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PREFACE

The Agricultural and Rural Development Policy and Strategy of the country which was designed nearly a decade and half ago, has highly emphasized the important role of agriculture as a means of ensuring rapid economic growth, enhancing benefits to the people, eliminating food aid dependency, and promoting the development of a market-oriented economy. The national plans, programs and projects focusing on the development of the agriculture sector have been implemented and are being implemented throughout the country towards answering the national Agricultural policy and strategy. Among such programs, the 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 end users, producing early generation seeds and other source technologies, and enabling the implementing institutions/centres through physical & human capacity building.

Oromia Agricultural Research Institute (IQQO) conducted 459 different research activities during the last three years (2016/17 – 2018/19) through its 15 implementing center. These include 188 research activities under technology generation, 130 pre-extension demonstration and 141 source technology production activities. About 349 research activities were completed so far. Among those, 100 deliverable technologies were generated (56 from demand driven and 44 from end stage verifications), 113 improved agricultural technologies were fully approved by 341 completed Farmers Research Extension Groups (FREGs) involving 5497 direct beneficiary farmers (28.3% were female). Besides, 474.6 tons of early generation crop seeds were multiplied; several physical capacity developments activities were implemented across the implementing centers. Overall, about 95% of the five years plan was implemented during the last three years.

In 2011 EFY, a total of 262 research activities were planned and have been implemented. Among those, 150 research activities were completed and 112 ongoing activities. Out of the completed activities, 24 (16.55%) were gender related, 38(26.21%) climate smart agriculture, 19 (13.10%) nutrition sensitive and 69 (44.14) activities were multipurpose. Under technology generation and adaptation, a total of 36 deliverable technologies were recommended and can be promoted to pre-extension demonstration stage. Under technology demonstration and popularization, 44 technologies were fully recommended based on biological data (yield and related traits) and social data (farmers' preference) and thus could be promoted to public extension service. A total of 91 mixed FREGs were completed involving 1594 participant farmers (28.73% women). This workshop is organized with the purpose of reviewing research findings related to technology and adaptation. The workshop involves researchers from the different disciplines of the 15 implementing research centers, director general, deputy director generals, research directorate directors and other stakeholders from Regional and Federal AGP-II coordination units.

Dagnachew Lule (PhD)

AGP-II Research Regional Coordinator

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CROP TECHNOLOGIES

The release and registration of new bread wheat variety "galan" for bale highland and similar agro-ecologies

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Abstract

*The name "**Galan**" designated by pedigree **ETBW 8003** is given to the newly released bread wheat (Triticum aestivum L.) variety. The variety was released by Sinana Agricultural Research Center on June 2019. **Galan** was primarily introduced through International Center for Agricultural Research in the Dry Areas* (*ICARDA*) *for evaluation under disease screening nursery trials during 2013 at Sinana. This variety is a medium maturity & its mean grain yield performance ranged from 4.87 to 5.93 t ha^{-1}on research field and 4.21 to 5.37 t ha^{-1} on farmers field. Stability analyses indicated that **Galan** is relatively better stable than the other genotypes used in the study. It is moderately susceptible reaction to both stem rust and yellow rust with 10% and 15% severity, respectively. The result of quality analyses showed that gluten, protein and zeleny index of **Galan** is 32.9%, 14.4% and 72.5%, respectively, which is acceptable and fulfill standard requirement of food factories.*

Keywords: ***Galan****; Grain yield; Stabile genotype; Yield performance*

Introduction

Ethiopia is the leading wheat producer in Sub Saharan Africa and total production is 4.64 million tons (CSA, 2018). The national average of wheat productivity is estimated to be 2.74 t ha^{-1} (CSA, 2018), which is below the world average of 3.0 t ha^{-1} (Hawkesford *et al*., 2013). Wheat produced in Ethiopia is used mainly for domestic food consumption, seed and raw material for agro-industries. It accounts for about 10-15% of all the calories consumed in the country (Berhane *et al.,* 2011). Moreover, estimated total wheat consumption (for food, seed and industrial use) is rapidly increasing at the national level (CSA, 2018). According to GAIN (2013), wheat consumption growth is higher in urban areas than other area due to higher population growth, changes in life style, and the rising prices for *teff*. However, production and productivity of wheat is highly constrained by the limited availability of high yielding and disease resistant varieties, which hampered our attempt to bridge the gap for the huge demand at national level. Therefore, the objective of this study was to evaluate and release stable high yielding and disease resistant/tolerant bread wheat variety for the highlands of Bale and other similar agro-ecology.

Variety origin and evaluation

Galan is ICARDA material and it was formerly introduced to Sinana Agricultural Research Center as bread wheat key location disease screening nursery 2013 (BWKLDN-13) from

Kulumsa Agricultural Research Center during 2013/14 cropping season. This genotype showed good field performance and then promoted to bread wheat preliminary yield trial 2014 (BWPYT-14). It was evaluated together with 35 other genotypes including standard checks at Sinana, Agarfa and Goba during 2015 and 2016 main growing season. ***Galan*** (ETBW 8003) showed better performance for grain yield and major disease than all the tested genotypes and checks.

Morphological and Agronomical characters

Galan has erect juvenile plant growth, an erected flag leaf with white glumes. The spike is owned, mid-dense, and tapering. The kernel is amber color and ovate in shape with angular cheeks and a narrow, mid deep crease. The brush on the kernel has a collar and is medium in length. ***Galan*** is relatively medium-tall variety with 102cm height but less than Sanate with erected type upright growth habit and low tillering capacity. This variety is a medium maturing cultivar; it takes an average of 68 days from planting to heading and 138 days to mature in Bale highland. The detail of morphological and agronomical character is shown in table 1.

Table 1. Agronomic and morphological descriptors of the released bread wheat

Variety Name	***Galan* (ETBW 8003)**
Adaptation area	Highlands of Bale and similar agro ecology
Altitude (m.a.s.l)	2200-2500
Rainfall (ml)	750-1500
Fertilizer (kg/ha)	
P_2O_5	41
N	46
Seed rate (kg/ha)	150
Days to heading	68
Days to mature	138
1000 seed weight(g)	49.2
Hectoliter weight(kg/hl)	84.3
Plant height(cm):	102
Yield (t ha^{-1})	
Research field	4.87-5.93
Farmers' field	4.21-5.37
Seed color	Amber
Growth habit	Erect
Spike density	Medium density
Seed shape	Oval shape

Grain Yield Stability Performance

Mean yield performance of variety ***Galan*** ranged from 4.87 to 5.93 t ha^{-1} on research field and 4.21 to 5.37 t ha^{-1} on farmers field. It has yield advantage of 22.7% over standard check Dambal, and 99.5% over Mada walabu. The analysis based on AMMI stability value revealed that ***Galan*** genotype is relatively more stable than other genotypes used in the study. Results from GGE biplot analysis also showed that ***Galan*** (genotype #28) fall close to the central circle away from vertical mean line, indicating its high yield potential, relative stability and wider adaptability compared to the other genotypes (Fig.1).

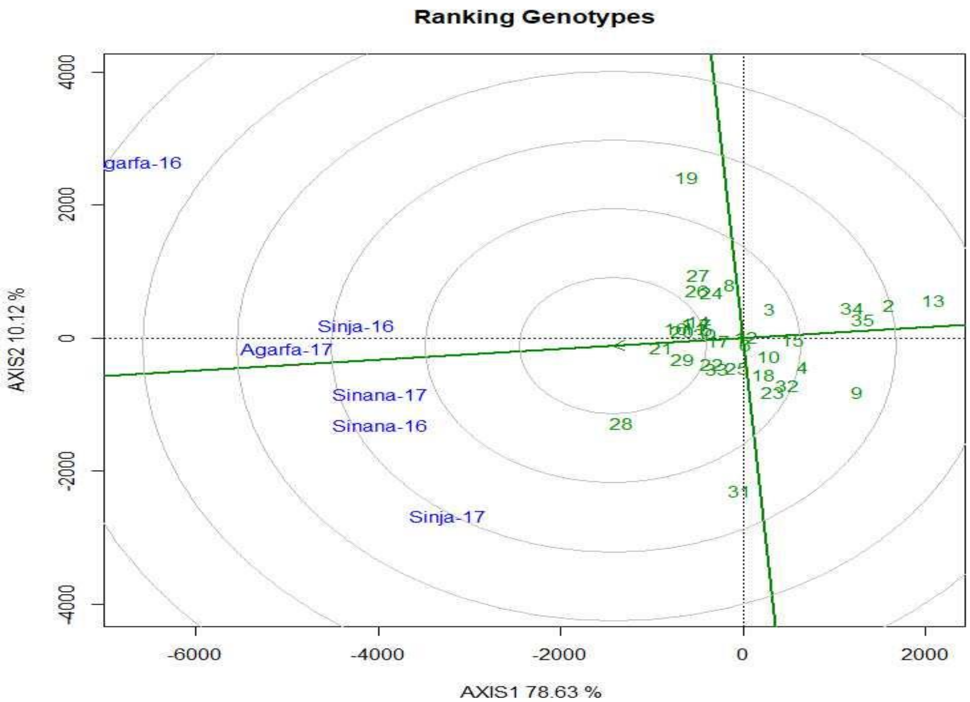

Figure 1: Ranking ideal genotypes for ideal environment

Disease Reaction

The variety ***Galan*** has moderately susceptible reaction to both stem rust and yellow rust with 10% and 15% severity, respectively (Table 2). Whereas, the maximum score of stem rust overall location for the checks Dambal, Mada walabu and Holandi were 5ms, 10ms and 40s; but yellow rust was scored 30s, 40s and 40s, respectively.

Table 2. The maximum Disease Reaction of variety ***Galan*** and checks

SN	Variety	Sr	Yr	Lr
1	Dambal (standard check)	5ms	30s	0
2	***Galan* (*ETBW 8003*)**	**10ms**	**15ms**	**0**
3	Mada walabu (standard check)	10ms	40s	0
4	Holandi (local check)	40s	40s	0

Key: Sr= stem rust (%), Yr= Yellow rust (%), Lr= leaf rust (%), s= susceptible reaction, ms= moderately susceptible reaction

Quality parameters

The nutritional quality analyses are presented in table 3. The result showed that variety ***Galan*** had high thousand kernel and hectoliter weight. ***Galan*** showed best quality for gluten content, protein content and zeleny index than the standard checks (Table 3). Therefore, this variety could be well accepted by food factories as its quality meet required standard.

Table 3. Bread wheat physical and chemical quality Analysis

Variety	TKW (gm)	HLW (hl/kg)	Gluten (%)	Moisture (%)	Protein (%)	Zeleny index (%)
Dambal	41.2	81.7	30.5	12.1	13.3	65.0
Galan (released variety)	49.2	84.3	32.9	12.1	14.4	72.5
Mada walabu (standard check)	35.8	77.2	18.8	12.0	10.1	47.4
Holandi (local check)	36.4	77.5	-	-	-	-

Key: TKW= thousand kernel weight, HLW= hectoliter weight

Availability/variety maintenance

Sinana Agricultural Research Center will be maintaining breeder seed of ***Galan***. Basic and Pre basic seed will be multiplied by SARC and other private or public seed producing enterprises. Seed sample will be deposited in the Ethiopian Biodiversity Institute (EBI) for genetic resources preservation.

Conclusion and recommendation

Galan is fully released for the highlands of Bale and similar agro-ecologies because it has high grain yield and quality, tolerant to disease, stable yield performance across environments and good agronomic trait. Therefore, smallholder farmers, private and public seed enterprises and other wheat producers in Bale highland and similar agro ecology can produce ***Galan*** with its full management recommendation.

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The release and registration of "*Jitu*" tef [*Eragrostis tef* (Zucc.)] variety

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Abstract

The name **Jitu** was given to tef [*Eragrostis tef* (Zucc.)] variety with the pedigree of DZ-01-256 which was developed by Bako Agricultural Research Center. **Jitu** was evaluated together with eleven pipelines genotypes and the standard check (Kena) and local check in regional variety trial at three locations (Arjo, Gedo and Shambu) for two consecutive years (2017 and 2018). The combined analysis of variance revealed highly significant ($p<0.01$) difference among genotypes for plant height, panicle length, lodging % and grain yield (kg ha^{-1}) and significant ($p<0.05$) for maturity date and shoot biomass. Genotype and Genotype by Environment interaction (GGE) biplot analysis revealed that **Jitu** (DZ-01-256) was the most stable and high yielding variety (2309.22 kg ha^{-1}) with 25% yield advantage over the standard check, Kena (1683.92 kg ha^{-1}), tolerant to lodging and thus was released in 2019 for the highlands of Arjo, Gedo, Shambu and similar agro-ecologies.

Keywords: *Bi-plot, Genotype and Genotype by Environment Interaction (GGE), Tef (Eragrostis tef (Zucc.),*

Introduction

Tef is among the major Ethiopian cereal crops grown on more than 3 million hectares annually (CSA, 2017), and serving as staple food for over 70 million people. Tef has an attractive nutritional profile, being high in dietary fiber, iron, calcium and carbohydrate (Hager *et al*., 2012). Besides, it has high level of phosphorus, copper, aluminum, barium, thiamine and excellent composition of amino acids essential for humans (Abebe *et al*., 2007). The straw (chid) is an important source of feed for livestock. Tef is also a resilient crop adapted to diverse agro ecologies with reasonable tolerance to both low (especially terminal drought) and high (water logging) moisture stresses. Tef, therefore, is useful as a low-risk crop to farmers due to its high potential of adaptation to climate change and fluctuating environmental conditions (Balsamo *et al*., 2005). Because of its gluten-free proteins and slow release carbohydrate constituents, tef is advocated and promoted as health crop at global level (Spaenij Dekking *et al*., 2005). Inadequate research investment to improvement of the crop is one among the major tef productivity constraints. Therefore, the objective of this activity was to evaluate and release high yielding, lodging and diseases tolerant variety for tef growing areas of western parts of the country

Varietal origin and evaluation

A total of 13 tef genotypes originally introduced from Ethiopian Institute of biodiversity and Debre Zeit Agricultural Research Center were evaluated at multi location (Shambu, Gedo and Arjo sub-sites) in 2016/17 and 2017/18 to identify stable high yield variety with other desirable traits. Accession DZ-01-256 (***Jitu***) gave the highest grain yield (2309.22kg ha^{-1}) followed by accession DZ-01-1576 (2105.72 kg ha^{-1}). The standard check Kena gave 1683.92 kg ha^{-1}. Besides, ***Jitu*** showed stable performance over the six environments (year by location). The two genotypes, Acc. DZ-01-256 (***Jitu***) and DZ-01-513 gave above 10 percent yield advantage and preferable desirable traits other over the standard check and thus selected and evaluated against local & standard checks in variety Verification trial at Shambu, Gedo and Arjo sub site and on farmers field during 2018/19 (Table 1).

Agronomic and Morphological Characteristics

Jitu variety is well adapted to the highlands of Western Oromia and has an average plant height of 106 cm and maturity date of 120 days. The variety has high tillering capacity, high shoot biomass (13.80 t ha^{-1}) and grain yield (2309.22 kg ha^{-1}). The caryopsis color of the variety is cream-white with thousand seed weight of 0.26 gram and the leaves are staying green even after maturity period (Table 1, 2 and 3).

Yield Performance

The average grain yield of ***Jitu*** combined over locations and years were 2309.22 kg ha^{-1}, which is higher than Kena (standard check),1683.92 kg ha^{-1}. Under research field, **Jitu** gave grain yield ranging from 2132.08-2532.5 kg ha^{-1} while on farmers' field it ranges from1961-2360 kg ha^{-1}.

Stability performance

Jitu variety showed stable yield performance across tested location over years. It performs best if it is produced with recommended fertilizer, seed rate and other recommended fertilizer rate in the recommended ecologies.

Conclusion

The new tef variety ***Jitu*** was released for its stable high grain yield and other desirable traits, wider adaptability, attractive seed color (cream white) and tolerant to tef leaf rust. This new variety was released in May 2019 and recommended for production around Shambu, Gedo, Arjo and similar agro-ecologies.

Table 1. Agronomic & morphological characteristics of Jitu tef variety

Variety name:	**Jitu (Acc. DZ-01-256)**
Agronomic & morphological characteristics	
Adaptation area:	Shambu, Gedo, Arjo, and similar agro ecologies of western highlands.
Altitude (masl)	1800-22500
Rainfall (mm)	1800-2000
Seeding rate (kg/ha)	10 for row & 15 broad casting
Spacing (cm)	20cm Between rows
Planting date	Early July
Fertilizer rate	100 kg ha^{-1}DAP at planting & split application of 50 kg ha^{-1} UREA
Days to heading	80 days
Days to maturity	120 days
1000 seed weight (g)	0.26
Plant height (cm)	106
Seed color	cream white
Panicle color	yellowish at maturity
Crop pest reaction*	Tolerant to leaf rust
Grain yield (qt/ha)	
On farmers field	1961-2360 kg ha^{-1}.
On-station	2130-2530 kg ha^{-1}.
Year of release	2019
Breeder/ maintainer:	BARC/IQQO

Key: *Tolerant to major Tef diseases (Head smudge and Rust) & tolerant to acidic soils of Western highlands of Oromia Regional state.

Table 2. Mean grain yield(kg/ha) of tef genotypes across locations and years

Genotypes	**Shambu**		**Gedo**		**Arjo**			**Yield advantage over st. check**
	2016/17	**2017/18**	**2016/17**	**2017/18**	**2016/17**	**2017/18**	**Mean**	
DZ-01-1122	1800	1660	1822	1849	1618	1531	1713.39	
DZ-01-512	1840	1815	1958	1878	1609	1682	1796.83	
Local	1690	1538	1964	1549	1569	1477	1631.11	
DZ-01-2014	1786	1689	1957	1643	1403	1496	1662.31	
Kena (st check)	1694	1651	1822	1857	1517	1563	1683.92	
DZ-01-61	1745	1883	1840	1647	1758	1845	1786.33	
DZ-01-513	2170	2167	1847	2028	1982	1895	2014.75	**19.65%**
DZ-01-1715	1593	1634	1865	1523	1695	1768	1679.53	
DZ-01-1108	1822	1909	1770	1719	1643	1544	1734.39	
DZ-01-1576	2268	2462	1990	2079	1893	1943	2105.72	**25.05%**
DZ-01-383	1960	1782	1766	1793	1703	1851	1808.92	
DZ-01-256	2450	2615	2307	2219	2036	2228	2309.22	**37.13%**
DZ-01-1118	1810	1869	1660	1681	1237	1654	1651.83	
Mean	**1755.07**	**1897.99**	**1889.79**	**1789.49**	**1306.49**	**1721.205**	**1813.71**	
CV%	**9.24**	**17.3**	**13.7**	**11.5**	**11.3**	**18.7**		
F test	**	**	**	**	**	**		
LSD 0.05	**240**	**224**	**178**	**167**	**174**	**189**		

Table 3. Mean grain yield and agronomic performance of 13 tef genotypes tested in regional variety trial combined over three locations for 2016/17 and 2017/18

Entry No.	Genotypes	PH (cm)	MD	PL (cm)	LOD%	ET	SBM (t/ha)	GY kg/ha
1	DZ-01-1122	88.33	116.67	28.27	43.33	6.20	10.60	1713.39
2	DZ-01-512	90.00	117.67	25.33	31.67	7.20	11.33	1796.83
3	Local	74.33	117.67	22.00	86.67	6.80	10.17	1631.11
4	DZ-01-2014	88.33	120.00	26.00	31.67	6.80	9.33	1662.31
5	Kena (st check)	88.00	117.67	23.73	86.00	6.13	9.33	1683.92
6	DZ-01-61	81.67	118.00	25.47	43.33	7.07	10.75	1786.33
7	DZ-01-513	96.67	117.00	30.60	31.67	6.07	10.50	2014.75
8	DZ-01-1715	81.00	119.33	23.07	33.33	6.4	9.00	1679.53
9	DZ-01-1108	92.00	120.67	30.87	35.00	6.93	10.16	1734.39
10	DZ-01-1576	86.67	118.67	31.07	40.00	6.47	9.30	2105.72
11	DZ-01-383	86.00	118.00	29.6	31.67	6.67	11.08	1808.92
12	DZ-01-256	106.00	119.67	37.53	31.33	6.87	13.80	2309.22
13	DZ-01-1118	78.00	119.67	22.13	38.33	6.47	12.33	1651.83
Mean		**87.46**	**118.51**	**27.36**	**44.49**	**6.62**	**8.41**	**1813.71**
CV %		**9.09**	**11.19**	**10.35**	**23.30**	**13.12**	**11.82**	**13.24**
F test		**	*	**	**	NS	*	**
LSD		**1.34**	**2.38**	**4.77**	**9.85**	**1.46**	**0.44**	**2.4**

Note: PH = plant height(cm), MD = maturity date, PL = panicle length (cm), LOD =lodging %, ET = effective tiller, SBM(kg) = shoot bio-mass, GY = grain yield(kg)

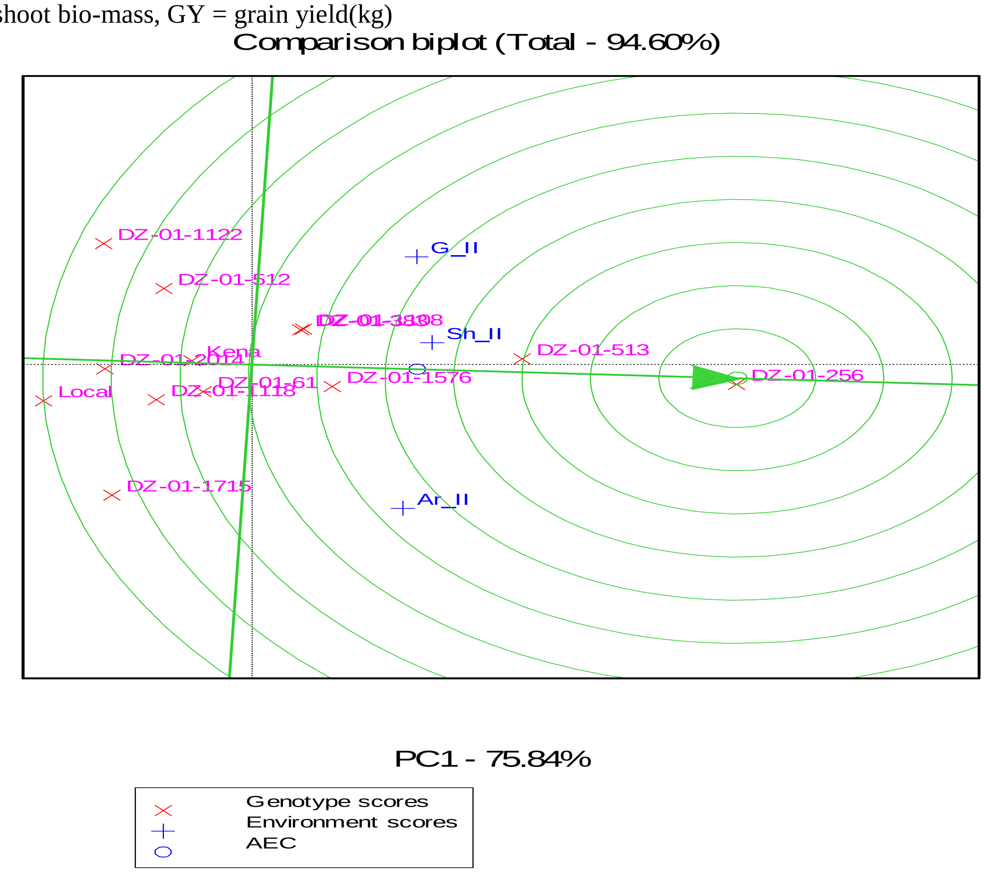

Fig.1 GGE bi-plot for stability test among tef genotypes

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The release and registration of "Fadis-01" sorghum variety

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Abstract

Fadis-01 is a common name given for Sorghum [Sorghum bicolor (L.) Monech] variety with pedigree designation of M-36121 X P-9403. The variety was developed and released by Fadis agricultural research center for yield and Striga resistance/tolerance in the lowlands of Hararghe. It was verified at on farm and sub site of Fadis, Babile, Harari, and Dire Dawa areas in 2018 main cropping season and released for yield and Striga resistance on June 2019. The variety showed the highest mean yield (3.9 tons ha^{-1}) among all genotypes evaluated at multi location and 25% yield advantage over the standard check (Hormat), early maturing (120 days) and showed stable yield performance across locations and years. It has good level of Striga resistance, which is a major threat to sorghum production in the study areas and the vicinities.

Keywords: *Sorghum [Sorghum bicolor (L.),* Striga resistance,

Introduction

Sorghum is among the main staple food crop in Ethiopia, ranking fourth after Tef, maize, and wheat, both in area coverage and production (CSA, 2016). It is adapted to a wide range of environment and hence can be produced in the highlands, medium altitude and lowland areas. The ability of the crop to withstand drought stress and reasonable yields under adverse environmental conditions made it important food security crop in arid and semi-arid lowlands. Its residues after harvest and green plants also provide sources of animal feed, building materials and fuel particularly in the semi-arid tropics (ICRISAT, 1997).

Even though, the crop is important for the Eastern Hararghe zone particularly to Babile, Fedis, Harari and Dire Dawa, several factors constrained productivity such as limited availability of improved varieties, striga infestation, moisture stress and other edaphic factors. Developing high yielding variety tolerant to *Striga* infestation and the fluctuating weather condition is the major target of sorghum improvement program. Therefore, the objective of this activity was to release high yielding & striga resistant/tolerant variety for sorghum growing lowland areas of Eastern Ethiopia.

Variety origin and evaluation

Fadis-01 (M-36121 X P-9403) was originally introduced from Melkassa sorghum improvement research program and developed through pure line selection method. Six selected genotypes were evaluated at multi locations against the standard check (Hormat) for three consecutive (2014, 2015 and 2016) main cropping seasons at Fadis and Babile (Erer) sub sites.

It was verified on farmers' field and research sub sites at Fadis, Babile, Harari and Dire Dawa areas during 2018 main cropping season. The variety was evaluated and officially released on June 2019 for its stable high yield performance and *Striga* resistant for wider production in the lowlands of Eastern Hararghe and areas with similar agro-ecologies.

Varietal Characteristics

Fadis-01 has semi compact head type, average days to flowering (77 days) and maturity (120 days) (Table 1). The variety has medium plant height (160 cm). This character is preferred by the local community as the larger biomass is used for multipurpose (livestock feed, fire wood and construction). The seed color is white and has average thousand-kernel weight of 30 g.

Yield Performance

The combined mean grain yield (3.9 tons ha^{-1}) of this variety was better than all other genotypes evaluated at multiplication. Beside, *Fadis -01* showed 25% yield advantage over the standard check, Hormat. On research field *Fadis-01* gave yield ranging from 3.8 to 4.1 ton ha^{-1}, whereas 3.5 to 4.0 tons ha^{-1} on farmers field (Table 1).

Table 1. Agronomic and morphological characteristics of Fadis01 (M-36121 X P-9403)

Agronomic characters and descriptions of Fadis	
Variety name:	Fadis01(**M-36121 X P-9403**)
Adaptation area:	Fadis, Babile, Harari, Dire Dawa and other lowland sorghum growing areas
Altitude (masl):	<1700
Rainfall (mm):	400-700
Seeding rate (kg/ha):	8-10 kg for row spacing
	12-20 kg for broadcasting
Spacing (cm):	20cm Between rows
Planting date:	Mid June to early July
Fertilizer rate (kg/ha):	100 NPS all at planting
	50 UREA at knee height
Days to flowering:	74-79, mean 77 days
Days to maturity:	120 days
1000 seed weight (g):	30
Panicle appearance	Semi compact and erect
Plant height (cm):	143-180, mean 162
Seed color:	White(creamy color)
Grain yield (qt/ha):	Research field: 38-48
	Farmers field: 30-41
Tillering:	No tillers
Crop pest reaction	Tolerant/resistant to striga weed
Year of release:	2019
Breeder/ maintainer:	FARC/OARI

Striga Reaction

Striga infestation data was recorded on field and at laboratory. Field data was collected at flowering and harvesting stage. The result showed that there were no significant difference in number of *Striga* both at flowering and harvesting (Table 2 and 3). Besides, there was no significant difference between the candidates and the standard check at field condition. The laboratory bioassay data of sorghum genotype 2006 MW 6031 showed the least value of MGD (maximum germination distance) and GR (germination rate) with 1.52 mm and 1.95%, respectively, followed by resistant check Hormat. The result revealed that there was no significant difference between Fadis-01 (M-36121 X P-9403) and standard check (Hormat) in MGD and GR (Table 4).

Table 2 Mean number of striga weed in multi-location trial and during different years at flowering stage

Genotypes	**Fadis14**	**Babile14**	**Fadis 15**	**Babile 15**	**Fadis 16**
2006 MW 6239	3(9.0)	3(8)	3(7)[ab]	28(812)[b]	0(0)
2006 MW 6031	5(22)	5(21)	3(14)[bc]	17(334)[ab]	0(0)
2006 MW 6044	2(4)	2(4)	3(10)[abc]	20(527)[ab]	0(1)
2006 MW 6001	4(13)	3(11)	2(4)a	14(258)ab	1(2)
2006 MW 6017(Fadis01)	5(30)	5(29)	2(6)[ab]	18(410)ab	1(2)
05 MW 6005	4(19)	4(18)	5(21)[bc]	12(165)a	1(3)
Hormat (St. check**)**	3(7)	3(7)	2(6)[ab]	12(159)a	0(1)
LSD	NS	NS	10.2	545	NS
CV	28.1	19.9	34.4	46.6	31.3

Key: Value in the parenthesis is the original values; numbers outside the parentheses are square root-transformed.

Table 3 Mean number of striga weed in multi-location trial and during different years at harvesting stage

Genotype/Check	**Fadis14**	**Babile14**	**Fadis 15**	**Babile 15**
2006 MW 6239	6(32)	1(2)[a]	4(13)	21(489)
2006 MW 6031	8(63)	6(33)[d]	4(18)	12(196)
2006 MW 6044	3(14)	3(7)[c]	3(12)	15(288)
2006 MW 6001	5(22)	2(3)[ab]	2(6)	10(134)
2006 MW 6017(Fadis01)	8(63)	2(5)[bc]	3(7)	13(252)
05 MW 6005	6(33)	2(4)[abc]	4(20)	10(128)
Hormat	5(20)	2(4)[abc]	3(7)	11(186)
LSD	NS	17.9	NS	NS
CV	18.2	22.5	35,1	47.8

Key: Value in the parenthesis is the original values; numbers outside the parentheses are square root-transformed.

Table 4.Mean comparison of Sorghum Genotypes for pre-attachment to *Striga* tested at bioassay lab during 2017 (2*2.5 cm near the host root)

	Treats			
Genotypes	**MGD**	**GR**	**HIP**	**GI**
2006 MW 6001	8.59[a]	12.03[b]	13.90[c]	1.30[a]
05 MW 6005	4.65[b]	5.98[c]	8.77[c]	1.08[b]
2006 MW 6017(Fadis-01)	1.48[c]	29.33[a]	23.07[ab]	1.18[ab]
2006 MW 6031	1.52[c]	1.94[c]	26.53[a]	1.07[b]
Hormat	0.83[c]	4.96[c]	14.67[bc]	1.27[a]
LSD (5%)	1.15	4.13	8.48	0.16
CV%	10.20	20.20	25.90	7.20

Key: MGD= Maximum Germination Distance of *Striga* from the host root; GR= Germination rate of *Striga*; HIP= Haustorial initiation percentage; GI= Germination index.

Stability performance

The Genotype and Genotype by Environment (GGE) biplot analysis revealed that the released variety Fadis01 (M-36121 X P-9403) fall relatively close to the concentric circle near to average environment axis, suggesting its potential for wider adaptability with better grain yield performance (Fig 1).

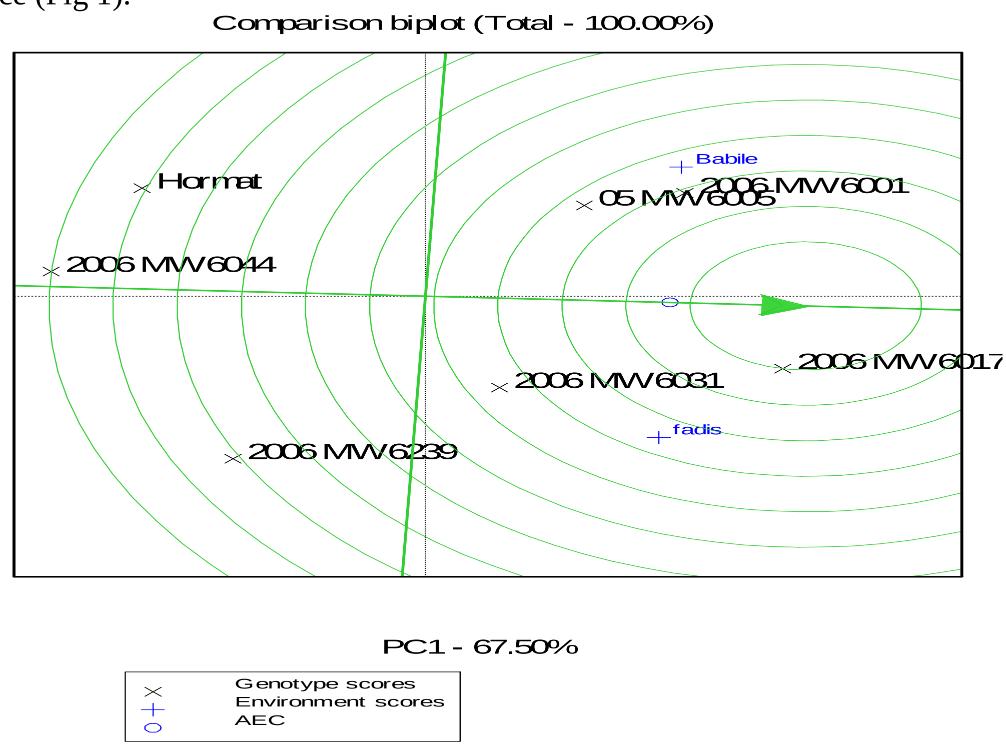

Fig 1: GGE biplot for grain yield kg ha^{-1} of sorghum genotypes tested at two locations during 2006, 2007 and 2008 main cropping season

Adaptation

Fadis-01 is released for the lowlands of eastern Hararghe and similar agro-ecology receiving sufficient amount of rainfall (400mm-710mm) and altitude ranges of 1200-1710 m.a.s.l. The variety performs best with its full agronomic recommendations as presented in Appendix 3. The variety matures at early and consequently has capacity to escape the recurrent terminal drought stress prevalent in lowland areas of Eastern Ethiopia particularly, Fadis and Babile (Erer) and areas with similar agro-ecology in the country.

Conclusion

Fadis-01 is stable in its grain yield, moderately resistance to *Striga* and has good agronomic traits that make it suitable for production in its recommended domain of Eastern Hararghe and areas with similar agro-ecology. The variety has several desirable traits for wider production mainly due to its yield performance, good plant height and relatively good striga resistant.

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The release and registration of "Yale" (EW002 x Dicho 5-3) sesame (*Sesamum indicum l.*) variety

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Abstract

Yale is a name given to a newly released sesame variety developed by Bako Agricultural Research Center and released in June 2019. Selection of this variety was made among recombinant inbred lines of sesame developed through pedigree breeding method. The two parents of the selected variety were collected from western Ethiopia. It was selected out of thirteen lines that were tested along with two standard checks viz., 'Chalasa' and 'Walin' at seven locations in year 2017 and at five locations in year 2018. Yale was the best high yielding variety with mean grain yield of 851 kg ha^{-1}. This variety was the most stable among all lines for its grain yield performance and has resistance to bacterial blight, high uniformity with maximum oil content (55.2%). It was identified to be the farmers' preferred variety.

Key words: Grain yield stability, Oil content, Sesame, Variety development

Introduction

Sesame (*Sesamum indicum* L.) is an important oilseed crop grown for local consumption and export in Ethiopia, and ranks first in area of production and as export crop among oilseed crops grown in the country (CSA, 2015). Ethiopia is among the world's top five producers of sesame and the third largest world exporter of the crop (Wijnands *et al*., 2011). Sesame production is increasing from year to year, which is mainly driven by increasingly high export market demand and availability of suitable agro-ecologies (Zerihun Jaleta, 2012).

Despite the potential for increasing the production and productivity of the crop, there are a number of challenges inhibiting sesame production and productivity. Among the many production constraints, the most important include limited availability of improved and stable high yielding varieties with desirable agronomic qualities, diseases/pests resistant for different agro-ecologies, and poor seed supply system (Negash Geleta, 2015). Western Ethiopia is one of the potential areas of the country where sesame is largely produced. Sesame breeding for this part of the country started in year 2005. So far, four varieties were released by simple selection method. As an effort of sesame breeding program for western Ethiopia, the new sesame variety, Yale was developed by crossing potential breeding lines.

Varietal Origin and Evaluation

The parents of this variety were collected from Western Ethiopia (east and west Wollega). Parent selection for crossing purpose was done in year 2010 and crossing of the parents was done in 2011 main season. Out of large number of crosses, thirteen recombinant inbred lines were developed by pedigree breeding method. The new variety, Yale was tested at multi location together with fifteen genotypes including two standard checks, '*Chalasa*' and '*Walin*' during 2017 & 2018 cropping season (Annex Table 2).

Agronomic and Morphological Characters

Detail of the agronomic and morphological characters of the new sesame variety was presented in Annex Table 1. This variety has determinate growth type. It has erect growth habit and the stem is green in color with alternate stem branching habit. It has basal branching character and thus better lodging resistance than the standard checks. It has opposite leaf arrangement with oval leaf shape. It has dentate basal leaf margin. Its calyx tip is purple in color.

Yield Performance

The variety *Yala* gave grain yield ranging from 600 to 1192 kg ha^{-1}. The result showed that the variety was the best for its grain yield (851 kg ha^{-1}). It has 53.6 and 23.1% grain yield advantage over the standard check, *Chalasa* and *Walin*, respectively.

Stability Performance

Based on the AMMI Stability Value (ASV), the new variety, Yale ranked first for its stability for grain yield performance and the GGE biplot confirmed that the variety is the most stable (Chemeda Daba and Solomon Bekele, 2018).

Disease Reaction

Bacterial blight is the most yield-limiting factor for sesame production in western Ethiopia as the disease is favored by the effect of high humidity and rainfall condition in the area. In addition to higher yield, this variety showed better resistance to bacterial blight than the standard checks.

Quality Analysis

Oil content analysis of the varieties indicated that new variety, Yale was the best with 55.2%, while the oil content of the standard checks were 54.7 and 54.7% for *Chalasa* and *Walin*, respectively.

Adaptation

The new variety, Yale is adapted to Angar, Gute, Bako, Boneya, Hagalo, Uke and Wama areas and similar agro-ecologies in altitude ranging from 1300 to 1650 meters above sea level. This variety can be grown in high rainfall areas where bacterial blight is a problem for sesame production.

Conclusions

Yale is the first variety that was developed by Bako Agricultural Research Center through the pedigree breeding method. It is stable variety across locations with high grain yield performance and high oil content. A new variety *Yale* was resistance to bacterial blight with good uniformity in height and resistant to lodging. *Yale* was released in June 2019 for western Oromia and similar agro-ecologies.

