, constructed, and managed. The average ranges vary from 50 to 70%. However, a more common value is 60% (FAO, 2002). For this particular experiment, irrigation efficiency was taken as 60%, which is common for surface irrigation methods in furrow irrigation. Based on the net irrigation depth and irrigation application efficiency, the gross irrigation water requirement was calculated based on equation 3.7.

$$Ig = \frac{In}{Ea} \quad 3.4$$

Where; I_g-Gross Irrigation Depth (mm), I_n-Net Irrigation Depth (mm) and E_a-Furrow Application Efficiency (%).

The time required to deliver the desired depth of water into each furrow was calculated using equation 3.5 given by Michael (2008).

$$T = \frac{Ig * W * L}{6Q} \quad 3.5$$

Where; Ig = gross depth of water applied (cm),T = Application Time (min), W= Space of Furrow ofthePlot (m), L= Length Furrow of the Plot (m) and Q= Flow Rate (l/s)

Irrigation Scheduling and Management

Irrigation scheduling was done based on control treatment (100% ETc). The control treatment (optimum irrigation) was irrigated based on the allowable moisture depletion level in the effective root depth that aims to refill the soil moisture to field capacity. Since onion is sensitive to water deficit, allowable moisture depletion was 25% of the TAW (ρ=25%) (Doorenbos and Kassam, 1979). The six treatments received a lower amount of irrigation water than the control treatment based on their level of deficit percentage.

Water Productivity

Water productivity is defined as crop yield per unit volume of water supply to the crops, Molden (1997), and is estimated by dividing crop yield by total applied water. In this study crop, water productivity was estimated as the ratio of onion bulb yield to the total irrigation depth applied to Onion during the season. It is expressed as:

$$WP = \frac{Y}{W} \quad 3.6$$

Where, Y is onion bulb yield (kg/ha) and W is irrigation depth applied during the season (m^3/ha).

The amount of water saved (SW) per hectare of land from irrigation deficit was computed by subtracting deficit water application levels from the irrigation treatment that used the highest irrigation water level, i.e. 100% ETc. The extra irrigable land area (A) in hectare which was served by the saved irrigation water was determined by dividing the total saved water per hectare of land (SW) in m^3 by the irrigation water use for a hectare of land (IWU) in m^3/ha as:

$$A = \frac{SW}{IWU} \qquad 3.7$$

Data Collection

To evaluate the effect of deficit irrigation treatments on onion yield, samples were collected from the central ridge to avoid border effects. Data on the growth parameter of onion was recorded from five randomly selected plants in three middle rows of each experimental plot and the same plant was used for subsequent measurement. Data on total yield and marketable onion yield was collected from three central rows by leaving the border effect on both sides from each experimental plot. Then the yield results were converted to a hectare basis using the following formula.

Economic Water Productivity

The partial budget analysis was used for economic water productivity analysis by considering the general relationship between the crop water use and crop yield per hectare of land at the different deficit irrigation application levels. Total revenue, the total variable cost, total fixed cost, total cost, net income and Benefit-cost ratio, of each treatment, were analyzed by partial budget analysis based on CIMMYT procedure (CIMMYT, 1988). The data used for economic analysis were fixed cost and variable cost. Fixed costs include seed cost, fertilizer cost, farm implement cost, and chemical cost. Variable cost includes the cost of irrigation water for each treatment and labor cost for each treatment.

For the calculation of total revenue, the average marketable yield of each treatment was taken and then adjusted by multiplying 10% following the procedure of CIMMYT. The assessment was undertaken to take the price of onion at the local market. Based on the assessment done 1 kg of onion was 8 ETB at a time at field level. For calculation of labor cost, the price of human labor was 50 ETB in the field. For calculation of irrigation water cost for each treatment, the price of water was taken as 3 ETB/1000 m^3 (Ayana et al., 2015). Net income (NI) in ETB/ha, generated from onion crop, was computed by subtracting the total cost (TC) in ETB/ha from the total return (TR) in ETB/ha obtained from onion sale (Kuboja and Temu, 2013). TC is the sum of FC and VC. Benefit cost ratio (BCR) of each treatment was computed as the ratio of NI earned to the TC expended.

Statistical Analysis of Data

All collected data were subjected statistical analysis system (SAS) version 9.0 statistical package using all of its procedures (SAS, 2002) for the variance analysis.