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Annex Table 1. Agronomic and morphological characters of the new sesame variety

1	Variety	Yale (EW002 x Dicho 5-3)
2	Agronomic & morphological characters	
	2.1.Adaptionarea:	Angar-Gute, Bako, Boneya, Hagalo, Uke,Wama& similar agro-ecologies
	Altitude(ma.s.l	1300-1650
	Rainfall (mm)	800-1100
	2.2.Fertilizerrate(kg/ha)	
	NPS	100
	Urea	50
	2.3.Seedrate(kg/ha)	5
	2.4.Spacing(cm)	40x5(InterandIntrarows)
	2.5.Plantingdate	Late May to early June
	2.6.Daystoflowering	56-66
	2.7.Daystomaturity	115-125
	2.8.Plantheight(cm)	116-140
	2.9.Branch height (cm)	15-40
	2.10.Capsule height (cm)	45- 70
	2.11.1000seedweight(g)	2-3
	2.12.Seedcolor(g)	White
	2.13.Oilcontent(%)	55.3
	2.14.Yield(Kg/ha)	
	Research field	600-1100
	Farmers field	700-900
3	Year of release	2019
4	Breeder seed maintainer	OARI/BARC

Annex Table 2. Mean grain yield (kg ha^{-1}) of 15 sesame genotypes across two years (2017 and 2018) and locations

No.	Variety	Year one (2017)							Year two (2018)					Mean
		Angar	Lugo	Uke	Wama	Bako	Boshe	Boneya	Bako	Hagalo	Lugo	Uke	Wama	
1	EW002 x Obsa 1-1	906	734	993	598	668	391	453	721	934	871	692	695	721
2	EW002 x Obsa16-1	729	908	643	776	505	414	494	900	786	467	567	469	638
3	EW002 x Obsa22-1	1042	778	957	801	682	644	666	514	570	870	770	932	769
4	Obsa x Dicho19-11	646	627	795	504	438	501	571	749	689	586	772	666	629
5	Obsa x Dicho19-3	1040	930	930	651	576	403	575	723	837	1013	809	937	785
6	OBSA x Dicho 27-1	839	600	738	519	358	469	600	901	689	360	683	376	594
7	EW002 x Dicho 1-1	569	720	558	647	444	311	538	690	246	453	611	473	522
8	EW002 x Dicho 5-3	867	1063	908	758	603	523	666	1192	960	943	935	799	851
9	EW002 x Dicho 12-1	614	743	466	712	316	327	512	360	579	450	542	400	502
10	EW002 x Dicho 17-2	619	640	436	706	278	628	481	968	724	566	430	638	593
11	EW002 x EW006 (3-1)	617	734	724	834	363	514	571	674	784	454	642	687	633
12	Dicho x EW006 (9-1)	450	809	678	576	444	374	313	610	677	586	649	391	546
13	Dicho x EW006 (9-1)	769	980	647	734	624	374	621	378	561	665	758	682	649
14	Chalasa(standard check)	527	732	503	620	390	501	446	709	634	575	575	435	554
15	Walin (standard check)	946	909	845	569	540	449	574	630	509	770	782	766	691
	Mean	745	794	721	667	482	455	539	715	679	642	681	623	

Association among quantitative and Qualitative traits in Ethiopian Durum Wheat (*Triticum turgidum* L.) landraces

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Abstract

Durum wheat is the second most important triticum species next to bread wheat. Ethiopia is one of the centers of diversity for durum wheat. The present study was conducted to determine the interrelationship and direct and indirect effects of major phenotypic traits on grain yield of Ethiopian durum wheat landraces for further breeding activities. A total of 97 durum wheat accessions along with 3 improved varieties were evaluated in 10 x 10 simple lattice design during 2018 main cropping season at Mata Sub site of Haro Sabu Agricultural Research Center. Analysis of variance revealed highly significant differences among accessions for all traits. More than 36% of accessions were superior in mean grain yield than the standard checks. Grain yield exhibited positive and significant correlation both at genotypic and phenotypic level with most of the characters such as plant height (rp = 0.22, rg = 0.25), harvest index (rp=0.79, rg = 0.78), biological yield (rp = 0.31, rg = 0.30), number of kernels per spike (rp = 0.17, rg = 0.21), spike length, (rp = 0.36, rg = 0.39), and hectoliter weight (kg hl^{-1}) (rp = 0.44, rg = 0.45). The association between yield, and yield related characters through phenotypic and genotypic path coefficients analysis revealed that biological yield, spike length, harvest index and plant height exerted the highest positive direct effect on grain yield. This suggests that simultaneous improvement in these characters might be possible

Keywords: correlation, direct and indirect effects, durum wheat, path coefficient analysis

Introduction

Durum wheat (*Triticum durum* L.) is a member of the Gramineae family, which belongs to the Triticeae tribe. It is an allotetraploid (two genomes: AABB) with 28 chromosomes (2n = 4x =28). (Colomba and Gregorini, 2011).Durum wheat is one of the important cereal crops in many countries in the world (Maniee *et al*., 2009; Kahrizi *et al*., 2010a, b; Mohammadi *et al*., 2010). Durum wheat global acreage is estimated at 17 million hectares (ha) and the most important growing areas are situated in the North America, North and East Africa and South West Asia (Maccaferri *et al*., 2014).However, in Ethiopia, it ranked 3rd after maize and rice in production tons per hectare (CSA, 2017/2018).The national average yield is still 2.74 tons ha^{-1}which is far less than potential yields of 8 to 10 tha^{-1} (CSA, 2017/2018).

There are two types of wheat grown in Ethiopia and both of them are produced under rainfed conditions: durum (pasta and macaroni) wheat, accounting for 40% of production, and bread wheat, accounting for the remaining 60% (Bergh *et al*., 2012).It is traditionally grown by small-scale farmers on the heavy black clay soils (Vertisols) of the high lands at altitude ranging between 1800 and 2800 meters above sea levels (masl) and rainfall distribution varying from 600 to more than 1200 mm per annum (Hailu, 1991). According to Tesfaye

(1986), close to 85 % of the cultivated durum wheat in Ethiopia are landraces. In crop plants, the most of the agronomic characters are quantitative in nature. Yield is one that character that results due to the actions and interactions of various component characters (Grafius, 1960). The genetic architecture of yield can be resolved better by studying its component characters. This enables the plant breeder to breed for high yielding genotypes with desired combinations of traits (Khan and Dar, 2010).

Correlation analysis is used as effective tool to determine the relationship among different traits in genetic diverse population for enhancement of crop improvement process (Kandel *et al*., 2018b; Dhami *et al*., 2018; Kharel *et al*., 2018). The correlations are very important in plant breeding because of its reflection in dependence degree between two or more traits. Correlation analysis shows the intensity of dependence (correlation) between studied traits. In wheat, many breeders try to explain the relations between grain yield and agronomic and morphological traits by using simple correlation coefficients. Path analysis provides a measure of relative importance of each independent variable to prediction of changes in the dependent one. A path coefficient is a standardized partial regression coefficient and as such measures the direct effect of one trait upon other and permits the separation of correlation coefficient into direct and indirect effects (Dewey and Lu, 1959; Phougat et al., 2017). Path coefficients show direct influence of independent variable upon dependent variable (Lidansky, 1988).

In agriculture, path coefficient analysis has been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Dewey and Lu, 1959; Milligan *et al*., 1990; Ahmed *et al*., 2003; Bhujel *et al*., 2018; Kandel *et al*., 2018a). Quantitative characters like as grain yield is a complex character influenced directly or indirectly by several genes present in the plant (Bhutta *et al*., 2005) that making difficult for direct selection. In most breeding programs, the strategy is based on simultaneous selection for several traits and therefore the knowledge on the genetic association between traits is very useful for the establishment of selection criteria. The objective of this study was to establish the interrelationship and direct and indirect effects of some yield components among themselves and with grain yield in durum wheat accessions.

Materials and Methods

Study Area

The experiment was conducted during the main cropping season of 2018 at Mata research sub-site of Haro-Sabu Agricultural Research Center (HSARC), Sayo district of Kellem Wollega Zone. Mata research sub-site is located at 652km West of Addis Ababa.It is located between $8^{o}10'00''$N to $8^{o}50'00''$N and $34^{o}39'30''$E to $34^{o}59'30''$E (Figure 1) with an elevation of 2025 meters above sea level.

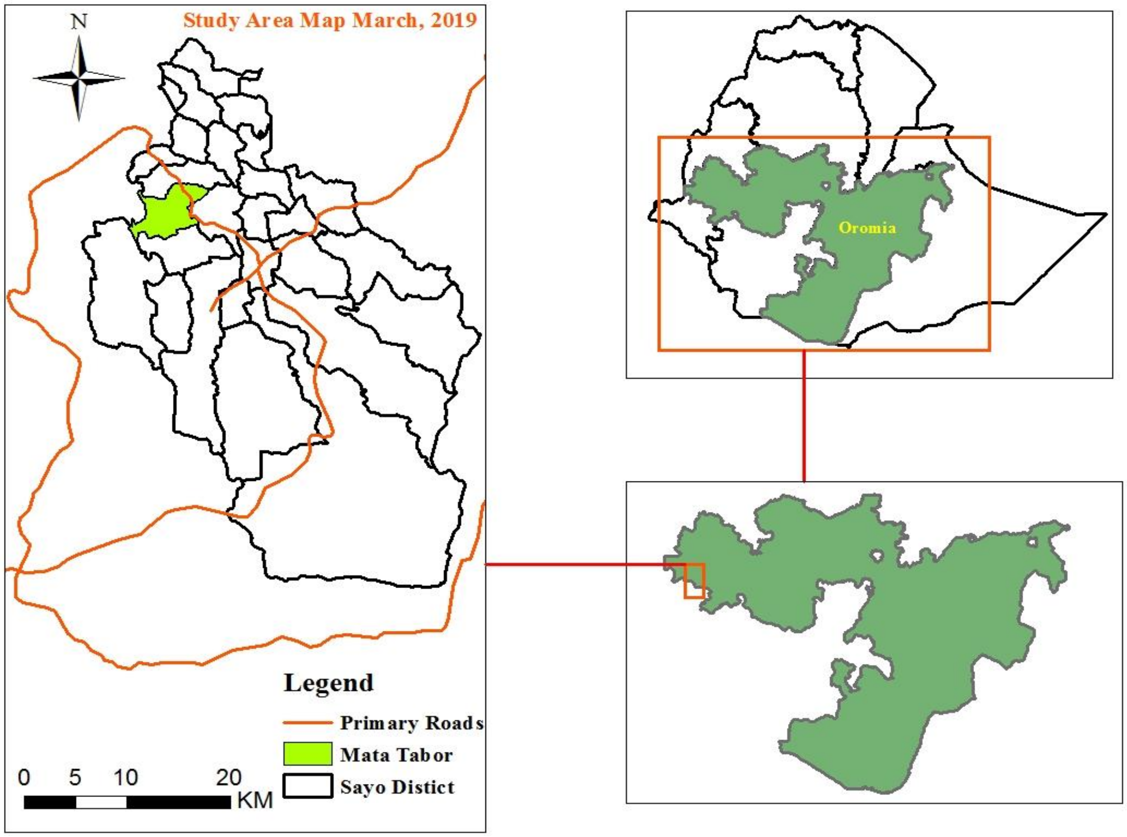

Figure 1: Map of the study area.

Soil types of the study area classified as 90% loam, 6% sand and 4% clay soil type. Mean annual rainfall of the area is 1219.15 mm and the minimum and maximum annual temperatures are16.21 and 27.77°C, respectively with the relative humidity of 67.5% Source: (Sayo district Agriculturen and Natural Resource office, Dembi Dollo, unpublished)

Experimental materials and the design

The experimental materials consisted of 100 genotypes of durum wheat, of which 97 are landraces (accessions) obtained from Ethiopia Biodiversity Institute (EBI) through Sinana Agricultural Research Center and three released varieties (Bekalcha, Dire and Obsa) as standard checks (Table 1). The experiment was sown in the first week of August 2018 in 10 x 10 simple lattice design with two replications. Seed was drilled on 20 cm rowspacing, 1m row length and 1 m spacing between each block. Seed rate of 150 kg ha^{-1} and fertilizer rate of 100/100 kg ha^{-1} NPS/UREA was used. UREA was applied in split form (half at planting and the rest half was applied at tiller initiation 35 days after emergence. Other crop management practices were undertaken as per the recommendation.

Data collection and statistical analysis

Ten plants were selected randomly before heading from each row and tagged with thread. All the necessary plant based measurable quantitative traits such as number of kernels per spike, plant height, spike length, spike weight per plant and number of spikelets per spike were collected and averaged from these ten sampled plants. Whereas, days to heading, days to maturity, days to grain filling period, thousand seed weight, grain yield, biological yield and harvest index were collected on plot bases.

ANOVA of the tested genotypes was conducted for the simple lattice for the quantitative and qualitative data. Associations between all possible pairs of quantitative traits were evaluated for their significance using SAS software version 9.2 (SAS, 2008). Phenotypic and genotypic correlations between yield and yield related traits were estimated using the method described by Miller *et al*. (1958) and Kashiani and Saleh (2010) from the corresponding variance and covariance components as follows:

Phenotypic correlation coefficient:

$$\mathrm{rpxy} = \frac{\mathrm{pcov\ x.y}}{\sqrt{\delta^2 \mathrm{px} * \delta^2 \mathrm{py}}}$$

Genotypic correlation coefficient:

$$\mathrm{rgxy} = \frac{\mathrm{gcov\ x.y}}{\sqrt{\delta^2 \mathrm{gx} * \delta^2 \mathrm{gy}}}$$

Where, rpxy= Phenotypic correlation coefficient between characters X and Y, rgxy= genotypic correlation coefficients between characters X and Y, pcovx.y and gcovx.y are phenotypic and genotypic covariance between variables x and y, respectively, σ^2p =Phenotypic Variance between characters X and Y, σ^2g =Genotypic Variance between characters X and Y. The calculated phenotypic correlation value was tested for its significance using t-test according to Sharma (1998):

$$\mathbf{t} = \frac{\mathbf{r_p}}{\mathbf{SE(r_p)}}$$

Where, rp = Phenotypic correlation; SE (rp) = Standard error of phenotypic correlation obtained using in the following procedure (Sharma, 1998).

$$\mathrm{SE}\ (r_p) = \sqrt{\frac{(1-r^2{}_p)}{(n-2)}}$$

Where, n is the number of genotypes tested, and rp is phenotypic correlation coefficient. The coefficients of correlations at genotypic levels were tested for their significance using the formula described by Robertson (1959) as indicated below:

$$t = \frac{\mathbf{r_{gxy}}}{\mathbf{SEr_{gxy}}}$$

The calculated "t" value was compared with the tabulated "t" value at (n-2) degree of freedom at 5% and 1% level of significance.Where, n = number of genotypes:

$$SEr_{gxy} = \sqrt{\frac{1-r^2{}_{gxy}}{2Hx.Hy}}$$

Where, H^2x = Heritability of trait x and H^2 y = Heritability of trait y.

Path coefficient analysis

Path coefficient analysis was computed by Dewey and Lu (1959) using the phenotypic and genotypic correlation coefficients as:rij = Pij + Σrik * Pkj Where, rij = mutual association between the independent character i (yield-related trait) and dependent character, j (grain yield) as measured by the genotypic correlation coefficients; Pij = components of direct effects of the independent character (i) on the dependent character (j) as measured by the path coefficients; and Σrikpkj = summation of components of indirect effects of a given independent character (i) on a given dependent character (j) via all other independent characters (k). The residual factor (PR), was calculated as:

$$P_R = \sqrt{(1 - \sum pijrij)}$$

Where, i=any trait in the model, j=dependent variable (grain yield) and r=correlation coefficient between any trait i and the dependent variable j. Residual (R) is the square root of non-determination; the magnitude of PR indicates how best the causal factors account for the variability of the dependent factor (Singh and Chaudhary,1999).

Table 1: List of durum wheat accessions collected from different regions of Ethiopia.

Entry code	Acc. No	Genus name	species name	Region	Latitude	Longitude	Altitude
1	7375	*Triticum*	*dicoccum*	Oromia	07-07-00-N	40-43-00-E	1710
2	5582	*Triticum*	*dicoccum*	Oromia	08-57-00-N	37-52-00-E	2280
3	7710	*Triticum*	*dicoccum*	Oromia	07-08-00-N	40-43-00-E	1980
4	238891	*Triticum*	*dicoccum*	Oromia	07-01-30-N	40-21-07-E	2200
5	7207	*Triticum*	*dicoccum*	Oromia	07-01-40-N	40-23-55-E	1990
6	5181	*Triticum*	*dicoccum*	Oromia	07-01-20-N	40-19-46-E	1900
7	242782	*Triticum*	*sp*	Amara	11-05-00-N	37-52-00-E	2400
8	242793	*Triticum*	*sp*	Amara	10-18-00-N	38-12-00-E	2460
9	7532	*Triticum*	*sp*	Amara	10-18-00-N	38-12-00-E	2460
10	7056	*Triticum*	*sp*	Oromia	09-00-00-N	38-07-00-E	2350
11	7880	*Triticum*	*sp*	Oromia	07-17-00-N	38-36-00-E	2030
12	242781	*Triticum*	*sp*	Oromia	07-44-00-N	39-34-00-E	2140
13	5182	*Triticum*	*sp*	Oromia	08-24-00-N	39-52-00-E	2040
14	5171	*Triticum*	*sp*	Amara	10-34-00-N	38-14-00-E	2390
15	222393	*Triticum*	*sp*	Oromia	08-49-00-N	38-54-00-E	2400
16	7649	*Triticum*	*sp*	Amara	10-26-00-N	38-20-00-E	2460
17	5216	*Triticum*	*sp*	Oromia	08-12-00-N	39-34-00-E	2150
18	5020	*Triticum*	*sp*	Oromia	08-24-00-N	39-52-00-E	2040
19	6102	*Triticum*	*sp*	Oromia	07-46-00-N	39-47-00-E	2440
20	242790	*Triticum*	*sp*	Oromia	07-41-00-N	40-13-00-E	2395
21	5184	*Triticum*	*sp*	Oromia	07-45-00-N	39-40-00-E	2400
22	5515	*Triticum*	*sp*	Oromia	07-44-00-N	39-53-00-E	2430
23	5528	*Triticum*	*sp*	Amara	10-18-00-N	38-12-00-E	2460
24	7084	*Triticum*	*sp*	Amara	10-14-00-N	38-01-00-E	2440
25	7683	*Triticum*	*sp*	Oromia	07-39-00-N	39-46-00-E	2430
26	242785	*Triticum*	*sp*	Oromia	07-50-00-N	39-38-00-E	2410
27	7343	*Triticum*	*sp*	Amara	10-18-00-N	38-12-00-E	2460
28	7832	*Triticum*	*sp*	Amara	11-21-00-N	39-18-00-E	2300
29	6983	*Triticum*	*sp*	Amara	10-28-00-N	38-17-00-E	2430
30	5472	*Triticum*	*sp*	Amara	10-28-00-N	38-18-00-E	2410
31	5354	*Triticum*	*sp*	Oromia	08-53-00-N	37-51-00-E	2310
32	5729	*Triticum*	*sp*	Amara	11-06-00-N	39-45-00-E	1790
33	7647	*Triticum*	*sp*	Amara	11-05-00-N	37-42-00-E	2470
34	6988	*Triticum*	*sp*	Oromia	09-14-00-N	41-09-00-E	2260
35	5583	*Triticum*	*sp*	Oromia	08-54-00-N	38-54-00-E	2300
36	7020	*Triticum*	*sp*	Oromia	09-00-00-N	39-07-00-E	2330
37	239694	*Triticum*	*sp*	Oromia	38-54-00-N	38-54-00-E	2300
38	5183	*Triticum*	*sp*	Oromia	08-47-00-N	39-15-00-E	2300
39	5556	*Triticum*	*sp*	Oromia	09-47-00-N	39-16-00-E	2200
40	5175	*Triticum*	*sp*	Oromia	08-52-00-N	39-01-00-E	2133
41	5373	*Triticum*	*sp*	Oromia	38-54-00-N	38-54-00-E	2300
42	6968	*Triticum*	*sp*	Oromia	09-24-00-N	38-47-00-E	2160
43	7664	*Triticum*	*sp*	Oromia	09-01-00-N	39-15-00-E	2300
44	7218	*Triticum*	*sp*	Oromia	09-00-00-N	39-07-00-E	2330
45	5043	*Triticum*	*sp*	Amara	08-50-00-N	39-19-00-E	2260
46	6978	*Triticum*	*sp*	Amara	08-50-00-N	39-19-00-E	2260
47	7009	*Triticum*	*sp*	Oromia	08-51-00-N	38-30-00-E	2333
48	5174	*Triticum*	*sp*	Oromia	08-59-00-N	38-52-00-E	2300
49	7709	*Triticum*	*sp*	Oromia	09-01-00-N	39-03-00-E	2450
50	230678	*Triticum*	*sp*	Oromia	08-51-00-N	38-52-00-E	2300

Entry code	Acc. No	Genus name	species name	Region	Latitude	Longitude	Altitude
51	242789	*Triticum*	*sp*	Oromia	08-54-00-N	39-01-00-E	2350
52	242792	*Triticum*	*sp*	Oromia	08-59-00-N	38-52-00-E	2300
53	5214	*Triticum*	*sp*	Oromia	08-58-00-N	39-00-00-E	2420
54	5428	*Triticum*	*sp*	Oromia	08-47-00-N	39-15-00-E	2300
55	7801	*Triticum*	*sp*	Oromia	09-01-00-N	39-15-00-E	2300
56	242791	*Triticum*	*sp*	Oromia	09-01-00-N	39-15-00-E	2300
57	5491	*Triticum*	*sp*	Oromia	08-59-00-N	38-52-00-E	2300
58	5510	*Triticum*	*sp*	Oromia	08-54-00-N	39-05-00-E	2200
59	7015	*Triticum*	*sp*	Oromia	08-49-00-N	39-00-00-E	1915
60	242784	*Triticum*	*sp*	Oromia	08-45-00-N	39-08-00-E	2350
61	5635	*Triticum*	*sp*	Tigray	14-10-00-N	38-42-00-E	2367
62	5609	*Triticum*	*sp*	Oromia	08-48-00-N	38-54-00-E	2080
63	5666	*Triticum*	*sp*	Tigray	14-07-00-N	38-29-00-E	2487
64	5572	*Triticum*	*sp*	Oromia	08-45-00-N	39-13-00-E	2070
65	5504	*Triticum*	*sp*	Oromia	08-45-00-N	39-15-00-E	2120
66	5197	*Triticum*	*sp*	Oromia	08-45-00-N	39-13-00-E	2160
67	7827	*Triticum*	*sp*	Oromia	08-47-00-N	39-15-00-E	2300
68	242786	*Triticum*	*sp*	Oromia	08-45-00-N	39-15-00-E	2120
69	5653	*Triticum*	*sp*	Oromia	08-45-00-N	39-08-00-E	2340
70	5534	*Triticum*	*sp*	Oromia	08-45-00-N	39-15-00-E	2120
71	242783	*Triticum*	*sp*	Oromia	09-47-00-N	39-46-00-E	2300
72	226897	*Triticum*	*sp*	Oromia	09-47-00-N	39-46-00-E	2300
73	5168	*Triticum*	*sp*	Oromia	09-47-00-N	39-16-00-E	2200
74	5179	*Triticum*	*sp*	Oromia	09-47-00-N	39-16-00-E	2300
75	7825	*Triticum*	*sp*	Oromia	09-47-00-N	39-16-00-E	2300
76	5198	*Triticum*	*sp*	Amara	08-50-00-N	39-19-00-E	2260
77	8072	*Triticum*	*sp*	Amara	08-50-00-N	39-19-00-E	2260
78	242779	*Triticum*	*sp*	Amara	08-50-00-N	39-19-00-E	2260
79	5492	*Triticum*	*sp*	Amara	08-50-00-N	39-19-00-E	2260
80	243733	*Triticum*	*sp*	SNNP	09-29-00-N	38-30-00-E	2333
81	5638	*Triticum*	*sp*	Oromia	08-51-00-N	38-30-00-E	2330
82	242780	*Triticum*	*sp*	Amara	08-50-00-N	39-19-00-E	2260
83	5597	*Triticum*	*sp*	Amara	12-38-00-N	37-28-00-E	2100
84	5044	*Triticum*	*sp*	Oromia	09-47-00-N	39-46-00-E	2300
85	5152	*Triticum*	*sp*	Oromia	08-47-00-N	39-46-00-E	2300
86	5554	*Triticum*	*sp*	Amara	10-34-00-N	37-29-00-E	2145
87	7018	*Triticum*	*sp*	Amara	11-00-00-N	36-54-00-E	2489
88	5669	*Triticum*	*sp*	Oromia	07-12-00-N	38-35-00-E	1773
89	7828	*Triticum*	*sp*	Oromia	08-50-00-N	38-22-00-E	1773
90	5367	*Triticum*	*sp*	Oromia	08-54-00-N	39-01-00-E	2350
91	5344	*Triticum*	*sp*	Amara	12-19-00-N	37-33-00-E	2145
92	5434	*Triticum*	*sp*	Oromia	08-47-00-N	39-15-00-E	2300
93	5166	*Triticum*	*sp*	Oromia	08-51-00-N	38-30-00-E	2333
94	5149	*Triticum*	*sp*	Oromia	08-16-00-N	38-52-00-E	1791
95	5169	*Triticum*	*sp*	Oromia	08-59-00-N	38-52-00-E	2300
96	5441	*Triticum*	*turgidum*	Oromia	07-47-00-N	39-39-00-E	2415
97	5557	*Triticum*	*polonicum*	Oromia	08-58-00-N	37-36-00-E	2430
98	Bekalcha	*Triticum*	Improved variety	Sinana ARC			
99	Dire	*Triticum*	Improved variety	Sinana ARC			
100	obsa	*Triticum*	Improved variety	Sinana ARC			

Source: Ethiopian Biodiversity Institute (EBI) and Sinana ARC

Results and Discussion

Analysis of variance

The result of relative efficiency of the design revealed that simple lattice design was more efficient than randomized complete block design for most characters (Table 2). The analysis of variance revealed that there were highly significant differences ($p<0.01$) among the accessions with respect to grain yield, yield related traits and quality parameters (Table 2). Significant differences were recorded for parameters like Days to heading, days to maturity, grain filling period, plant height, biological yield, grain yield, harvest index, spike weight, thousand kernel weight (TKW), number of kernels per spike, number of spikelets per spike, spike length, gluten (%), moisture (%), protein (%), hectoliter weight and Water absorption (%) exhibited highly significant difference ($p<0.01$) among accessions. The significant differences of the parameters indicated that, there is considerable amount of genetic variation among the studied landraces (Table 2). This variation would offer an opportunity to select for desirable traits. Several researchers reported significant differences among bread and durum wheat genotypes studied (Kifle *et al*., 2016; Kumar *et al*., 2016; Wolde *et al*., 2016; Birhanu *et al*., 2016). Similarly, significant differences were reported for major traits in bread wheat (Kalimullah *et al*., 2012; Shashikala, 2006; Naik *et al*., 2015; Rahman *et al*., 2016)

Genotypic and phenotypic correlation of grain yield with other traits.

In the present study, the predictable values of phenotypic and genotypic correlation coefficients between all pairs of characters are presented in Table 3. The analyses showed, genotypic correlation coefficient values were greater than their corresponding phenotypic correlation coefficient values for most of the characters, indicating the inherent association of the characters and better opportunity for direct selection.

Phenotypic correlations

Grain yield per plant showed positive and high significant ($p<0.01$) correlation with spike length ($r_p = 0.359$), hectoliter weight ($r_p = 0.443$), biological yield ($r_p = 0.297$), and harvest index ($r_p = 0.790$) (Table 3). The studies conducted by Kifle *et al*. (2016), Kole (2006) and Anwar *et al.* (2009) showed that grain yield per plant had positive and significant correlations with spike length, biological yield, harvest index, number of kernels per spike and plant height both at genotypic and phenotypic levels. At phenotypic level, grain yield per plant was positively and significantly associated with biological yield and harvest index (Amardeep *et al*., 2017). Moreover, grain yield showed negative and highly significant phenotypic correlation with percent of protein ($r_p = -0.548$) (Table 3). Blanco *et al.* (2010) reported negative and significant correlation between days to heading and lodging.

Table **2**: Mean squares, degrees of freedom and some of statistical parameters of all studied traits of durum wheat landraces evaluated in 201**8** season using simple lattice design. for 20 traits in 100 Accessions

Traits	Treatments	Replications	Blocks within Replications	Intra Block Error	Grand Mean	CV%	Mean± SE	LSD 5%	Eff	R^2 (%)
	DF=99	DF=1	DF=18	DF=81						
DH	18.41**	1.28	0.99	0.85	68.77	1.34	68.77(±)0.92	1.86	100.38	97
DM	33.58**	0.05	0.77	1.14	103.57	1.03	103.57(±)1.07	2.06	94.12	97
GFP	52.75**	1.81	1.78	1.55	34.8	3.83	34.80(±)1.33	2.61	108.69	97
PH	366.00**	9.25	58.76	58.76	87.54	8.76	87.54(±)7.67	15.21	100	90
BY	9.29**	1.83**	0.02	0.03	8.6	1.88	8.60(±)0.16	0.32	96.61	100
GY	1.10**	0.02	0.05	0.04	1.57	11.93	1.57(±)0.19	0.38	101.69	97
HI	147.33**	1.78	6.45	5.37	18.88	12.27	18.88(±)2.32	4.68	100.6	97
SWT	0.44**	4.81**	0.01	0.01	1.39	7.25	1.39(±)0.10	0.20	101.14	98
TKW	206.23**	18.91*	6.95*	3.87	32.43	6.07	32.43(±)1.97	4.18	105.92	99
NKPS	102.31**	2461.91**	0.02	0.02	42.61	0.29	42.61(±)0.12	0.25	101.29	100
NSPS	40.51**	2119.01**	0.81	0.51	30.4	2.36	30.40(±)0.72	1.50	103.63	99
SL	9.39**	109.52**	0.22	0.21	7.61	5.99	7.61(±)1.46	0.91	100.04	99
GLT	16.77**	33.29**	0.49	0.6	31.72	2.44	31.72 (±)0.77	1.53	96.67	97.6
MTR	0.30**	17.36**	0.04	0.07	10.56	2.49	10.56 (±)0.26	0.52	92.26	90.2
PRT	7.95**	11.43**	0.04	0.03	16.61	1.04	16.61(±)0.17	0.34	100.52	99.7
HLW	76.80**	9.54**	0.05	0.03	69.43	0.23	69.42(±)0.16	0.32	105.44	100
WAB	25.99**	42.30**	0.26	0.38	16.38	3.74	16.38 (±) 0.61	1.22	94.29	99

Key: *and ** indicates significance at 0.05 and 0.01 probability levels, respectively. CV (%) = coefficient of variation, DF= degree of freedom Eff. = efficiency of lattice design relative to randomized complete block design and R^2= r- square, SE= standard error; LSD=least significant difference, BY= biological yield tons ha-,^{1} DH= days to heading, DM= days to maturity, GLT= gluten (%), GFP = grain filling period, GY = grain yield tons ha-,^{1}, HI = harvest index (%), HLW= hectoliter weight (kg hl^{-1}), MTR= moisture (%),NKPS= number of kernels per spike, NSPS=number of spikelets per spike,PH = plant height(cm), PRT= protein (%),SL= spike length(cm), SW = spike weight(g), , TKW = thousand kernels weight(g), and WAB=water obsorption (%)

Genotypic correlations

Grain yield showed positive and highly significant correlation with spike length (rg = 0.389), hectoliter weight (rg = 0.450), biological yield (rg = 0.300), and harvest index (rg = 0.784). This might be due to the presence of common genetic elements that controlled the characters in the same and/or in different direction. The observed significant positive correlation could be either due to the strong coupling linkage between the genes or was the result of pleiotropic genes that controlled these characters in the same direction (Kearsey and Pooni, 1996). Similarly, grain yield had positive and highly significant genotypic correlation with 1000-kernel weight and biological yield in all environments (Azeb *et al*., 2016) and with biological yield and plant height at the genotypic level (Amardeep *et al*., 2017). The work of Surma *et al*. (2012) showed positive and significant correlation of grain yield with thousand kernel weight, hectoliter weight and starch content. The yield components exhibited varying trends of association among themselves. Lodging (rg = -0.509) and percent of protein (rg = -0.563) had highly significant negatively correlation with grain yield (Table 3) which was also similarly reported by Negash *et al*. (2019). Singh (2014) reported the presence of negative correlation between grain yield and plant height. Azeb *et al*. (2016) also reported negative and highly significant genotypic correlation of grain yield with days to heading and days to maturity.

Therefore, positive correlation coefficients of grain yield with most of the traits implied that, improving one or more of these traits could result in high grain yield (Yagdi and Sozen, 2009). Furthermore, plant height had positive significant association with number of kernels per spike, number of spikelets per spike, spike length, and hectoliter weight. Spike length had positive and highly significant correlation with biological yield and harvest index. The correlation of hectoliter weight,with plant height, number of kernels per spike, number of spikelets per spike, harvest index and spike length was positive and significant number of kernels per spike had positive and significant correlation with grain yield, hectoliter weight, plant height and biological yield (Table 3). The positive significant associations between grain yield and plant height is because of these tall genotypes generally excelled in their capacity to support kernel growth by stem reserve mobilization (Blum *et al*., 1989). Therefore, selection for tall plants tends to increase grain yield per plant.

Table 3. Phenotypic (rp) and genotypic (rg) correlation coefficients of studied traits of durum wheat accessions evaluated in 2018 season.

Traits		GY	DH	DM	GFP	PH	BY	HI	SWT	TKW	NKPS	NSPS	SL	GLT	MTR	PRT	HLW	WAB
GY	rg	1	-0.019	0.111	0.098	0.267*	0.300**	0.784**	0.082	-0.094	0.208*	0.091	0.389**	-0.231*	-0.080	-0.563**	0.450**	0.003
	rp		-0.007	0.106	0.086	0.217*	0.297**	0.790**	0.069	-0.09	0.175*	0.080	0.359**	-0.221*	-0.057	-0.548**	0.443**	0.004
DH	rg		1	-0.055	-0.631**	-0.030	-0.022	0.001	-0.025	-0.008	-0.103	-0.019	-0.148	0.092	0.051	0.127	-0.070	0.132
	rp			-0.049	-0.630**	-0.026	-0.023	0.011	-0.015	-0.003	-0.080	0.007	-0.144*	0.088	0.025	0.120	-0.068	0.122
DM	rg			1	0.809**	-0.044	0.050	0.113	0.054	0.063	-0.020	0.002	0.109	-0.022	-0.050	-0.067	0.100	0.295**
	rp				0.806**	-0.034	0.047	0.108	0.045	0.062	-0.020	-0.016	0.103	-0.016	-0.056	-0.067	0.099	0.284**
GFP	rg				1	-0.017	0.052	0.088	0.056	0.054	0.045	0.013	0.171	-0.071	-0.070	-0.127	0.118	0.151
	rp					-0.010	0.050	0.077	0.044	0.050	0.032	-0.017	0.166*	-0.064	-0.058	-0.123	0.117	0.148
PH	rg					1	0.339*	-0.015	0.041	0.033	0.253*	0.214*	0.356*	-0.069	-0.020	-0.249*	0.221*	0.094
	rp						0.310**	-0.021	0.034	0.025	0.216*	0.158*	0.317**	-0.058	-0.022	-0.234*	0.206*	0.081
BY	rg						1	-0.300*	0.052	-0.140	0.294*	0.279*	0.501**	-0.204*	-0.060	-0.254*	0.408**	0.102
	rp							-0.293**	0.036	-0.140*	0.247*	0.236*	0.484**	-0.193*	-0.018	-0.246*	0.408**	0.106
HI	rg							1	0.040	-0.028	0.009	-0.062	0.034	-0.180	-0.020	-0.438**	0.212*	-0.031
	rp								0.031	-0.026	0.001	-0.050	0.027	-0.172*	-0.015	-0.426**	0.209*	-0.030
SWT	rg								1	0.119	-0.124	0.099	0.222*	-0.050	-0.017	-0.042	0.061	0.001
	rp									0.118	0.027	0.131	0.102	-0.086	-0.179*	-0.072	0.048	-0.036
TKW	rg									1	-0.089	-0.119	-0.081	-0.100	0.136	0.091	-0.075	0.010
	rp										-0.07	-0.093	-0.083	-0.102	0.089	0.086	-0.075	0.007
NKPS	rg										1	0.507**	0.152	-0.223*	-0.030	-0.253*	0.231*	-0.029
	rp											0.453**	-0.002	-0.250*	-0.254*	-0.272**	0.194*	0.004
NSPS	rg											1	0.145	-0.248*	0.002	-0.299*	0.256*	-0.034
	rp												0.073	-0.227*	-0.053	-0.265*	0.215*	0.122
SL	rg												1	-0.085	-0.110	-0.217*	0.340*	0.193
	rp													-0.037	0.097	-0.169*	0.330**	0.284**
GLT	rg													1	-0.384**	0.554**	-0.395**	-0.071
	rp														-0.216*	0.551**	-0.382**	-0.030
MTR	rg														1	0.045	-0.046	0.141
	rp															0.096	-0.020	0.151
PRT	rg															1	-0.602**	-0.013
	rp																-0.594**	-0.036
HLW	rg																1	-0.004
	rp																	0.007
WAB																		1

Key : BY= biological yield tons ha-,^{1} DH= days to heading, DM= days to maturity, GLT= gluten (%), GFP = grain filling period, GY = grain yield tons ha-,^{1}, HI = harvest index (%), HLW= hectoliter weight (kg hl^{-1}), MTR= moisture (%),NKPS= number of kernels per spike, NSPS=number of spikelets per spike,PH = plant height(cm), PRT= protein (%),SL= spike length(cm), SW = spike weight(g), TKW = thousand kernels weight(g), and WAB=water obsorption (%)

Path coefficient analysis

Path coefficient analysis was conducted to identify the important yield attributes by estimating the direct effects of traits contributing to grain yield and separating the direct from the indirect effects through other related traits by partitioning the correlation coefficient and finding out the relative importance of different characters as selection criteria (Tables 4 and 5). This analysis was conducted using grain yield as dependent variable and all other traits studied as independent (causal) variables.

Genotypic path coefficient

Harvest index had positive and significant correlation coefficient and it showed the highest positive direct effect (0.93) on grain yield. Harvest index also exerted large indirect effects on grain yield through plant height, biological yield, number of kernels per spike, spike length, gluten and hectoliter weight. The direct effect of biological yield followed by spike length, plant height, number of kernels per spike, hectoliter weight, and gluten on grain yield was positive with significant correlation and so exerted positive direct effect (Table 4).

Biological yield, harvest index, plant height and spike length revealed positive direct effect and had positive genetic correlation explaining the existence of real relation between the characters and grain yield. This indicated that, indirect selection of yield via this characteristic is effective. Similarly, Negash *et al*. (2019) reported positive direct effect of the biological yield on grain yield in Ethiopian barley landraces. Azeb *et al*. (2016) indicated that biological yield exerted maximum positive direct effect on grain yield across locations. The studies made by Kifle *et al*. (2016), Kole (2006) and Anwar *et al.* (2009) showed that grain yield per plant had positive and significant correlations with spike length, biological yield, harvest index, number of kernels per spike and plant height both at genotypic and phenotypic levels. Protein exerted negative direct effects on grain yield also negative and highly significant association at genotypic levels. The indirect effects of protein with other characters were mostly negative and negligible. Singh and Chaundhary (1985) suggested that an indirect effect seemed to be the cause of correlation and hence, these indirect causal factors (traits) should be considered simultaneously for selection (Table 4). Besides, plant height, biological yield, harvest index, number of kernels per spike, spike length, gluten and hectoliter weight exhibited positive direct effects on grain yield indicating that an improvement in those traits could possibly to increase grain yield. The genotypic residual value (0.04) showed that, the characters under study accounted for 96% of the variability with grain yield components (Table 4).

Table 4: Estimates of direct (bold diagonal) and indirect effect (off-diagonal) at genotypic level of 8 traits on grain yield of 100 durum wheat accessions

Traits	PH	BY	HI	NKPS	SL	GLT	PRT	HLW	rg
PH	**0.05**	0.12	-0.01	0.01	0.01	0.00	0.01	0.01	0.27*
BY	0.01	**0.52**	-0.20	0.01	0.02	-0.01	0.01	0.01	0.46*
HI	0.00	-0.11	**0.93**	0.00	0.00	-0.01	0.01	0.01	0.78**
NKPS	0.01	0.10	0.01	**0.05**	0.01	-0.01	0.01	0.01	0.21*
SL	0.01	0.18	0.02	0.01	**0.08**	0.00	0.01	0.01	0.39**
GLT	0.00	-0.07	-0.12	-0.01	0.00	**0.05**	-0.01	-0.01	-0.23*
PRT	-0.01	-0.09	-0.29	-0.01	-0.01	0.03	**-0.03**	-0.02	-0.56**
HLW	0.01	0.14	0.14	0.01	0.01	-0.02	0.02	**0.04**	0.45**

Key: BY = biological yield tons ha-^{1}, GLT= gluten (%), rg =genotypic correlations, HI = harvest index (%), HLW= hectoliter weight (kg hl^{-1}), KNPS=kernel number per spike, PH=plant height, PRT =protein (%), residual effect = 0.04 is unexplained, 0.96 is explained and SL=spike length

Phenotypic path coefficient analysis

Harvest index and biological yield showed positive and significant correlation (r = 0. 79; r = 0.30) and the highest direct effect (0.94 and 0.53) on grain yield, respectively. The existence of negligible and positive indirect effect of harvest index and biological yield with most of the other characters determines that the correlation of these traits with grain yield were found to be due to the direct effect (Table 5). Plant height, spike length, number of kernels per spike, gluten and hectoliter weight have positive but negligible direct effect on grain yield and the phenotypic correlation they had with grain yield were positive. The indirect effect of harvest index through plant height, spike length, number of kernels per spike, gluten and hectoliter and biological yield counter balanced the direct effect of harvest index on grain yield. The indirect effect of biological yield through harvest index (-0.20) counter balanced the direct effect of biological yield on grain yield (0.53). The residual value (0.05) showed the characters under the study accounted 95% of the variability in grain yield (Table 5).

Table 5: Estimates of direct (bold diagonal) and indirect effect (off-diagonal) at phenotypic level of 8 traits on grain yield of 100 durum wheat accessions

Traits	PH	BY	HI	NKPS	SL	GLT	PRT	HLW	rp
PH	**0.05**	0.12	0.00	0.01	0.01	0.00	0.01	0.01	0.22*
By	0.01	**0.53**	-0.20	0.01	0.02	0.00	0.01	0.01	0.30**
HI	0.00	-0.11	**0.94**	0.00	0.00	0.00	0.01	0.01	0.79**
NKPS	0.01	0.10	0.00	**0.05**	0.00	0.00	0.01	0.01	0.17*
SL	0.01	0.19	0.02	0.00	**0.07**	0.00	0.00	0.01	0.36**
GLT	0.00	-0.07	-0.10	-0.01	0.00	**0.06**	0.00	-0.01	-0.22*
PRT	-0.01	-0.10	-0.30	-0.01	0.00	0.03	**-0.03**	-0.02	-0.55**
HLW	0.01	0.16	0.15	0.01	0.01	0.00	0.02	**0.03**	0.44**

Key: BY = biological yield tons ha-^{1}, GLT= gluten (%), HI = harvest index (%) , HLW= hectoliter weight (kg hl^{-1}), KNPS=kernel number per spike, PH=plant height, PRT =protein (%), rp = phenotypic correlations residual effect = 0.05 is unexplained, 0.95 is explained and SL=spike length

Conclusions

Study of relationship between yield and yield contributing characters in durum wheat through genotypic and phenotypic correlations suggests that grain yield (ton ha^{-1}) had shown significant positive phenotypic and genotypic correlation with thousand seed weight, plant height, biological yield, harvest index, number of kernels per spike, spike length, gluten and hectoliter weight had positive. This implied that the significant influences of these traits on grain yield and grain yield could be improved directly by improving these traits. Grain yield had positive but not significant correlation at genotypic and phenotypic level with number of spikelet per spike, spike weight and water obsorption. Generally, significant differences of the characters showed the availability of substantial of genetic variation among the studied materials. Besides, strong association between most of the studied characters could provide basic information for further breeding activities.

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Genetic Variability and Heritability among Durum Wheat (Triticum turgidum L.) Landraces for Yield and Yield Related Trait Performance

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Abstract

*Durum wheat is the second most important triticum species next to bread wheat. Ethiopia is one of the centers of diversity for durum wheat. The aim of this study was to find out variability, heritability and genetic advance for some yield and yield related traits among durum wheat accessions. Out, 97 durum wheat accessions along with 3 improved varieties were evaluated in 10 x 10 simple lattice design during 2018 main cropping season at Mata Sub site of Haro Sabu Agricultural Research Center. Twenty parameters were evaluated. Variances component method was used to estimate variability, broad sense heritability and genetic advance of yield and yield related characters.Statistically, significant ($p \leq 0.01$) variation was observed among materials tested for important quantitative and qualitative traits. Genotypic coefficient of variation (GCV) varied from 3.77% to 44.81% for days to maturity and grain yield tons ha^{-1}, respectively. Broad sense heritability ranged from 72.33% to 99.95% for plant height and number of kernels per spike respectively.Highest genetic advance as percent of mean recorded for grain yield tons ha^{-1} (*88.80 %*) and the least for moisture (*5.22 %*). Generally, the magnitude of genetic variability among the studied durum wheat materials showed great variations for desirable traits and thus confident enough to expect genetic progress if further breeding activities are carried out.*

Keywords**:** Coefficient of Variation, durum wheat (*Triticum turgidum* L.), Genetic advance, and Heritability

Introduction

Durum wheat (*Triticum durum* L.) is a monocotyledonous plant of the *Gramineae* family. It is the only tetraploid (AABB, 2n=4x=28) species of wheat which has commercially a great importance and is a promising and viable alternative crop for farmers (Blanco *et al*., 1998; Shewry, 2009). Durum wheat is one of the important cereal crops in many countries in the world (Maniee *et al*., 2009; Kahrizi *et al*., 2010a, b; Mohammadi *et al*., 2010). It is a tetraploid cereal crop grown in a range of climatic zones varying from warm and dry to cool and wet environments (Giraldo *et al*., 2016). Durum wheat global acreage is estimated at 17 million hectares (ha) and the most important growing areas are situated in the North America, North and East Africa and South West Asia (Maccaferri *et al*., 2014).

However, in Ethiopia, wheat ranked 3rd after maize and rice in production tons per hectare (CSA, 2017/2018). The average national yield (2.74 t ha^{-1}) is low compared to that reported from experimental fields (4 t ha^{-1}) and variable from season to season. Durum wheat has been under cultivation in Ethiopia since ancient times and the country is considered as center of genetic diversity for durum wheat (Vavilov, 1951). Reduction in the genetic variability makes the crops increasingly vulnerable to diseases and adverse climatic changes (Aremu, 2012). The introduction of exotic wheat replacing the durum wheat landraces resulted in the loss of genetically diverse, locally well-adapted landraces (Royo *et al*., 2009). The research finding shows that narrowing of the gene pool in durum wheat leads to an increased risk of vulnerability to diseases and pests (Frankel *et al*., 1995). For effective selection in durum wheat, breeders should increase their efforts to know the genetic variability and heritability of important agronomic traits (Abinasa *et al*., 2011).

Genetic variability, which is due to genetic differences among individuals within a population, is the foundation of plant breeding since proper management of diversity can produce permanent gain in the performance of plant and can safeguard against seasonal fluctuations (Sharma, 2004; Welsh, 2008). Phenotypic variation, is the observable variation present in a character of a population, includes both genotypic and environmental components of variation and, as a result, its magnitude differs under different environmental conditions (Singh, 2006). Heritability in broad sense, can be defined, as the proportion of the genotypic variability to the total variance (Allard, 2006). It refers to the portion of phenotypically expressed variation, within a given environment and it measures the degree to which a trait can be modified by selection (Christianson and Lewis, 2003). Heritability is a property not only of a character being studied but also of a population being sampled, of the environmental circumstance to which the individuals are subjected, and the way in which the phenotype is measured (Falconer and Mackay, 1996). Even though, estimates of heritability provide the basis for selection on phenotypic performance, estimates of heritability and genetic advance should be considered simultaneously because high heritability should not always associate with high genetic advance (Amin *et al.*, 2004). Hence, high heritability coupled with genetic advance is more dependable for selection breeding, but high heritability coupled with low genetic advance indicates the presence of non-additive gene action (Vimal and Vishwakarma, 2009). Therefore, the present study was designed to determine the extent of genetic variability present in the available germplasm and to explore the possibility of improving them through breeding programme.

Materials and Methods

The experiment was conducted during 2018 main cropping season at Mata research sub-site of Haro-Sabu Agricultural Research Center (HSARC), Western Oromia, Ethiopia. Mata research sub-site is located at 652km West of Addis Ababa.It is located between 8^{o}10’00’’N to 8^{o}50’00’’N and 34^{o}39’30’’E to 34^{o}59’30’’E with an elevation of 2025 meters above sea level. Soil types of the study area classified as 90% loam, 6% sand and 4% clay soil type.Mean annual rainfall of the area is 1219.15 mm and the minimum and maximum annual temperatures are 16.21 and 27.77°C, respectively.

The experimental materials consisted of 100 genotypes of durum wheat, of which 97 are landraces (accessions) obtained from Ethiopia Biodiversity Institute (EBI) through Sinana Agricultural Research Center and three released varieties (Bekalcha, Dire and Obsa) as standard checks (Table 1). The experiment was sown in the first week of August 2018 in 10 x

10 simple lattice design with two replications. Seed was drilled on 20 cm rowspacing, 1m row length and 1 m spacing between each block. Seed rate of 150 kg ha^{-1} and fertilizer rate of 100/100 kg ha^{-1} NPS/UREA was used. UREA was applied in split form (half at planting and the rest half was applied at tiller initiation 35 days after emergence. Other crop management practices were undertaken as per the recommendation.

Data collection and statistical analysis

Ten plants were selected randomly before heading from each row and tagged with thread. All the necessary plant based measurable quantitative traits such as number of kernels per spike, plant height, spike length, spike weight per plant and number of spikelets per spike were collected and averaged from these ten sampled plants. Whereas, days to heading, days to maturity, days to grain filling period, thousand seed weight, grain yield, biological yield, lodging index, harvest index and susceptibility to stem rust (*Puccinia graminis*) and leaf rust (*Puccinia triticina*) were collected on plot bases. All measured agro-morphological traits were subjected to analysis of variance using Proc lattice and Proc GLM procedures of SAS version 9.2 (SAS, 2008).

Table 1**:** The structure of ANOVA Table for Simple Lattice Design

Source of variation	DF	SS	MS	F-value	Pr>F
Replication	(r-1)	SSR	MSR		
Genotype					
-(Unadj.)	(k^2-1)	SSG_U	MSG_U		
-(adj.)	(k^2-1)	SSG_A	MSG_A		
Blocks within rep (adj.)	r(k-1)	SSB_A	MSB		
Error					
-Effective	(k-1) (rk-k-1)				
-RCB Design	$(r-1)(k^2-1)$				
-Intra block	(k-1) (rk-k-1)	SSE	MSE		
Total	(rk^2-1)	TSS			

Key: k =blocks, r = number of replications, G = genotype, MSR = mean square of replication, MSG_A = mean square of genotype adjusted, MSG_U = mean square of genotypes unadjusted, MSE = Environmental variance (error mean square) = σ^2e

Analysis of phenotypic and genotypic coefficient of variation

Quantitative traits variances (phenotypic, genotypic and environmental variances) and the respective coefficient of variations were calculated following the formula suggested by Burton and DeVane (1953) as follows;

$$\text{Genotypic Variance } (\sigma^2 g)\text{: } \sigma^2 g = \frac{MSg - MSe}{r}$$

Where MSg= mean square of genotypes, MSe = error mean square, r = number of replications.

$$\text{Environmental Variance or error variance } (\sigma^2 e)\text{: } \sigma^2 e = MSe$$

$$\text{Phenotypic Variance } (\sigma^2 p)\text{: } \sigma^2 p = \sigma^2 g + \sigma^2 e$$

Estimates of coefficient of variation were carried out as follows.

Phenotypic Coefficient of Variation (PCV %):

$$PCV = \frac{\sqrt{\sigma^2 p}}{\bar{X}} x100$$

Genotypic Coefficient Variation (GCV %):

$$GCV = \frac{\sqrt{\sigma^2 g}}{\bar{X}} x100$$

Environmental coefficient of variations (ECV%):

$$ECV = \frac{\sqrt{\sigma^2 e}}{\bar{X}} x100$$

Where $\bar{x}$= mean for the trait considered; σ^2p=phenotypic variance; $\sigma^2 g$ =genotypic variance; σ^2e= environmental variance, PCV(%)= Phenotypic coefficient of variation; GCV(%)= Genotypic coefficient of variation, ECV(%)=Environmental coefficient of variations.

Broad sense heritability (H^2) and genetic advances

Heritability (H^2): Heritability in broad sense for all characters were computed using the formula given by Falconer (1996).

$$H^2= (\delta^2 g/\delta^2 p) \times 100$$

where H^2 = heritability in broad sense δ^2g = genotypic variance and δ^2p = phenotypic variance.

Genetic advance under selection (GA):

Expected genetic advance for each character assuming a selection intensity at 5% (K =2.056) were computed using the formula developed by Johnson *et al.* (1955) as:

$$GA = k (\sqrt{\delta^2 p})\, H^2$$

Where GA = expected genetic advance, k is constant (selection differential (K=2.056 at 5% selection intensity), $\sqrt{\delta^2 p}$ = is the square root of the phenotypic variance. Genetic advance as percent of mean (GAM) was calculated to compare the extent of predicted advance of different traits under selection using the formula.

$$GAM = \frac{GA}{\bar{X}} X\ 100$$

Results and Discussion

Analysis of Variance

Analysis of variance (ANOVA) showed mean square due to genotypes were highly significant ($p<0.01$) difference for all traits recorded in the present study (Table 2). Several researchers reported significant differences among bread and durum wheat genotypes studied (Kifle *et al*., 2016, Kumar *et al*., 2016, Wolde *et al*., 2016; Birhanu *et al*., 2016). Similarly, significant differences were reported for major traits in bread wheat (Kalimullah *et al*., 2012; Shashikala, 2006; Naik *et al*., 2015; Rahman *et al*., 2016)

Table 2: Analysis of variance (ANOVA) for quantitative and qualitative traits of 100 durum wheat accessions evaluated

Traits	Mean squares						
	Treatments DF=99	Replications DF=1	Blocks within Replications DF=18	Intra Block Error DF=81	CV%	Eff	R^2(%)
Days to heading	18.41**	1.28	0.99	0.85	1.34	100.38	97.00
Days to maturity	33.58**	0.05	0.77	1.14	1.03	94.12	97.00
Grain filling period	52.75**	1.81	1.78	1.55	3.83	108.69	97.00
Plant height (cm)	366.00**	9.25	58.76	58.76	8.76	100.00	90.00
Biological yield (t ha^{-1})	9.29**	1.83**	0.02	0.03	1.88	96.61	100.00
Grain yield (t ha^{-1})	1.10**	0.02	0.05	0.04	11.93	101.69	97.00
Harvest index (%)	147.33**	1.78	6.45	5.37	12.27	100.60	97.00
Lodging (%)	0.72**	3.43**	0.06*	0.02	9.06	116.47	98.00
spike weight (g)	0.44**	4.81**	0.01	0.01	7.25	101.14	98.00
Thousand kernel weight (g)	206.23**	18.91*	6.95*	3.87	6.07	105.92	99.00
Number of kernels per spike	102.31**	2461.91**	0.02	0.02	0.29	101.29	100.00
Number of spikelet per spike	40.51**	2119.01**	0.81	0.51	2.36	103.63	99.00
Spike length (cm)	9.39**	109.52**	0.22	0.21	5.99	100.04	99.00
Leaf rust	0.46**	0.12	0.07	0.05	8.52	103.20	93.00
Stem rust	0.57**	0.00	0.07	0.04	11.65	102.75	94.00
Gluten (%)	16.77**	33.29**	0.49	0.60	2.44	96.67	97.60
Moisture (%)	0.30**	17.36**	0.04	0.07	2.49	92.26	90.20
Protein (%)	7.95**	11.43**	0.04	0.03	1.04	100.52	99.70
Hectoliter weight (kg hl^{-1})	76.80**	9.54**	0.02	0.03	0.23	96.44	100.00
Water absorption (%)	25.99**	42.30**	0.26	0.38	3.74	94.29	99.00

Key *and ** indicates significance at 0.05 and 0.01 probability levels, respectively. CV (%) = coefficient of variation, DF= degree of freedom Eff. = efficiency of lattice design relative to randomized complete block design and R^2= r- square,

Variance components and coefficients of variation

In the present study, phenotypic variance was found relatively greater than its corresponding environmental variance (Table 3). Environmental variance was found to be lower than its corresponding genotypic variance for most of the quantitative traits as well as for all quality parameters. In agreement with the present finding, Ahmed *et al.* (2008) reported high level of genotypic variance than the environmental variance for days to heading, day to maturity, spikelets per spike, grains per spike, spike weight, thousand kernel weight, Spike length, plant height, and biological yield. Selection is more effective when the genetic variance is higher relative to environmental variance (Poehlman and Sleeper, 2005).

Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values greater than 20% are regarded as high values, PCV and GCV values between 10% and 20% are regarded as medium values and PCV and GCV values that are less than 10% are regarded as low values (Deshmukh *et al*. 1986). High phenotypic coefficient of variations (PCV) were recorded for biological yield (25.10), grain yield (46.59), lodging (37.55), harvest index (46.28), spike weight per plant (34.13), thousand-seed weights (31.60), and spike length (28.79) (Table 3). In line with our present finding, Chand *et al.* (2008) reported higher phenotypic coefficient of variation (PCV) for grain yield per plant and number of grains per spike. In this study, high genotypic coefficient of variations (GCV) were recorded for biological yield (25.02), grain yield (44.81), lodging (36.52), harvest index (44.62), spike weight per plant (33.36), thousand-seed weights (31.02), and spike length (28.15).This implied that the genotypic component had higher roles for phenotypic expression while environmental effects had lower share in the expression of these traits. In agreement to this result, Chand *et al.* (2008) and Jalata *et al.* (2010) reported high values of GCV for grain yield and biological yield. Several authors' also supportive findings in line with the present results (.Sharma *et al.,* 2005; Amsal *et al*., 2006; Desalegn *et al*., 2007; Bekele *et al.*, 2008)

Broad sense heritability and genetic advance

Heritability values classified as very high (≥ 80%), moderately high (60-79%), moderate (40-59%) and low (≤ 40% (Pramoda and Gangaprasad, 2007). If heritability of a character is very high, selection for such characters could be very easy. Heritability values were ranged of 62.16% for moisture contents and 99.95% for number of Kernals per spike, respectively. Genetic advance as per cent of mean varied from 5.22% for the moisture contents to 88.80% for grain yield tons ha^{-1}**,** respectively. While genetic advance varied from 0.55 for the moisture contents% to 21.71 cm for plant height respectively. (Table 3).

In the preset study, the magnitude of heritability was very high for all the characters recorded except for plant height (72.33%) and percent moisture (62.16%) which was moderately high (Table 3). Similar findings were reported by many authors (Azeb *et al*., 2016; Shankarrao *et al.,* 2010; Abinasa *et al*., 2011; Dwived *et al.,* 2002 and Yousaf *et al.*, 2008). In addition, Tazeen *et al.* (2009) found high heritability for days to heading and thousand kernels weight in wheat. Besides, Kumar *et al. (*2014) reported high estimates of heritability for days to heading, number of spikelet per spike, days to maturity, spike length, grain yield, biological yield and harvest index. Falconer and Mackay (1996) classified genetic advance as percent of mean as low (0 -10%), medium (10 - 20%) and high (20% and above). Accordingly, for characters like grain filling period (28.89), plant height (24.81), biological yield (51.38), grain yield (88.80), harvest index (88.63), lodging (73.17), number of kernel per plant (31.93), spike weight (67.17), protein (%) (24.59), thousand kernels weight (62.71), spike length (56.71) and water obsorpitn (44.35) showed higher genetic advance as percent of mean (Table 5). This indicates that most likely the heritability of these characters is due to additive gene effects, and selection might be effective for these characters (Salman *et al*., 2014; Rahman *et al*., 2016).

Similarly, Johnson *et al.* (1955) and Johnson *et al.* (2010b) reported that the estimate of genetic advance is more useful as a selection tool when considered jointly with the estimates of heritability. This means that, heritability value by itself cannot provide the amount of genetic progress that would result from selection of the best individuals. It is not necessarily true that high estimates of heritability are always associated with high genetic gain (Ghuttai *et al.,* 2015). Singh *et al*. (2013) reported high magnitude of heritability and high genetic advance as percentage of mean along with high genotypic and phenotypic coefficient of variation for number of grains per spike, thousand grain weights and grain yield per hectare. Selection based on these characters would be fruitful for improvement in durum wheat. This suggests that these characters were governed by additive genes and recurrent selection could be effective. As a result there is a wide genetic variability within the studied accessions and hence several traits can be improved through conventional breeding activities.

Table 3**:** Estimation of the different variance parameters, heritability and genetic advance for 18 traits of 100 durum wheat accessions

Traits	Mean± SE	Estimates of σ^2 e	σ^2 g	σ^2 p	PCV (%)	GCV (%)	ECV (%)	H^2 (%)	GA (5%)	GAM (%)
DH	68.77(±)0.92	0.85	8.78	9.63	4.51	4.31	1.34	91.17	5.83	8.48
DM	103.57(±)1.07	1.14	15.24	16.38	3.91	3.77	1.03	93.04	7.76	7.49
GFP	34.80(±)1.33	1.78	25.49	27.27	15.00	14.51	3.83	93.47	10.05	28.89
PH	87.54(±)7.67	58.76	153.62	212.38	16.65	14.16	8.76	72.33	21.71	24.81
Bytha	8.60(±)0.16	0.03	4.63	4.66	25.10	25.02	2.01	99.36	4.42	51.38
Gytha	1.57(±)0.19	0.04	0.50	0.54	46.59	44.81	12.74	92.52	1.39	88.80
HI	18.88(±)2.32	5.37	70.98	76.35	46.28	44.62	12.27	92.97	16.73	88.63
LDG	1.62(±)0.15	0.02	0.35	0.37	37.55	36.52	8.73	94.59	1.19	73.17
SWT	1.39(±)0.10	0.01	0.22	0.23	34.13	33.36	7.19	95.56	0.93	67.17
TKW	32.43(±)1.97	3.87	101.18	105.05	31.60	31.02	6.07	96.32	20.34	62.71
NKPS	42.61(±)0.12	0.02	43.64	43.66	15.51	15.50	0.33	99.95	13.60	31.93
NSPS	30.40(±)0.72	0.51	6.18	6.69	8.51	8.17	2.35	92.37	4.92	16.18
SL	7.61(±)1.46	0.21	4.59	4.80	28.79	28.15	6.02	95.63	4.32	56.71
GLT	31.72 (±)0.77	0.60	8.09	8.69	9.29	8.96	2.44	93.09	5.65	17.82
MTR	10.56 (±)0.26	0.07	0.12	0.19	4.07	3.21	2.51	62.16	0.55	5.22
PRT	16.61(±)0.17	0.03	3.96	3.99	12.03	11.98	1.04	99.25	4.08	24.59
HLW	69.42(±)0.16	0.03	38.39	38.42	8.93	8.92	0.25	99.92	12.76	18.38
WAB	16.38 (±)0.61	0.38	12.81	13.19	22.17	21.85	3.76	97.12	7.26	44.35

Key: * The selection differential =2.06 at 5% selection intensity, BY= biological yield tons ha-,[1] H^2(%)= broad sense heritability, DH= days to heading, DM= days to maturity, ECV(%) =environmental coefficient of variation, σ^2e = environmental variance, GAM(%) = genetic advance as percent of mean, GA(5%) = genetic advance, GCV(%) = genotypic coefficient of variation, σ^2g = genotypic variance, GLT= gluten (%),GFP = grain filling period, GY = grain yield tons ha-,[1] HI = harvest index (%),HLW= hectoliter weight (kg hl^{-1}), LDG = lodging(%), MTR= moisture(%),NKPS= number of kernels per spike, NSPS= number of spikelets per spike, PCV(%)= phenotypic coefficient of variation, σ^2p = phenotypic variance , PH = plant height(cm), PRT= protein (%), SL= spike length(cm) , SW = spike weight(g), TKW = thousand kernels weight(g) and WAB=water obsorption (%)

Patterns of quantitative and qualitative traits variation and its importance value for breeding

Wider ranges of variations were observed among durum wheat accessions for all quantitative and qualitative Traits (Table 4). Wider range of variations were observed between genotypes for days to heading, maturity and grain filling period which ranged from 54.50 to 73.00 days (with mean of 68.77 days) and 99.00 to 124.50 days (with mean of 103.57days) and 27.50 to 55.50 days (with mean of 34.80 days), respectively. The present study offers great flexibility for developing improved varieties suitable for various agro-ecologies with variable length of growing period. Early maturing genotypes were desirable in areas where the terminal moisture is the limiting factors for durum wheat production. It also guides breeders to develop a variety which can escape late season drought by improving traits which correlate to days to maturity in the required direction. Supportive findings were reported by (Wosene *et al.*, 2015 and Wolde *et al.*, 2016).The mean of plant height was in the range of 54.25 to 128.75 cm. However, Wolde *et al* (2016) report indicated that plant height for durum wheat varied from 81-144.15 cm. Spike length varied from 4.75 to 19.25 cm. This variability was resulted from the morphological character of the accessions that might be due to variable genetic expression among genotypes and /or spatail environmental influence on the genotypes (Eid, 2009). In some accessions there were absence of exact correspondence between days to heading and days to maturity. That means most accessions with early heading did not show early maturity and late in days to heading were not matched with late maturing (Appendix Table B). This is in agreement with the finding of Khan (2013) who reported that the two characters do not coincide with each other for most of the studied genotypes. However, Mollasadeghi *et al.* (2012) reported that days to heading and maturity coincides each other.

Grain yield, spike weight and number of spikeletes per spike were ranged from 0.64 to 4.58 tons per hectare (with an average of 1.57), 0.70 to 3.00 gram (with an average 1.39 gram), and 21.50 to 42.75 (with an average 30.40) respectively. Parameters like 1000-seed weight, biological yield and harvest index ranged between 13.14 to 48.50 gram (with an average 32.43 gram), 4.33 to 14.94 tons per hectare (with an average 8.60) and 6.28 to 52.76 % (with an average of 18.88%) respectively. (Table 4). The wider variation in grain yield, grain weight per spike, spike weight per plant, number of spikeletes per spike, 1000-seed weight, biological yield and harvest index implied the possibility to develop a variety with higher grain yield and/or other biological yields (Appendix Table B) Variation for percent gluten varied from 126.25 to 39.40 % (with mean of 31.72 %), 99, 54, 41 and 98 were the test entries that showed higher values for gluten contents, moisture content from (9.82 to 12.30 % and mean of 10.56%), protein (from 12.30 to 23.40 % with mean of 16.61%) 81, 91, 41 and 98 were the test entries that showed higher values for protein contents and water absorption from 8.65 to 24.69 % with mean of 16.38 % . Hectoliter weight (kg hl^{-1}) varied from 54.90 to 87.60 kg hl^{-1} (with mean value of 32.70 kg hl^{-1}). 9, 3, 36 and 64 were the test entries that showed higher values for Hectoliter weight leaf rust tolerance. The mean scores for leaf rust and stem rust were ranged from 1.65 to 4.00 (1 to5 scale) (with mean of 2.53) and 1.00 to 3.50 (1 to5 scale) (with mean of 1.82), respectively (Table 4) 48, 9, 41 and 88 were the test entries that were higher tolerance to leaf rust and stem rust tolerance

Table 4: Summary of descriptive statistics of mean performances for 15 and 5 quantitative, and qualititative traits of 100 durum wheat accessions respectively.

Traits	Mean± SE	Min	Max	CV	LSD 5%	Pr > F
Days to heading	68.77(±)0.92	54.50	73.00	1.34	1.86	**
Days to maturity	103.57(±)1.07	99.00	124.50	1.03	2.06	**
Grain filling period	34.80(±)1.33	27.5	55.50	3.83	2.61	**
Plant height (cm)	87.54(±)7.67	54.25	128.75	8.76	15.21	**
Biological yield (t ha-^{1})	8.60(±)0.16	4.33	14.94	1.88	0.32	**
Grain yield (t ha-^{1})	1.57(±)0.19	0.64	4.58	11.93	0.38	**
Harvest index (%)	18.88(±)2.32	6.28	52.76	12.27	4.68	**
Lodging (%)	1.62(±)0.15	0.96	2.85	9.06	0.33	**
spike weight(g)	1.39(±)0.10	0.70	3.00	7.25	0.20	**
Thousand kernel weight (g)	32.43(±)1.97	13.14	48.50	6.07	4.18	**
Number of kernels per spike	42.61(±)0.12	26.00	58.55	0.29	0.25	**
Number of spikelet per spike	30.40(±)0.72	21.50	42.75	2.36	1.50	**
Spike length (cm)	7.61(±)1.46	4.75	19.25	5.99	0.91	**
Leaf rust	2.53(±)0.23	1.65	4.00	8.52	0.45	**
Stem rust	1.82(±)0.22	1.00	3.50	11.65	0.44	**
Gluten (%)	31.72 (±)0.77	26.25	39.40	2.44	1.53	**
Moisture (%)	10.56 (±)0.26	9.82	12.30	2.49	0.52	**
Protein (%)	16.61(±)0.17	12.30	23.40	1.04	0.34	**
Hectoliter weight (kg hl^{-1})	69.42(±)0.16	54.90	87.60	0.23	0.32	**
Water absorption (%)	16.38 (±)0.61	8.65	24.69	3.74	1.22	**

Key: CV=coefficient of variation, LSD = Least significant difference at 5% ,SE=standard error of mean, Min = minimum, Max = maximum, ** significance at 0.01 probability levels,

Conclusions and Recommendations

From this study, it can be concluded that there are comprehensive genetic variability among the studied materials with better agronomic performance that can provide basic information for further breeding activities and thus confident enough to expect genetic progress if further breeding activities are carried out. Accessions, such as Acc.No 5510, 242784, 7375, 7683, 5609, 7710, and 5666 were found to have high grain yield and most of these accessions were more tolerant to economically important leaf rust and stem rust diseases reaction and suggested to be used in breeding programs. Generally, the present findings revealed adequate existence of variability for most of the traits in the studied accessions which need to be exploited in future durum wheat breeding program for the study area.

The present data was generated from an experiment conducted for one season at one location. Therefore, efficient utilization of the available genetic resource and identification of superior genotypes for future breeding still urges intensive and mulit-location morphological diversity study supported by molecular marker system.

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APPENDICES

Appendix Table A: list of checks and 97 durum wheat accessions collected from different regions of Ethiopia and standard checks (Bekalcha, Dire and Obsa) from sinana ARC

Entry code	Acc. No	Region	Latitude	Longitude	Altitude (m.a.s.l)	Entry code	Acc. No	Region	Latitude	Longitude	Altitude (m.a.s.l)
1	7375	Oromia	07-07-00-N	40-43-00-E	1710	26	242785	Oromia	07-50-00-N	39-38-00-E	2410
2	5582	Oromia	08-57-00-N	37-52-00-E	2280	27	7343	Amara	10-18-00-N	38-12-00-E	2460
3	7710	Oromia	07-08-00-N	40-43-00-E	1980	28	7832	Amara	11-21-00-N	39-18-00-E	2300
4	238891	Oromia	07-01-30-N	40-21-07-E	2200	29	6983	Amara	10-28-00-N	38-17-00-E	2430
5	7207	Oromia	07-01-40-N	40-23-55-E	1990	30	5472	Amara	10-28-00-N	38-18-00-E	2410
6	5181	Oromia	07-01-20-N	40-19-46-E	1900	31	5354	Oromia	08-53-00-N	37-51-00-E	2310
7	242782	Amara	11-05-00-N	37-52-00-E	2400	32	5729	Amara	11-06-00-N	39-45-00-E	1790
8	242793	Amara	10-18-00-N	38-12-00-E	2460	33	7647	Amara	11-05-00-N	37-42-00-E	2470
9	7532	Amara	10-18-00-N	38-12-00-E	2460	34	6988	Oromia	09-14-00-N	41-09-00-E	2260
10	7056	Oromia	09-00-00-N	38-07-00-E	2350	35	5583	Oromia	08-54-00-N	38-54-00-E	2300
11	7880	Oromia	07-17-00-N	38-36-00-E	2030	36	7020	Oromia	09-00-00-N	39-07-00-E	2330
12	242781	Oromia	07-44-00-N	39-34-00-E	2140	37	239694	Oromia	38-54-00-N	38-54-00-E	2300
13	5182	Oromia	08-24-00-N	39-52-00-E	2040	38	5183	Oromia	08-47-00-N	39-15-00-E	2300
14	5171	Amara	10-34-00-N	38-14-00-E	2390	39	5556	Oromia	09-47-00-N	39-16-00-E	2200
15	222393	Oromia	08-49-00-N	38-54-00-E	2400	40	5175	Oromia	08-52-00-N	39-01-00-E	2133
16	7649	Amara	10-26-00-N	38-20-00-E	2460	41	5373	Oromia	38-54-00-N	38-54-00-E	2300
17	5216	Oromia	08-12-00-N	39-34-00-E	2150	42	6968	Oromia	09-24-00-N	38-47-00-E	2160
18	5020	Oromia	08-24-00-N	39-52-00-E	2040	43	7664	Oromia	09-01-00-N	39-15-00-E	2300
19	6102	Oromia	07-46-00-N	39-47-00-E	2440	44	7218	Oromia	09-00-00-N	39-07-00-E	2330
20	242790	Oromia	07-41-00-N	40-13-00-E	2395	45	5043	Amara	08-50-00-N	39-19-00-E	2260
21	5184	Oromia	07-45-00-N	39-40-00-E	2400	46	6978	Amara	08-50-00-N	39-19-00-E	2260
22	5515	Oromia	07-44-00-N	39-53-00-E	2430	47	7009	Oromia	08-51-00-N	38-30-00-E	2333
23	5528	Amara	10-18-00-N	38-12-00-E	2460	48	5174	Oromia	08-59-00-N	38-52-00-E	2300
24	7084	Amara	10-14-00-N	38-01-00-E	2440	49	7709	Oromia	09-01-00-N	39-03-00-E	2450
25	7683	Oromia	07-39-00-N	39-46-00-E	2430	50	230678	Oromia	08-51-00-N	38-52-00-E	2300

Appendix Table A: Continued

Entry code	Acc. No	Region	Latitude	Longitude	Altitude (m.a.s.l)	Entry code	Acc. No	Region	Latitude	Longitude	Altitude (m.a.s.l)
51	242789	Oromia	08-54-00-N	39-01-00-E	2350	76	5198	Amara	08-50-00-N	39-19-00-E	2260
52	242792	Oromia	08-59-00-N	38-52-00-E	2300	77	8072	Amara	08-50-00-N	39-19-00-E	2260
53	5214	Oromia	08-58-00-N	39-00-00-E	2420	78	242779	Amara	08-50-00-N	39-19-00-E	2260
54	5428	Oromia	08-47-00-N	39-15-00-E	2300	79	5492	Amara	08-50-00-N	39-19-00-E	2260
55	7801	Oromia	09-01-00-N	39-15-00-E	2300	80	243733	SNNP	09-29-00-N	38-30-00-E	2333
56	242791	Oromia	09-01-00-N	39-15-00-E	2300	81	5638	Oromia	08-51-00-N	38-30-00-E	2330
57	5491	Oromia	08-59-00-N	38-52-00-E	2300	82	242780	Amara	08-50-00-N	39-19-00-E	2260
58	5510	Oromia	08-54-00-N	39-05-00-E	2200	83	5597	Amara	12-38-00-N	37-28-00-E	2100
59	7015	Oromia	08-49-00-N	39-00-00-E	1915	84	5044	Oromia	09-47-00-N	39-46-00-E	2300
60	242784	Oromia	08-45-00-N	39-08-00-E	2350	85	5152	Oromia	08-47-00-N	39-46-00-E	2300
61	5635	Tigray	14-10-00-N	38-42-00-E	2367	86	5554	Amara	10-34-00-N	37-29-00-E	2145
62	5609	Oromia	08-48-00-N	38-54-00-E	2080	87	7018	Amara	11-00-00-N	36-54-00-E	2489
63	5666	Tigray	14-07-00-N	38-29-00-E	2487	88	5669	Oromia	07-12-00-N	38-35-00-E	1773
64	5572	Oromia	08-45-00-N	39-13-00-E	2070	89	7828	Oromia	08-50-00-N	38-22-00-E	1773
65	5504	Oromia	08-45-00-N	39-15-00-E	2120	90	5367	Oromia	08-54-00-N	39-01-00-E	2350
66	5197	Oromia	08-45-00-N	39-13-00-E	2160	91	5344	Amara	12-19-00-N	37-33-00-E	2145
67	7827	Oromia	08-47-00-N	39-15-00-E	2300	92	5434	Oromia	08-47-00-N	39-15-00-E	2300
68	242786	Oromia	08-45-00-N	39-15-00-E	2120	93	5166	Oromia	08-51-00-N	38-30-00-E	2333
69	5653	Oromia	08-45-00-N	39-08-00-E	2340	94	5149	Oromia	08-16-00-N	38-52-00-E	1791
70	5534	Oromia	08-45-00-N	39-15-00-E	2120	95	5169	Oromia	08-59-00-N	38-52-00-E	2300
71	242783	Oromia	09-47-00-N	39-46-00-E	2300	96	5441	Oromia	07-47-00-N	39-39-00-E	2415
72	226897	Oromia	09-47-00-N	39-46-00-E	2300	97	5557	Oromia	08-58-00-N	37-36-00-E	2430
73	5168	Oromia	09-47-00-N	39-16-00-E	2200	98	Bekalcha	SARC			
74	5179	Oromia	09-47-00-N	39-16-00-E	2300	99	Dire	SARC			
75	7825	Oromia	09-47-00-N	39-16-00-E	2300	100	obsa	S ARC			

Appendix Table B: Mean for **agro-morphological** traits of durum wheat accessions tested in 2018 cropping season

E.C	Acc. No	DH	DM	DGFP	PH	LDG	SL	BY	GY	HI	SWT	TKW	NKPS	NSPS
1	7375	67.50	104.00	36.50	105.00	1.25	8.50	10.78	3.13	29.04	1.02	35.50	39.50	32.00
2	5582	69.50	101.00	31.50	101.25	1.25	7.50	7.19	1.28	17.70	1.41	15.50	36.55	28.50
3	7710	66.50	105.50	39.00	128.75	1.00	19.25	13.47	2.88	21.32	1.95	17.00	50.00	25.50
4	238891	69.00	104.50	35.50	89.00	1.60	8.00	8.52	0.97	11.31	0.83	14.50	49.00	31.50
5	7207	70.00	101.50	31.50	95.25	1.60	7.25	10.90	1.49	13.65	1.02	36.00	43.00	24.50
6	5181	66.50	107.50	41.00	84.00	1.60	11.50	9.82	1.88	19.17	3.00	15.50	26.00	29.00
7	242782	67.00	99.50	32.50	94.00	1.00	7.50	9.72	1.84	18.90	1.84	15.50	50.00	29.50
8	242793	69.50	103.00	33.50	107.75	1.00	7.00	12.66	1.82	14.34	1.54	32.50	46.00	28.00
9	7532	70.50	101.00	30.50	90.00	2.60	8.00	10.16	0.64	6.28	0.79	45.50	40.00	30.00
10	7056	64.50	105.50	41.00	97.00	1.60	7.25	8.07	1.84	22.81	1.13	44.50	44.80	29.50
11	7880	72.00	106.50	34.50	92.50	2.85	8.00	10.02	1.08	10.75	1.21	15.50	48.45	37.50
12	242781	70.00	104.00	34.00	106.50	1.00	7.00	8.88	2.54	28.59	1.33	41.50	56.00	33.50
13	5182	65.50	105.50	40.00	69.25	1.60	7.75	11.14	1.42	12.70	1.54	39.50	47.50	34.50
14	5171	66.50	103.50	37.00	78.00	1.00	5.00	6.98	1.97	28.08	1.21	36.50	38.00	32.00
15	222393	66.00	102.50	36.50	88.25	1.60	8.25	7.35	1.97	26.76	2.62	42.50	46.00	22.50
16	7649	70.50	101.50	31.00	90.25	2.85	7.00	9.84	0.94	9.54	1.31	32.50	50.00	34.50
17	Bekalcha	67.50	103.50	36.00	96.00	1.75	7.75	10.12	1.78	17.58	2.01	29.00	49.20	36.00
18	5216	67.50	102.50	35.00	85.50	1.50	7.00	12.15	1.36	11.12	2.02	14.75	35.00	22.75
19	5020	72.00	102.50	30.50	116.25	1.00	9.50	11.12	2.52	22.63	2.14	39.50	50.80	38.75
20	6102	71.50	103.00	31.50	76.75	2.85	6.00	6.39	0.75	11.75	2.37	45.50	40.00	24.00
21	242790	68.50	102.00	33.50	71.25	1.00	6.00	8.45	1.96	23.06	0.82	15.50	46.50	27.00
22	5184	71.50	100.00	28.50	91.75	1.50	6.50	7.59	1.16	15.12	1.39	37.50	48.80	30.75
23	5515	71.50	99.50	28.00	97.00	2.70	6.50	5.62	0.95	16.90	1.19	19.00	35.00	29.00
24	5528	72.50	101.50	29.00	91.25	2.70	6.50	7.03	0.73	10.30	1.38	18.50	53.50	24.50
25	7084	71.00	99.00	28.00	84.25	1.50	7.00	8.45	1.70	20.09	1.64	32.50	42.00	30.00
26	7683	71.50	99.50	28.00	65.75	1.00	6.50	7.64	2.99	39.04	1.76	18.50	33.55	26.00
27	242785	66.50	103.00	36.50	85.25	2.70	7.00	9.98	0.75	7.52	1.31	45.50	38.50	32.00
28	7343	72.00	100.50	28.50	96.00	1.60	6.00	7.77	1.86	23.82	1.06	17.50	42.45	31.75
29	7832	63.50	104.50	41.00	89.25	1.25	6.50	8.29	2.72	32.78	1.57	40.50	42.00	29.00
30	6983	69.50	106.00	36.50	93.75	1.25	9.25	9.12	1.19	13.03	1.27	18.75	44.00	35.25
31	5472	68.50	103.50	35.00	66.00	1.25	7.75	5.18	1.52	29.19	2.40	37.50	26.00	29.00
32	5354	67.50	102.00	34.50	87.25	1.25	5.75	4.33	0.99	22.91	1.11	36.50	38.00	30.00
33	5729	72.50	101.00	28.50	105.25	1.25	6.50	9.98	1.46	14.55	1.13	43.50	34.60	32.25
34	7647	66.00	106.50	40.50	90.25	1.25	9.25	9.20	2.14	23.26	1.08	31.50	42.80	25.50
35	6988	65.50	103.50	38.00	60.50	2.60	8.25	9.24	0.72	7.71	1.61	32.50	46.00	40.50
36	5583	69.50	109.00	39.50	104.25	1.25	5.75	10.37	1.99	19.16	1.07	46.50	45.30	25.00
37	7020	64.00	100.50	36.50	93.00	2.60	7.25	8.54	0.73	8.49	1.62	39.50	44.60	35.00
38	239694	69.50	101.00	31.50	94.75	1.25	8.25	9.10	1.47	16.09	1.09	42.50	48.00	36.50
39	5183	69.00	101.50	32.50	96.25	1.25	9.00	7.97	1.77	22.12	1.10	46.50	52.00	39.00
40	5556	71.50	120.00	48.50	75.00	2.75	8.25	12.35	1.87	15.10	1.38	45.50	44.70	29.00
41	5175	66.50	104.50	38.00	96.25	2.75	7.00	7.96	0.69	8.64	1.74	44.50	29.50	26.00
42	5373	69.00	103.50	34.50	80.25	2.75	6.25	9.98	0.84	8.40	1.05	38.50	43.40	28.50
43	6968	69.50	104.50	35.00	101.50	1.35	7.75	9.10	2.72	29.79	1.23	39.50	52.00	26.00
44	7664	65.50	103.50	38.00	62.75	1.25	4.75	6.23	1.79	28.67	0.99	14.50	42.00	23.75
45	7218	68.50	104.50	36.00	79.50	1.00	7.00	8.28	1.28	15.38	2.95	38.75	42.70	36.25
46	5043	69.00	103.00	34.00	95.50	1.75	7.25	12.41	1.06	8.47	1.26	14.50	43.60	28.75
47	6978	70.50	100.00	29.50	98.75	1.60	9.00	8.89	0.98	10.96	1.59	39.50	49.00	36.00
48	7009	71.50	103.50	32.00	79.50	2.85	7.75	7.24	0.65	8.99	1.81	41.50	26.00	23.00
49	5174	73.00	124.00	51.00	65.25	1.60	6.50	6.21	1.25	20.12	1.28	38.50	38.50	37.25
50	7709	64.50	105.50	41.00	69.25	1.60	8.25	6.36	1.88	29.56	1.19	18.50	48.45	32.75
51	230678	67.00	109.00	42.00	83.50	1.75	9.00	14.22	1.01	7.04	0.98	16.50	43.00	31.25
52	242789	69.00	103.50	34.50	94.00	1.60	5.75	9.53	1.73	18.10	1.44	40.50	42.40	32.75
53	242792	69.50	101.00	31.50	66.75	2.60	7.25	8.05	0.94	11.67	0.75	37.50	56.00	40.00
54	5214	69.00	104.00	35.00	75.75	1.85	5.25	6.48	0.88	13.47	1.22	13.50	32.35	25.25
55	5428	69.50	107.00	37.50	90.25	2.35	5.50	7.43	0.86	11.47	1.04	34.50	40.00	27.75
56	7801	70.50	100.50	30.00	65.00	1.25	5.75	8.04	2.15	26.74	1.81	43.50	40.00	32.50
57	242791	69.00	100.50	31.50	65.75	1.25	7.75	6.23	1.67	26.49	1.85	37.50	35.55	26.00
58	5491	65.50	103.50	38.00	86.75	1.85	7.00	7.57	1.00	13.24	1.17	13.00	49.60	31.75