RESULT AND DISCUSSION

Analysis of Soil Physical Property of Experimental Site

The result of soil physical property analysis shown that the average composition of clay, silt, and sand percentages was 32.25, 24.75, and 43, respectively (Table 2).Thus, according to the

USDA soil textural classification, the particle size distribution of the experimental site revealed that the soil textural class is clay loam. The result shown that bulk density of experimental site was found between the range of 1.02 g/cm^3-1.21 g/cm^3. Analysis of FC, PWP, and TAW are shown that there was a variation between different soil depths (Table 2).

Table 15: Analysis of soil physical property of the experimental site

Depth (cm)	Particle size distribution (%)			Soil textural classes	Bulk density (g/cm3)	FC (%)	PWP (%)	TAW (mm)
	Sand	clay	silt					
0-15	46	28	26	Sandy clay loam	1.21	30.40	19.05	20.60
15-30	44	31	25	Clay loam	1.02	30.00	15.00	22.95
30-45	42	34	24	Clay loam	1.12	33.30	14.28	31.95
45-60	40	36	24	Clay loam	1.16	38.51	15.78	39.55
Total available water in an effective root zone of 60cm								115.05

Note: FC- Field Capacity, PWP –Permanent Wilting Point, TAW- Total Available Water

Soil Infiltration Rate and Cumulative Infiltration of Study Area

The soil infiltration rate of the experimental site was conducted using the double-ringin filtrometer. The test was done at three locations on a diagonal basis. The average basic infiltration rate of the experimental site was 7.2 mm/hr.

Soil and Water Chemical Property Analysis

The result of irrigation water quality analysis shown that the average PH value was 7.20 and the electrical conductivity of irrigation water was 0.37 ds/m. According to FAO (1985) electrical conductivity of irrigation water (ECw) classification of < 0.7 ds/m (no salinity effect), 0.7– 3 ds/m (slight to moderate salinity effect), > 3 ds/m (severe salinity effect). Based on FAO classification the irrigation water quality of the study area was classified as no salinity effect. According to Bryan et al. (2007), the irrigation water is classified in terms of pH <7 low, 7-8 slight to moderate, and >8 severe. Based on this classification, the pH value of irrigation water in the study area shown that slight to moderate.

From the result of soil chemical property analysis, the soil had an average electrical conductivity of 0.29dS/m. From the obtained result the soil is safe in terms of salinity and no need of considering leaching requirements in the determination of irrigation needed. The result also revealed that the average soil PH study area was 7.13 which are suitable for the growth of onion because the result implies that moderate in both acidity and alkalinity. According to FAO (2008) soil reaction (PH) classification, soils are classified as strongly alkaline (> 8.5), moderately alkaline (7.1-8.5), neutral (7,) slightly acidic (6.6 - 6.9), moderately acid (5.6 - 6.5), strongly acid (4.6 - 5.5) and very strong acid (< 4.5). Accordingly, the soil of the study area is classified as moderately alkaline.

Crop Water Requirement of Onion

Seasonal water demand for onion was determined start from seasonal water application depth from transplanting to harvest and vary between treatments according to their deficit level percentage. The Seasonal crop water requirement of onion determined for the control treatment (100% ETc) was 423.80 mm (Table 4). There was an occurrence of rainfall during the study which was deducted from total crop water demand. The total rainfall recorded

during the experiment was 21 mm which was recorded in March and April 2019. The total effective rainfall was 16.8 mm from two months. The obtained effective rainfall was reduced from the net irrigation requirement of onion.

Table 16: Irrigation water and soil chemical property of the experimental site

Soil depth(cm)	Soil chemical property				Irrigation water chemical property	
	PH	EC(dS/m)	OM (%)	OC (%)	PH	EC(dS/m)
0-15	6.70	0.30	4.30	2.50		
15-30	7.41	0.29	4.15	2.41		
30-45	7.30	0.31	3.61	2.10	7.20	0.37
45-60	7.10	0.27	3.20	1.86		
Average	7.13	0.29	3.81	2.22		

* EC-electrical conductivity, OM-organic matter and OC- organic carbon

The maximum amount of net irrigation (407 mm) was consumed by control treatment (Application level of 100% ETc). The minimum amount of net irrigation (162.80 mm) was consumed by T7 (Application level of 40% ETc). The intermediate treatments obtain net irrigation water between 407 mm to 162.80 mm according to their deficit level percentage (Table 4).