Appendix Table B: Continued

E.C	Acc. No	DH	DM	DGFP	PH	LDG	SL	BY	GY	HI	SWT	TKW	NKPS	NSPS
59	5510	67.00	106.00	39.00	108.25	1.25	17.25	11.14	4.58	41.06	1.44	20.00	44.00	25.75
60	7015	69.50	101.50	32.00	54.25	1.25	9.25	11.76	1.87	15.84	1.28	21.50	49.50	26.00
61	242784	65.50	104.50	39.00	78.50	1.60	8.75	13.49	3.69	27.33	0.97	19.50	46.00	27.25
62	5635	64.50	112.00	47.50	99.75	1.25	6.75	5.87	2.27	38.53	0.77	31.50	49.00	28.00
63	5609	71.50	101.00	29.50	71.25	1.25	6.00	5.52	2.92	52.76	1.57	19.50	36.40	30.75
64	5666	67.50	104.00	36.50	120.00	1.25	18.00	14.94	2.86	19.08	1.89	43.50	49.00	23.50
65	5572	71.00	102.50	31.50	63.25	2.60	9.50	8.66	1.89	21.81	0.74	36.50	36.35	37.75
66	5504	70.00	102.00	32.00	85.25	2.85	7.00	10.18	0.80	7.88	1.40	30.50	42.45	27.00
67	5197	72.00	99.50	27.50	94.25	1.00	6.50	8.58	1.94	22.57	1.18	35.50	46.00	32.50
68	7827	72.50	102.50	30.00	73.75	1.25	5.00	5.98	1.28	21.39	1.22	41.50	26.00	25.75
69	242786	71.50	101.50	30.00	96.25	1.25	6.75	5.08	1.22	23.84	1.28	43.50	32.45	35.00
70	5653	69.00	102.00	33.00	88.75	1.00	6.00	11.05	2.54	22.96	0.79	14.50	48.00	29.00
71	5534	72.50	100.50	28.00	90.25	1.35	6.00	5.20	1.22	23.26	0.80	35.50	38.00	28.50
72	242783	71.50	100.00	28.50	72.75	1.25	7.50	8.93	1.08	12.03	2.23	43.50	31.55	29.25
73	226897	68.50	104.50	36.00	91.50	2.60	9.00	10.97	1.17	10.62	0.75	36.50	46.00	32.50
74	5168	71.50	102.50	31.00	68.50	1.60	8.50	5.16	1.03	19.94	1.35	18.50	27.00	34.25
75	5179	69.50	103.50	34.00	67.00	1.25	5.75	4.71	1.87	39.58	0.80	36.50	48.00	32.25
76	7825	69.50	102.50	33.00	68.75	2.60	8.50	8.52	0.97	11.33	0.91	31.50	45.35	34.00
77	5198	69.00	124.50	55.50	89.25	1.25	8.00	6.46	2.19	33.88	2.03	35.50	36.00	29.75
78	8072	68.50	104.00	35.50	87.50	1.00	7.25	5.19	1.30	24.94	1.02	41.50	37.00	35.00
79	242779	72.50	101.50	29.00	79.00	1.00	9.25	9.46	2.44	25.82	2.16	41.50	48.00	42.00
80	5492	65.00	102.50	37.50	105.25	1.60	8.50	7.89	1.64	20.80	1.24	45.50	45.00	42.75
81	243733	68.50	103.50	35.00	85.25	2.60	7.25	5.26	0.74	14.07	1.57	48.50	44.00	26.50
82	5638	71.00	102.50	31.50	95.25	1.60	7.50	10.64	1.18	11.06	1.10	17.00	41.30	21.50
83	242780	70.50	101.00	30.50	75.50	1.00	8.25	6.87	0.89	12.97	0.95	48.50	37.00	25.00
84	5597	72.50	103.50	31.00	108.75	1.25	7.25	10.47	2.15	20.57	1.22	16.25	50.00	21.50
85	5044	71.00	103.00	32.00	112.00	1.25	7.25	8.38	2.54	30.32	2.11	36.50	48.00	34.75
86	5152	72.50	103.50	31.00	92.00	1.50	7.25	6.49	0.73	11.18	0.70	17.75	36.00	27.50
87	5554	55.50	101.50	46.00	96.00	1.00	5.75	6.77	1.16	17.06	1.39	35.50	30.00	28.25
88	7018	68.00	102.50	34.50	71.75	1.60	6.50	8.37	0.73	8.67	1.62	18.50	45.55	26.25
89	5669	68.00	101.00	33.00	101.25	1.00	6.00	6.94	1.27	18.22	1.42	31.50	40.00	29.25
90	7828	65.00	107.00	42.00	87.25	2.60	7.25	7.73	0.81	10.37	1.95	43.50	44.50	34.25
91	5367	68.00	102.50	34.50	90.00	1.00	8.25	6.14	1.01	16.31	1.24	35.50	35.65	36.50
92	5344	54.50	101.50	47.00	85.25	1.25	10.50	9.01	1.00	11.11	1.07	39.50	48.00	37.00
93	5434	69.00	100.00	31.00	95.25	1.00	7.25	8.88	1.29	14.54	0.98	19.50	55.00	29.00
94	5166	67.00	102.00	35.00	100.25	2.25	6.25	9.37	0.97	10.28	1.35	24.50	42.35	28.75
95	5149	71.00	101.50	30.50	97.00	1.00	5.75	8.87	2.41	27.06	1.24	40.50	46.00	26.50
96	5169	68.00	103.50	35.50	90.25	1.00	6.75	7.53	1.69	22.39	1.19	44.50	56.00	37.00
97	5441	72.00	102.00	30.00	85.75	1.60	6.75	10.27	2.48	24.11	0.77	41.50	40.20	25.00
98	5557	65.00	106.00	41.00	73.50	1.00	4.75	5.12	1.02	19.80	1.38	41.50	58.55	24.75
99	Dire	71.00	102.50	31.50	73.25	2.35	6.75	9.89	0.99	10.00	0.89	38.50	26.25	30.00
100	obsa	72.00	103.50	31.50	99.25	1.25	8.75	11.24	1.11	9.78	2.33	41.50	41.50	35.75
	Minimum	54.50	99.00	27.50	54.25	0.96	4.75	4.33	0.64	6.28	0.70	13.14	26.00	21.50
	Maximum	73.00	124.50	55.50	128.75	2.90	19.25	14.94	4.58	52.76	3.00	48.79	58.55	42.75
	Mean	68.77	103.57	34.80	87.54	1.62	7.61	8.60	1.57	18.88	1.39	32.43	42.61	30.40
	SE(±)	0.92	1.07	1.33	7.67	0.15	0.46	0.16	0.19	2.32	0.10	1.97	0.12	0.72
	CV%	1.34	1.03	3.83	8.76	9.06	5.99	1.88	11.93	12.27	7.25	6.07	0.29	2.36
	LSD 5%	1.86	2.06	2.61	15.21	0.33	0.91	0.32	0.38	4.68	0.20	4.18	0.25	1.50

Key: E.C = entry code Acc. No = accession number, DH = days to heading, DM= days to maturity, DGFP =days to grain filling period, PH=plant height, LDG = lodging (1-5 scale) and SL = spike length, BY= biological yield tons ha,$^{-1}$ GY = grain yield tons ha^{-},^{1} HI = harvest index (%), SW = spike weight(g), TKW = thousand kernels weight(g), NKPS= number of kernels per spike, NSPS= number of spikelets per spike, SE=standard error of mean, CV%= coefficient of variation, LSD 5%= least significant difference at 5%.

Appendix Table B: Major disease and qualitative traits mean performance for 100 durum wheat accessions tested in 2018/19 cropping season.

E.C	Acc. No	LR	SR	GLT	MTR	PRT	HLW	WAB
1	7375	3.75	3.25	34.35	10.35	16.75	70.75	12.82
2	5582	2.50	1.70	28.30	12.30	13.35	73.00	16.09
3	7710	3.50	3.00	33.00	9.96	14.25	83.00	22.30
4	238891	2.00	1.50	30.95	10.40	19.15	73.40	12.91
5	7207	2.50	1.70	30.40	10.30	15.80	72.20	15.62
6	5181	2.60	1.85	32.75	10.15	15.30	66.10	15.64
7	242782	2.55	1.75	30.45	10.50	17.40	70.40	10.01
8	242793	2.55	1.75	32.70	10.50	16.20	74.20	14.30
9	7532	1.70	1.00	35.40	10.20	17.15	81.90	23.02
10	7056	2.60	1.85	27.45	10.55	16.15	69.95	17.22
11	7880	2.25	1.60	27.45	10.55	15.95	69.95	23.89
12	242781	3.10	2.50	29.50	10.55	13.45	72.20	17.57
13	5182	2.50	1.70	26.80	11.10	15.85	68.00	17.87
14	5171	2.65	1.90	27.85	10.15	13.10	70.20	11.13
15	222393	2.65	1.90	29.30	10.30	16.80	69.40	14.58
16	7649	2.00	1.50	30.85	10.45	15.40	70.55	12.77
17	Bekalcha	2.55	1.75	31.45	11.15	15.20	72.60	15.40
18	5216	2.50	1.70	31.00	11.10	15.10	71.80	16.65
19	5020	3.10	2.50	31.35	10.55	14.10	76.60	23.98
20	6102	2.00	1.00	31.45	10.25	15.10	67.80	18.15
21	242790	2.65	1.90	35.45	10.15	17.15	71.80	15.56
22	5184	2.25	1.60	36.85	10.24	18.10	61.80	17.58
23	5515	2.25	1.60	36.75	10.35	18.19	62.50	15.21
24	5528	1.75	1.25	35.35	10.35	19.15	57.30	17.80
25	7084	2.55	1.75	30.90	10.70	15.05	71.50	15.96
26	7683	3.75	3.25	31.30	10.45	15.35	74.60	11.49
27	242785	1.75	1.00	28.25	11.35	19.50	58.50	22.95
28	7343	2.60	1.85	34.40	10.55	17.25	64.10	17.36
29	7832	3.50	3.00	26.40	10.45	12.30	77.40	18.11
30	6983	2.50	1.70	33.90	10.35	19.75	73.00	16.84
31	5472	2.50	1.70	27.25	11.85	17.20	78.60	22.46
32	5354	2.25	1.60	30.45	10.45	15.35	68.20	11.63
33	5729	2.50	1.70	32.30	10.30	15.00	74.20	16.54
34	7647	2.70	2.00	30.30	10.40	14.25	75.00	13.40
35	6988	1.85	1.00	33.05	10.10	16.55	77.80	17.63
36	5583	2.65	1.90	29.75	10.45	13.95	85.40	15.25
37	7020	1.95	1.00	31.25	10.30	16.75	62.90	10.50
38	239694	2.50	1.70	31.25	10.60	15.90	72.60	19.86
39	5183	2.55	1.75	27.85	11.15	16.25	69.80	13.29
40	5556	2.60	1.85	28.95	10.75	16.40	69.80	17.66
41	5175	1.75	1.00	39.40	10.25	23.15	55.30	14.64
42	5373	2.00	1.50	28.90	11.05	18.30	68.60	15.76
43	6968	3.50	3.00	29.90	10.35	14.15	73.80	17.47
44	7664	2.60	1.85	32.30	10.20	15.15	76.20	11.09
45	7218	2.50	1.70	35.35	10.10	17.24	71.40	14.02
46	5043	2.50	1.70	29.35	10.55	16.05	73.80	18.74
47	6978	2.25	1.60	26.30	10.40	16.75	68.20	13.14
48	7009	1.65	1.00	37.80	10.75	22.20	58.50	16.44
49	5174	2.50	1.70	34.40	10.45	16.35	66.10	24.69
50	7709	2.60	1.80	35.30	10.35	15.40	75.80	12.94
51	230678	2.25	1.60	34.55	10.20	17.75	69.80	12.87
52	242789	2.55	1.75	32.55	10.40	15.45	70.60	15.93
53	242792	2.25	1.60	26.75	10.85	18.05	60.50	15.01
54	5214	2.25	1.35	38.85	10.15	20.31	70.20	14.13
55	5428	1.95	1.25	34.30	10.10	16.45	59.70	18.79
56	7801	2.70	2.00	30.80	11.05	17.07	68.60	14.13
57	242791	2.55	1.75	31.45	10.90	15.20	67.80	18.18
58	5491	2.25	1.60	30.70	10.70	15.80	75.40	16.62

Appendix Table B: Continued

E.C	Acc. No	LR	SR	GLT	MTR	PRT	HLW	WAB
59	5510	4.00	3.50	33.35	10.15	14.30	67.80	21.53
60	7015	2.65	1.90	29.75	10.40	17.20	78.60	16.65
61	242784	4.00	3.50	32.95	10.40	15.45	76.60	13.31
62	5635	2.70	2.00	27.90	11.15	13.15	78.20	17.07
63	5609	3.75	3.25	28.90	9.82	15.00	60.50	18.96
64	5666	3.50	3.00	30.60	10.30	13.40	87.60	15.07
65	5572	2.65	1.90	34.45	10.05	16.15	76.60	23.19
66	5504	1.75	1.25	28.85	10.60	17.30	66.60	23.19
67	5197	2.65	1.90	26.25	10.95	15.40	81.00	16.49
68	7827	2.50	1.70	35.90	10.55	19.22	55.30	13.88
69	242786	2.50	1.70	32.95	10.20	17.25	69.80	11.83
70	5653	3.10	2.50	28.00	11.15	15.85	73.80	15.80
71	5534	2.50	1.70	33.80	10.65	17.88	68.20	13.33
72	242783	2.25	1.60	31.40	10.50	20.70	69.40	14.26
73	226897	2.50	1.70	28.80	11.25	16.45	69.00	22.03
74	5168	2.25	1.60	31.75	10.90	17.15	62.10	18.19
75	5179	2.65	1.90	31.25	10.80	15.45	63.30	16.23
76	7825	2.25	1.60	33.90	10.90	18.10	63.70	10.99
77	5198	2.70	2.00	27.95	10.55	16.30	73.80	22.64
78	8072	2.50	1.70	33.70	10.95	17.30	59.70	22.92
79	242779	2.70	2.00	30.40	10.60	14.45	69.40	10.18
80	5492	2.55	1.75	34.05	11.20	17.75	64.50	18.37
81	243733	2.00	1.00	34.95	11.00	22.20	65.70	14.35
82	5638	2.50	1.70	28.90	10.60	18.07	64.90	18.84
83	242780	2.00	1.50	28.10	10.45	17.10	74.40	10.72
84	5597	2.70	2.00	30.20	10.20	14.10	76.60	24.01
85	5044	3.10	2.50	30.45	10.15	13.60	80.20	8.65
86	5152	2.00	1.00	36.75	10.05	17.35	62.50	9.85
87	5554	2.5.00	1.70	32.50	10.35	16.25	65.70	11.40
88	7018	1.75	1.00	32.85	10.05	16.35	64.10	16.32
89	5669	2.50	1.70	31.75	10.45	16.35	63.70	19.81
90	7828	2.00	1.25	34.95	10.10	17.10	67.60	18.72
91	5367	2.50	1.70	33.40	10.95	22.60	60.90	21.55
92	5344	2.25	1.60	26.75	10.25	13.35	69.80	15.75
93	5434	2.50	1.70	33.65	10.65	17.00	62.90	17.31
94	5166	2.25	1.60	34.90	10.75	17.60	61.70	16.85
95	5149	3.10	2.50	31.20	11.00	16.15	70.20	17.60
96	5169	2.55	1.75	34.05	10.85	17.45	67.80	15.45
97	5441	3.10	2.50	30.50	10.75	15.25	68.60	12.54
98	5557	2.50	1.70	39.40	10.30	23.40	54.90	15.32
99	Dire	2.25	1.60	37.85	10.20	19.30	58.50	18.29
100	obsa	2.50	1.70	28.40	11.30	17.45	64.90	15.25
	Minimum	1.65	1.00	26.25	9.82	12.30	54.90	8.65
	Maximum	4.00	3.50	39.40	12.30	23.40	87.60	24.69
	Mean	2.53	1.82	31.72	10.56	16.61	69.42	16.38
	SE(±)	0.22	0.21	0.77	0.26	0.17	0.16	0.61
	CV%	8.52	11.65	2.44	2.49	1.04	0.23	3.74
	LSD 5%	0.45	0.44	1.53	0.52	0.34	0.32	1.22

Key: E.C = entry code, Acc. No = accession number, LR =leaf rust, SR = stem rust (1-5 scale), GLT= gluten (%), MTR= moisture (%), PRT = protein (%), HLW= hectoliter weight (kg hl^{-1}) and WAB = Water absorption (%) SE=standard error of mean, CV%= coefficient of variation, LSD 5%= least significant difference at 5%

Heterosis and combining ability among sorghum (*Sorghum bicolor* (L.) Moench) genotypes in Western Ethiopia

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Abstract

High-yielding sorghum genotypes with farmer-preferred agronomic traits and durable anthracnose resistance are key drivers of productivity and adoption of sorghum. The objective of this study was to determine heterosis and combining ability effects of selected sorghum genotypes for yield, yield-related traits and anthracnose resistance, to be able to identify superior parents and families for further selection and breeding. Nine selected sorghum genotypes with known resistance to anthracnose were crossed, using a 9 x 9 half-diallel mating design. Parents and F_1 families were evaluated across two locations, using a randomized complete blocks design with three replications. Significant ($p < 0.01$) genotype, location and genotype x location interaction effects were observed for most of the traits and anthracnose resistance, indicating mixed performances of the tested genotypes, allowing for further selection. General Combining Ability (GCA) and Specific Combining Ability (SCA) effects were also significant ($p < 0.01$) for most of the traits, including anthracnose resistance, indicating both additive and non-additive gene action underlying inheritance of the studied traits. Parental genotypes such as Bt-623, 210903, 234112 and 226057 showed positive and significant GCA effects for grain yield. Parents such as 74222, 214852 and 71708 showed negative and significant GCA for anthracnose resistance. The following families: Bt-623 x Gemedi, Bt-623 x 214852, Bt-623 x Chemeda, 214852 x Chemeda, Bt-623 x 226057, 74222 x 234112 and 210903 x 226057showed positive for grain yield and Bt-623 x 234112, Chemeda x 71708, Bt-623 x 74222, 226057 x 71708, Gemedi x 71708, Bt-623 x Chemeda and Bt-623 x 210903 negative SCA effects and anthracnose severity were selected for further breeding for yield gain and anthracnose resistance. The identified parents and crosses are useful sorghum genetic resources for yield gains and anthracnose resistance in future improvement programs in Ethiopia or similar agro-ecologies.

Keywords: Diallel analysis, gene action, general combining ability effect, specific combining ability effect, sorghum breeding

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench, 2n=2x=20) is an important cereal grain and ranks 5th globally after maize, wheat, rice and barley, in terms of total production (FAO, 2017). The grains are energy rich ($\geq$340 calorie per 100 g), high in the levels of protein ($\geq$11.6%), carbohydrates (73%) and fat (3%) (Sebnie and Mengesha, 2018). Sorghum is a staple food for over 500 million people in the semi-arid tropics of sub-Saharan Africa (SSA) and Asia. It adapts to being grown under arid and semi-arid conditions where other major crops fail. Sorghum has various industrial uses, including in the manufacture of beer, syrups, starch, molasses, and livestock feed (Doggett, 1988; House, 1995). Globally, the leading sorghum producing countries are the United States of America, Mexico, Nigeria, Sudan and India, producing approximately 37.8 million tons per annum (FAO, 2014). In Sub-Saharan Africa (SSA), the leading sorghum producers are Ethiopia, Burkina Faso, Nigeria, Sudan, Niger and Mali, with a total annual production estimated at 21.8 million tons (FAO, 2017).

In Ethiopia, sorghum ranks third after tef and maize (CSA, 2017). The area devoted to sorghum production in the country has remained the same between 2010 and 2017 (~ 1.8 million hectares). Contrastingly, total sorghum production increased from 4 to 5 million tons between the same periods (FAO, 2017). Yields during the same period increased from 2.0 to 2.5 tons ha^{-1}. High yields were attributed to, but not limited to, the development and cultivation of improved varieties and the use of other production technologies. However, sustainable sorghum production is affected by abiotic and biotic constraints (Derese *et al*., 2018). Among the biotic constraints, anthracnose caused by the fungal pathogen *Colletotrichum sublineolum* (Henn.) results in significant yield and grain quality losses (Crouch and Beirn, 2009; Sharma *et al*., 2012; Tesso *et al*., 2012). Anthracnose is more prevalent in warmer regions of Ethiopia, including the Southern Nations, Nationalities, and Peoples'; Oromia, Amhara and Tigray, where temperatures and relative humidity are relatively high, favoring disease development. Anthracnose in Ethiopia may cause losses of up to 67% in susceptible varieties (Thomas *et al*., 1996; Thakur and Mathur, 2000; Chala *et al*., 2007; Crouch and Beirn, 2009; Patil *et al*., 2017; Mengistu *et al*., 2018). Moreover, due to limited access to improved and suitable varieties, most small-holder farmers grow poorly adapted, low-yielding and unimproved sorghum genotypes that are highly susceptible to anthracnose (Mengistu *et al*., 2018). Therefore, breeding sorghum genotypes with high yield potential, combining biotic and abiotic stress tolerance and desirable agronomic traits, would be useful for sustainable sorghum production and productivity in Ethiopia. In the past, efforts to develop genotypes with improved yield and yield related traits, and anthracnose resistance have been partially successful (Derese *et al*., 2018; Mengistu *et al*., 2018). This has resulted in a limited release of improved varieties for cultivation, despite tremendous genetic diversity of sorghum present in Ethiopia that can be tapped in breeding programs, nationally and internationally (Adugna, 2014; Weerasooriya *et al*., 2016).

Exploiting heterosis or hybrid vigor among genetically divergent sorghum genotypes can aid in the development of desirable recombinants for high yield-potential and other key yield-influencing traits (Mohammed *et al*., 2015), and anthracnose resistance. Analysis of combining ability of complementary genotypes is a useful tool for the classifying of parental genotypes into distinct heterotic groups to aid identification of “better” combiners that may be hybridized to produce high performing progenies, to be used in production, and for further selection and breeding (Singh and Chaudhary, 1985). A diallel mating design is a commonly used scheme to assess progeny performance based on General Combining Ability (GCA) and Specific Combining Ability (SCA) effects. Combining ability analysis aims to discern the nature of gene action underlying expression of yield and yield related traits (Sprague and Tatum, 1942; Griffing, 1956; Yan and Hunt, 2002). GCA measures mean performance of a genotype in a series of crosses, whereas SCA measures deviation from the predicted performance of a cross, based on the summed general abilities of the associated parents (Schlegel, 2010). GCA and SCA effects are attributed to additive and non-additive gene action, respectively (Acquaah, 2009). Understanding genetic effects underlying trait expression can facilitate development and implementation of appropriate sorghum breeding schemes to develop genotypes with suitable agronomic and grain quality traits, and for resistance to anthracnose (Tariq *et al*., 2014).

Ethiopia is one of the centers of diversity of sorghum. Wider genetic variation is present in the country to select breeding genotypes with tolerance to biotic and abiotic constraints (Weerasooriya *et al*., 2016). Previously, phenotypic and genetic diversity studies (Mengistu *et al*., 2010; Amelework *et al*., 2016; Mindaye *et al*., 2015, 2016; Derese *et al*., 2018) identified and selected genetically differentiated sorghum genotypes. However, information is scarce on heterosis and combining ability of Ethiopian sorghum germplasm for yield performance and resistance to anthracnose. Attempts were made previously to increase sorghum yields in Ethiopia through the introduction and cultivation of genetically superior hybrids. However, most hybrids were poorly adopted by farmers condition due to a lack of suitable yield and yield-related traits (e.g. due to their reduced plant height, early maturity, and small grain size) (Mekbib, 2006; Mindaye *et al*., 2016). Breeding for yield and yield-related traits, and disease resistance, using locally-adapted and genetically complementary sorghum germplasm would be a viable way to boost sorghum production. The objective of this study was to determine combining ability effects and heterosis of selected sorghum genotypes for yield, yield-related traits and anthracnose resistance, as a basis for choosing superior parents and families for further selection and breeding program.

Materials and methods

Plant materials

Nine sorghum genotypes were used in the study, eight of which have moderate resistance and one is susceptible to anthracnose (Table 1). The genotypes were selected for their variation in yield and yield-related traits.

Establishment of diallel crosses

The selected genotypes were crossed using a 9 x 9 half-diallel mating design, at the Bako Agricultural Research Center (BARC), Ethiopia (9º6’ north and 37º09’ east) during 2018 cropping season. This resulted in 36 crosses. The crosses were made by hand emasculation and subsequent pollination. A total of 45 genotypes (36 F_1s and 9 parents) were planted at two locations, namely Bako and Gute, which are situated in western part of Ethiopia. The experiment was laid out in a randomized complete blocks design with three replications. A plot consisted of single row of 2.1 m length with inter-row spacing of 0.75 m and intra-row spacing of 0.15 m was used. Urea/NPS fertilizer was applied at a rate of 100 kg ha^{-1} in two splits (i.e. half at planting and the other half at a plant height of roughly 60 cm). Other cultural practices were done as required.

Table 1 Sorghum genotypes used in a 9 x 9 half diallel crosses in the study.

Genotype Name	Source, country	Reaction to anthracnose
71708	Gambella Region, Ethiopia	Moderately resistant
74222	Tigray Region, Ethiopia	Moderately resistant
210903	Southern Nations, Nationalities, and Peoples' Region, Ethiopia	Moderately resistant
234112	Tigray Region, Ethiopia	Moderately resistant
226057	Amhara Region, Ethiopia	Moderately resistant
214852	Amhara Region, Ethiopia	Moderately resistant
Chemeda	Bako ARC, Ethiopia	Moderately resistant
Gemedi	Bako ARC, Ethiopia	Moderately resistant
Bt-623	Kansas State University, USA	Susceptible

ARC=Agricultural Research Center; USA=United States of America

Data collection

Data were collected on the following agronomic traits: days to flowering (counted as the number of days from sowing to when 50% of the plants flowered), days to maturity (counted as the number of days from sowing to when 95% of the plants reached physiological maturity), plant height (measured in cm from the base to tip of the panicle after flowering), panicle length (cm), panicle width (cm), thousand kernel weight (grams), and grain yield (tons ha^{-1}). Anthracnose severity (%) was determined at physiological maturity. The percentage of total leaf area of plants damaged by anthracnose was recorded, following Chala and Tronsmo (2012). Data were collected on five randomly selected and tagged plants for all characters except for days to flowering, days to maturity, grain yield and anthracnose resistance, which were recorded on a plot basis.

Data analysis

Analysis of variance was computed using SAS software (SAS Institution, 2004). A test of homogeneity of error variance of the locations was performed before combining ability analysis. Combining ability effects were computed using a Diallel SAS 05 program (Zhang *et al*., 2005), according to Griffing (1956) Model I, Method 2, a fixed effect model (Table 2), which involves parents and one set of F_1 hybrids to determine variance components of GCA and SCA, using the following mathematical model:

$$X_{ij} = \mu + g_i + g_j + s_{ij} + \frac{1}{bc}\sum_k \sum_l e_{ijkl} \qquad \begin{cases} i, j = 1, \ldots, p, \\ k = 1, \ldots, b, \\ l = 1, \ldots, c. \end{cases}$$

Where,

X_{ij} = the value of a character measured on cross of i^{th} and j^{th} parents.

μ = population mean

g_i (g_j) = the general combining ability effect

s_{ij} = the specific combining ability effect

e_{ijkl} = the effect peculiar to the $ijkl^{th}$ observation

p, b and c = number of parents, blocks and sampled plants, respectively.

Estimation of variance components and gene action

Variance components of GCA and SCA were calculated using the formula adopted from Singh and Chaudhary, 1985.

i. Variance due to GCA

$$\frac{1}{P-1}\sum g_i^{\,2} = \frac{M_g - M_e'}{p+2}$$

ii. Variance due to SCA

$$\frac{2}{p(p-1)}\sum_{i<j}\sum S_{ij}^{\,2} = M_S - M_e'$$

The predominance of additive vs non-additive gene action was compared from the ratio of components of GCA variance to SCA variance as follows (Baker, 1978):

$$\frac{\frac{1}{p-1}\sum g_i 2}{\frac{2}{p(p-1)}\sum_{i<}\sum_{j} s_{ij} 2} = \frac{\frac{M_g - M_e'}{p+2}}{M_s - M_e'}$$

Where,

M_g = mean sum of squares due to general combining ability

M_s = mean sum of squares due to specific combining ability

M_e' = error mean sum of squares in the combining ability ANOVA

P = number of parents

A GCA/SCA ratio that is greater than unity indicates the predominance of additive gene action, whereas ratios of less than unity indicate the predominance of non-additive gene action for the trait (Baker, 1978).

Estimates of heterosis

The Mid Parent (MP) heterosis and Better Parent (BP) heterosis in percentage were calculated for characters that showed significant differences between genotypes, following a method suggested by Falconer and Mackay (1996):

Mid parent heterosis (%) = $\frac{F_1 - MP}{MP}$ x 100

Better parent heterosis (%) = $\frac{F_1 - BP}{BP}$ x 100

Where, F_1 = mean value of the cross, MP = mean value of the two parents (mid-parent value) and BP = mean value of the better parent

The standard error of the difference for heterosis was calculated as follows:

SE (m) for MP = $\pm\sqrt{\frac{3Me}{2r}}$ and SE (m) for BP = $\pm\sqrt{\frac{2Me}{r}}$

The test of significance for heterosis was calculated as follows:

SE (d) for MP = MP heterosis /$\pm\sqrt{\frac{3Me}{2r}}$, compared with t value at error degree of freedom

SE (d) for BP = BP heterosis /$\pm\sqrt{\frac{2Me}{r}}$, compared with t value at error degree of freedom

Where, SE (m) is standard error of the mean, SE (d) is standard error of the difference, Me is error mean square and r is the number of replications. The minimum values were considered as better parent in the case of disease reactions.

Table **2** Analysis of variance for combining ability for Method 2 and Model I with expected mean squares (Griffing, 1956)

Source	DF	Sum of Squares	Mean Squares	Expectation of Mean Squares Model I
General Combining Ability (GCA)	p-1	S_g	M_g	$\sigma^2 + (p+2)\left(\frac{1}{p-1}\right)\sum g_i^2$
Specific Combining Ability (SCA)	p (p-1)/2	S_s	M_s	$\sigma^2 + \frac{2}{p(p-1)}\sum_i \sum_j s_{ij}^2$
Error	(r-1) ((p(p+1)/2)-1)	S_e	M_e'	σ^2

DF= degree of freedom, p=parents, r=reps, S_g= GCA sum of square (), S_s= SCA sum of square (), S_e= sum of square of error, M_g=mean square of GCA, M_s=mean square of SCA, M_e= mean square of error, g_i = GCA effect, S_{ij}= SCA effect, σ^2 = error variance

Results

Analysis of variance

Combined analysis of variance revealed highly significant ($p < 0.001$) differences among test genotypes for all the traits and their anthracnose reaction (Table 3). Significant ($p < 0.001$) differences were also observed for genotype x location interaction effects for all the traits, suggesting the existence of varied genotypic performance across test locations. GCA by location, SCA by location, and GCA and SCA main effects were significant ($p < 0.001$) for most traits. Highly significant GCA and SCA effects indicate the role of both additive and non-additive gene action in the inheritance of studied traits, respectively.

Performance of test materials for agronomic traits and reaction to anthracnose

Mean values of agronomic traits and reaction to anthracnose among sorghum parental genotypes and crosses are presented in Table 4. Among parental genotypes, days to flowering ranged from 80 days for 71708 to 103 days for Gemedi, with a mean of 88 days. Among crosses, DF varied from 98 days for Bt- 623 x Gemedi to 137 days for 214852 x Chemeda, with a mean of 118 days. Crosses Bt-623 x Gemedi, 234112 x 226057 and 226057 x 214852 were early flowering with 98, 103 and 104 days to flowering, respectively. Contrastingly, crosses Bt-623 x 74222, 210903 x Chemeda, 214852 x Gemedi, 214852 x 71708, Chemeda x Gemedi and 214852 x Chemeda were late flowering with flowering dates of 130, 131, 132, 132, 133 and 137 respectively.

Table 3 Analysis of variance showing mean square values due to location (Loc), replications (location), genotypes, General Combining Ability (GCA) by location, Specific Combining Ability (SCA) by location, and GCA and SCA effects for yield, yield-related traits and anthracnose resistance in sorghum genotypes.

Characters	Mean squares								
	Loc (Df =1)	Rep (L (Df =4)	genotypes (Df =44)	Loc* Entrie (Df =44	GCA* Loc (Df =8)	SCA* Loc (Df = 36)	GCA (Df =8)	SCA (Df = 36)	Error (Df=176)
DF	8170.8**	89.3**	1465.3**	122.7**	155.2**	115.5**	6273.1**	396.9**	19.3
DM	15112.6**	28.0ns	868.7**	160.9**	334.9**	122.2**	3743.5**	229.8**	56.5
PH	132313.1**	2468.2	10650.1**	11408.2**	19002.2**	9720.7**	34292.2**	5396.3**	1234.2
PL	4.2ns	3.0ns	90.8**	20.7**	13.5ns	22.3**	148.0**	78.0**	8.1
PW	2491.0**	9.5ns	45.0**	18.5**	26.7**	16.6**	81.5**	36.9**	4.5
TKW	1091.2**	15.2*	87.3**	9.9**	10.4*	9.8**	294.8**	41.2**	4.8
GY	0.7ns	1.7ns	11.3**	2.6**	5.0**	2.0**	13.0**	10.9**	0.9
Anth	540.5**	26.0ns	468.4**	100.6**	54.5ns	110.8**	389.0**	486.1**	47.2

Days to maturity among parental genotypes ranged from 143 days for Bt- 623 to 157 days for 214852 and Gemedi, with a mean of 150 days. Among crosses, DM varied from 157 days for Bt-623 x 210903 to 188 days for 214852 x Chemeda, with a mean value of 172 days. Crosses Bt-623 x 210903, 210903 x 71708 and 226057 x 214852 reached maturity in ~ 157 days, which was similar to parents 124852 and Gemedi. Crosses 214852 x Chemeda, Chemeda x Gemedi, 214852 x Gemedi, 74222 x Gemedi and 74222 x Chemeda were late maturing (~188 days), whereas crosses Bt-623 x 210903, 210903 x 71708, 226057 x 214852, Bt-623 x 234112 and 210903 x 214852 were early maturing with ~ 157 days to mature.

Cross 74222 x 234112 recorded plant heights of 415 cm which was more than its tall parent 74222 (328 cm). In addition, four crosses with taller plant heights were derived from the same parent (i.e. 74222). Conversely, significantly shorter crosses such as Bt-623 x 234112, Bt-623 x 226057, Bt-623 x Chemeda, Bt-623 x 71708 and Bt-623 x 214852 recorded similar plant height (~ 300 cm) to the short parent Bt-623, which was significantly shorter than other parental genotypes. Crosses 74222 x 234112, 210903 x Gemedi, Gemedi x 71708, Chemeda x Gemedi and 226057 x 71708 recorded high values for plant height, whereas crosses Bt-623 x 226057, Bt-623 x 234112, Bt-623 x Chemeda, Bt-623 x 71708 and Bt-623 x 214852 recorded lower values for plant heights, which were similar to the parental genotype Bt-623.

Panicle length (PL) varied from 23.3 cm for parent Bt-623 to 34.5 cm for parent Gemedi, with a mean of 30.0 cm. For crosses, PL ranged from 22.2 cm for 226057 x 214852 to 40.1 cm for 74222 x Gemedi, with a mean of 31.3 cm. Most crosses exhibited longer panicle length than their respective parents. The greatest panicle width of 21.2 cm was observed for 210903 x Chemeda, whereas the smallest panicle width (9 cm) was exhibited by 226057 x 214852. Panicle width among parents ranged from 8.2 cm for Bt-623 to 19.3 cm for Gemedi, with a mean of 13.5 cm. Five crosses, namely 210903 x Chemeda, 74222 x Gemedi, Chemeda x 71708, 210903 x 226057 and 210903 x Gemedi recorded greater panicle width values than their parents, 21.2, 20.3, 18.2, 17.4 and 17.4 cm, respectively. Almost half of the crosses showed an improvement over their parents for this trait. PW varied from 26.2 g for parents Bt- 623 to 127.1 g for Chemeda.

Table 4 Mean values of agronomic traits and reaction to anthracnose among nine sorghum parents and 36 crosses.

Entry	**DF**	**DM**	**PH**	**PL**	**PW**	**TKW**	**GY**	**Anth**
Parents								
Bt- 623	85	143	272	23.3	8.2	23.	1.7	57.5
210903	85	154	273	28.0	12.0	28.	4.4	21.7
74222	81	148	328	29.8	11.1	32.	4.7	21.7
234112	87	151	265	28.2	10.8	26.	3.5	23.8
226057	89	152	211	31.3	15.8	25.	4.0	25.0
214852	86	157	329	29.9	14.3	27.	3.3	21.7
Chemeda	98	150	285	33.5	16.9	29.	2.5	20.0
Gemedi	103	157	312	34.5	19.3	28.	2.4	26.7
71708	80	146	350	31.5	13.6	29.	3.0	25.8
Parents mean	**88**	**150**	**292**	**30.0**	**13.5**	**27.**	**3.3**	**27.1**
Crosses								
Bt-623 x 210903	107	157	340	33.2	13.2	22.	5.3	21.7
Bt-623 x 74222	130	172	337	26.3	12.5	25.	4.9	23.3
Bt-623 x 234112	107	160	300	34.5	16.6	29.	5.1	20.0
Bt-623 x 226057	110	162	300	29.2	13.9	23.	6.6	48.3
Bt-623 x 214852	112	173	319	28.1	14.5	21.	7.2	28.3
Bt-623 x Chemeda	123	180	308	29.5	12.5	18.	6.1	23.3
Bt-623 x Gemedi	98	172	333	36.3	12.6	27.	6.4	20.8
Bt-623 x 71708	119	174	309	29.0	14.8	26.	6.1	26.7
210903 x 74222	120	179	331	36.4	16.2	25.	5.0	28.3
210903 x 234112	104	164	353	33.2	14.2	29.	5.8	23.3
210903 x 226057	107	168	356	36.2	17.4	24.	5.8	32.5
210903 x 214852	115	160	383	31.1	13.5	21.	3.1	20.0
210903 x Chemeda	131	178	340	37.9	21.2	23.	3.1	24.2
210903 x Gemedi	124	167	411	36.4	17.4	22.	4.3	25.8
210903 x 71708	100	157	372	31.9	15.6	27.	5.1	23.3
74222 x 234112	119	178	415	25.7	12.5	25.	7.2	22.5
74222 x 226057	124	173	372	32.1	17.1	25.	6.4	25.0
74222 x 214852	110	174	322	30.6	12.7	22.	5.1	29.2
74222 x Chemeda	123	182	353	31.8	16.1	23.	4.5	43.3
74222 x Gemedi	127	183	388	40.1	20.3	21.	4.4	35.0
74222 x 71708	112	178	356	31.3	14.6	28.	5.6	27.5
234112 x 226057	103	163	369	24.4	9.7	19.	4.7	22.5
234112 x 214852	112	160	375	26.0	11.0	19.	5.9	34.2
234112 x Chemeda	127	179	385	33.1	13.5	20.	4.8	25.0
234112 x Gemedi	128	181	372	35.8	15.6	19.	5.2	55.0
234112 x 71708	115	172	371	35.3	14.5	21.	6.5	25.0
226057 x 214852	104	157	385	22.2	9.0	20.	5.0	24.2
226057x Chemeda	124	178	340	29.9	12.6	22.	6.5	44.2
226057x Gemedi	123	180	320	30.7	12.4	21.	2.7	25.0
226057x 71708	118	164	390	30.5	14.5	21.	6.3	23.3
214852 x Chemeda	137	188	351	27.5	14.7	15.	4.4	26.7
214852 x Gemedi	132	184	343	29.5	15.8	18.	4.4	27.5
214852 x 71708	132	179	342	29.6	14.2	19.	5.7	24.2
Chemeda x Gemedi	133	186	394	28.0	13.6	19.	3.3	24.2
Chemeda x 71708	128	175	380	29.2	18.2	19.	2.9	21.7
Gemedi x 71708	118	166	400	34.3	15.8	24.	4.	19.2
Cross Mean	**118**	**172**	**356**	**31.3**	**14.6**	**22.**	**5.2**	**27.6**
Mean	112	168	343	31	14	24	4.8	27.5
CV%	4	5	10	9	15	9	24	25
LSD (5%)	5	9	40	3	2	3	1	8
F test	**	**	**	**	**	**	**	**

** = 1% significant level, CV= Coefficient of Variation, LSD=Least Significant Difference, DF= Days to Flowering, DM= Days to Maturity, PH=Plant Height (cm), PL=Panicle Length (cm), PW=Panicle Width (cm), , TKW= Thousand Kernel Weight (g), GY= Grain Yield (ton ha^{-1}), Anth=Anthracnose severity

Thousand kernel weight (TKW) was the highest (32.0 g) for parent 74222 and the lowest (23.8 g) for Bt-623. Among crosses, the highest TKW (29.9 g) was recorded for Bt-623 x

234112 and 210903 x 234112, whereas the lowest (15.3 g) was recorded from cross 214852 x Chemeda. Grain yield varied from 4.7 tons ha^{-1} for parent 74222 to 1.7 tons ha^{-1} for parent Bt-623, with a mean value of 3.3 tons ha^{-1}. Grain yield ranged from 7.2 tons ha^{-1} for cross Bt-623 x 214852 to 2.7 tons ha^{-1} for cross 226057 x Gemedi. High grain yield (> 6.4 tons ha^{-1}) was recorded for crosses Bt-623 x 214852, 74222 x 234112, Bt-623 x 226057, 234112 x 71708, 226057 x Chemeda, Bt-623 x Gemedi and 74222 x 226057, whereas relatively low grain yield (< 3.3 tons ha^{-1}) was recorded from crosses 226057 x Gemedi, Chemeda x 71708, 210903 x 214852, 210903 x Chemeda and Chemeda x Gemedi.

Parents and progenies differed significantly with regards to anthracnose resistance. All parents including standard check varieties were found to be moderately resistant to anthracnose disease. Parent Bt-623, which is a susceptible check variety, recorded the highest disease severity score of 57.5%, reflecting its anthracnose susceptibility. Many crosses such as Gemedi x 71708, Bt-623 x 234112, 210903 x 214852, Bt-623 x Gemedi, Bt-623 x 210903 and Chemeda x 71708 exhibited the lowest scores for anthracnose disease. However, some crosses, e.g., 234112 x Gemedi, Bt-623 x 226057, 226057 x Chemeda and 74222x Chemeda, showed high levels of anthracnose susceptibility score.

Estimates of GCA effects among sorghum parental genotypes

Estimated values of GCA effects among sorghum parental genotypes for yield, yield-related traits and anthracnose resistance are presented in Table 5. Negative and highly significant ($p < 0.01$) GCA effects were recorded for parents Bt-623, 74222 and 214852 in a desirable direction for days to flowering, reflecting their contribution to the breeding of early maturing varieties. Conversely, positive and highly significant ($p < 0.01$) GCA effects was observed for days to flowering for Chemeda, Gemedi and 71708 for the same trait, suggesting that these parents promoted late flowering in their crosses in undesirable manner. The highest significant and negative GCA effect of -22.1 was exhibited by parent Bt-623, whereas a positive GCA effect of 12.8 was exhibited by parent Chemeda for days to flowering.

Parents such as Bt-623, 7422 and 214852 recorded significant ($p < 0.05$) and negative GCA effects for days to maturity in a desirable direction while parents such as 234112, Chemeda and Gemedi recorded significant and positive GCA effects for days to maturity. Contrastingly, parents 71708, Gemedi, 214852 234112 and 210903 showed positive and significant ($p < 0.05$) GCA effects for plant height. Parents with significant and positive GCA effects were better combiners, resulting in increased plant height in their progeny, while those with significant and negative GCA effects resulted in reduced plant height. Parents such as 226057 and Chemeda were average combiners for this trait, showing non-significant GCA effects. A direct relationship was also observed between GCA effects of parents and crosses with regards to plant height. The tallest crosses involved at least one parent with a high GCA effect for plant height, whereas reduced plant height in the crosses involved at least one parent with a low GCA effect.

Parents Gemedi and 210903 were good combiners for panicle length (PL) recording positive and highly significant GCA effects of 1.6 and 2.3, respectively. Bt-623 and 214852 were poor combiners for PL, recording negative and highly significant ($p < 0.001$) GCA effects. Parents

210903, Chemeda, Gemedi and 71708 exhibited positive and significant GCA effects for panicle width, whereas negative and significant GCA effects for PW with values of -1.8, -1.2, -0.7, and -0.5 were observed for parents 214852, Bt- 623, 74222 and 226057, in that order.

Table 5 Estimates of General Combining Ability (GCA) effects for yield, yield-related traits and anthracnose resistance among nine sorghum parental genotypes.

	Parents								
Traits	Bt-623	74222	210903	234112	226057	214852	Chemeda	Gemedi	71708
DF	-22.1^{**}	-2.1^{**}	1.0^{ns}	0.8^{ns}	-0.4^{ns}	-1.4^{**}	12.8^{**}	9.8^{**}	1.6^{**}
DM	-16.4^{**}	-1.9^{*}	-0.9^{ns}	3.7^{**}	-0.5^{ns}	-1.8^{*}	9.7^{**}	8.3^{**}	-0.2^{ns}
PH	-48.4^{**}	-24.9^{**}	0.1^{*}	9.8^{*}	4.4^{ns}	10.8^{**}	-2.9^{ns}	19.6^{**}	21.6^{**}
PL	-1.6^{**}	-0.3^{ns}	2.3^{**}	0.3^{ns}	-0.2^{ns}	-2.6^{**}	-0.1^{ns}	1.6^{**}	0.6^{ns}
PW	-1.2^{**}	-0.7^{**}	1.1^{**}	0.3^{ns}	-0.5^{*}	-1.8^{**}	0.8^{**}	1.4^{**}	0.7^{**}
TKW	3.3^{**}	0.8^{**}	1.7^{**}	1.9^{**}	-1.7^{**}	-1.7^{**}	-2.8^{**}	-1.9^{**}	0.4^{ns}
GY	0.3^{**}	-0.1^{ns}	0.4^{**}	0.4^{**}	0.4^{**}	0.0^{ns}	-0.6^{**}	-0.7^{**}	0.1^{ns}
Anth	4.8^{**}	-3.0^{**}	0.2^{ns}	0.1^{ns}	1.8^{*}	-1.6^{*}	1.0^{ns}	0.2^{ns}	-3.0^{**}

^{ns} =non-significant, *= significant at 5% level of significance, ** = significant at 1% level of significance, DF= Days to Flowering, DM= Days to Maturity, PH=Plant Height (cm), PL=Panicle Length (cm), PW=Panicle Width (cm), , TKW= Thousand Kernel Weight (g), GY= Grain Yield (ton ha^{-1}), Anth=Anthracnose severity

Positive and significant GCA effects were observed for thousand kernel weight (TKW) among four parents namely: Bt-623, 74222, 210903 and 234112 While parents such as 226057, 214852, Chemeda and Gemedi recorded negative significant GCA effects for TKW. Parent 71708 was an average combiner for TKW, with non-significant GCA effect. A positive and significant GCA effect was observed for grain yield among parents Bt-623, 210903, 234112 and 226057 while, parents 74222 and 71708 showed negative and positive non-significant GCA effects for grain yield, indicating that they are average combiners. Chemeda and Gemedi exhibited highly significant ($p < 0.001$) and negative GCA effects for GY.
With regards to anthracnose resistance, three parents, viz. 74222, 214852 and 71708, showed negative and significant GCA effects. Susceptible check varieties such as Bt-623 and 226057 showed positive and significant GCA effects for anthracnose susceptibility suggesting that these parents are not good combiners for improving anthracnose resistance.

Estimates of SCA effects among sorghum crosses

Estimates of SCA effects for agronomic traits and anthracnose among sorghum crosses are presented in Table 6. Crosses Bt-623 x 74222, Bt-623 x 234112, Bt-623 x Chemeda, 210903 x 234112, 210903 x Gemedi, 74222 x 234112, 74222 x 226057, 74222 x 71708 and 226057 x 71708 recorded negative and significant SCA effects for days to flowering (DF). This indicated that these crosses flowered earlier, based on their parental performance. The remaining 12 crosses recorded negative SCA effects for DF, of which nine had significant effects. Notably, crosses such as 210903 x Gemedi, Bt-623 x 74222, 74222 x 234112, 74222 x 71708, 226057 x 71708, Bt-623 x Chemeda, 74222 x 226057, Bt-623 x 234112, Bt-623 x

210903, Bt-623 x 214852, 234112 x 214852 and Bt-623 x 226057) involved at least one parent with low GCA effects for DF.

Regarding Days to Maturity (DM), crosses Bt-623 x Chemeda, 210903 x 234112, 74222 x Gemedi and 214852 x 71708 displayed significant and negative SCA effects. Other crosses such as Bt-623 x 214852, 210903 x 214852 and 214852 x Gemedi had positive and significant SCA effects for DM, suggesting that these combinations resulted in late maturity. Crosses Bt-623 x 234112, Bt-623 x 226057, 210903 x 234112, 74222 x 71708, 234112 x 214852 and 214852 x Gemedi had negative and significant SCA effects for plant height. Crosses Bt-623 x 71708, 74222 x Gemedi, 234112 x 71708, 226057 x Chemeda and 214852 x 71708 had positive and significant SCA effects for plant height, suggesting that, their value for sorghum breeding for enhanced plant height. All crosses with significant positive SCA effects involved at least one parent (e.g. 71708, Gemedi, 214852 and 234112) with good combining ability for plant height. On the contrary, most crosses with negative SCA effects involved recombination of parental genotypes with low GCA effects.

Table 6 Estimates of Specific Combining Ability (SCA) effects for agronomic traits and resistance to anthracnose among sorghum crosses.

	Characters							
Crosses	DF	DM	PH	PL	PW	TKW	GY	Anth
Bt-623 x 210903	-2.72^{ns}	4.45^{ns}	3.1^{ns}	-1.17^{ns}	-0.44^{ns}	0.68^{ns}	-0.75^{ns}	-7.64**
Bt-623 x 74222	-9.75**	-3.05^{ns}	23.7^{ns}	-2.00^{ns}	-3.13**	3.20**	-0.73^{ns}	-9.16**
Bt-623 x 234112	-3.95*	-4.64^{ns}	-39.9**	-1.53^{ns}	-2.72**	-3.01**	-0.35^{ns}	-12.28**
Bt-623 x 226057	-0.83^{ns}	1.25^{ns}	-88.0**	2.09^{ns}	3.12**	-0.43^{ns}	1.23**	14.25**
Bt-623 x 214852	-2.34^{ns}	6.74*	23.5^{ns}	3.07**	3.03**	2.46**	2.19**	-2.34^{ns}
Bt-623 x Chemeda	-5.44**	-11.56**	-6.6^{ns}	4.03**	2.96**	4.85**	2.10**	-8.70**
Bt-623 x Gemedi	3.24^{ns}	-2.87^{ns}	-2.0^{ns}	3.36**	4.81**	3.06**	2.82**	-12.42**
Bt-623 x 71708	4.79**	2.15^{ns}	60.2**	-3.22**	-3.94**	-4.23**	-2.68**	17.82**
210903 x 74222	19.19**	6.21^{ns}	8.8^{ns}	-6.76**	-2.18**	-0.88^{ns}	-0.09^{ns}	3.57^{ns}
210903 x 234112	-4.01*	-10.38**	-28.1*	3.49**	2.58**	3.39**	0.30^{ns}	-1.22^{ns}
210903 x 226057	0.36^{ns}	-3.49^{ns}	-22.5^{ns}	-1.33^{ns}	0.70^{ns}	0.77^{ns}	1.06*	6.15^{ns}
210903 x 214852	2.80^{ns}	8.34**	-10.2^{ns}	-0.01^{ns}	2.67**	-1.65*	-1.97**	-2.95^{ns}
210903 x Chemeda	0.34	4.53^{ns}	-7.7^{ns}	-1.17^{ns}	-1.97*	-2.85**	-0.60^{ns}	-0.14^{ns}
210903 x Gemedi	-21.65**	-2.44^{ns}	-4.9^{ns}	3.86**	-2.41**	5.28**	0.46^{ns}	0.31^{ns}
210903 x 71708	6.45^{ns}	0.25^{ns}	15.1^{ns}	0.38^{ns}	0.76^{ns}	-1.88*	0.80^{ns}	1.84^{ns}
74222 x 234112	-9.71**	-6.55^{ns}	-9.7^{ns}	-0.38^{ns}	-1.54^{ns}	2.49**	1.17**	-5.23*
74222 x 226057	-5.50**	1.68^{ns}	-1.8^{ns}	3.09**	2.46**	0.86^{ns}	0.88*	-4.54^{ns}
74222 x 214852	2.82^{ns}	-5.50^{ns}	19.3^{ns}	0.43^{ns}	-0.10^{ns}	-2.62**	-0.01^{ns}	3.04^{ns}
74222 x Chemeda	4.47**	1.03^{ns}	-9.8^{ns}	4.67**	4.98**	1.13^{ns}	0.17^{ns}	15.84**
74222 x Gemedi	1.15^{ns}	-8.77**	37.8**	1.46^{ns}	0.62^{ns}	-1.19^{ns}	0.49^{ns}	6.30*
74222 x 71708	-8.82**	2.59^{ns}	-35.6*	-1.25^{ns}	-0.80^{ns}	-0.70^{ns}	-0.87^{ns}	-3.54^{ns}
234112 x 226057	11.30**	1.42^{ns}	15.1^{ns}	1.07^{ns}	2.85**	1.12^{ns}	-1.15**	-6.82*
234112 x 214852	-2.21^{ns}	4.07^{ns}	-41.4**	1.93^{ns}	-0.16^{ns}	-1.27^{ns}	0.39^{ns}	8.25**
234112 x Chemeda	-2.56^{ns}	0.60^{ns}	3.3^{ns}	0.57^{ns}	0.66^{ns}	0.83^{ns}	0.72^{ns}	-2.28^{ns}
234112 x Gemedi	4.28**	3.30^{ns}	15.2^{ns}	7.13^{ns}	4.23**	-2.60**	0.63^{ns}	26.51**
234112 x 71708	2.26^{ns}	9.48^{ns}	33.4*	-6.42^{ns}	-3.37**	0.69^{ns}	-0.11^{ns}	-3.24^{ns}
226057 x 214852	1.33^{ns}	-5.37^{ns}	17.0^{ns}	-2.14*	-1.00^{ns}	-0.54^{ns}	0.13^{ns}	-3.55^{ns}
226057 x Chemeda	1.81^{ns}	2.00^{ns}	40.2**	2.34**	-1.1^{ns}	0.66^{ns}	0.36^{ns}	15.08**

226057 x Gemedi	6.65^{**}	4.86^{ns}	4.5^{ns}	3.33^{**}	0.33^{ns}	-0.47^{ns}	-1.64^{**}	-5.29^{*}
226057 x 71708	-6.63^{**}	1.33^{ns}	18.6^{ns}	-2.28^{ns}	-3.71^{**}	-1.41^{ns}	0.14^{ns}	-9.15^{**}
214852 x Chemeda	0.14^{ns}	1.98^{ns}	-11.2^{ns}	1.54^{ns}	-0.70^{ns}	3.51^{**}	1.24^{**}	0.99^{ns}
214852 x Gemedi	2.64^{ns}	5.85^{*}	-53.0^{**}	0.69^{ns}	-1.53^{ns}	0.92^{ns}	0.20^{ns}	0.62^{ns}
214852 x 71708	0.34^{ns}	-8.89^{**}	35.3^{*}	-2.00^{ns}	-0.50^{ns}	-0.76^{ns}	-0.70^{ns}	-1.42^{ns}
Chemeda x Gemedi	-2.70^{ns}	-1.62^{ns}	-16.7^{ns}	-3.13^{**}	-0.70^{ns}	-0.77^{ns}	-0.65^{ns}	-4.08^{ns}
Chemeda x 71708	4.80^{**}	2.04^{ns}	-5.6^{ns}	-5.40^{**}	-2.89^{**}	-4.50^{**}	-2.26^{**}	-9.68^{**}
Gemedi x 71708	5.59^{**}	0.29^{ns}	7.4^{ns}	-10.41^{**}	-1.83^{*}	-3.55^{**}	-1.42^{**}	-9.15^{**}

^{ns} =non-significant, *= significant at 5% level of significance, ** = significant at 1% level of significance, DF= Days to Flowering, DM= Days to Maturity, PH=Plant Height (cm), PL=Panicle Length (cm), PW=Panicle Width (cm), , TKW= Thousand Kernel Weight (g), GY= Grain Yield (ton ha^{-1}), Anth=Anthracnose severity

With regards to panicle length, crosses Bt-623 x 71708, 210903 x 74222, 226057 x 214852, Chemeda x Gemedi, Chemeda x 71708, Gemedi x 71708 showed negative and significant SCA effects, whereas crosses Bt-623 x 214852, Bt-623 x Chemeda, Bt-623 x Gemedi, 210903 x 234112, 210903 x Gemedi, 74222 x 226057, 74222 x Chemeda, 226057 x Chemeda, 226057 x Gemedi expressed positive and significant SCA effects.

Grain yield of eight crosses (i.e. Bt-623 x 226057, Bt-623 x 214852, Bt-623 x Chemeda, Bt-623 x Gemedi, 210903 x 226057, 74222 x 234112, 74222 x 226057 and 214852 x Chemeda) exhibited positive and significant SCA effects. This suggested that these crosses had contributions to improved grain yield (GY). Significant and positive SCA effects were associated with a higher mean performance for GY in the progeny. Crosses Bt-623 x 210903, Bt-623 x 74222, Bt-623 x 234112, Bt-623 x Chemeda, Bt-623 x Gemedi, 74222 x 234112, 234112 x 226057, 226057 x Gemedi, 226057 x 71708, Chemeda x 71708, and Gemedi x 71708 recorded negative and significant SCA effects for anthracnose severity, indicating their valuable resistance to anthracnose. Seven crosses, namely Bt-623 x 226057, Bt-623 x 71708, 74222 x Chemeda, 74222 x Gemedi, 234112 x 214852, 234112 x Gemedi and 226057 x Chemeda had positive and significant SCA effects for anthracnose susceptibility.

Estimates of variance components

Variance components due to GCA, SCA and GCA/SCA ratio are presented in Table 7. The GCA and SCA variance for days to flowering were 94.88 and 45.72, respectively. Higher GCA variance (56.0, 0.71, 194.33 and 18.46) and low SCA variance (26.7, 0.68, 141.50 and 6.96) were observed for days to maturity. Higher SCA variance values and low GCA variance values were recorded for plant height, panicle length, panicle width, thousand kernel weight, grain yield and anthracnose severity. The ratio of GCA to SCA variances was greater than unity for days to flowering and days to maturity indicating that additive gene action predominantly underlies expression of these traits.

Table 7 Estimates of variance components for GCA, SCA and ratio of GCA/SCA for yield, yield-related traits and resistance to anthracnose in sorghum genotypes studied in this experiment.

Characters	Variance components		
	GCA	SCA	GCA/SCA
Days to flowering	94.88	45.72	2.08
Days to maturity	56.70	26.70	2.12
Plant height (cm)	506.72	813.84	0.62
Panicle length (cm)	2.22	12.46	0.18
Panicle width (cm)	1.23	6.01	0.20
Thousand kernel weight	4.43	5.83	0.76
Grain yield (tonne ha^{-1})	0.18	1.43	0.13
Anthracnose (%)	5.99	79.33	0.08

GCA = variance component for general combining ability, SCA= variance component for specific combining ability

Heterosis among sorghum progenies

Estimates of heterosis among sorghum progenies for yield, yield-related traits and reaction to anthracnose are presented in Table 8. Mid parent heterosis (MPH) for days to flowering (DF) ranged from 4.3% for cross Bt-623 x Gemedi to 59.0% for cross 71708 x Chemeda. Better parent heterosis (BPH) varied from -4.9% to 53.5% for the same crosses. Thus, it appeared that the earliest parent Bt-623 contributed to ear genotypes, whereas the late flowering parent Chemeda contributed to lateness. Except for one cross, Bt-623 x Gemedi, all other crosses expressed positive and significant MPH and BPH for DF.

High and positive MPH and BPH were recorded for all progenies for days to maturity (DM), except for Bt-623 x 210903, Bt-623 x 234112, Bt-623 x 226057, 210903 x 74222, 210903 x 226057, 210903 x 214852, 210903 x Gemedi, 210903 x 71708, 234112 x 226057, 210903 x 214852, 226057 x 214852 and Gemedi x 71708. About 64 and 69% of the progenies had positive MPH and BPH for DM.

The lowest MPH and BPH values for plant height of 0.7 and -2.3 % were recorded for 214852 x 71708, whereas the highest values of 55.0 and 39.2 were recorded for 234112 x 226057, respectively. None of the progenies exhibited negative and significant MPH, except two crosses that showed non-significant negative values. About 4 (11%) of crosses showed negative and significant BPH for plant height.

Ten crosses (28%) showed negative and significant MPH values for panicle length (PL). Cross 226057 x 214852 recorded a significant and negative MPH value of -27.5, whereas Bt-623 x 234112 recorded a positive and significant MPH value of 34.0. BPH values ranged from -29.1% for 226057 x 214852 to 22.3% for Bt-623 x 234112. Among all crosses, ten (28%) showed positive and significant BPH values and 17 (47%) crosses showed negative and significant BPH values for PL. Among 36 crosses, eight (22%) displayed positive and significant MPH values for panicle width (PW). The highest MPH value of 207.4% was recorded for Bt-623 x 234112, whereas the lowest MPH value of 22.8% was recorded for 234112 x 226057 for PW. All crosses displayed highly significant and positive MPH values for PW. BPH values ranged from -38.6% for cross 234112 x 226057 to 53.7% for Bt-623 x 234112 for PW. About 58 and 42% of the crosses recorded significant positive and negative BPH values for PW, respectively.

Three crosses (e.g. Bt-623 x 234112, Bt-623 x Gemedi and 210903 x 234112) exhibited positive and significant MPH values, whereas two crosses (e.g. Bt-623 x 234112 and 210903 x 234112) displayed high BPH values for thousand kernel weight (TKW). MPH values ranged from -46.3% for 214852 x Chemeda to 20.1% for Bt-623 x 234112, whereas BPH values ranged from -47.6% to 15.0% for TKW. About 92 and 94% of the crosses recorded significant and negative values for MPH and BPH values for TKW, respectively. MPH values for grain yield (GY) ranged from -19.5% for cross 210903 x 214852 to 212.2% for Bt-623 x Gemedi. Out of 36 crosses, 32 (89%) recorded positive and significant MPH values for GY, whereas three (8.3%) crosses recorded significant and negative MPH values for GY. The highest BPH value of 166.7% was observed for Bt-623 x Gemedi, whereas the lowest value (-32.5%) was recorded the cross 226057 x Gemedi. About 83 and 17% of the crosses recorded positive and negative BPH values for GY, respectively.

With regards to anthracnose resistance, 15 (42%) crosses expressed significant and negative MPH values, whereas eight (22%) of the crosses recorded positive and significant MPH values. Crosses with negative MPH values such as Bt-623 x 210903, Bt-623 x 74222, Bt-623 x 234112, Bt-623 x 214852, Bt-623 x Chemeda, Bt-623 x Gemedi, Bt-623 x 71708 and Gemedi x 71708 were tolerant to anthracnose. MPH values ranged from -50.8% for cross Bt-623 x 234112 to 117.8% for 234112 x Gemedi. BPH values ranged from -25.6% for cross Gemedi x 71708 to 131.1% for 234112 x Gemedi.

Table 8 Mid-parent (MPH) and better parent (BPH) heterosis for yield, yield-related traits and resistance to anthracnose among sorghum progenies.

	DF		DM		PH		PL		PW		TKW		Yield		Anth	
	Percent of heterosis over															
Crosses	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
Bt-623 x 210903	25.9^{**}	25.9^{**}	5.7^{ns}	1.9^{ns}	24.8^{ns}	24.5^{ns}	29.4^{**}	18.6^{**}	120.0^{**}	10.0^{**}	-14.1^{**}	-21.3^{**}	73.8^{**}	20.5^{**}	-45.2^{**}	0.0^{ns}
Bt-623 x 74222	56.6^{**}	52.9^{**}	18.2^{**}	16.2^{**}	12.3^{ns}	2.7^{ns}	-0.9^{ns}	-11.7^{**}	125.2^{**}	12.6^{**}	-9.0^{ns}	-20.6^{**}	53.1^{**}	4.3^{**}	-41.2^{**}	7.4^{ns}
Bt-623 x 234112	24.4^{**}	23.0^{**}	8.8^{ns}	6.0^{ns}	11.7^{ns}	10.3^{ns}	34.0^{**}	22.3^{**}	207.4^{**}	53.7^{**}	20.1^{**}	15.0^{**}	96.2^{**}	45.7^{**}	-50.8^{**}	-16.0^{**}
Bt-623 x 226057	26.4^{**}	23.6^{**}	9.8^{ns}	6.6^{ns}	24.2^{ns}	10.3^{ns}	7.0^{**}	-6.7^{**}	75.9^{**}	-12.0^{**}	-2.9^{ns}	-5.2^{**}	131.6^{**}	65.0^{**}	17.1^{**}	93.2^{**}
Bt-623 x 214852	31.0^{**}	30.2^{**}	15.3^{**}	10.2^{*}	6.2^{ns}	-3.0^{ns}	5.6^{**}	-6.0^{*}	102.8^{**}	1.4^{ns}	-17.8^{**}	-23.7^{**}	188.0^{**}	118.2^{**}	-28.5^{**}	30.4^{**}
Bt-623 x Chemeda	34.4^{**}	25.5^{**}	22.9^{**}	20.0^{**}	10.6^{ns}	8.1^{ns}	3.9^{*}	-11.9^{**}	47.9^{**}	-26.0^{**}	-28.7^{**}	-35.3^{**}	190.5^{**}	144.0^{**}	-39.9^{**}	16.5^{**}
Bt-623 x Gemedi	4.3^{ns}	-4.9^{**}	14.7^{**}	9.6^{*}	14.0^{ns}	6.7^{ns}	25.6^{**}	5.2^{*}	30.6^{**}	-34.7^{**}	7.3^{**}	-1.1^{ns}	212.2^{**}	166.7^{**}	-50.6^{**}	-22.1^{**}
Bt-623 x 71708	44.2^{**}	40.0^{**}	20.4^{**}	19.2^{**}	-0.6^{ns}	-11.7^{ns}	5.8^{**}	-7.9^{**}	117.6^{**}	8.8^{**}	-3.2^{*}	-13.0^{**}	159.6^{**}	103.3^{**}	-35.9^{**}	3.5^{ns}
210903 x 74222	44.6^{**}	41.2^{**}	18.5^{**}	16.2^{**}	10.1^{ns}	0.9^{ns}	26.0^{**}	22.1^{**}	191.9^{**}	45.9^{**}	-17.5^{**}	-21.9^{**}	9.9^{ns}	6.4^{**}	30.4^{**}	30.4^{**}
210903 x 234112	20.9^{**}	19.5^{**}	7.5^{ns}	6.5^{ns}	31.2^{ns}	29.3^{ns}	18.1^{**}	17.7^{**}	163.0^{**}	31.5^{**}	9.5^{**}	4.5^{*}	46.8^{**}	31.8^{**}	2.4^{ns}	7.4^{ns}
210903 x 226057	23.1^{**}	20.2^{**}	9.8^{ns}	9.1^{*}	47.1^{ns}	30.4^{ns}	22.1^{**}	15.7^{**}	120.3^{**}	10.1^{**}	-7.8^{**}	-13.6^{**}	38.1^{**}	31.8^{**}	39.2^{**}	49.8^{**}
210903 x 214852	34.5^{**}	33.7^{**}	2.9^{ns}	1.9^{ns}	27.2^{ns}	16.4^{ns}	7.4^{**}	4.0^{ns}	88.8^{**}	-5.6^{**}	-24.8^{**}	-25.9^{**}	-19.5^{**}	-29.5^{**}	-7.8^{ns}	-7.8^{ns}
210903 x Chemeda	43.2^{**}	33.7^{**}	17.1^{**}	15.6^{**}	21.9^{ns}	19.3^{ns}	23.3^{**}	13.1^{**}	150.9^{**}	25.4^{**}	-17.6^{**}	-18.5^{**}	-10.1^{**}	-29.5^{**}	16.1^{**}	21.0^{**}
210903 x Gemedi	31.9^{**}	20.4^{**}	7.4^{ns}	6.4^{ns}	40.5^{ns}	31.7^{ns}	16.5^{**}	5.5^{*}	80.3^{**}	-9.8^{**}	-21.1^{**}	-21.7^{**}	26.5^{**}	-2.3^{**}	6.6^{ns}	18.9^{**}
210903 x 71708	21.2^{**}	17.6^{**}	4.7^{ns}	1.9^{ns}	19.4^{ns}	6.3^{ns}	7.2^{**}	1.3^{ns}	129.4^{**}	14.7^{**}	-6.0^{**}	-8.0^{**}	37.8^{**}	15.9^{**}	-1.9^{ns}	7.4^{ns}
74222 x 234112	41.7^{**}	36.8^{**}	19.1^{**}	17.9^{**}	40.0^{ns}	26.5^{ns}	-11.4^{**}	-13.8^{**}	131.5^{**}	15.7^{**}	-10.7^{**}	-19.1^{**}	75.6^{**}	53.2^{**}	-1.1^{ns}	3.7^{ns}
74222 x 226057	45.9^{**}	39.3^{**}	15.3^{**}	13.8^{**}	38.0^{ns}	13.4^{ns}	5.1^{*}	2.6^{ns}	116.5^{**}	8.2^{**}	-11.9^{**}	-21.6^{**}	47.1^{**}	36.2^{**}	7.1^{ns}	15.2^{**}
74222 x 214852	31.7^{**}	27.9^{**}	14.1^{**}	10.8^{**}	-2.0^{ns}	-2.1^{ns}	2.5^{ns}	2.3^{ns}	77.6^{**}	-11.2^{**}	-24.1^{**}	-29.1^{**}	27.5^{**}	8.5^{**}	34.6^{**}	34.6^{**}
74222 x Chemeda	37.4^{**}	25.5^{**}	22.1^{**}	21.3^{**}	15.2^{ns}	7.6^{ns}	0.5^{ns}	-5.1^{*}	90.5^{**}	-4.7^{**}	-22.5^{**}	-25.9^{**}	25.0^{**}	-4.3^{**}	107.7^{**}	116.5^{**}
74222 x Gemedi	38.0^{**}	23.3^{**}	20.0^{**}	16.6^{**}	21.3^{ns}	18.3^{ns}	24.7^{**}	16.2^{**}	110.4^{**}	5.2^{**}	-29.9^{**}	-34.1^{**}	23.9^{**}	-6.4^{**}	44.6^{**}	61.3^{**}
74222 x 71708	39.1^{**}	38.3^{**}	21.1^{**}	20.3^{**}	5.0^{ns}	1.7^{ns}	2.1^{ns}	-0.6^{ns}	114.7^{**}	7.4^{**}	-8.2^{**}	-11.3^{**}	45.5^{**}	19.1^{**}	15.8^{**}	26.7^{**}
234112 x 226057	17.1^{**}	15.7^{**}	7.6^{ns}	7.2^{ns}	55.0^{ns}	39.2^{**}	-18.0^{**}	-22.0^{**}	22.8^{**}	-38.6^{**}	-22.0^{**}	-23.5^{**}	25.3^{**}	17.5^{**}	-7.8^{ns}	-5.5^{ns}
234112 x 214852	29.5^{**}	28.7^{**}	3.9^{ns}	1.9^{ns}	26.3^{ns}	14.0^{**}	-10.5^{**}	-13.0^{**}	53.8^{**}	-23.1^{**}	-26.4^{**}	-28.8^{**}	73.5^{**}	68.6^{**}	50.3^{**}	57.6^{**}
234112 x Chemeda	37.3^{**}	29.6^{**}	18.9^{**}	18.5^{**}	40.0^{ns}	35.1^{**}	7.3^{**}	-1.2^{ns}	59.8^{**}	-20.1^{**}	-27.5^{**}	-31.5^{**}	60.0^{**}	37.1^{**}	14.2^{**}	25.0^{**}
234112 x Gemedi	34.7^{**}	24.3^{**}	17.5^{**}	15.3^{**}	28.9^{ns}	19.2^{**}	14.2^{**}	3.8^{ns}	61.7^{**}	-19.2^{**}	-27.3^{**}	-30.1^{**}	76.3^{**}	48.6^{**}	117.8^{**}	131.1^{**}
234112 x 71708	37.7^{**}	32.2^{**}	15.8^{**}	13.9^{**}	20.7^{ns}	6.0^{ns}	18.3^{**}	12.1^{**}	113.2^{**}	6.6^{**}	-22.4^{**}	-27.4^{**}	100.0^{**}	85.7^{**}	0.8^{ns}	5.0^{ns}
226057 x 214852	18.9^{**}	16.9^{**}	1.6^{ns}	0.0^{ns}	42.6^{ns}	17.0^{**}	-27.5^{**}	-29.1^{**}	25.9^{**}	-37.1^{**}	-23.1^{**}	-27.0^{**}	37.0^{**}	25.0^{**}	3.6^{ns}	11.5^{*}
226057 x Chemeda	32.6^{**}	26.5^{**}	17.9^{**}	17.1^{**}	37.1^{ns}	19.3^{**}	-7.7^{**}	-10.7^{**}	49.1^{**}	-25.4^{**}	-15.9^{**}	-21.9^{**}	100.0^{**}	62.5^{**}	96.4^{**}	121.0^{**}
226057 x Gemedi	28.1^{**}	19.4^{**}	16.5^{**}	14.6^{**}	22.4^{ns}	2.6^{ns}	-6.7^{**}	-11.0^{**}	28.5^{**}	-35.8^{**}	-21.1^{**}	-25.5^{**}	-15.6^{**}	-32.5^{**}	-3.3^{ns}	0.0^{ns}
226057 x 71708	39.6^{**}	32.6^{**}	10.1^{ns}	7.9^{*}	39.0^{ns}	11.4^{**}	-2.9^{ns}	-3.2^{ns}	113.2^{**}	6.6^{**}	-20.6^{**}	-27.1^{**}	80.0^{**}	57.5^{**}	-8.3^{ns}	-6.8^{ns}
214852 x Chemeda	48.9^{**}	39.8^{**}	22.5^{**}	19.7^{**}	14.3^{ns}	6.7^{ns}	-13.2^{**}	-17.9^{**}	74.0^{**}	-13.0^{**}	-46.3^{**}	-47.6^{**}	51.7^{**}	33.3^{**}	28.1^{**}	33.5^{**}
214852 x Gemedi	39.7^{**}	28.2^{**}	17.2^{**}	17.2^{**}	7.0^{ns}	4.3^{ns}	-8.4^{**}	-14.5^{**}	63.7^{**}	-18.1^{**}	-34.6^{**}	-35.1^{**}	54.4^{**}	33.3^{**}	13.6^{**}	26.7^{**}
214852 x 71708	59.0^{**}	53.5^{**}	18.2^{**}	14.0^{**}	0.7^{ns}	-2.3^{ns}	-3.6^{ns}	-6.0^{**}	108.8^{**}	4.4^{**}	-31.4^{**}	-33.8^{**}	81.0^{**}	72.7^{**}	1.9^{ns}	11.5^{**}
Chemeda x Gemedi	32.3^{**}	29.1^{**}	21.2^{**}	18.5^{**}	32.0^{ns}	26.3^{ns}	-17.6^{**}	-18.8^{**}	40.9^{**}	-29.5^{**}	-32.8^{**}	-33.9^{**}	34.7^{**}	32.0^{**}	3.6^{ns}	21.0^{**}
Chemeda x 71708	43.8^{**}	30.6^{**}	18.2^{**}	16.7^{**}	19.7^{ns}	8.6^{ns}	-10.2^{**}	-12.8^{**}	167.6^{**}	33.8^{**}	-34.3^{**}	-35.1^{**}	5.5^{**}	-3.3^{**}	-5.2^{ns}	8.5^{ns}
Gemedi x 71708	29.0^{**}	14.6^{**}	9.6^{ns}	5.7^{ns}	20.8^{ns}	14.3^{ns}	3.9^{*}	-0.6^{ns}	132.4^{**}	16.2^{**}	-17.0^{**}	-19.4^{**}	51.9^{**}	36.7^{**}	-26.9^{**}	-25.6^{**}
S.E (Mean)	**3.1**	**3.6**	**5.3**	**6.1**	**24.8**	**28.7**	**2.0**	**2.3**	**1.5**	**1.7**	**1.5**	**1.8**	**0.7**	**0.8**	**4.9**	**5.6**

^{ns}=non-significant, *= 5% significant level, ** = 1% significant level, SE= standard error, MP=mid parent, BP=better parent, DF= Days to Flowering, DM= Days to Maturity, PH=Plant Height (cm), PL=Panicle Length (cm), PW=Panicle Width (cm), , TKW= Thousand Kernel Weight (g), GY= Grain Yield (ton ha^{-1}), Anth=Anthracnose severity

Discussion

Genotype, environment and genotype x environment interaction effects

Development of sorghum genotypes with high yield potential and resistance to anthracnose would enhance sorghum production and productivity. Heterosis and combining ability analysis of genetically diverse and complementary genotypes is useful as a basis from which to develop superior hybrids (Kenga *et al*., 2004). The current study estimated heterosis and combining ability for yield, yield-related traits and anthracnose resistance among sorghum crosses to identify suitable hybrids for further selection and breeding. Analysis of variance revealed significant ($P<0.01$) genotype, location and genotype x location interaction effects for most of the studied traits (Table 1). This indicated the existence of considerable variability for selection. Other researchers (Makanda *et al*., 2009; Akabari *et al*., 2012; Mindaye *et al*., 2016; Chikuta et *al*., 2017; Jadhav and Deshmukh, 2017) have also reported significant variations among genotypes, environments and their interactions for yield and yield-related traits in sorghum. Furthermore, GCA by location effect, SCA by location effect, and GCA and SCA effects were highly significant ($P < 0.001$) for most of the traits and for anthracnose resistance. Significant ($P < 0.05$) location x GCA and location x SCA interaction effects suggested that both additive and non-additive effects of the environment on trait expression, respectively (Kenga *et al*., 2004; Makanda *et al*., 2009; Mohammed *et al*., 2015).

General and specific combining ability effects

Breeding population development is depend on targeted crosses of complementary genotypes possessing yield-influencing and adaptive traits to enhance genetic gains in the progeny. Early flowering and maturity are important phenological traits related to yield-performance and are important traits for ensuring farmer adoption of newly-released sorghum cultivars (Mekbib, 2006). In the current study, the parental genotypes Bt-623, 74222 and 214852 exhibited negative and significant GCA effects for days to flowering and maturity (Table 5), suggesting the value of these genotypes for breeding early flowering and maturing varieties. However, most crosses, including Bt-623 x 74222, Bt-623 x Chemeda, 74222 x 234112, 74222 x 226057 and 74222 x 71708 derived from these parental genotypes (i.e. Bt-623 and 74222) were late flowering (98 to 137 days) and maturing (157 to 188 days) despite the parents exhibiting negative and significant SCA effects for these traits (Table 6). In contrast to the present study, sorghum progenies flowered and matured early than parental genotypes due to additive gene effects in inheritance of these traits (Kenga *et al*., 2004; Makanda *et al*., 2009). Plant height is an important trait for improving biomass production in sorghum (Aruna *et al*., 2013; Reddy *et al*., 2013). In the present study, crosses such as Bt-623 x 234112, Bt-623 x 226057, 210903 x 234112, 74222 x 71708, 234112 x 214852 and 214852 x Gemedi exhibited negative and significant SCA effects for plant height and grew as taller plants than their respective parents (Table 6). This suggested additive gene action in inheritance of plant height. Contrastingly, crosses involving the short parental genotype Bt-623 showed reduced plant height, indicating these crosses inherited height-reducing genes from this parent. Similar results were also reported by Mohammed *et al*. (2015), in sorghum.