The maximum amount of gross irrigation (678.33 mm) was consumed by control treatment (Application level of 100% ETc) and the lowest amount of gross irrigation (271.33 mm) was consumed by application level of 40% ETc. For intermediate treatments T2,T3,T4,T5, and T6 the calculated gross irrigation application was 610.50 mm, 542.67 mm, 474.83 mm, 407.00 mm, and 339.16 mm. The obtained seasonal water demand for onion in this study is in agreement with the report of Ketame Tazara (2018) and Dirirsa et al.(2017) in which they report that maximum gross irrigation (664.30 mm) and 672.16 mm for onion production was consumed by 100% ETc (control treatment) respectively.

Table 17: Seasonal Irrigation Water Applied for Each Treatment

Treatments	Total ETc (mm)	Total net irrigation (mm)	Total gross irrigation (mm)
T1 (100% ETc)	423.80	407.00	678.33
T2 (90% ETc)	381.42	366.30	610.50
T3 (80% ETc)	339.04	325.60	542.67
T4 (70% ETc)	296.66	284.90	474.83
T5 (60% ETc)	254.28	244.20	407.00
T6 (50% ETc)	211.90	203.50	339.16
T7 (40% ETc)	169.52	162.80	271.33

* ETc- Crop-Evapotranspiration.

Effects of Deficit Irrigation on Growth Parameters of Onion

Leaf Number per Plant

The result from the analysis of variance shown that there was significant difference between treatments in case of the number of leaf per plant (Table 5). Statistically, there was no

significant difference between T1, T2, and T3. This implies that leaf number was not highly affected by irrigation deficit up to 80% ETc application level. The result obtained in line with Enchalew (2016) who reports that vegetative growth of onion decrease as the application level of irrigation water decrease. Similarly, the report of Ketama (2018) and Yetagasu (2019) also shown that number of leaves decreased with decreasing soil moisture level and a high amount of leaf number was obtained by application level of 100% ETc.

Plant and Leaf Height

The result shown that the highest plant height of onion 56.67cm was recorded from the control treatment (T1). The minimum plant height 35cm was recorded from treatment T7 and which was significantly different from all other treatments. The highest leaf height 53 cm was recorded from control treatment T1. The minimum leaf height of 32.33 cm was recorded from treatment T7. The results are in agreement with Metwally (2011)who report that the higher water supply resulted in the higher vegetative parameters (plant and leaf height).This finding also in line with the results of Aklilu (2009) and Takele (2009) who reported that plant height of onion decreased with decreased irrigation levels and also increase with the irrigation water level.

Leaf Diameter

There was significant difference ($p<0.05$) between different application levels of irrigation water on onion leaf diameter. Thus treatment that irrigated by full irrigation water had the widest leaf diameter (1.810cm) than the others deficit level. The smallest leaf diameter (0.587cm) was obtained by T7 which gets the smallest amount of irrigation water. Statistically, there was no significant difference between T1 and T2 and also no significant difference was observed between T2, T3, and T4. The result has shown that decreasing the amount of irrigation required decreases the leaf diameter of onion.

Table 18: Effect of deficit irrigation on the growth parameter of onion

Treatments	Leaf Number per plant	Plant Height (cm)	Leaf Height (cm)	Leaf Diameter (cm)
T1	12.667a	56.67 a	53.00a	1.810a
T2	11.667ab	55.33ab	48.00a	1.583ab
T3	11.000ab	52.33b	46.67ab	1.257b
T4	10.000b	47.67c	44.00ab	1.113bc
T5	7.333c	40.33d	36.33bc	0.687cd
T6	7.333c	40.33d	36.33bc	0.640cd
T7	6.667c	35.00e	32.33c	0.587d
CV%	7.5	2.3	7.9	14.0
L.S.D.	1.27	1.91	5.97	0.27

Note: Different letters in a column implysignificantly different and those followed by the same letter are not significantly different according to LSD at $P<0.05$ level of significance.

Effect of Deficit Irrigation on Yield and Yield Component of Onion

The result on the Effect of Deficit Irrigation on Yield and Yield Component of Onion were presented in Table 6 below.