Varied GCA and SCA effects were observed for panicle length and panicle width. Crosses Bt-623 x 210903, Bt-623 x 234112, Bt-623 x Gemedi recorded higher values for these traits than the parental genotypes, suggesting genetic gains for these traits. Similar observations were also reported by Bunphan *et al*. (2015) and Chikuta *et al*. (2017) in sorghum. Parental genotypes Bt-623, 74222, 210903 and 234112 showed significant and positive GCA effects for thousand kernel weight (Table 5), whereas several crosses developed from these parents showed varied SCA effects for TKW (Table 6). Crosses Bt-623 x 234112, Bt-623 x Gemedi, 210903 x 234112 and 74222 x 71708 produced kernel weight ≥ 27 g, which were greater than the other crosses and some parental genotypes (Table 4). These suggested parental genotypes contributed to enhanced kernel weight in the progenies. Crosses produced higher grain yield, which varied from 2.7 tons ha^{-1} for 226057 x Gemedi to 7.2 tons ha^{-1} for Bt-623 x 214852, for whereas parents showed lower grain yield ranging from 1.7 tons ha^{-1} for Bt-623 to 4.7 tons ha^{-1} for 74222 (Table 4). Similar to these findings, Bunphan et al. (2015) and Mindaye *et al*. (2016) reported higher grain yield among sorghum hybrids compared to parental genotypes. Higher yields in progenies is indicative of genetic gains for this trait. Seven crosses, namely Bt-623 x 214852, 74222 x 234112, Bt-623 x 226057, 74222 x 226057, Bt-623 x Gemedi, Bt-623 x Chemeda and 214852 x Chemeda exhibited positive and significant SCA effects for grain yield (Table 6).

Anthracnose is a major limiting factor to sustainable sorghum production in Ethiopia (Chala *et al*., 2007; Mengistu *et al*., 2018), resulting in severe yield losses in susceptible varieties. Breeding for anthracnose resistance is key to improving yield levels. Crosses Bt-623 x 234112, Bt-623 x Gemedi, Bt-623 x 210903, Bt-623 x 74222, Bt-623 x Chemeda, Bt-623 x 71708 and Bt-623 x 214852 recorded negative and significant SCA effects for anthracnose resistance (Table 6), which resulted in lower anthracnose severity levels of 20.0, 20.8, 21.7, 23.3, 23.3, 26.7 and 28.3%, respectively (Table 4). The identified progenies serve as useful genetic pool and are recommended for breeding for higher levels of anthracnose resistance in sorghum improvement programmes in Ethiopia. The ratio of GCA to SCA variances was less than unity for plant height, panicle length, panicle width and anthracnose resistance, suggesting non-additive gene action conditioning the inheritance of these traits. Similar to the present study, non-additive gene action was reported for panicle length (Mengistu et al., 2010) in sorghum. Grain yield and thousand kernel GCA/SCA variance components were lower, suggesting these traits were mainly controlled by additive gene action. In contrast to the present study, Hariprasanna et al. (2012) and Mohammed et al. (2015) reported non-additive gene action for grain yield and thousand kernel weight in sorghum.

Estimates of heterosis

Significant variation for Mid-Parent Heterosis (MPH) and Better-Parent Heterosis (BPH) were observed for the studied agronomic traits and anthracnose resistance among crosses (Table 8). This indicated genetic divergence to identify promising crosses for breeding. MPH for days to flowering varied from 4.3 to 59.0%, whereas BPH varied from -4.9 to 53.5%, which were higher than those found in several reports (Reddy *et al*., 2007; Patel et al., 2018; Jaikashan *et al*., 2018) among sorghum progenies. Positive and significant MPH (1.6 to 22.9%) and BPH (0 to 21.3%) values observed in the present study suggest that crosses had positive gains for flowering and maturation times (Table 8). Plant height in sorghum is controlled by several dwarfing genes that probably acted additively, resulting in shorter progenies in the present study (Shukla et al., 2017).

In the present study, varied MPH and BPH values were observed for panicle length and panicle width, concurring with previous reports in sorghum (Ringo et al., 2015; Jaikishan et al., 2018). Desirable combinations (i.e., positive and significant MPH and BPH values) for panicle length and panicle width were observed for crosses Bt-623 x 210903, Bt-623 x 234112, 210903 x 74222, 210903 x 234112, 210903 x 226057, 210903 x Chemeda, 210903 x Gemedi and 234112 x 71708 (Table 8).

Breeding for better yield-related traits is an important breeding objective to increase yield levels in sorghum (Shehzad et al., 2015). MPH and BPH values for thousand kernel weight ranged from -46.3% to 20.1% and -47.6% to 15.0% (Table 8), which are lower than the MPH (0.69 to 48.52) and BPH (-1.13 to 32.14) values reported by Jaikishan et al. (2018) among sorghum crosses. MPH and BPH values for grain yield ranged from -19. to 212.2% and -32.5 to 166.7% among crosses, respectively (Table 8). Similar to the current study, Jaikishan et al. (2018) reported higher MPH (7.10 to 103.28%) and BPH (-3.80 to 88.49%) values among sorghum progenies. Crosses Bt-623 x Gemedi, Bt-623 x Chemeda, Bt-623 x 214852, Bt-623 x 226057, 234112 x 71708, 74222 X 234112 and 74222 x 226057 exhibited positive and significant BPH and MPH values for grain yield, producing higher yields of 6.4, 6.1, 7.2, 6.6, 6.1, 7.2 and 6.4 tons ha^{-1}, respectively (Table 4). The current mean sorghum yield in Ethiopia is ~ 2.5 tons ha^{-1} (FAO, 2017). The identified genotypes provide an excellent genetic pool for improving grain yield potential in Ethiopia. Yield levels of the identified crosses are higher than those reported by Reddy et al. (2007). The current study identified anthracnose resistant crosses such as Bt-623 x 210903, Bt-623 x 74222, Bt-623 x 234112, Bt-623 x 214852, Bt-623 x Chemeda, Bt-623 x Gemedi, Bt-623 x 71708 and Gemedi x 71708. These serve as useful source of genes for breeding for higher levels of anthracnose resistance.

Conclusion

In the present study, combining ability and heterosis were estimated for agronomic traits and anthracnose resistance to identify promising sorghum hybrids for further selection and breeding. Sorghum hybrids Bt-623 x 210903, Bt-623 x 234112, Bt-623 x Chemeda, Bt-623 x Gemedi, 210903 x 234112, 210903 x 71708, 74222 x 234112, 74222 x 226057, 234112 x 71708, 226057 x 214852, 226057 and 214852 were identified with high yields and anthracnose resistance that could be useful for breeding or direct production.

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Analysis of Genotype - by - Environment Interaction and Grain Yield Stability of Medium Maturing Sorghum [*Sorghum bicolor* (L.) Moench] in Western Oromia, Ethiopia

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Abstract

Multi-environment sorghum regional variety trial was carried out using twenty-one genotypes and two standard checks, "Gemedi and Chemeda", in the main cropping seasons of 2017-2018 at Bako and Billo Boshe; but in 2017 at Uke and in 2018 at Gute to identify a stable and better yielding sorghum varieties for the sorghum-growing areas of western Oromia, Ethiopia. The trial was laid down in randomized complete block design in three replications. The ANOVA result showed that large variability exists between the tested sorghum genotypes for grain yield across environments. The combined ANOVA based AMMI model, Environment, Genotype, GxE interactions and PCA 1 revealed highly significant variations. About 49.06% of GxE interaction is explained by IPCA1 and 25.75% by IPCA2. AMMI analysis result showed that ETSL101371 and ETSL100601 attain IPCA values relatively close to zero (-0.06401 and -0.24887) and hence are the best stable and widely adaptable genotypes across locations with higher yield. ETSL 100569, ETSL 100691 and ETSL 10165 scored IPCA values close to zero (0.08628, 0.14570, and -0.16994, respectively) and are stable but with relatively lower mean grain yield. AMMI analysis and GGE biplot based on grain yield data revealed that genotypes ETSL101371 and ETSL10601 were superior to the standard checks in grain yield and stability.

Key Words: AMMI, GxE, Grain yield, GGE Biplot analysis, Sorghum,

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 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). It is an important food grain crop of Ethiopia which contributes about 18% of the total cereal production (CSA, 2017).

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 (Doggette, 1988; Reddy *et al.* 2009). As a major centre of origin and diversity for sorghum (EBI, 2007; Dillon *et al*., 2007; Brenton *et al*., 2016), extensive genetic variation of Ethiopian sorghum were reported.

Phenotypic expression and yield potential of a given genotype is the result of its genetics, the environment and the GXE interactions (Yan, 2001; Yan and Hunt, 2001). 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

Test Materials and Study Area

Twenty-one Sorghum genotypes originally selected from Sorghum and Millets Innovate Lab (SMIL) core collection and the standard checks “Gemedi and Chemeda” were used for this study. The study was conducted for two consiquetive (2017-2018) main cropping season at Bako and Billo Boshe; and for one season Uke in 2017 and Gute research stations in 2018.

Experimental Design and Treatment Arrangement

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

Analysis of variance

Analysis of variance of the randomized complete block design (RCBD) was performed for each of the six environments on the basis of individual plot observation. All data were subjected to analysis of variance (ANOVA) using GenStat Discovery Edition 18^{th} soft ware. Mean comparisons were carried out using unprotected fisheries test model at 5% level of significance.

Additive main effect and multiplicative interaction (AMMI) model

The AMMI model equation was used:

Yger =µ+ág+âe+”nënãgnäen+ åger+ñge;

Where:

Yger is the observed yield of genotype (g) in environment (e) for replication (r); Additive parameters: µ is the grand mean; ág is the deviation of genotype g from the grand mean, âe is the deviation of the environment e; Multiplicative parameters: ën is the singular value for IPCA, ãgn is the genotype eigenvector for axis n, and äen is the environment eigenvector; åger is error term and ñge is PCA residual.

Genotype and genotype by environment interaction (GGE) biplot

The genotypes and genotype by environment (GGE) biplot analysis is the most common and currently utilized efficient model (Yan and Tinker 2005; Yan *et al.*, 2007) to determine genotype by environment interaction and stability. GGE biplot analysis was carried out using Genstat soft ware 16th edition and using the method proposed by Yan (2001) for multi environment data.

To analysis, different methods were used.

Table 1. Designation, name and Collection Areas of Sorghum Genotypes tested across environments in Ethiopia

S no	Genotype	Acc No	Source	Region of Collection
1	Chemeda	(Acc.BRC-18)	OARI/BARC	Oromiya
2	ETSL 100126	2001PWColl#076	EIAR/MARC	B. Gumuz
3	ETSL 100560	25130	EIB	Amahara
4	ETSL 100569	69078	EIB	SNNP
5	ETSL 100601	69251	EIB	Amahara
6	ETSL 100622	69358	EIB	Gambela
7	ETSL 100652	69426	EIB	Gambela
8	ETSL 100691	69500	EIB	SNNP
9	ETSL 100705	69538	EIB	Oromiya
10	ETSL 100743	70526	EIB	Oromiya
11	ETSL 100810	71143	EIB	Oromiya
12	ETSL 100845	71484	EIB	Tigray
13	ETSL 100914	71720	EIB	Gambela
14	ETSL 101371	212642	EIB	Amahara
15	ETSL 101519	235622	EIB	SNNP
16	ETSL 101651	239241	EIB	Amahara
17	ETSL 101849	71500	EIB	Oromiya
18	Gemedi	Acc.BRC-05	OARI/BARC	Oromiya
19	IS 25531	IS 25531	EIAR/MARC	-
20	IS 25542	IS25542	EIAR/MARC	-
21	IS 38279	IS38279	EIAR/MARC	Amahara

Results and Discussion

Analysis of variance

The analysis of variance (ANOVA) result indicated that the main effects of environments showed highly significant differences ($p \leq 0.001$) between the tested genotypes for the grain yield in all environments (Appendix Table 1). This is due to the presence of genetic variability among the genotypes in the varied environments; i.e. genotypes were responded differently at different test environments. The mean grain yield of the twenty-one tested genotypes ranged from 2.28 t ha^{-1} (Chemeda) to 5.35 t ha^{-1} (ETSL101371), with grand mean of 3.67 t ha^{-1} (Table 3).

Additive Main Effects and Multiplicative Interaction (AMMI) Model

The result for the additive main effects and multiplicative interaction (AMMI) model across the six test environments is shown in Table 2. The pooled analysis of variance gave an estimate of genotype × environment interaction, which measures changes in rank and magnitude of fluctuations about the mean of different environments. The AMMI analysis of variance for grain yield (ton ha^{-1}) showed that the mean squares due to environments, genotypes, genotype × environment interaction and PCA 1and 2 were highly significant ($p \leq 0.001$) (Table 2). The analysis result indicates the existence of variability among the genotypes for grain yield and the test environments were highly variable. The mean grain yield across the six environments ranged from 2.859 t ha^{-1} at Billo Boshe in 2018 to 5.001 t ha^{-1} at Gute in 2018 (Table 3). This implies, different locations during the different seasons significantly influenced grain yield. The presence of significant genotype by environment interaction indicates that, genotypes responded differently to the variation in environmental conditions of test sites emphasizing the need for testing sorghum genotypes at multiple locations. Similar results were reported by, Gebeyehu *et al*, 2019 Abebe *et al.*, (1984) on sorghum; Kebede *et al*. (2019) in black seeded finger millets.

The GXE interaction effect was further partitioned into two interaction principal component axis (IPCA) and IPCA values of genotypes in AMMI analysis are an indication of the wide adaptability over environments and association between genotypes and environments. The first interaction principal component (IPCA1) explained 49.06% and the second IPCA2 further explained 25.76% and the cumulative principal components explained 74.82% of the genotype by environment interaction sum of square. Since the first two interaction principal component axes (IPCA) were significant, they were selected to describe genotype by environment interaction and placement on the bi-plots. When the two interaction principal components were significant ($P \leq 0.001$) while the others IPCA were non-significant, the AMMI-1 with only the two interaction principal component axis was the best predicative model for grain yield (Gollob 1968; Zobel *et al.* 1988 and Alberts, 2004). So, the interactions of the 21 genotypes with six environments were best predicted by the two interaction principal components. Similar report was suggested by Sintayehu and Kassahun, 2017 on GXE interaction and Stability study of Ethiopian sorghum.

In the present study based on the AMMI model analysis result, genotype ETSL101371 and ETSL100601 attained IPCA value of (-0.06401 and -0.24887), respectively with relatively closer to zero, and gave high yield. Hence, these genotypes are the best stable and high yielder across locations than the standard check (Gemedi) with 0.01096 PCA 1 value and other tested genotypes (Table 3) ETSL 100569, ETSL 100691 and ETSL 10165 scored IPCA values close to zero 0.08628, 0.14570, and -0.16994) respectively, but recorded lower mean grain yield. Therefore, genotypes ETSL 101371 and ETSL 100601 are selected as potential candidates for variety verification (Table 4)

Table 2: Analysis of variance for grain yield using AMMI model

				% Explained		
Source	d.f.	s.s.	m.s.	Total	GXE	Cumulative interaction
Environments	5	237.6	47.529**	49.28		
Genotypes	20	169.9	8.495**	21.99		
GXE Interactions	100	247	2.470**	28.73		
IPCA 1	24	121.2	5.049**		49.06	49.06
IPCA 2	22	63.6	2.892**		25.76	74.82
Residuals	240	177.8	0.741			
Total	377	850.9	2.257			

LSD testing done at $\alpha = 0.05$; ** = highly significant with $p \leq 0.001$, * = significant with $p \leq 0.05$.
df= degree of freedom, SS=sum of squares, MS= mean squares, IPCA=Interaction Principal Component Axis

Table 3. Grain yield (GY) (t ha-1) and IPCA1 scores of tested sorghum genotypes

S no	Genotype	Mean	IPCA1	IPCA2
1	Chemeda	2.279	-0.58624	0.25579
2	ETSL 100126	3.503	0.53479	-0.35872
3	ETSL 100560	3.563	0.52753	-0.49199
4	ETSL 100569	3.73	0.1457	-0.2826
5	ETSL 100601	3.986	-0.24887	-0.1612
6	ETSL 100622	2.37	-0.95428	0.9171
7	ETSL 100652	3.337	-0.93323	-0.46067
8	ETSL 100691	3.045	-0.16994	0.10632
9	ETSL 100705	3.616	-0.63358	0.22937
10	ETSL 100743	2.868	-0.57811	-0.23843
11	ETSL 100810	3.801	0.6819	-0.50309
12	ETSL 100845	2.822	0.77158	0.63228
13	ETSL 100914	4.286	0.40958	0.11323
14	ETSL 101371	5.348	-0.06401	0.18957
15	ETSL 101519	4.197	0.38888	0.91817
16	ETSL 101651	3.716	0.08628	0.0703
17	ETSL 101849	3.462	0.85214	0.27859
18	Gemedi	3.625	0.01096	0.00146
19	IS 25531	3.375	0.59243	-0.25516
20	IS 25542	2.829	-0.4535	-1.0867
21	IS 38279	3.117	-0.38	0.12634
Environment				
1	BB2017		2.859	-0.71534
2	BB2018		2.924	0.12767
3	Bk 2018		3.985	0.33889
4	BK2017		2.807	-0.5018
5	Gt2018		5.001	1.98449
6	UKe2017		3.246	-1.23391

BB2017=Billo Boshe2017, BB2017=Billo Boshe 2018, Bk 2018=Bako2017, BK2017= Bako2018, Gt2018=Gute2018, UKe2017=Uke2017

Biplot analysis

The AMMI model was used to analyze Biplot graph (Figure 1) using individual environments and mean grain yield performances of sorghum genotypes in XY plan. X-axis is designated for mean grain yield, while Y-axis for IPCA 1 scores. A single arrowed line that passes through the biplot origin and points to higher mean yield across environments was drawn. The line is called the average environment coordination (AEC) abscissa. The arrow directs towards higher average yield and hence genotypes on the right side most of this line have the highest average yield. Single arrowed line that is perpendicular to AEC abscissa was also drown and this line is called the AEC ordinate and is labeled as Perpendicular Line (PL). This line points towards greater variability in either direction and hence genotype that has longer vector along this line is highly unstable (Ilker *et al*., 2011).

As indicated in Figure 1, each environment and variety main effect was plotted along the abscissa against their respective IPCA1 score as ordinate. The vertical line that crosses through the centre of the biplot is represented by the experimental grand mean of grain yield derived from all varieties and environments, while the horizontal line illustrates the point where IPCA1 score =0. Genotypes and Environments that fall on the right side of the vertical line of grain yield are rated as high-yielding genotypes and potential ideal environments, and the remaining fall on the left side of the line are low-yielding genotypes and low-potential environments for sorghum production. Genotypes and environments positioned at the same side of the IPCA axis are interacting positively and produce desirable effects.

Therefore, in this study, genotypes ETSL101371, ETSL100601 and ETSL100914 gave high grain yield above the mean, while ETSL100845, ETSL100622, ETSL1007431, Chemeda, IS38279, and ETSL100691 gave lower yield below the mean and are considered as low-yielding genotypes. Environments Gute-2018, Uke-2017, Billo Boshe-2017 and Bako-2018 are high-potential environments, while Billo Boshe2018 and Bako2017 are poor-yielding/potential environments. In other hand, Genotype ETSL101371, ETSL100601 and ETSL100914 are best suited to environments Bako2018 and Gute 2018 and genotypes ETSL100622 and ETSL 652 to environments Uke2017 and Billo Boshe2017.

Genotypes and environments contribution to the GXE interaction were estimated based on the magnitude of the corresponding IPCA 1 score, which is measured as the perpendicular distance from the benchmark, IPCA 1 = 0; thus, the more genotypes or environments deviate from the IPCA1 axis, the more they contribute to the GXE interaction variances and are the more unstable. Accordingly, genotypes ETSL100652, IS25531, ETSL101819 and ETSL100705 had a very low contribution to the total GXE interaction sum square, whereas, ETSL101371, ETSL100914, Chemeda and ETSL10062, highly contributed to the GXE interaction sum square, suggesting that they are highly interactive with growing environments. Similar results were reported by Sintayehu and Kassahun (2017) for Ethiopian sorghum and Al-Naggar *et al*., (2018) for Some Agronomic and Yield Traits of Sorghum in Egypt.

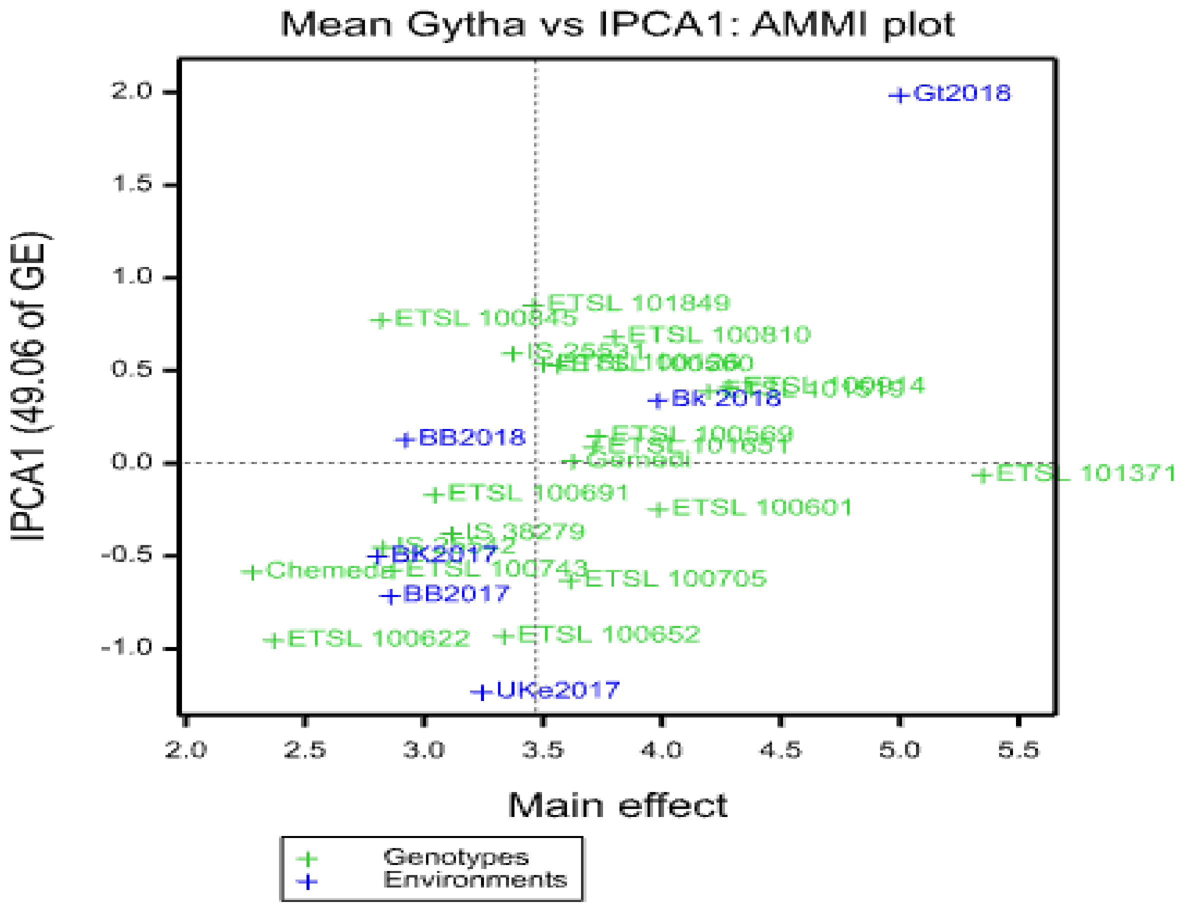

Figure1. AMMI biplot illustrating the two main axes of interaction (IPCA2 Vs IPCA1) in twenty- one sorghum genotypes evaluated for grain yield at four sites of western Oromia, Ethiopia during 2017 to 2018.

The GGE Biplot also indicated ETSL101371 is positioned in the first concentric circle and away from the mean vertical line to the right closer to the stability arrow followed by ETSL100601. This showed that, these two genotypes are the most stable and high yielding genotypes. The biplot result is also in harmony with the AMMI model.

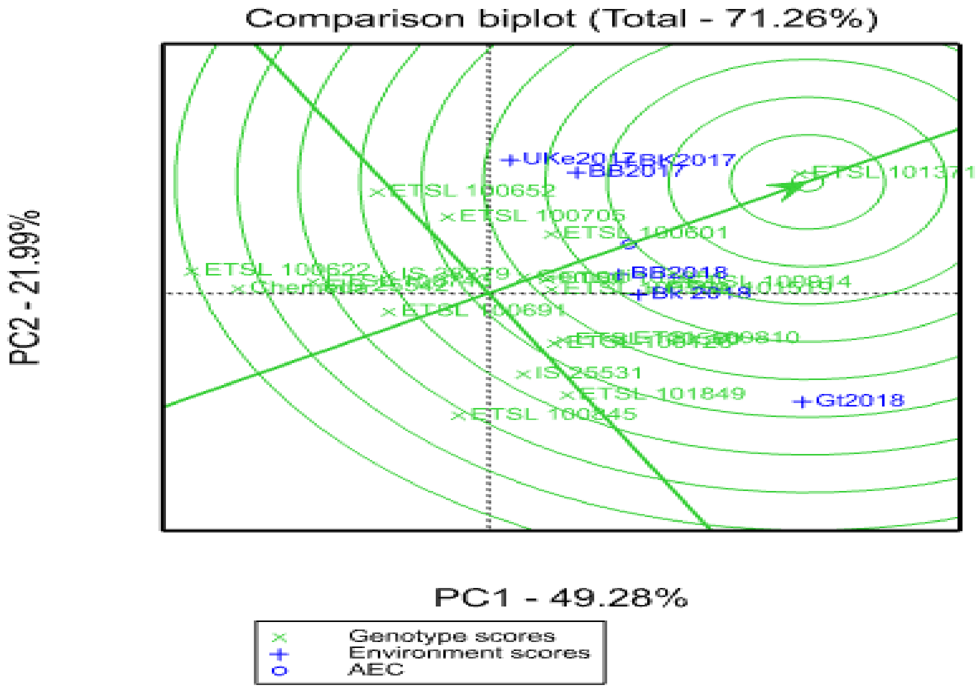

Fig 2: GGE biplot analysis showing stability of genotypes and test environments

Conclusion

This study result revealed highly significant (P≤0.001) difference among environment (E), genotype (G) and genotype × environment interaction (GxE). Environment explained 49.28% of the total variation, whereas G and GxE interaction explained 21.99 and 28.73% of the total variation, respectively. The magnitude of the environment was much greater than the genotype, indicating that a large variation in grain yield was due to the environment. Based on the combined analysis of variance over locations, the mean grain yield of environments ranged from 2.807 t ha^{-1} in Bako2017 to 5.001tha^{-1}. Based on analysis result, sorghum genotypes ETSL101371 and ETSL100601 gave high grain yield, better adaptability and more stable performance than all tested genotypes & checks. The genotypes are also relatively tolerant to foliar and grain disease (Appendix Table 1). Mean GxE interaction of 49.06% is explained by IPCA1 and 25.75% is by IPCA2. AMMI analysis result revealed that ETSL101371 and ETSL100601 attain IPCA values relatively close to zero (-0.06401 and -0.24887) and hence are the best stable and widely adaptable genotypes across location. ETSL 100569, ETSL 100691 and ETSL 10165 scored IPCA values close to zero 0.08628, 0.14570, and -0.16994) respectively, but recorded relatively lower mean grain yield. ETSL100845, ETSL100622, ETSL1007431, Chemeda, IS38279, and ETSL100691 gave lower yield below the mean and are considered as low-yielding genotypes. Environments Gute2018, Uke2017, Billo Boshe2017 and Bako2018 are high-potential environments, while Billo Boshe2018 and Bako2017 are poor-yielding environments. Both AMMI and GGE Biplot analyses result revealed ETSL101371 and ETSL100601 are the most stable and high yielding genotypes and as a result, they were proposed as candidate variety for verification at Bako, Gute, Billo Boshe, Uke and similar agro ecologies of the western Oromia, Ethiopia.

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APPENDIX Table 1: Mean Grain yield (ton ha^{-1}) of Genotypes over the tested location & across years

Genotype	Mean Grain Yield tonha^{-1}							GM Se (1-5)	Anth Se(1-5)	GY advant (%)
	Bako		B. Boshe		Gute	Uke				
	2017	2018	2017	2018	2018	2017	Mean			
1. Chemeda	2.37	1.23	2.38	1.10	2.97	2.18	2.28	1.5	2	
2. ETSL 100126	1.88	4.72	3.01	3.89	4.26	3.58	3.56	1.5	2	
3. ETSL 100560	2.39	5.71	2.16	2.52	4.81	2.18	3.29	1.5	4	
4. ETSL 100569	4.61	4.65	2.49	2.64	4.89	3.14	3.74	1.0	2	
5. ETSL 100601	3.75	5.28	3.25	4.53	5.35	2.08	4.04	1.0	1.5	6.5
6. ETSL 100622	3.28	1.24	2.74	1.62	3.23	3.67	2.63	1.0	2	
7. ETSL 100652	4.23	3.81	4.69	2.48	4.53	3.94	3.95	1.5	1.5	
8. ETSL 100691	3.69	4.43	4.10	3.13	4.56	3.43	3.89	1.0	2	
9. ETSL 101371	4.79	6.41	4.53	5.96	6.16	4.24	5.35	1.0	1	40
10.ETSL 100743	3.49	5.39	2.36	1.86	3.42	3.41	3.32	2.5	3	
11.ETSL 100810	3.25	5.24	3.61	3.43	4.89	2.34	3.79	1.0	2	
12.ETSL 100845	2.64	1.72	2.83	4.12	6.22	3.63	3.53	1.0	1	
13.ETSL 100914	4.37	6.56	3.69	3.19	4.42	3.25	4.25	1.0	2	
14.ETSL 100705	2.80	6.20	1.14	3.28	5.38	2.31	3.52	1.5	3	
15.ETSL 101519	3.69	4.76	3.46	4.24	3.61	3.03	3.80	1.0	3.5	
16.ETSL 101651	1.45	3.11	2.03	3.07	4.97	2.20	2.81	1.5	3	
17.ETSL 101849	3.47	5.42	4.05	3.00	5.77	3.10	4.13	1.0	3	
18. Gemedi	**3.45**	**4.31**	**3.18**	**2.88**	**5.82**	**3.14**	**3.80**	**1.0**	**2**	
19. IS 25531	4.86	6.21	4.22	3.77	5.27	4.67	4.83	1.5	1.5	
20. IS 25542	4.25	3.93	4.46	2.62	4.58	3.76	3.93	2.0	2.5	
21. IS 38279	1.54	4.38	0.68	2.62	4.49	2.44	2.69	2.0	1.5	
G. Mean	3.35	4.51	3.10	3.14	4.74	3.13	3.67			
LSD	0.41	1.63	0.93	1.10	0.82	0.71				
CV	14.7	22.1	18.1	21	10.5	13.8				
F-value	**	**	**	**	**	**				
Pooled ANOVA							*F. Pr*			
Environment							**			
Genotype							**			
G X E							**			

LSD= Least significant difference, CV= Coefficient of variation, GXE= Genotype by Environment interaction, GM S = Grain mold Severity (1-5), Anth Se = Anthracnose Severity (1-5)

APPENDIX Table 2: Mean agronomic traits across years and Locations

S No	Genotype	GYt h^{-1}	DTH	DTF	DTM	PH	PnLg	TGWt
1	Chemeda	2.04	131.5	137.5	178	391.5	26.3	32
2	ETSL 100126	3.56	81.5	88.5	145	329.5	32.3	35.6
3	ETSL 100560	3.29	91	97.5	154	322	23	39.3
4	ETSL 100569	3.74	104	110	148	395.5	34	26.1
5	ETSL 100601	4.04	96.5	87.5	144	359	15.6	27.2
6	ETSL 100622	2.63	80.5	86.5	153	370	20.8	34.6
7	ETSL 100652	3.95	94	100	151	408.5	30.7	25.3
8	ETSL 100691	3.89	99.5	105.5	148	353.5	24.2	32.2
9	ETSL 101371	5.35	99	105	156	366.5	24	26.5
10	ETSL 100743	3.32	102	108	151	347	19.5	28.8
11	ETSL 100810	3.79	107	114	153	345	18.3	32.1
12	ETSL 100845	3.53	88	97.5	151	291	33.5	25.1
13	ETSL 100914	4.25	105	111.5	153	359	20.5	30.5
14	ETSL 100705	3.52	93.5	100.5	152	421.5	19.8	23.9
15	ETSL 101519	3.80	95.5	101.5	147	387.5	17.4	26.6
16	ETSL 101651	2.81	80	87	143	374	28.3	31.7
17	ETSL 101849	4.13	96	102	145	314.5	23.7	31.1
18	Gemedi	3.80	110	117	176	381	25.8	31.2
19	IS 25531	4.83	92	98.5	148	259	24.6	28.6
20	IS 25542	3.93	86.5	93.5	147	374.5	17.1	26.6
21	IS 38279	2.69	100.5	106.5	154	358.5	15.7	32.4
	Mean	3.67	**97.6**	**103.74**	**148**	**351**	**22.92**	**31.95**
	LSD	0.204	**11.7**	**12.391**	**4.76**	**75.2**	**3.612**	**9.795**
	CV	**17**	**8.5**	**9.5**	**4.3**	**15.2**	**11.2**	**21.6**
	F -value	**	**	**	**	**NS**	**	Ns

Participatory Variety Selection of Quality Protein Maize Varieties at Dugda District, Mid Rift Valley of East Shoa Zone

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Abstract

Participatory evaluation of released quality protein maize was conducted at Dugda district of east Shoa zone with the objective of identifying adaptable and most preferred quality protein maize variety for the area and similar agro-ecologies. Three quality protein maize varieties viz., Melkassa 1Q, Melkassa 6Q and BHQ138 were tested on two farmer's field. Significantly highest grain yield was obtained from Melkassa 6Q and MHQ138 than that of Melkassa 1Q. Based on grain yield performance of the varieties and farmers preferences, two varieties namely Melkassa 6Q and MHQ138 were recommended for Dugda district of east Shoa zone and similar agro ecologies.

Keywords: Grain Yield; Participatory Variety Selection; Quality Protein Maize

Introduction

Maize *(Zea mays L.)* is the third most important cereal crop in the world after rice and wheat, and it is believed originated in Mexico, and have been introduced to Ethiopia in the 1600s to 1700s (McCann, 2005). Maize is high yielding, easy to process, readily digested and cheaper than other cereal crops and the second most important food crop in Ethiopia (CSA, 2016). The term Quality Maize Protein (QPM) refers to maize genotypes whose lysine and tryptophan levels in the endosperm of the kernels are about twice higher than in Conventional Maize (CM) varieties. Lysine levels in CM and QPM maize average 2.0% and 4.0% of total protein in whole grain flour, respectively. These levels can vary across genetic backgrounds with ranges of 1.6-2.6% in CM and 2.7 - 4.5% in converted QPM counterparts (Vivek *et al*., 2008). Despite the nutritional differences, QPM varieties look and perform like CM varieties and one cannot visually distinguish between the two by the physical appearance of the plants or their ears and grains alone. Rather, biochemical analysis is required to determine the lysine and tryptophan content of the seed and confirm whether or not it is QPM. QPM is a cheap source of protein, given that farmers can grow, manage, harvest, and consume it in the same way they do CM varieties (Adefris *et al.*, 2015). The national mean grain yield of QPM is very low particularly due to depleted soil fertility, low fertilizer usage and the unavailability of other improved crop management and inputs. In addition to these facts, no improved QPM varieties recommended for the study area.

The basic source of QPM's nutritional benefits is the *Opaque-2* mutation. The higher Lysine and Tryptophan contents of QPM varieties, compared to CM varieties, provide a more balanced protein for humans and other mono gastric animals. There is an overwhelming amount of data demonstrating the nutritional superiority of QPM over CM (Adefris, *et.al*., 2015). The nutritional benefits, especially for people who depend on maize for their energy, protein, and other nutrients, are sufficient to justify its wide scale production and promotion.

Besides doubling the biologically usable protein in a maize diet, QPM also confers the following nutritional benefits: better *Leucine: Isoleucine* ratio; higher *Niacin* availability; higher Calcium. These should be additional bonuses for farmers to produce and consume QPM and mitigate malnutrition, specifically in communities with poor quality protein intake and *Lysine* deficiency (Bressani, 1992; Graham *et al.*, 1990).

The nutritional and biological superiority of QPM has also been amply demonstrated in model systems such as rats and pigs. The superior quality of QPM protein was first demonstrated in feeding trials with rats (Mertz *et al.*, 1965). Growth in rats that were fed a diet of 90% QPM (97 g) increased more than three-fold over the growth of rats fed CM (27 g). The nutritional advantage of QPM over CM was most extensively demonstrated in pigs (Maner, 1975). Generally, at suboptimal protein levels, feeding pigs with QPM instead of an equal amount of CM resulted in significant growth increase. Some studies indicated that pigs fed a diet of QPM alone, except for vitamins and minerals, grew twice as fast as those fed CM (Osei *et al.*, 1994; Vivek *et al.*, 2008). Diets incorporating QPM are also more economical, as they can lead to progressive reductions in the use of fishmeal and synthetic lysine additives (Qi *et al.*, 2004).

Currently, the hybridization programs focus on disease resistant and high yielding types. Rather than starting breeding program which takes a longer period, conservation of the well-adapted varieties in to their disease resistance and good yielding potential is followed as a first priority to achieve the desired goal within a short period of time. Therefore, adaptation trial of nationally released varieties were proposed with objective of identifying, adaptable and most preferred variety for further production in the study area.

Materials and Methods

Three quality protein maize varieties viz Melkassa 1Q, Melkassa 6Q and BHQ138 were included in this study. The characteristic of each variety is presented in Table 1. Those three quality protein maize varieties were brought from Melkassa Agricultural Research Center. All the varieties were released for their quality protein in moisture stress areas of the country. The study was conducted at Dugda district of east Shoa zone, Wayo Gabriel kebele. One FREG was established and three host farmers were selected per kebele.

Table1. Yield potential and other agronomic traits of QPM varieties

Variety	Year of release	Adaptation	Plant height (cm)	Ear Height(cm)	Days to maturity	Seed Color	Yield (qt/ha)* RC	FF
Melkassa 1Q	2013	Low moisture stress	140-160	65-70	90	Yellow	35-45	25-35
Melkassa 6Q	2008	Low moisture stress	165-175	70-75	120	White	45-55	30-40
MHQ138	2012	Low moisture stress &moist mid altitude	200-235	100-120	140	White	75-80	55-65

Key: RC= research field, FF=farmers' field

The experiment was laid out in randomized block design and each host farmer was considered as replication. The experimental plots were prepared following the appropriate practice before the planting time. In accordance with the specifications of the design, field layout was prepared and each treatment was assigned randomly to the experimental plots within a block. Maize varieties were sown at the rate of 25 kg/ha with spacing of 75 cm between rows and 25 cm between plants. Mineral fertilizer (NPS) was applied at the rate of 100 kg/ha and urea at the rate of 150 kg/ha was applied half at 20-25th day and the remaining half at 35-40th day. The plots were 1 m apart from each other. Each plot was consisted 6 rows of 5 m in length. The net plot size was 5 m*5 m from which 25 m^2. All other recommended cultural practices were properly followed to produce a successful result.

One FREG consisting of 15 farmers was organized. From the established FREG three farmers were selected as the host field trials. Participatory evaluation of quality protein maize varieties was done at early harvest of the crop. Farmers in the FREG were invited to determine their own selection criteria. Firstly, discussion was made among farmers on plant characters to be used for quality protein maize variety selection. From the discussion made, traits such as full kernels, number of cobs, seed color, drought tolerance, early maturity and yield were raised as important criteria. Finally, traits such as grain yield, drought tolerance and early maturity were identified as the top three criteria for selection. Grain yield and other traits like days to tasseling, days to maturity, plant height, cobs per plant, seed per cobs, stand count, and biomass weight were recorded and analyzed.

Results and Discussion

Analysis of variance showed that there was highly significant variation among studied varieties for days to maturity, plant height, seeds per cob, stand count and biomass yield where as significant variation among varieties for grain yield and cobs per plant (Table 2). However, the differences among the varieties for days to tasseling were not statistically significant.

Table 2. Mean square for agronomic characteristics of quality protein maize

Source of variations	Degree of freedom	Days to tasseling	Days to maturity	Plant height(cm)	Cobs per plant	Seeds per cob	Stand count	Biomass yield	Grain yield (qtl/ha)
Rep (Farmers)	1	2.66^{ns}	10.66^{ns}	73.50^{ns}	0.13^{ns}	00.00^{ns}	4.16^{ns}	0.67^{ns}	1.12^{ns}
Varieties	2	72.60^{ns}	1204.66^{**}	2276.00^{**}.	0.70^{*}	4256.70^{**}	751^{**}	3785.16^{**}	78.00^{*}
Error		16.67	0.67	8.78	0.02	00.00	1.17	23.17	1.63

In terms of grain yield performance Melkassa 6Q and MHQ138 gave comparable yield and showed better than Melkassa 1Q (Table 3). Grain yield, drought tolerance and early maturity were among the top three farmers selection criteria for selecting quality protein maize varieties. Other traits such as seed color, full kernels, number of cobs and biomass of the varieties were considered for ranking the varieties. At Wayo Gabriel Kebele of Dugda district, Melkassa 6Q and MHQ138 were selected as a top two preferred quality protein maize varieties (Table 4).