Table 19: Effect of Deficit Irrigation on Yield and Yield Components of Onion

Treatments	Total bulb yield (t/ha)	Avg. bulb weight (g)	Onion bulb diameter(cm)	Marketable onion yield (t/ha)
T1	38.09a	136.8a	6.923a	37.03a
T2	36.66a	132.0a	6.773a	33.39b
T3	34.33ab	123.6b	6.290b	32.03b
T4	32.49ab	117.0b	6.100b	31.66b
T5	29.08bc	104.7c	5.567c	27.02c
T6	25.21cd	90.8d	4.720d	24.31d
T7	22.23d	80.0e	4.060e	21.13e
CV%	10.4	4.0	4.6	4.6
L.S.D.	5.756	8.02	0.47	2.424

Total Bulb Yield

Maximum yield (38.09 t/ha) was obtained by non-deficit treatment (T1) while the lowest application level of irrigation water had the lowest yield of 22.23 t/ha. The other treatments T2, T3, T4, T5 and T6 produce yields of 36.66 t/ha, 34.33 t/ha, 32.49 t/ha, 29.08 t/ha, and 25.21t/ha respectively. Up to 70% ETc application of irrigation water statistically similar yield was obtained (Table 6). But from 60% ETc up to 40% ETc application of irrigation water total bulb yield was reduced and affected by decreased application level of irrigation water. The result is also in agreement with the finding of David et al. (2016) who report that yield decreased with increasing water stress signifying the more stress the crop is subjected to, the slower it is for it to recover leading to progressively lower yield.

Average Weight of Onion Yield

The analysis on average onion bulb shown that significant difference was observed between treatments due to different deficit irrigation levels (Table 6). These findings indicate that individual onion bulb weight was affected by the deficit application level. Up to 30% deficit of irrigation water optimum bulb weight was obtained which produces optimum total onion yield. But from 40% up to 60% deficit of irrigation water, the average weight of onion bulb was reduced. Statistically, no significant difference was observed between T4 and T3.

Bulb Diameter of Onion

The result on onion bulb diameter shown that there was significantly different ($p<0.05$) between treatments due to deficit irrigation level. Onion bulb diameter was determined as an indicator of the size and it was found to be significantly influenced by deficit irrigation level. Statistically, there was no significant difference between T1 and T2. Also, no significant difference was observed between T3 and T4 in case of bulb diameter.

Marketable Onion Yield

The result of marketable yield of onion revealed that there was significant difference ($p<0.05$) between treatments due to the application level of irrigation water. The maximum amount of marketable yield (37.03 t/ha) was obtained by control treatment (100% ETc of application level). Minimum marketable onion yield (21.13 t/ha) was produced by the smallest application of irrigation water (40% ETc application).The intermediate treatments produce marketable onion yield between 37.03 t/ha and 21.13 t/ha (Table 6). The result is in agreement with the finding of Tsegaye et al. (2016), higher marketable bulbs of onion at

higher irrigation levels might be due to the increase in the formation of growth measurements causing faster synthesis and transportation of photosynthesis.

Effect of Deficit Irrigation on Water Productivity

The result on WP shown that there was significant difference ($p<0.05$) between different deficit irrigation levels. Maximum WP (12.85 kg/m^3) was obtained by minimum application of irrigation water (40% ETc) while the lowest value 9.36 kg/m^3 of WP was obtained from T1 (100% ETc). Statistically, water productivity of T4 (70% ETc application level) had no significant difference with the treatment which produce maximum water productivity (40% ETc application) (Table 7). By saving 30% of irrigation water, the application of 70% ETc produces optimum yield which produces optimum water productivity. The intermediate treatment produces the WP between 12.85 kg/m^3 and 9.36 kg/m^3 (Table 7). The result is in agreement with the finding of David et al. (2016) who report that water productivity for onion yield was affected significantly by deficit irrigation treatments up to 80% ETc application and increase from 70% ETc application to the most deficit irrigation level treatment.

Table 20: Effect of Deficit Irrigation on Water Productivity

Treatments	Onion Yield(kg/ha)	Water productivity (kg/m^3)
T1	38086a	9.36c
T2	36657a	9.96bc
T3	34326ab	10.43bc
T4	32490ab	11.20abc
T5	29077bc	11.58ab
T6	25213cd	11.89ab
T7	22228d	12.85a
CV%	10.4	9.6
L.S.D.	5756.1	1.885

Effect of Deficit Irrigation on Water Saving and Yield Reduction

The result showed that the amount of irrigation water saved which can irrigate another additional area was increase as decreasing application level (Table 8).