Table 3. The mean values of yield and yield parameters quality protein maize varieties evaluated at Dugda district

Varieties	Days to tasseling	Days to maturity	Plant height(cm)	Cobs per plant	Seeds per cob	Stand count	Biomass yield	Grain yield(qtl/ha)
Melkassa 1Q	69.00^{a}	$91.00.^{c}$	143.90^{c}	1.10^{b}	376.80^{b}	75.00^{c}	117.50^{c}	25.50^{b}
Melkassa 6Q	66.00^{a}	118.00^{b}	168.40^{b}	2.15^{a}	408.00^{a}	103.50^{b}	207.00^{b}	36.70^{a}
MHQ138	71.00^{a}	140.00^{a}	210.60^{a}	2.10^{a}	317.20^{c}	112.00^{a}	334.50^{a}	35.90^{a}
CV (%)	6.25	0.70	1.70	6.86	1.71	1.10	2.19	3.90
Mean	65.33	116.33	174.30	1.78	367.33	96.83	219.60	32.70
LSD (5%)	17.56	3.51	12.73	0.52	27.00	4.64	20.70	5.48

Table 4. Farmers preference ranking value of QPM at Wayo Gabriel Kebele of Dugda district

Varieties	Early Maturity	Drought tolerance	Seed Color	Full Kernels	Number of Cobs	Biomass yield	Grain yield	Ranking index	Overall Rank
Melkassa 1Q	1	1	3	1	3	3	3	45	3
Melkassa 6Q	2	2	2	2	2	2	1	39	1
MHQ138	3	3	1	3	1	1	2	42	2

Participatory evaluation of quality protein maize varieties conducted at early harvesting stage of the crop by 15 farmers (6 women and 9 men). The farmers agreed that early maturity, drought tolerance, seed color, full kernels, number of cobs per plant, biomass yield and yield are important parameters. Among these traits, grain yield, spike length and early maturity were selected as the top three important selection criterions. Accordingly, Melkassa 6Q and MHQ138 were selected as the best two preferred quality protein maize variety by the farmers (Table 4).

Conclusion and Recommendation

Based on the top three farmers selection criterion yield, drought tolerance and early maturity, Melkassa 6Q and BHQ138 were selected as the best two preferred quality protein maize varieties. Thus, Melkassa 6Q and BHQ138 were the best two varieties selected by farmers for Dugda district and similar agro-ecologies.

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Participatory Variety Selection of Tef Varieties at Dugda and Lume Districts, Mid Rift Valley of East Shoa Zone

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Abstract

Participatory evaluation of released tef varieties was conducted in Dugda and Lume districts of East Shewa with the objective of identifying & select adaptable tef varieties for the areas and similar agro-ecologies. Six improved tef varieties viz., Boset, Simada, Kuncho, Tseday and Amarach were tested on field of six farmers at two Kebeles during 2018/19 cropping season. The combined analysis of variance showed that there was significant variation among the studied varieties and locations main effect for days to heading, days to maturity, plant height, panicle length, harvest index, biological yield, and grain yield. Tseday and Simada varieties were early to head and early to mature in both locations while Amarach and Quncho were late to head and mature. Boset (13.44qt/ha) and Simada (12.64 qt/ha) gave higher grain yield and biological yield than other varieties in over location. Variety Amarach had lower plant height, panicle length, harvest index, biological yield and grain yield. Based on high grain and biomass yield, drought tolerance, high capacity of tillering and early maturing (farmer's selection criteria) Simada and Boset were selected as the best two preferred tef varieties at Dugda and Lume. Therefore, Boset and Simada varieties were recommended for the study area and similar agro-ecologies.

Keywords: Eragrostis tef, Farmer's Criteria, Grain Yield and Participatory Variety Selection

Introduction

Ethiopia is the center of origin and diversity for tef. It is adapted to a wide range of environments and is presently cultivated under diverse agro-climatic conditions. It performs well between 1700 and 2400 m; however, it can grow from sea level up to 2800 meters above sea level. Also, grow in low rainfall and drought-prone areas characterized by protracted growing seasons and frequent terminal moisture stress. Most of the Ethiopian farmers motivated to cultivate tef because of its relative merits over other cereals in the use of both the grain and straw. It is primarily grown for human consumption of its grain which is used to prepare a favorite food of most Ethiopian people called *Enjera* (Engdawork. 2009).

Tef is a highly valued crop and is primarily grown for its grain that is used for preparing injera, which is a staple and very popular food in the national diet of Ethiopians. It can also be used in many other food products such as *kitta*, porridge and an alcoholic beverage such as *tella* and *katikala* (Hailu et al., 2003). In addition, its high price in the market, reduction of post-harvest management cost, fewer disease and pest problems and sustained demand from the consumer, are some of the specific merits that make tef important and preferred by farmers (Seyfu, 1993)

Tef is the most commonly grown in the East Shoa zone with the production of 17.56 qt/ha which is greater than national average (16.64 qt/ha) (CSA 2016/17). According to Fikirneh, Fiseha and Shimalis (2018) report on agricultural constraint analysis in East and North Shoa, the most dominant and preferred varieties of tef in the lowland and midland of Dugda and Lume is Dz-Cr-37 followed by Kuncho, whereas Kuncho is the most preferred variety in the highlands of the district. These show that only a few verities were dominantly grown in the area. In such area, Participatory variety selection on farmers management condition may have many advantages, such as increased and stable crop productivity, faster release and adoption of varieties, better understanding farmers' criteria for variety selection, enhanced biodiversity, increased cost effectiveness, facilitated farmers learning and empowerment. Participatory variety selection of tef in these Districts is important for the farmers to select best varieties based on their own criteria for the varieties which largely depend on the importance of the crop in the farming system and uses. Therefore the experiment was conducted with the objective of identifying adaptable tef variety for the areas and to select well-performed tef variety.

Materials and Methods

Study Area and Description

The study was conducted at Dudga and Lume districts. The districts located in the mid-rift valley of East Shoa zone of Oromia. Based on district office of agriculture data on the area of production and productivity of tef one PA's was selected for the experiment per districts. From each PA three farmers were selected for the study based on the active involvement of the farmers in the production of tef in the district.

Experimental Material

Six improved varieties of tef selected for the trial.

Table 1. The characteristics of varieties

Variety	Year Release	Adaptation	Rainfall (mm)	Maturity days	Yield	
					Research	Farmers
Tseday	2007	1450-1695	690-965	62-83	13-20	14
Kuncho	2006	1800-2500	800-1200	86-151	25-27	16-20
Amarach	2006	1600-1700	500-850	63-87	13	12
Simada	2009	Low land	500-700	88	16	10
Boset	2012	Low land	NA*	NA*	NA*	NA*
Magna	1978	NA*	NA*	NA*	NA*	NA*

NA*= Not available

Experimental Design

The experiment was laid down in randomized complete block design with three replications and three trial farmers were assigned as replications. It was carried out during 2018/19 cropping seasons in East Shoa Zone Dugda and Lume District. Site for participatory variety selection was selected based on Tef production potential. The experimental field was prepared following the conventional tillage practice using oxen plow. A plot size of 5m by 5m plot size with a between the distance of 1m and 20cm between rows were used in the experiment. Field layout was prepared and each variety was assigned to experimental plots within a farmer field.

Planting was done in row by drilling at a seed rate of 15 kg ha^{-1}. NPS was applied at the rate of 130 kg ha^{-1} at sowing. UREA was applied at the rate of 80 kg/ha. Half was applied at the time of planting while the remaining the second half at the time of tillering. Participatory Varietal Selection (PVS) was done by members of FREG. Two FRG approach was formed per PA having 15 members who considered the following traits: early maturing, drought tolerance, grain yield, tillering capacity, shattering and biomass yield. Farmers gave rank to each cultivar for all traits. Overall Preferential Rank (OPR) was also calculated.

Data to be collected

The phonological, agronomic and yield and yield components were considered in the current experiment. Those includes; Days to the heading (DH), Days to maturity, (DM) Biological yield (kg ha^{-1}), Grain yield (kg ha^{-1}), Harvest index (%): Plant height (cm), Number of productive tillers per plant and Panicle length (cm).

Data Analysis

All the data were subjected to ANOVA by using the GLM Procedure of Genstat software ver.15. Mean separation was performed at P<0.05 using the least significant difference at p<0.05%.

Result and Discussion

The combined analysis of variance showed that there was significant variation at (P≤0.05 and P≤0.01) among the studied varieties and locations main effect for days to heading, days to maturity, plant height, panicle length, harvest index, biological yield, and grain yield Table 2. This indicates that agronomic and grain yield performance in Dugda and Lume was different in changing its magnitude. However, effective tillers are not affected due to varieties, locations, and genotype by location interaction. Days to maturity and panicle length were affected by genotype by location interaction while other studied parameters were not affected genotype by location interaction. In this study, there is no significant variation among replication (farmers) for the studied parameters except for harvest index and biological yield.

Table 2. Combined analyses for tested tef varieties in Dugda and Lume districts

Source of Variation	Df	Mean Square							
		DF	DM	ET	PH	PL	HI	BY	GY
Rep	2	1.44ns	9.25ns	2.85ns	44.46ns	4.19ns	7.15*	850.4*	10.24ns
Varieties	5	169.51**	608.6**	1.45ns	391.15**	99.18*	13.53**	937.4**	40.89**
Location	1	312.7**	1024**	0.34ns	8790.63**	523.27**	70.09**	9906.9**	414.52**
Genotype x Location	5	1.378ns	14.47*	4.21ns	125.18ns	27.62**	3.34ns	126.6ns	4.06ns

Key: DH = Days to heading, DM= Days to maturing, ET= Effective tiller, PH= plant height, PL= Panicle length, HI= Harvest Index, GY= Grain Yield, BY= Biological Yield

The present study showed that Tseday and Simada varieties were early to head and early to mature in both Dugda and Lume locations. However, Amarach and Quncho were late to head and mature. Quncho and Magna varieties had higher plant height and panicle length. Boset variety had higher harvest index, biological yield and grain yield in over location analysis. However, Amarach variety had lower plant height, panicle length, harvest index, biological yield and grain yield in over location.

Table.3 Combined mean yield and agronomic traits for tested tef varieties in Dugda and Lume districts

Varieties	DF	DM	ET	PH(cm)	PL(cm)	HI%	GY (qt ha^{-1})	BY (qt ha^{-1})
Boset	51^{b}	93.83^{b}	4.56	97.07^{abc}	35.13^{bc}	13.24^{a}	13.44^{a}	87.63^{a}
Simada	41.5^{a}	79.0^{a}	5.3	89.87^{bc}	35.03^{bc}	11.64^{ab}	12.41^{ab}	93.63^{a}
Tseday	42.33^{a}	77.5^{a}	4.33	85.80^{c}	34.07^{bc}	11.65^{ab}	9.79^{b}	72.77^{ab}
Magna	50.5^{b}	93.33^{b}	5.20	101.33^{ab}	39.10^{ab}	10.22^{bc}	9.7^{b}	80.50^{ab}
Quncho	52.67^{bc}	100.0^{c}	4.07	103.80^{a}	43.73^{a}	11.09^{abc}	9.46^{b}	72.77^{ab}
Amarach	53.67^{c}	100.3^{c}	4.92	84.91^{c}	32.79^{c}	8.77^{c}	5.98^{c}	58.37^{b}
CV%	2.8	2.4	20.0	7.8	9.4	12.6	17.6	16.1
SE (±)	1.37	2.155	0.94	7.31	3.44	1.67	1.78	12.5
LSD $_{0.05}$	1.64	2.58	NS	8.75	4.116	1.4	2.13	14.96

Key: Means followed by the same letter in each column are not significantly different. DH = Days to heading, DM= Days to maturing, ET= Effective tiller, PH= plant height, PL= Panicle length, HI= Harvest Index, GY= Grain Yield, BY= Biological Yield

Mean Performance of the Varieties at Lume District

The analysis of variance revealed that there is significant variation among observed agronomic traits except for effective tiller and harvest index of tested tef varieties at Lume Districts. Simada and Tseday varieties were showed early to head and to mature while other varieties were late as compared with these varieties. Quncho had higher plant height (125.3 cm) and panicle length (51.33 cm) followed by Magna varieties. Boset variety had higher biological (110 qt ha^{-1}) and grain yield (17.15 qt ha^{-1}) followed by Simada and Magna varieties at Lume District.

Table.4 Combined mean yield and agronomic traits for tested tef varieties in Lume district

Varieties	DF	DM	ET	PH(cm)	PL(cm)	HI	GY (qt ha^{-1})	BY (qt ha^{-1})
Boset	54^{a}	101^{ab}	4.53	112.5^{abc}	38.27^{bc}	13.49	17.15^{a}	110^{a}
Simada	45^{b}	83^{c}	4.46	101.7^{bc}	36.33^{c}	12.71	14.76^{ab}	102.27^{ab}
Tseday	45^{b}	83^{c}	3.47	95.3^{c}	37.2^{bc}	13.1	13.13^{ab}	88.93^{bc}
Magna	54^{a}	97.67^{b}	4.86	116.9^{ab}	43.80^{b}	12.69	14.27^{ab}	100.0^{ab}
Quncho	55.33^{a}	107^{a}	4.13	125.3^{a}	51.33^{a}	13.06	13.27^{ab}	89.33^{bc}
Amarach	56^{a}	105.3^{a}	3.467	104.7^{bc}	35.8^{c}	10.07	8.57^{b}	74.8^{c}
CV%	2.4	2.9	24.1	6.2	5.9	10.7	17.7	7.2
SE (±)	1.25	2.74	1.15	6.75	2.39	1.34	2.38	6.77
LSD $_{0.05}$	0.27	4.98	ns	12.28	4.3	ns	4.35	12.31

Key: Means followed by the same letter in each column are not significantly different. DH = Days to heading, DM= Days to maturing, ET= Effective tiller, PH= plant height, PL= Panicle length, HI= Harvest Index, GY= Grain Yield, BY= Biological Yield

Mean Performance of the Varieties at Dugda District

Simada and Tseday varieties were showed early to head and to mature followed by Boset variety while Amarach was late to head and maturity at Dugda District. Therefore Simada, Tseday and Boset varieties were suitable for this area because of its earliness it can escape the moisture stress which mostly occurred in the later growing stages. But Amarach variety is not recommended for Dugda district because of its late maturity and inferior germination percentage. Boset (12.97 qt ha^{-1}) had higher harvest index followed by Simada (10.57qt ha^{-1}) while Amarach (7.48 qt ha^{-1}) showed the minimum harvest index. Simada variety had higher grain yield (10.06 qt ha^{-1}) and biological yield (85 qt ha^{-1}) followed by Boset (9.73 qt ha^{-1}) and (78.27 qt ha^{-1}) but (not statistically different). However, Amarach variety showed lowest agronomic performance for the effective tiller, harvest index, grain yield, and biological yield in the studied varieties.

Table.5 Combined mean yield and agronomic traits for tested tef varieties in Dugda district

Varieties	DH	DM	ET	PH(cm)	PL(cm)	HI	GY (qt ha^{-1})	BY (qt ha^{-1})
Boset	47^{b}	86.67^{c}	4.6^{bcd}	81.6	32	12.97^{a}	9.73^{a}	78.27^{a}
Simada	38^{c}	75^{d}	6.13^{a}	78.07	33.75	10.57^{ab}	10.06^{a}	85^{a}
Tseday	39.67^{c}	72^{d}	5.2^{ab}	76.27	30.93	10.21^{abc}	6.44^{b}	56.87^{b}
Magna	48^{ab}	90^{bc}	5.53^{ab}	85.73	34.4	7.88^{bc}	5.143^{bc}	61^{b}
Quncho	50.0^{a}b	93^{ab}	4.0^{cd}	82.27	36.13	9.13^{bc}	5.6^{b}	52.2^{b}
Amarach	51.33^{a}	95.33^{a}	3.5^{d}	65.08	29.78	7.48^{c}	3.39^{c}	41.93^{c}
CV%	2.9	1.9	10.9	9.9	11.8	10.7	10.2	6.7
SE (±)	1.317	1.6	0.53	7.72	3.87	1.04	0.69	4.07
$LSD_{0.05}$	2.39	2.93	0.95	ns	ns	1.89	1.23	7.14

Key: Means followed by the same letter in each column are not significantly different. DH = Days to heading, DM= Days to maturing, ET= Effective tiller, PH= plant height, PL= Panicle length, HI= Harvest Index, GY= Grain Yield, BY= Biological Yield

Participatory Variety Selection

One FREG per district were established consisting of 15 farmers. From the FREG members, three farmers were selected to host the field trials. Participatory evaluation of tef varieties was done at early harvest of the crop. Farmers in each FREG were invited to set their own selection criteria. Accordingly, farmers set, traits such as seed quality, early maturity, drought tolerance, biomass yield, tillering ability, none shattering, and grain yield as decisive criteria for tef production in the study area. Accordingly, Simada and Boset were best preferred tef varieties followed by Magna both in Lume and Dugda districts Table 6 and 7. However, Amarach was the least preferred in both locations due to its poor performance.

Table.6 Farmers' Tef variety ranking index at Dugda District

Varieties	Farmer's Selection Criteria								
	Early Maturity	Drought tolerance	Seed color	Tillering ability	None shattering	Biomass yield	Grain yield	Ranking index	Overall Rank
Amarach	6	6	5	4	4	6	6	222	6
Boset	3	4	2	1	3	2	2	102	2
Magna	4	3	1	5	1	3	5	132	3
Quncho	5	5	3	2	6	5	4	180	5
Simada	2	1	4	3	2	1	1	84	1
Tseday	1	2	6	6	5	4	3	162	4

Table.7 Farmers' Tef variety ranking index at Lume District

Varieties	Farmer's Selection Criteria								
	Early Maturity	Lodging	Seed Size	Tillering Capacity	None shattering	Biomass yield	Grain yield	Ranking index	Overall Rank
Amarach	6	6	5	4	4	6	6	222	6
Boset	3	4	2	1	3	1	1	72	1
Mangna	4	3	1	5	1	3	3	120	3
Quncho	5	5	3	2	6	4	4	174	4
Simada	2	1	4	3	2	2	2	96	2
Tseday	1	2	6	6	5	5	5	180	5

Summary and Conclusion

The combined analysis of variance showed that there was significant variation at ($P \leq 0.05$ and $P \leq 0.01$) among the studied varieties and locations main effect for days to heading, days to maturity, plant height, panicle length, harvest index, biological yield, and grain yield. Simada had the highest grain yield at Dugda followed by Boset and Tseday varieties. Based on farmer's selection criteria, Simada, and Boset were selected as the best two preferred tef varieties. While in Lume District, Boset had the highest grain yield followed by Simada. Similarly, based on farmer's selection criteria, Boset and Simada were selected as the top two preferred tef varieties. Therefore based on the analysis and participatory evaluation results, the improved tef varieties Boset and Simada were recommended for the study area and similar agro-ecologies.

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Yield stability and genotype x Environment Interaction of Late Set Soybean Genotypes inWestern Oromia

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Abstract

A total of 12 late set soybean genotypes were evaluated at three locations (Bako, Billo and Gute) for two consecutive years (2017/18 – 2018/19) to estimate the magnitude of GEI effects and to identify broadly or specifically adapted genotypes. The genotypes were arranged in Randomized Complete block Design with three replications. Combined ANOVA and GGE bi plot models were used to analyze the data. GGE biplot analysis showed the presence of one mega environment. Based on analysis of grain yield stability and adaptability, genotype PM-12-12 showed better stability followed by PM-12-51 and PM-12-3 across locations with grain yield of 2538.9, 2564.5 and 2779.2 Kg ha^{-1}, respectively.

Key words: *GxE interaction, Soybean, Stability*

Introduction

Soybean is a multipurpose crop, which can be used for a variety of purposes including preparation of different kinds of soybean foods, animal feed, soy milk, raw material for the processing industry, and it counter effects depletion of plant nutrients in the soil resulting from continuous mono-cropping of cereals, especially maize and sorghum, thereby contributing to increasing soil fertility (Hailegiorgis, 2010). There is also a potential to intercrop soybean with long stem crops such as maize and sugarcane (Jagwe and Owuor, 2004). Food insecurity and malnutrition are among the urgent challenges that developing countries face these days. The major staple food crop of most developing Sub Saharan African Countries including Ethiopia, maize, contains low protein (5.2-13.7 %) (FAO, 2010). It is the most nutritionally rich crop, as its dry seed contains the highest protein and oil content among grain legumes (40 to 42% protein) with a good balance of the essential amino acids and has 18-20% oil on a dry seed weight basis. It is cheap and rich source of protein for poor farmers, who have less access to animal source protein, because of their low purchasing capacity (Osho, 1995).

The demand for soybean has increased in Africa and Ethiopia rapidly, driven by the growing feed industry for poultry, aquaculture and home consumption in the form of processed milk, baked beans and for blending with maize and wheat flour. The demand for soybean in Africa so far outweighs the supply; hence the deficit is mainly covered through imports of soybean products such as soybean meal. The area under soybean production has increased in response to the growing demand, a trend that is expected to continue in the coming years. As the production area increases, diseases and insect pests, declining soil fertility and other abiotic factors pose a major challenge. Soybean rust disease is among the major threats to soybean production in Ethiopia due to its rapid spread as a result of the ease by which its spores are dispersed by the wind. Since 1950 efforts have been made in soybean variety development and/or adaptation with different agronomic and other management options in Ethiopian agricultural production systems. Hence**,** since soybean is an important crop with multiple benefits, which can be grown in rotation with cereals like maize, finger millet, and sorghum. Due to this fact developing new varieties that adapt with the newly emerging climate problem is imperative for end user. Therefore, the activity initiated with the general objectives of to develop soybean varieties adaptale to Western Oromia.

Materials and Methods

Twelve late maturity classes of soybean genotypes including standard check PARC-2 were evaluated (Table 1) at Bako, Gute and Billo experimental sites in 2017 and 2018 main cropping season (Table 2). Planting was done in mid-June at each location. The design was randomized complete block design with three replications. Each plot consisted of six rows of 4 m length with 60 inter row and 10 cm intra row spacing. Four middle rows were used for data collection and harvesting. Fertilizer was applied at the rate of 100 kg NPS ha-^{1} during planting time. All other management practices were applied as per the recommendations.

Table 2: Lists of Materials Used In Study

S.N	Genotypes	Source
1	PM 12-3	JARC
2	PM 12-4	JARC
3	PM 12-14	JARC
4	PM 12-9	JARC
5	PM 12-51	JARC
6	PM 12-11	JARC
7	PM 12-16	JARC
8	PM 12-15	JARC
9	Pun 11-1	JARC
10	PM 12-12	JARC
11	PM 12-8	JARC
12	Check (PARC-2)	PARC

JARC= Jimma Agricultural Research Center PARC= Pawe Agricultural Research Center

Table 3: Testing Environments and their main characteristics.

Location	Longitude (E)	Latitude (N)	Altitude (m a.s.l)	RF (mm)	Soil texture	Soil color
Bako	37°09'	09°06'	1650	1431	Sandy-clay	Red
Gute	036^{0}38.196’	09^{0}01.061’	1915	NI	Clay	Reddish brown
Billo	037^{0}00.165’	09^{0}54.097’	1645	1500	Clay loam	Reddish brown

E= East N=North m= meter a.s.l. =above sea level mm=millimeter

Result and Discussion

Combined Analysis of Variance

There were statistically significant differences (P<0.01) among evaluated soybean genotypes, environment and their interaction for seed yield (Table 3). This suggests the existence of genetic variation among the soybean genotypes and possibility to select high yielding and stable variety (s), the environments are variable and the differential response of soybean genotypes across the testing environments. Similar result were reported for common bean and groundnut varieties by Zeleke *et al.* (2016) and Alemayehu *et al*. (2016), respectively.

Table 4: Combined analysis of variance for grain yield of medium soybean genotypes evaluated at six locations in western Oromia.

Source of variation	DF	Mean Square
Genotypes	11	3400556.04**
Environments	2	9587.97**
Interaction	22	1002119.84**
LSD (0.05	123.35	
CV (%)	9.3	

LSD=Least Significant differences, CV=coefficient of variation, **= significant at P = 0.01, ns = nonsignificant

Performance of common bean genotypes across environments

The mean seed yield of late maturity classes of soybean genotypes across environment (G X E) ranged from 2779.2 to 1525.8 kg ha^{-1} (Table 3). The highest grain yield was obtained from genotype PM 12-3 followed by PM 12-51 and PM 12-12. Whereas, the lowest seed yield was recorded from genotype Pun 11-1. This difference may be due to their genetic potential. PM 12-3 genotype was the top ranking genotype across year and location except Billo 2018.

Table 5: The difference in yield rank of varieties across the environments revealed the high crossover type of GxE interaction.

Trt	Varieties	Year 1			Year 2 (2018)			Combined
		Bako	Gute	Billo	Bako	Gute	Billo	(kg ha^{-1})
1	PM 12-3	2903.48^{a}	2161.33^{a}	2123.66a	3189.6^{a}	3072.1^{a}	2075.77^{b}	2779.17^{a}
2	PM 12-4	1520.38^{e}	1729.73^{cb}	1333.37^{e}	2588.1^{c}	1415.8^{fg}	1081.63^{g}	1695.19^{fe}
3	PM 12-14	2305.05^{b}	1607^{ed}	1801.83^{c}	2611.7^{c}	946.3^{g}	1671.3d^{c}	1743.11^{e}
4	PM 12-9	2211.08^{cb}	1938.27^{b}	1712.7^{d}	2903.7^{b}	1660.4^{fe}	1506.07^{de}	2023.39^{d}
5	PM 12-51	2761.03^{a}	1722.93^{cd}	1903.67^{b}	2941.3^{b}	2537^{b}	2491.97^{a}	2564.51^{b}
6	PM 12-11	1774.75^{d}	1409.83^{gf}	1341.34^{e}	1783.8^{e}	1650.2^{fe}	1241.43^{fg}	1558.48^{g}
7	PM 12-16	2236.5^{cb}	1819.27^{cb}	1767.36^{dc}	2421.4^{dc}	1924.9^{ced}	1556.4^{de}	1967.57^{d}
8	PM 12-15	1496.35^{e}	1252.6^{gh}	1132.97^{f}	1636.2^{e}	1347.6^{fg}	1752.97^{c}	1578.93^{fg}
9	Pun 11-1	2168.55^{cb}	1822.9^{cb}	1703.54^{d}	1216.7^{f}	1713.4^{fed}	1647.23^{dc}	1525.80^{g}
10	PM 12-12	2269.35^{cb}	1542.5^{ef}	1738.94^{dc}	3092.1^{ba}	2393.1^{cb}	2263.73^{b}	2538.99^{b}
11	PM 12-8	1852.4^{d}	1220.23^{h}	1309.67^{e}	2318.7^{d}	1639.1^{fe}	1763.33^{c}	1907.03^{d}
12	PARC-2	2099.88^{c}	1747.6^{cd}	1723.5^{dc}	3312.2^{a}	2138.4^{cbd}	1410fe	2314.32^{c}
Mean		2133.2	1664.5	955.9	2501.3	1869.9	1705.153	2016.4
LSD (0.05)		201.2	174.4	113.2	220.71	474.24	192.23	123.35
CV (%)		6.4	6.1	7.0	5.21	14.97	6.7	9.3

Table 6: Yield related Traits across Years and Locations for Late set Soybean Variety Trial

Trt.	Genotypes	PH (cm)	DF	DM	PPPT	SPP	HSW (g)
1	PM 12-3	75.1^{a}	74.6^{de}	140.2^{dc}	80.6^{ba}	2.8^{a}	19.7^{a}
2	PM 12-4	69$^{.bdc}$	72.1^{fe}	141.5^{dc}	62.6^{dc}	2.6^{ba}	15.2^{b}
3	PM 12-14	67.8^{bdc}	81.3^{a}	150.4^{a}	83.8^{a}	2.5^{bac}	13.3^{de}
4	PM 12-9	69.8^{bdc}	75.9^{dc}	141.3^{dc}	78.6^{ba}	2.3^{c}	12.6^{e}
5	PM 12-51	68.4^{bdc}	75.8^{dc}	143.3^{c}	84.6^{a}	2.8^{a}	15.3^{b}
6	PM 12-11	71.7^{bac}	80.3^{ba}	145.8^{b}	72.4^{bac}	2.4^{bc}	14.2^{c}
7	PM 12-16	70.3^{bc}	77.8^{bc}	142.7^{c}	83.^{a}	2.4^{bc}	14.2^{c}
8	PM 12-15	70.4^{bc}	70.6^{f}	141.4^{dc}	68.7^{bc}	2.5^{ba}	15.2^{b}
9	Pun 11-1	71.9^{bac}	79.9^{ba}	149.8^{a}	65.8^{c}	2.6^{ba}	12.7^{e}
10	PM 12-12	71.3^{bac}	80.9^{a}	146.6^{b}	81.1^{ba}	3.0^{ba}	18.8^{a}
11	PM 12-8	72.7^{ba}	79.4^{ba}	151.8^{a}	63.2^{dc}	2.5^{ba}	15.1^{b}
12	PARC-2	67.8^{dc}	71.2^{f}	139.1^{e}	53.1^{d}	2.6^{ba}	18.9^{a}

GGE Biplot Analysis

An ideal genotype is defined as genotype with the greatest PC1 score (mean performance) and with zero GEI, as represented by an arrow pointing to it (Figure 2). The ranking based on the genotype-focused scaling assumes that stability and mean yield are equally important. In this study, genotype PM 12-12 which fell in the concentric circle was identified as the most desirable genotype as compared to the rest of the tested soybean bean genotypes (Figure 2). Similar result was reported by Alemayehu et al. (2016) and Abate et al. (2015).

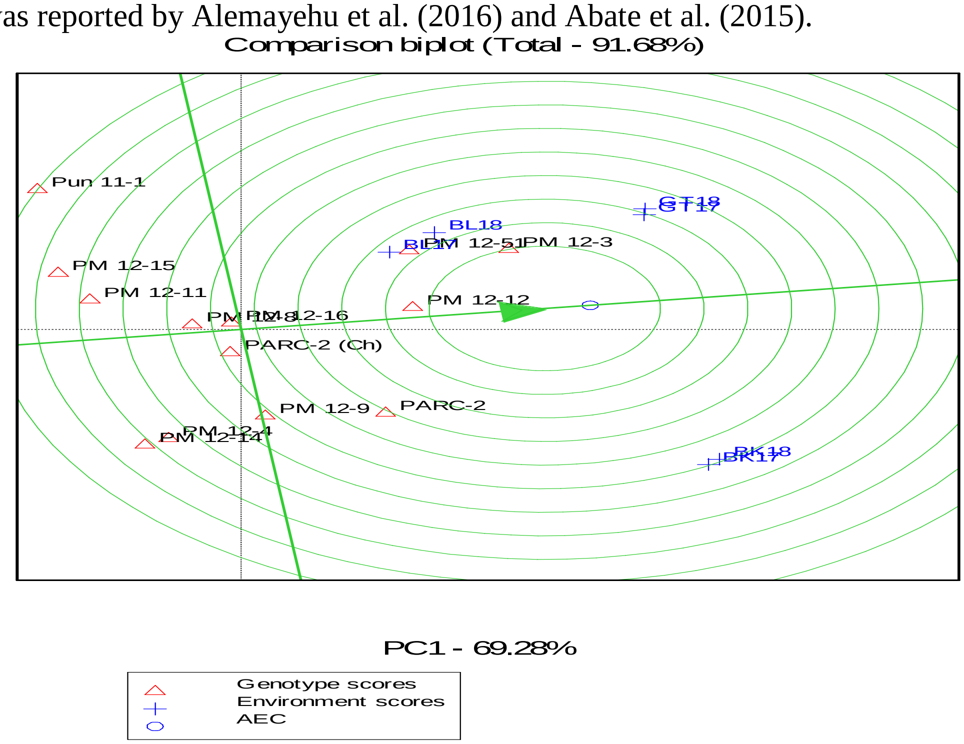

Figure 2 GGE biplot based on genotype-focused scales for comparison the genotypes with the ideal genotype.

Conclusion & Recommendation

GEI is differential phenotypic performance of the same genotypes across test environments. Soybean genotypes evaluated showed highly significant genetic differences for seed yield performance and occurrence of significant GEI complicated selection of high yielding and broadly adapted genotypes. GGE biplot enabled the identification of both high yielding and broadly adapted genotypes better than AMMI biplot. Among the evaluated late set soybean genotypes PM 12-12 was both high yielder and broadly adapted genotype to the tested environments followed by PM 12-3 and PM 12-51. Hence, PM-12-12, PM-12-3 and PM-12-51 were identified and recommended for further verification in the target environments.

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Genotype x Environment Interaction and Yield stability of Medium Set Soybean Genotypes in Western Oromia

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Abstract

A total of 17 medium set soybean genotypes were evaluated at three locations (Bako, Billo and Gute) to estimate the magnitude of GEI effects and to identify broadly or specifically adapted genotypes during 2017 and 2018 main cropping seasons. The genotypes were arranged in Randomized Complete block Design with three replications. Combined ANOVA and GGE bi plot models were used to analyze the data. GGE biplot analysis revealed the presence of one mega environment and also identified that genotypes PM-12-37 and PM-12-20 are broadly adapted. Thus, genotype PM-12-37 showed better stability followed by PM-12-20 and PM-12-31 across locations with grain yield of 2480.6, 2389.9 and 2155.8 kg ha^{-1}, respectively.

Key words: GGE, Soybean, Stability,

Introduction

Soybean (Glycine max L.) is one of the very important leguminous and oil crops with worldwide importance as food and market crop. This is mainly because of its high grain nutritional value with 40% protein and 20% oil (Fekadu *et al*., 2009) that makes it an important raw material for food and oil processing industries. It is also a very important crop for rotation with cereals like maize and sorghum because of biological nitrogen fixation it helps in improving soil fertility. In addition, soybean provides health benefits in consumption, and also considered as a strategic crop in fighting the worlds' food shortage and malnutrition problems, and most food aids to displaced and malnourished people are fortified with soybean (Thoenes, 2004). There is also a potential to intercrop soybean with long stem crops such as maize and sugarcane (Jagwe and Owuor, 2004).

Food insecurity and malnutrition are among the urgent challenges that developing countries face these days. The major staple food crop of most developing SubSaharan African Countries including Ethiopia, maize, contains low protein (5.2-13.7 %) (FAO, 2010). soybean is the most nutritionally rich crop, as its dry seed contains the highest protein and oil content among grain legumes (40 to 42% protein) with a good balance of the essential amino acids and has 18-20% oil on a dry seed weight basis. It is cheap and rich source of protein for poor farmers, who have less access to animal source protein, because of their low purchasing capacity (Osho, 1995). The demand for soybean has increased in Africa and Ethiopia rapidly, driven by the growing feed industry for poultry, aquaculture and home consumption in the form of processed milk, baked beans and for blending with maize and wheat flour. The demand for soybean in Africa so far outweighs the supply; hence the deficit is mainly covered through imports of soybean products such as soybean meal. The area under soybean production has increased in response to the growing demand, a trend that is expected to continue in the coming years. As the production area increases, diseases and insect pests, declining soil fertility and other abiotic factors pose a major challenge. Soybean rust disease, earliness and reduction in productivity among the major threats to soybean production in Ethiopia due to its rapid spread as a result of the ease by which its spores are dispersed by the wind. Since 1950 efforts have been made in soybean variety development and/oradaptation with different agronomic and other management options in Ethiopian agricultural production systems. Hence, since soybean is an important crop with multiple benefits, which can be grown in rotation with cereals like maize, finger millet, and sorghum. Due to this fact developing new varieties that adapt with the newly emerging climate problem is imperative for end user. Therefore, the activity initiated with the general objectives of **to** develop soybean varieties adaptale to Western Oromia.

Materials and Methods

Seventeen medium maturity classes of soybean genotypes including standard check Keta were evaluated (Table 1) at Bako, Gute and Billo experimental sites in 2017 and 2018 main cropping season (Table 2). Planting was done in mid-June at each location. The design was randomized complete block design with three replications. Each plot consisted of six rows of 4 m length with 60 inter row and 10 cm intra row spacing. Four middle rows were used for data collection and harvesting. Fertilizer was applied at the rate of 100 kg NPS ha-^{1} during planting time. All other management practices were applied as per the recommendations.

Table 1: Lists of medium maturity classes of soybean genotypes used In study

S,N	**Genotypes**	**Source**
1	PM-12-31	JARC
2	PM-12-25	JARC
3	PM-12-43	JARC
4	PM-12-32	JARC
5	PM-12-21	JARC
6	PM-12-37	JARC
7	PM-12-38	JARC
8	PM-12-22	JARC
9	PM-12-20	JARC
10	PM-12-18	JARC
11	PM-12-44	JARC
12	PM-12-39	JARC
13	PM-12-35	JARC
14	PM-12-30	JARC
15	PM-12-45	JARC
16	PM-12-29	JARC
17	Keta (Check)	BARC

JARC= Jimma Agricultural Research Center BARC= Bako Agricultural Research Center

Table 2:Testing Environments and their main characteristics.

Location	Longitude (E)	Latitude (N)	Altitude (m a.s.l)	RF (mm)	Soil texture	Soil color
Bako	37°09'	09°06'	1650	1431	Sandy-clay	Red
Gute	036^{0}38.196’	09^{0}01.061’	1915	NI	Clay	Reddish brown
Billo	037^{0}00.165’	09^{0}54.097’	1645	1500	Clay loam	Reddish brown

Results and Discussion

Combined Analysis of Variance

There were statistically significant differences (P<0.01) among evaluated soybean genotypes, Genotypes, environment and their interaction for seed yield (Table 3). This suggests the existence of genetic variation among the soybean genotypes and possibility to select high yielding and stable variety (s), the environments are variable and the differential response of soybean genotypes across the testing environments. Similar result was reported for common bean and groundnut varieties by Zeleke *et al.* (2016) and Alemayehu *et al*. (2016), respectively.

Table 3: Combined analysis of variance for grain yield of medium soybean genotypes evaluated at six environments in western Oromia.

Source	DF	Mean Square
Environment	2	20563147.12**
Genotype	16	1024439.89**
Interaction	32	350272.45**
LSD (0.05)		86.12
CV (%)		6.66

LSD=Least Significant differences, CV=coefficient of variation, **= significant at P = 0.01, ns = nonsignificant

Performance of common bean genotypes across environments

The combined mean seed yield of medium maturity classes of soybean genotypes across environment (G X E) ranged from 2779.2 to 1525.8 kg ha^{-1} (Table 4). The highest grain yield was obtained from genotype PM-12-37 followed by PM-12-20andPM-12-31, while the lowest seed yield recorded from genotype PM-12-29 (Table 4). This difference may be due to their genetic potential. PM-12-37andPM-12-20 genotypes were the top ranking genotype across year and location at Bako and Gute.