Table 21: Effect of Deficit Irrigation on Water Saving and Yield Reduction

T	WU(m^3/ha)	TY t/ha)	WS (%)	WS(m^3/ha)	YD (%)	AIBSW	Yield to be gain (t/ha)
T1	6783.30	38.086	0	0	0	0	0
T2	6105.00	36.657	10	678.3	3.75	0.11	4.03
T3	5426.70	34.326	20	1356.6	9.87	0.25	8.58
T4	4748.30	32.49	30	2035	14.69	0.43	13.97
T5	4070.00	29.077	40	2713.3	23.65	0.66	19.20
T6	3391.60	25.213	50	3391.7	33.79	1.00	25.213
T7	2713.30	22.228	60	4070	41.64	1.50	33.34

Note: T-treatment, WU-water use, TY-total yield, WS-water saved, YD-yield decrease, AIBSW-area to be irrigated by saved water.

Even though there was relative yield reduction, there was the additional yield gain due to irrigating additional areas by saved water from deficit irrigation level (Table 8). Additional yield which can be irrigated by saved irrigation water from T2,T3 ,T4 ,T5 , T6 and T7 were

4.03, 8.58,13.97,19.20, 25.213 and 33.34 /ha respectively (Figure 9). The results in line with Ali et al. (2007) who reported water saved by DI can be used to irrigate more land on the same farm or in the water user's community, which, given the high opportunity cost of water, and may largely compensate for the economic loss due to yield reduction.

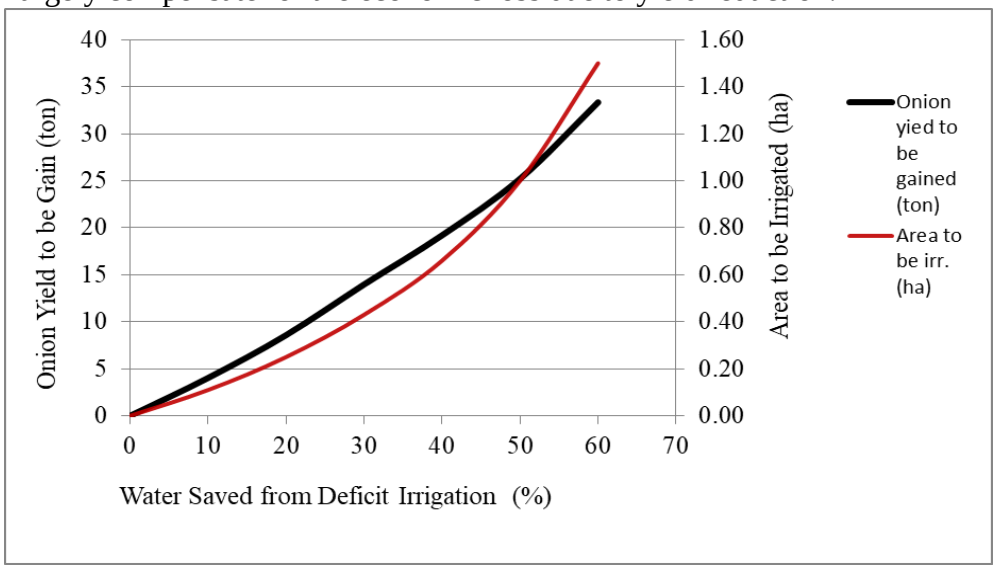

Figure 5: Effect of deficit irrigation on water saving and an additional area that to be irrigated.

The result showed that the water saved by T4 (application of 70% ETc) can irrigate additional land of 0.40 ha which can produce 13.11 ton of additional onion bulb yield (Table 8) with the minimum yield reduction factor (ky) (Table 9) by saving 30% of irrigation water.

Yield Response Factor

The study revealed that yield response factor (ky) increases with decreasing irrigation water application level. Since the obtained Ky<1, the crop is more tolerant to water deficit, and recovers partially from a deficit, exhibiting less than proportional reductions in yield with reduced water use.

When Ky> 1, the crop response is very sensitive to water deficit with proportional larger yield reductions; Ky< 1, the crop is more tolerant to water deficit, and recovers partially from stress, exhibiting less than proportional reductions in yield with reduced water use; Ky = 1, the yield reduction is directly proportional to reduced water use (Doorenbos and Kassam, 1979).

Table 22: Yield Response Factor of Onion

Treatments	ETc (mm)	Onion yield (kg/ha)	$1-\frac{Ya}{Ym}$	$1-\frac{ETa}{ETm}$	Ky
T1	423.8	38086	0	0	0
T2	381.42	36657	0.037	0.1	0.37
T3	339.04	34326	0.098	0.2	0.48
T4	296.66	32490	0.1469	0.3	0.49
T5	254.28	29077	0.236	0.4	0.59
T6	211.90	25213	0.3379	0.5	0.68
T7	169.52	22228	0.4163	0.6	0.69

Note: ETc-crop evapotranspiration (mm), Ky- yield response factor ,Eta- actual Evapotranspiration(mm) , ETm- maximum evapotranspiration(mm),Ya-actual yield(kg/ha) and Ym-maximum yield (kg/ha).

Effect of Deficit Irrigation on Economic Water Productivity

Data concerning economic comparison was presented in Table 10. The detailed evaluation of the economic analysis of irrigation treatments had shown that there was an increasing trend of net income (NI) for an increase in the water application level. This was because the unit price of irrigation water of 3 birr/1000m^3, the rate of farms in the area pay for irrigation water was very low. As a result, the direct impact of water saving in generating NI was very low for a hectare of land per season which means the very small value from a hectare. Maximum total cost (42439.7 ETB) was obtained by control treatment whereas the minimum variable cost (24175.9 ETB) was obtained by T7.

Benefit-cost ratio (BCR) of each treatment was computed as the ratio of NI earned to the TC expended. Accordingly, maximum BCR (6.28) was obtained by T4 means that treatment which receives an application level of 70% ETc. However, the lower BCR was recorded by T1 and T2. This implies that even though the maximum yield was obtained by those treatments they were economically not more attractive. From this economic analysis T4 (70% ETc application level of irrigation water) was the most economically attractive treatment with high BCR and optimum net benefit.

Table 23: Partial Budget Analysis for Deficit Irrigation

T	I. water (m^3/ha)	UMY(Kg/ha)	AMY(Kg/ha)	TR (ETB/ha)	TVC (ETB/ha)	TFC (ETB/ha)	TC(ETB/ha)	NI (ETB/ha)	BCR
T1	6783.3	37026	33323.4	266587.2	30439.7	12000	42439.7	236147.5	5.56
T2	6105.0	33390	30051.0	240408.0	27395.8	12000	39395.8	213012.3	5.41
T3	5426.7	32026	28823.4	230587.2	24351.8	12000	36351.8	206235.4	5.67
T4	4748.3	31998	28798.2	230385.6	21306.8	12000	33306.8	209078.8	6.28
T5	4070.0	27017	24315.3	194522.4	16727.6	12000	28727.6	177794.8	6.19
T6	3391.6	24313	21881.7	175053.6	15219.9	12000	27219.9	159833.7	5.87
T7	2713.3	21128	19015.2	152121.6	12175.9	12000	24175.9	139945.7	5.79

Note: T- Treatment, UMY-unadjusted marketable yield, AMY- adjusted marketable yield, TR-total revenue, TVC-total variable cost, TFC-total fixed cost, TC-total cost, NI-net income, BCR-benefit-cost ratio.

CONCLUSION AND RECOMMENDATION

The finding showed that water productivity increase as water application level decrease and vice versa. This implies that water productivity reduced as more water was consumed even though the maximum yield was obtained. Statistically, water productivity of T4 (70% ETc application level) had no significance different from the treatment which produces maximum water productivity (40% ETc application level). By saving 30% of irrigation water, the application of 70% ETc was producing optimum yield with optimum water productivity than

other treatments. Economic analysis shown that BCR of treatments was affected by different application levels of irrigation water. Even though the net income of control treatment (100% ETc application level) was high, the BCR obtained by this treatment was small.

Based on water productivity, economic visibility, total yield, percent of yield reduction, and yield response factor, 70% ETc application level of irrigation water was recommended as the best application-level than the other treatments. Since the water productivity value obtained by 100% ETc application level was very small, a full application of irrigation water should not be used for the production of onion in water-scarce area. The deficit irrigation strategy should be adopted by farmers and other users to save scarce water resource in water-limited area.

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