GGE Biplot Analysis:

An ideal genotype is defined as genotype with the greatest PC1 score (mean performance) and with zero GEI, as represented by an arrow pointing to it (Figure 2). A genotype is more desirable if it is located closer to the concentric circle. The ranking based on the genotype-focused scaling assumes that stability and mean yield are equally important. In this study, genotype PM 12-37 and PM-12-20 which fell closest to the concentric circle are identified as the most desirable genotype as compared to the rest of the tested soybean genotypes (Figure 2). Similarly, Alemayehu et al. (2016) and Abate et al. (2015) identified ideal genotype based on the genotype-focused scaling**.**

Table 4: The difference in yield rank of varieties across the environments revealed the high crossover type of GxE interaction

Trt.	Genotypes	Year -1			Year -2			Combined GY
		Bako	Gute	Billo	Bako	Gute	Billo	(kg ha^{-1})
1	PM-12-31	3293.8^{cd}	1975.7^{cbd}	1598.9^{def}	2654.7^{a}	1985.57^{cb}	1426.3^{fec}	2155.8^{c}
2	PM-12-25	3433.7^{cd}	1701.8^{feg}	2188.8^{b}	1857.6^{fhg}	1331.1^{ef}	1258.9^{hig}	1962.0^{fg}
3	PM-12-43	3685.4^{b}	1909.7^{cd}	1716.1^{dc}	1964.3^{feg}	1849.17^{c}	1171.8^{hi}	2049.4^{de}
4	PM-12-32	2854.9^{ef}	2002.4^{cbd}	1749.9^{dc}	1875.7^{fheg}	1532.93^{d}	1907.3^{c}	1987.2^{fe}
5	PM-12-21	2612.9^{gf}	1672.87^{fg}	1419.9^{f}	1818^{fhg}	1410.8^{edf}	1563.3^{de}	1749.6^{ji}
6	PM-12-37	4020.4^{a}	2427.5^{a}	1520.3f^{e}	2396.9^{bc}	1876.63^{cb}	2641.7^{a}	2480.6^{a}
7	PM-12-38	3024.1^{ed}	1687^{fg}	1801.4^{c}	1804.5^{fhg}	1528.63^{ed}	1804.9^{c}	1941.8^{fg}
8	PM-12-22	3257.1^{cd}	1395.8^{i}	2182.5^{b}	1366.9^{i}	1227.03^{f}	1202.7^{hi}	1772.0^{ji}
9	PM-12-20	3097.5^{ed}	1942.9^{cbd}	2920.1^{a}	2474^{ba}	2050.63^{b}	1854.4^{c}	2389.9^{b}
10	PM-12-18	3023.^{7ed}	2103.3^{b}	2026.9^{b}	2075.4^{de}	2075.23^{b}	1741.8^{dc}	2174.4^{c}
11	PM-12-44	2031^{h}	1577.6^{hg}	2016.2^{b}	1753.4^{h}	1391.77^{edf}	1367.6^{fheg}	1689.6^{jk}
12	PM-12-39	3140.5^{d}	1823.1^{feg}	1525.9^{fe}	2653.3^{a}	1393.87^{edf}	2168.8^{b}	2117.6^{dc}
13	PM-12-35	2713.2^{gf}	2103.9^{b}	1514.6^{fe}	1188.3^{i}	1813.7^{c}	1292.8^{fhig}	1771.1^{j}
14	PM-12-30	2856.4^{ef}	1438.2^{ih}	1621.1d^{ce}	1777.6^{hg}	2363.03^{a}	1236.7^{hig}	1882.2^{hg}
15	PM-12-45	3077.5^{ed}	1287.1^{i}	1230.7^{g}	2226.1^{dc}	1527.63^{ed}	1563.8^{de}	1818.8^{hi}
16	PM-12-29	2608g^{f}	2065.6^{cb}	1151.5^{g}	1335.1^{i}	1459.17^{ed}	1091.7^{i}	1618.5^{k}
17	Keta	2458.9g^{f}	1880.8ed	1632.8dce	2010.7f^{e}	1817.57^{c}	1479.9^{fe}	1880.1^{hg}
Mean		3011.1	1823.3	1753.9	1954.845	1684.380	1574.973	1967.1
LSD (0.05)		278.3	180.38	180.74	209.3	201	214.3	86.9
CV (%)		5.57	5.94	6.2	6.4	7.2	8.2	6.7

Table 7: Yield related Traits across Years and Locations for Late set Soybean Variety Trial

Trt no	Genotypes	DF	DM	PH	PPPT	SPP	HSW
1	PM-12-31	77.0^{dc}	139.8^{g}	73.2^{bac}	69.6^{fed}	3	17.5^{a}
2	PM-12-25	76.4^{dce}	141.9^{feg}	69.1^{bda}	75.1^{bc}	2	13.3^{g}
3	PM-12-43	75.6^{e}	144.1^{de}	68.7^{bdc}	63.8^{fed}	3	15.0^{de}
4	PM-12-32	79.3^{b}	149.7^{ba}	71.3^{bac}	78.9^{ba}	2	15.0^{de}
5	PM-12-21	76.9^{dc}	141.8^{fg}	62.5^{fe}	67.2^{fecd}	3	13.3^{g}
6	PM-12-37	75.9^{e}	142.4^{fe}	71.1^{bac}	67.7^{fecd}	3	17.4^{ba}
7	PM-12-38	78.9^{b}	141.3^{fg}	69.8^{bdac}	86.9^{a}	3	13.9^{gef}
8	PM-12-22	76.3^{de}	142.^{6fe}	69.7^{bdac}	66.9^{fecd}	3	13.0^{g}
9	PM-12-20	82.9^{a}	151.2^{a}	59.9^{f}	73.5^{bcd}	2	14.9^{de}
10	PM-12-18	77.3^{c}	147.7^{bc}	72.1^{ba}c	68.3^{ecd}	3	16.3^{bc}
11	PM-12-44	75.7^{e}	142.9^{fe}	62.6^{fe}	69.0^{becd}	2	14.0^{gef}
12	PM-12-39	75.8^{e}	141.1^{fg}	71.6^{bac}	67.7^{f}	3	16.9^{ba}
13	PM-12-35	73.8^{f}	145.6^{dc}	64.7^{fde}	61.1^{fe}	3	13.8^{gf}
14	PM-12-30	75.5^{e}	145.4^{d}	74.0^{ba}	67.0^{fecd}	3	15.6^{dc}
15	PM-12-45	78.8^{b}	142.0^{fe}	72.6^{bac}	57.2^{f}	3	14.6^{def}
16	PM-12-29	78.8^{b}	146.1^{dc}	67.8^{dec}	59.9^{fe}	3	14.0^{gef}
17	Keta	74.4f	140.8^{fg}	74.6^{a}	66.8^{fecd}	3	17.6^{a}
Mean		77.0	143.9	69.1	67.6	2.3	15.1
	CV (%)	1.9	2.4	12.2	23.6	14.9	10.7
	Genotype	87.3***	188.4***	335.0***	4.13***	3.64***	16.6***
	YR*Loc	2996.2***	6074.2***	1280.4***	39.7***	1.36*	5.6***
	YR*Trt	18.4**	30.9***	65.7*	1.34*	1.37*	3.4***
	YR*Loc*Trt	11.2***	29.5***	101.5*	1.46*	1.1*	1.9***

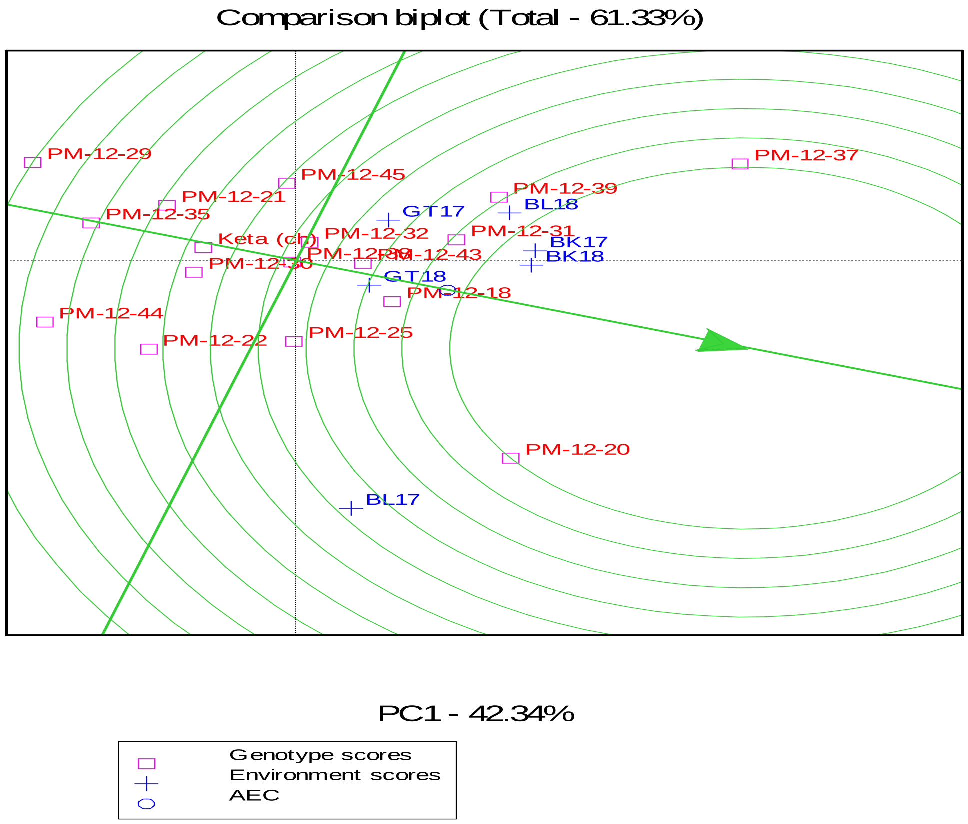

Figure 3 GGE biplot based on genotype-focused scales for comparison the genotypes with the ideal genotype.

Conclusion & Recommendation

GEI is differential phenotypic performance of genetically uniform genotypes across test environments. Soybean genotypes evaluated showed highly significant differences for seed yield performance and occurrence of significant GEI that complicated selection of high yielding and broadly adapted genotypes. GGE biplot enabled the identification of both high yielding and broadly adapted genotypes better than AMMI biplot. Among the evaluated medium set soybean genotypes, PM 12-37 and PM-12-20 were both high yielder and broadly adapted genotype to the test environments followed by PM 12-3 and PM 12-31. Hence, PM-12-37, PM-12-20 and PM-12-31 were identified as candidate varieties to be verified for the coming year for possible release.

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Genetic variability and traits associations among soybean Genotypes

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Abstract

Field experiment was conducted to assess the extent of genetic variability and traits associations in soybean genotypes for yield and its related traits and thereby generate information as well as identify superior genotypes for further research program. A total of thirty six Soybean genotypes were evaluated using simple lattice design at Fedis during 2018 cropping season. Data were recorded for major quantitative and qualitative traits and analyzed using appropriate statistical software. High values of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad sense heritability (H^2), and genetic advance as percent of mean (GAM) were observed for plant height, primary branches/plant, pods/plant, seeds/pod, and grain yield. Relatively high heritability coupled with high genetic advance as percent of mean was noted for pods/plant (59.15), plant height (57.48), grain yield (55.68), primary branches/plant (37.56), and hundred seeds weight (30.63) indicating the ease of phenotypic selection for the improvement of these traits. Most of the traits showed positive correlations among themselves both at phenotypic and genotypic levels. Grain yield had highly significant and positive genotypic and phenotypic correlation with primary branches/plant, pods/plant, seeds/pod and plant height, indicating that simultaneous improvement of the grain yields with the associated traits is possible. Plant height exerted the highest genotypic (0.74) and phenotypic (0.54) direct effect on grain yield, followed by hundred seeds weight and number of pods per plant. This indicated that attention should be given for these traits primarily for direct and indirect selection for variety development. The first three PCA explained 74.75% of the total variation and the traits such as hundred seeds weight (0.55), days to maturity (0.83), days to flowering (0.68), pods/plant (0.78), grain yield (0.72), primary branches/plant (0.52), seeds/pod (0.40) and plant height (0.39) accounted for the variability. The tested genotypes exhibited a wide range of variability for most of the traits. In order to get more reliable information on the variability and identify high yielding varieties, it is recommended to repeat the trial across years & locations.

Keywords: *Genetic variation, Genetic advance, Heritability, Selection intensity*

Introduction

Soybean (*Glycine max* (L.)) is emerging as important feed, food as well as raw material for producing high-quality protein and oil products in the world and in Africa including Ethiopia (Deresse, 2017). Its production in Ethiopia is very crucial to overcome malnutrition and it is cheap substitute for expensive animal protein (Zinaw *et al*., 2013). Due to the economic importance of the crop, soybean has been the focus of research, especially in the area of genetic improvement, to obtain improved cultivars, carrying genes capable of expressing broad adaptation and tolerance to biotic and abiotic factors, representing significant contributions to the productive sector (Soares *et al*., 2015). It has fairly wide range of adaptation involving a wide array of climatic, soil and growth conditions though it is mostly grown under rain-fed condition (Fageria *et al*., 1997). Genetic diversity is important for crop improvement and high levels of variations for different morphological traits including yield attributes and seed yield among the newly developed genotype of soybean (Malek *et al*., 2014). Despite the multiple benefits that soybean could provide to subsistence farmers of sub-Saharan Africa, its productivity is very low particularly in Ethiopia (2.2 tons ha^{-1}), far below many other sub-Saharan Africa (2.7 tons ha^{-1}) (FAOSTAT, 2017) Several production constraints are accountable for the low productivity including poor soils fertility, limited availability of early maturing or drought tolerant variety, limited availability of high yielding varieties, disease and pest. To increase production and productivity of the crop, particularly in eastern Hararghe; characterizing and screening for early maturing, and stress tolerant genotypes with proper plant architecture is paramount important. Therefore, this study was initiated to assess genetic variability and trait associations among soybean genotypes and identify adaptable genotypes to the study area for further breeding activities.

Materials and Methods

Experimental Site and Materials

The study was conducted at Fedis Agricultural Research Center, Eastern Hararghe zone. Fedis, is located at the latitude of 09^{o} 07' North and longitude of 042^{o} 04' East. In this experiment, five released soybean varieties and 31 accessions, a total of 36 genotypes (table 1) obtained from Bako Agricultural Research Center (BARC) were used for the experiment. The genotypes were grown under rainfed conditions. The experiment was planted on June 28, 2018 by hand drilling and covered lightly with soil.

Table 1 List of soybean genotypes that were used for the study at Fedis

No.	Genotypes	No	Genotypes
1	TGX-1990-95F	19	JM-PR142-H3-15-SB
2	TGX-1989-75FNF	20	JM-CLK/CRFD-15-SD
3	TGX-1989-53FN	21	JM-DAV/PR142-15-SA
4	TGX-1989-11F	22	TGX-1990-8F
5	TGX-1990-107FN	23	BRS-286
6	TGX-1993-4FN	24	PI-471904
7	TGX-110F	25	PI-567025A
8	TGX-1989-42F	26	PI-605829
9	TGX-1990-111FN	27	PI-605891B
10	TGX-1990-114FN	28	PI-567061
11	(M) TGX-1990-8F	29	Clark 63
12	TGX-1990-106FN	30	PI-230970
13	TGX-1989-45F	31	PI-567190
14	DAV/ALM-15-SA	32	Korme
15	JM-CLK/CRFP-15-SA	33	Awasa04
16	JM-ALM/PR142-15-SC	34	Keta
17	JM-ALM/H3-15-SC-1	35	Didessa
18	JM-PR142-SLK-15-SC-2	36	Awasa95

Note: Korme, Awasa04, Keta, Didessa Clark 63 and Awasa 95 are released varieties and all the rests are introduced materials

Experimental Design and Data collection

The field experiment was laid out in 6 x 6 simple lattice designs with two replications. The experimental plots consisted of four rows of 3 m length, 1.80 m width and 0.45 m row space with plot size of 5.40 m^2. The spacing between adjacent replications, blocks and plots were 1 m, 0.5 m and 0.5 m, respectively. Data for quantitative traits such as days to flowering, days to maturity, plant height (cm), primary branches per plant, secondary branches per plant, pods per plant, seed per plant, grain yield and hundred seeds weight (g) were collected. Five plants were randomly selected per plot at early vegetative stage for plant based data collected.

Data Analysis

Analysis of variance was done using Proc lattice and Proc GLM procedures of SAS version 9.0, (SAS, 2002). The differences among treatments means were compared using DMRT at 5% probability level.

Estimation of genetic variability and coefficients of variations

The genetic parameters like genotypic and phenotypic coefficients of variation were calculated according to the formula given by Falconer (1981).

Estimation of heritability in broad sense

Heritability in the broad sense was calculated using Hallauer and Miranda (1988) as follows:

$$H^2 = [\frac{\sigma^2 g}{\sigma^2 p}] * 100$$

Estimation of genetic advance

Genetic advance in absolute unit (GA) and percent of the mean (GAM), assuming selection of superior 5% of the genotypes was estimated and categorized as low (0-10%), moderate (10-20%) and high (20% and above) as illustrated by Johnson *et al*. (1955):

$$GA = k * \sigma p * H^2$$

$$\text{Genetic advance (as \% of mean)} = \left(\frac{GA}{Grand\ mean}\right) * 100$$

Estimation of correlation coefficient

Phenotypic and genotypic correlations were estimated using the standard procedure suggested by (Falconer *et al*., 1996) from the corresponding variance and covariance components using the equations:

$$\gamma pxy = \frac{\sigma pxy}{\sqrt{\sigma^2 Px \ X \ \sigma^2 Py}}$$

Estimate of path coefficient analysis

Path coefficient analysis was conducted as suggested by Wright (1921) and worked out by Dewey and Lu (1959) using the phenotypic as well as genotypic correlation coefficients to determine the direct and indirect effects of yield components on seed yield based on the following relationship.

$$r_{ij} = p_{ij} + \sum r_{ik} p_{kj}$$

Principal component analysis (PCA)

PCA was computed by using XLSTAT 2014.5.03 computer software Standardized quantitative data was used for the analysis.

Cluster analysis
The analysis was based on all yield and yield contributing traits. Clustering of genotypes were done using the PROC clustering strategy of SAS 9.0 (SAS, 2002) and appropriate numbers of clusters were determined from the values of Pseudo F and Pseudo T2 statistics (SAS, 2002).

Result and Discussion

Estimation of variance components
The highest genotypic coefficient of variation (30.84%) was observed for pods per plant followed by grain yield (28.77%), plant height (28.46%) and primary branches per plant (20.59%) which indicated the possibility to further improve these traits (table 2). Similar results were reported by Badkul *et al*. (2013); Sunday and Omolara (2014) and Soleh *et al*. (2016). Moderate genotypic and phenotypic coefficients of variation were estimated for days to maturity (11.39%, 11.51%), seeds per pod (14.27%, 16.53%) and hundred seeds weight (14.38%, 16.43%), respectively. Similarly, Badkul *et al*. (2013) reported moderate PCV and GCV for plant height (18.29% and 17.23%), hundred seeds weight (16.93% and 16.17%), seeds/pod (13.87% and 10.45%), harvest index (12.28% and 10.84%) and vegetative phase (10.12% and 9.91%).

Table 2. Estimation of genotypic and phenotypic variance, coefficient of variation, heritability in broad sense, genetic advance and genetic advance as percent of mean for quantitative traits of soybean

Traits	Mean	Range	sd	GV	PV	GCV	PCV	H^2	GA	GAM
Days to flowering	59.00	50.0-70.0	3.07	27.38	30.98	8.86	9.43	88.38	10.14	17.20
Days to maturity	119.00	96.0-141.0	3.39	184.62	188.76	11.38	11.51	77.80	27.72	23.23
Primary branches/plant	4.63	2.5-7.4	4.82	0.91	1.17	20.59	23.30	78.13	1.74	37.56
Secondary branches/plant	0.18	0.0-1.3	14.288	0.12	0.14	18.60	20.46	85.33	0.64	19.42
Plant height	52.80	20.6-117.4	5.39	225.92	235.74	28.46	29.07	95.83	30.35	57.48
Pods/plant	64.98	1.4-2.8	5.75	401.65	464.70	30.84	33.17	86.43	38.43	59.15
Seeds/pod	2.16	17.1-84.7	4.06	0.09	0.13	14.27	16.53	74.45	0.54	25.40
Hundred seed weight	14.38	10.6-21.8	4.26	5.59	6.85	16.43	18.19	81.58	4.40	30.63
Grain yield (tons/ha)	2406.93	0.5-3.7	5.53	47.96	54.51	28.77	30.67	87.99	1340.20	55.68

Key: sd= standard deviation GV=genotypic variance, PV=phenotypic variance, GCV=genotypic coefficient of variation, PCV=phenotypic coefficient of variation, H^2=heritability in broad sense, GA=genetic advance and GAM=genetic advance as percent of mean

Broad sense heritability (H^2) and genetic advance
The highest heritability (95.83%) was estimated for plant height, followed by days to flowering (88.37%), grain yield per hectare (87.98%), pods/plant (86.43%), secondary branches per plant (85.33%), hundred seeds weight (81.58%), primary branches/plant (78.13%), days to maturity (77.80%), and seeds per pod (74.44%), indicating that traits have high selection response. Similarly, Ramteke *et al*. (2010); Badkul *et al*. (2013), Teixeira *et al*. (2017), Bizari *et al*. (2017) Joshi *et al*. (2018), Neelima *et al*., (2018) and Shruti and Basavaraja (2019) reported supportive results for some of the traits. Contrary to the present

result, Sunday and Omolara, (2014) reported low genetic advance and also low GAM for plant height (0.87%) and pods per plant (4.36%).

Correlation Coefficient analysis

The magnitude of genotypic correlation is relatively higher than phenotypic correlation which indicated the presence of inherent association among various traits (table 3). Similarly, as reported by Machado *et al*. (2017) for most traits, genotypic correlations were higher than the phenotypic correlation. Almeida *et al*. (2010), Nogueira *et al*. (2012), Leite *et al*. (2015) and Sousa *et al*. (2015) found that phenotypic correlation is less than genotypic correlation, indicating the genetic factors contributed more than the environmental factor to the variations among the studied materials. Contrary, Ali *et al*., (2009) reported phenotypic correlation values were higher than the genotypic correlation values suggesting the importance of environmental effects.

Table 3. Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for traits of soybean genotypes

Traits	DF	DM	PB	SB	PPP	SPP	PH	HSW	GY
DF	**1.00**	0.79**	0.06	0.15	0.19	0.10	0.50**	-0.18	0.33*
DM	0.76**	**1.00**	-0.27*	0.04	-0.08	-0.15	0.39*	0.14	0.36*
PB	0.07	0.23	**1.00**	0.27*	0.69**	0.25	0.06	-0.22	0.59**
SB	0.14	0.05	0.29*	**1.00**	0.30*	-0.05	0.29*	-0.34*	0.35*
PPP	0.17	-0.07	0.66**	0.29*	**1.00**	0.51**	0.32*	-0.26*	0.72**
SPP	0.10	-0.12	0.24	-0.03	0.52**	**1.00**	0.26*	0.08	0.57**
PH	0.50**	0.39*	0.08	0.29*	0.33*	0.26*	**1.00**	-0.33*	0.43*
HSW	-0.17	0.14	-0.16	-0.30*	-0.23	0.06	-0.31*	**1.00**	0.27*
GY	0.32*	-0.26*	0.54**	0.32*	0.69**	0.52**	0.41**	0.25*	**1.00**

Key: * Significant ($P \leq 0.05$) and ** =highly significant ($P \leq 0.01$), DF= days to flowering, DM= days to maturity, PB= primary branches/plant, SB= secondary branches/plant, PPP= pods/plant, SPP=seeds/pod, PH=plant height, HSW=hundred seeds weight and GY=grain yield

Grain yield had highly significant and positive genotypic and phenotypic correlation with primary branches per plant, pods per plant, seeds per pod and plant height, indicating that it is favorable for the plant breeders for simultaneous improvement of the grain yields with the associated traits. The results were agreed with the work of Soleh *et al*. (2016) that grain yield showed significant positive correlations with branches per plant, pod length, pods per plant, seeds per plant and hundred seed weight.

On the other hand, grain yield had negative significant phenotypic correlation with days to maturity implying that early maturing soybean genotypes were high yielder than the late maturing genotypes. Besides, the result revealed that those materials are better adapted to moisture stress environments where there is short rainy season. The correlation study done by Malik *et al*. (2006) and Rajkumar *et al*. (2010) showed that yield was negatively associated with both days to flowering and maturity. Selection based on the knowledge and direction of association becomes very useful in identifying key characters which can be perfectly exploited in a short time to achieve yield improvement in soybean (Baig *et al*., 2017).

Path coefficient analysis

Estimation of direct and indirect effects for genotypic correlation revealed that hundred seeds weight has the highest positive direct effect on grain yield (0.803) followed by plant height (0.735) and pods/plant (0.489) (table 4). While, seeds/pod (0.176), primary branches/plant (0.127) and secondary branches/plant showed non significant and positive direct effect. So, the improvement of grain yield is as the expense of hundred seeds weight, plant height, pods/plant, secondary branches/plant, primary branches/plant and seeds/pod. Similarly, Gyanesh *et al*. (2016) and Soleh *et al.* (2016) reported the highest positive indirect effects on yield/plant were the number of pods/plant; followed by the number of branches/plant, the number of seeds/plant, hundred seed weight, pod length and days to flowering. Alcantara *et al*. (2011), Silva *et al*. (2014), Malek *et al*. (2014) and Rodrigues *et al*. (2015) also reported that the number of pods per plant was the most soybean yield influencing trait.

Table 4. Estimates of direct (bold diagonal) & indirect effect (off diagonal) at genotypic level

Traits	DF	DM	PB	SB	PPP	SPP	PH	HSW	r_g
DF	**-0.045**	-0.062	0.008	0.006	0.095	0.019	0.375*	-0.067	0.329*
DM	-0.004	**-0.668***	-0.035	0.005	-0.041	-0.027	0.287*	0.119	-0.364*
PB	-0.003	0.186	**0.127**	0.032	0.340*	0.044	0.049	-0.18	0.594**
SB	-0.002	-0.031	0.035	**0.115**	0.295	-0.009	0.22	-0.274*	0.348*
PPP	-0.009	0.057	0.088	0.069	**0.489***	0.003	0.24	-0.216	0.722**
SPP	-0.005	0.101	0.032	-0.006	0.009	**0.176**	0.194	0.065	0.566**
PH	-0.023	-0.261	0.008	0.034	0.16	0.046	**0.735***	-0.272*	0.428**
HSW	0.004	0.099	-0.028	-0.039	-0.132	0.014	-0.249	**0.803***	0.274*

Key: *=significant (P≤0.05), **= highly significant (P≤0.01), Residual effect=0.39, DF=days to flowering, DM=days to maturity, PB=primary branches/plant, PPP=pods/plant, SPP=seeds/pod, PH=plant height and HSW=hundred seeds weight, r_g =genotypic correlation with grain yield

Estimation of path coefficient revealed that primary branches per plant exerted positive genotypic direct effect to grain yield and also showed positive genotypic indirect effect through pods per plant and seeds per plant to grain yield. The causes of the positive association of primary branches per plant with yield were mainly due to its positive direct effect and indirect effects through pods/plant and seeds/pod. In general, the study suggested that pods per plant, plant height, hundred seeds weight and primary branches per plant should be given more emphasis while determining selection breeding strategies for successful soybean yield improvement. Similarly, Malek *et al*. (2014) reported that the important yield attributes are the number of pods per plant, seeds per pod and hundred seed weight, which determine the seed yield of soybean.

Table 5. Estimates of direct (bold diagonal) & indirect effect (off diagonal) at genotypic level

Traits	DF	DM	PB	SB	PPP	SPP	PH	HSW	r_p
DF	**0.091**	-0.317	0.108	0.01	0.111	0.042	0.268	0.001	0.315*
DM	0.033	**-0.864****	0.045	0.004	0.172	0.027	0.317	0.002	-0.264*
PB	0.053	-0.207	**0.187**	0.007	0.291	0.052	0.152	0.001	0.535**
SB	0.013	-0.147	0.056	**0.024**	0.186	0.029	0.161	0.00	0.321*
PPP	0.016	-0.237	0.031	0.007	**0.625****	0.069	0.177	0.006	0.694**
SPP	0.018	-0.112	0.046	0.003	0.204	**0.21**	0.143	0.004	0.516**
PH	0.045	-0.512	0.072	0.007	0.207	0.056	**0.536****	0.00	0.411*
HSW	0.043	-0.121	0.012	-0.007	0.27	0.055	-0.011	**0.013**	0.255*

Key: *=significant (P≤0.05), **=highly significant (P≤0.01) and Residual effect=0.36, DF=days to flowering, DM=days to maturity, PB=branches/plant, PPP= pods/plant, SPP= seeds per pod, PH=plant height and HSW=hundred seeds weight r_p= phenotypic correlation with grain yield

Cluster analysis

Cluster analysis revealed that the 36 soybean genotypes were grouped into 4 clusters (Fig 1). Cluster I was the largest cluster with 14 (38.89%) genotypes followed by cluster II which contained 12 (36.11%) genotypes, cluster III contains 6 genotypes (19.44%) and Cluster IV contained 4 genotypes which is 5.56% of the total population.

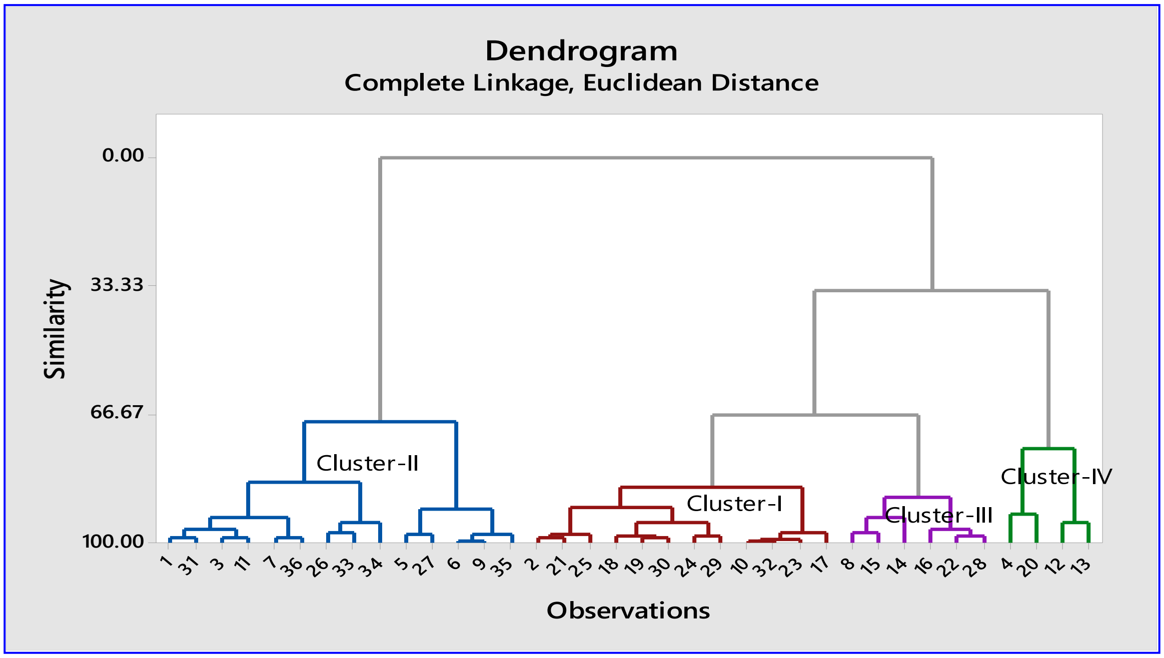

Figure 1. Dendogram showing the similarities based on nine major quantitative traits for standardized data among the 36 soybean genotypes

The number of clusters represents the number of groups in which a genotype can be classified on the basis of D^2 analysis. The genotypes falling in the same cluster are more closely related than those belonging to another cluster. In order words, the genotypes grouped together in one cluster are less divergent than those which are placed in a different cluster. It provides information about relationship between various clusters. Among the four clusters the highest cluster mean for traits such as plant height (59.40 cm), days to flowering (61.73 days) and days to maturity (124.21 days) were found in cluster I. The second cluster was characterized by the highest mean grain yield (3.20 tons ha^{-1}), number of pods per plant (81.64), number of seeds per pod (2.40) and number of branches per plant (5.16). Cluster IV had the highest hundred seeds weight (16.40 g) (data not shown).

Principal component analysis (PCA)

The first three principal components with Eigen values greater than one cumulatively explained about 74.75% of the total variation (Table 6). In line with the present study, Wallace *et al*. (2018) reported the first three principal components with eigenvalues higher than one explaining 67.58% of the total variance contained in eight original variables.

Table 6 . The first three principal components of 36 soybean genotypes

	Major Principal Components		
Traits	PCA-I	PCA-II	PCA-III
Day to flowering	0.14	0.68	0.02
Days to maturity	0.00	0.83	0.07
Hundred seed weight	0.11	0.03	0.55
Primary branches/plant	0.52	0.12	0.03
Secondary branches/plant	0.17	0.03	0.38
Plant height	0.39	0.26	0.00
Pods/plant	0.78	0.04	0.00
Seeds/pod	0.40	0.06	0.27
Grain yield	0.72	0.06	0.06
Eigenvalue	3.25	2.11	1.37
Percent of variance explained (%)	36.05	23.47	15.23

Key: PCA- principal component axis

Estimation of principal component analysis revealed that pods per plant (0.78), grain yield (0.72) primary branches per plant (0.52), seeds per pod (0.40) and plant height (0.39) were the major contributors for the variation observed in the first principal component. Similarly, days to maturity (0.83) and days to flowering (0.68) contributed to variation observed in the second principal component; hundred seeds weight (0.55) and secondary branches per plant (0.38) were shows significant contribution in the third principal component. Zafar *et al*. (2008) reported that the first two PCA explained total variance of 77.0%. Similarly, Ghafoor *et al*. (2003) and Malek *et al*. (2014) reported the first three to four principal component contributes significantly to the overall variations, respectively.

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Evaluation of Early Maturing Sorghum Varieties and Cowpea Genotypes Intercropping for Their Land Productivity and Animal Nutritive Value in Fedis District, Eastern Ethiopia

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Abstract

Shortage of arable land and shortage of livestock feed are major constraints in East Hararghe Zone. Thus, a field study was conducted to evaluate an early maturing sorghum varieties intercropped with cowpea genotypes for both food and feed production at Fedis Agricultural Research Center, eastern Ethiopia in 2018 cropping season. Two cowpea genotypes (9333 and 9334) were intercropped with three varieties of early maturing sorghum (Teshale, Birhan and Melkam) and compared with sole cropping of all the varieties. The design was randomized complete block design with three replications. The analyzed result showed the total land productivity of component crops in sorghum-cowpea varieties intercropping was highly superior to and more advantageous over sole cropping. The value of Land Equivalent Ratio (LER) ranges from 1.21 for Sorghum (Teshale) + Cowpea (9334) to 1.36 for sorghum (Birhan) + cowpea (9333). The overall mean LER was obtained as 1.30. Intercropping sorghum improved the Crude Protein (CP) of sorghum stover mean from sole (5.31%) to intercropped (6.03%), the neutral detergent fiber (NDF) content was significantly different (p < 0.05) among intercropped and sole sorghum the maximum NDF was recorded from sole sorghum Teshale (69.56%) and the minimum sorghum Birhan + cowpea (9333)(57.75%). Cropping systems and cowpea genotypes were significantly affected (p < 0.05) the content of CP and NDF. Maximum CP obtained from cowpea (9334) + sorghum Teshale variety (29.19%), and the minimum CP obtained from sole cowpea (9333) (24.38%).Generally, the results of this study showed that intercropping of sorghum-cowpea were increased the productivity of grain yields and biomass yields of sorghum varieties and it increased nutritional quality of cowpea and sorghum stover. Based on the results of this study, it could be concluded that intercropping sorghum with forage cowpea; preferably sorghum Melkam + cowpea (9333) to be appropriate to increase the productivity and quality of sorghum stover in the study area.

Keywords: Chemical composition, Forage legumes, Land equivalent ratio

Introduction

Ethiopian has a large livestock population and diverse agro-ecological zones suitable for livestock production and for growing diverse types of food and fodder crops. However, livestock production has mostly been subsistence-oriented and characterized by very low reproductive and production performance. This is primarily due to shortages of quality and quantity of animal feed (Maleda, 2013). The constraint of livestock feed due to land degradation, land shortage and poor soil fertility (Tewoderos *et al*., 2007) and also as the result of a rapidly increasing human population pressure, cropping is expanding and grazing areas are shrinking (Adugna, 2007). Intercropping is a system that has long been practiced by smallholder farmers in various tropical and sub-tropical regions worldwide (Brooker *et al*., 2016). Intercropping is a potentially beneficial system to mitigate risks associated with crop failure (Kermaha *et al*., 2017). Cereal-legume intercropping increases yields compared with sole crops Hu *et al*. (2016) because one component can enhance the survival and growth of the other component in the system. Cereal-legume intercrops have greater nutrient use efficiency because legume has the ability to fix atmospheric N and make available to the cereal crop Musa *et al*. (2012) and hence improve animal nutritional quality of the component crops.

The released varieties of sorghum have a yield potential of 4.0 to 6.0 t ha^{-1}, which are two to three-fold higher from the national average yield. However, there has been limited adoption rate of the improved varieties mainly due to lower biomass production of these varieties in comparison to the long maturing landraces as the farmers predominantly prefer for its high biomass for fuel and animal feeds. However, the long maturing varieties are unable to escape the drought period and hence lead to crop failure. Therefore, it is very crucial to increase the adoption rate of early maturing varieties by increasing its productivity through appropriate agronomic practices. Intercropping of compatible crops/ like sorghum and legume crops, are one of the best practice to insure the crop yield productivity while reducing the possibility of crop failure due to drought problem. Cowpea is among the most widely used legumes in the tropical world. It can be incorporated into cereal cropping system to address soil fertility decline and cereals to the provision of better legume/stover to cereal (Cook *et al*., 2005). Compatible companion crops in intercropping systems under limited external inputs could provide a potential productivity and profitability (Yildirim and Guyenc, 2005), and a potential systems to reduce shortage of animal feeds, particularly in areas where cropland is in scarce.
The main objectives of this study was to evaluate system productivity of sorghum-cowpea intercropping & evaluate nutritional quality of sorghum stover and cowpea herbage for animal feed in intercropping and sole cropping systems.

Materials and Methods

Description of the Study Area

The study was conducted at Boko substation of Fedis Agricultural Research Center under rainfed condition. The station is found in eastern parts of Ethiopia, which is 550 km to the East of Addis Ababa and 24 km southeast of Harari city. Fedis Woreda is situated at an altitude of 1050 to 2118 m above sea level (Fuad *et al*., 2018). The amount of rainfall varies between 650 and 750 mm, while the average temperature of the Woreda ranges between 25 and 30°C (Zenna, 2016).

Description of the Experimental Materials

Two-cowpea genotypes (9334 and 9333) were used with three varieties of early maturing sorghum (Teshale, Birhan and Melkam) and all the materials were obtained from Fedis Agricultural Research Center. The experimental materials were selected on the basis of their current and potential importance and mainly on their productivity and heights of the plants.

Treatments and Experimental Design

Cowpea and sorghum under sole and intercropping systems were laid out in a randomized complete block design (RCBD) with three replications in a plot area of (3×3) m^2, 1m between plot and 1.5m between block. Sorghum was planted at a spacing of 75 cm between rows and 20 cm between plants for sole and intercropping. Cowpea in intercropping was planted after twenty days of sorghum planting. Cowpea was planted in central rows of sorghum, which was 37.5 cm far away from sorghum row under intercropping and between sole rows of cowpea. In other words, intercropped cowpea was planted at a spacing of 75cm between rows. Sorghum-Cowpea intercropping were planted 1:1(one row of cowpea with one row sorghum) row arrangement as a recommended of Tajudeen and Aliyu (2010) and seed proportion for intercropping 75:25 sorghum + cowpea respectively, whereas Sorghum + Cowpea in 70:30 seed proportion biomass increment by 52% (Zamir *et al*., 2016). And more seed proportion percentage was taken by sorghum because Sorghum was the main crops in the area. The sole cowpeas were planted in 37.5 cm between rows and 10 cm between plants.

Table 1. Treatment arrangements of the crops and seed proportion

Treatments	Treatment descriptions	Sowing proportion in % (cowpea: sorghum)
T1	Cowpea (9334) + Sorghum (Teshale)	25:75
T2	Cowpea (9334) + Sorghum (Birhan)	25:75
T3	Cowpea (9334) +Sorghum(Melkam)	25:75
T4	Cowpea (9333) +Sorghum (Teshale)	25:75
T5	Cowpea (9333) + Sorghum (Birhan)	25:75
T6	Cowpea (9333) + Sorghum (Melkam)	25:75
T7	Cowpea (9334) sole	100
T8	Cowpea (9333) sole	100
T9	Sorghum(Teshale) sole	100
T10	Sorghum (Melkam) sole	100
T11	Sorghum (Birhan) sole	100

Experimental Procedure and Field Management

Land preparation was done at the middle of April with a tractor, harrowed and leveled before planting. The seed rate of 12 kg ha^{-1} and 9 kg ha^{-1} for sole and intercropping sorghum respectively was planted at row spacing of 75 cm through drip sowing with 5cm deeps when the soil has enough moisture for seed germination. After twenty days, cowpea genotypes were planted with the seed rate of 30 kg ha^{-1} and 8 kg ha^{-1} for sole and intercropping, respectively. Application of NPS (19% N, 38% P_2O_5 and 7% S) and Urea (46% N) at 100 kg ha^{-1} rate was uniformly applied the time of sorghum planting while urea at the rate of 100 kg ha^{-1} was uniformly applied after plants emerged 2-3 leaves. Before urea application, thinning should be done to reduce the population of sorghum to normal plant population and weeds were also cleared.

Data Collection and Measurement

Chemical and nutritional quality parameters of cowpea-sorghum intercropping

Chemical and quality parameters: five randomly sampled plants were taken at 50% flowering stage for both crops to determine dry biomass yield. The dry biomass weight of the sample taken after partial sun-dried of 150 g and then the samples were oven-dried at 65 °C for 72 hours to determine dry matter yield. The samples were analyzed for Dry Matter (DM), Crude Protein (CP), fiber and Ash at Holeta Agricultural Research Center nutrition laboratory.

Crude protein (**CP**): nitrogen concentration of sorghum/cowpea was determined by grinding the plant material, its digestion and distillation by micro-Kjeldahl method (AOAC, 1994).The crude protein content was determined as a product of N x 6.25 (Jackson, 1962).

Fiber: Alternative procedure for fiber which had been developed by Van Soest method (detergent Method) used to determine insoluble cell wall matrix (Van Soest, 1967) such as;

Neutral detergent fiber (NDF): which was the residue after extraction with boiling neutral solutions of sodium lauryl sulfate and ethylene-diamine tetra acetic acid, consists mainly of lignin, cellulose and hemicellulose

Acid detergent fiber (ADF): it was the residue after refluxing with 0.5 M sulphuric acid and cetyltrimethyl-ammonium bromide, and represents the crude lignin and cellulose fractions of plant material

Acid detergent lignin (ADL): it was determination involves the preparation of acid detergent fiber as the preparatory step. The ADF was treated with 72 percent sulphuric acid, which dissolves cellulose. Ashing the residue determines crude lignin

Ash: it was determined by igniting the dried sample in a muffle furnace at 500°C overnight and Cool in a desiccator and take weigh.

In vitro **dry matter digestibility (IVDMD)**: it was a laboratory test used as a plant quality index for animal feed by animal nutritionists (Tilley and Terry 1963, Harris 1970). *In vitro* dry matter digestibility (IVDMD) was analyzed at Holetta Agricultural Research Center. The two-stage Rumen liquor was collected from two ruminally fistulated steer and transported to the laboratory using thermos flask that has been pre-warmed to 39 °C. Rumen liquor was taken in the morning before animals were offered a feed. A duplicate sample (0.5 g each) was incubated with 30 ml of rumen liquor in 100 ml test tube in a water bath at 39 °C for a period of 48 hours for microbial digestion followed by another 48 hours for enzyme digestion with acid pepsin solution. Drying of samples residues was done at 105 °C for 24 hours. IVDMD was calculated (Jeans and Yolande, 2007)

The sample was then ashed to estimate *In vitro* OM digestibility as:

$$\frac{\text{OM in the feed- (OM in residue – blank)}}{\text{OM in the feed}} \times 100$$

where OM = DM- Ash (measured after incineration of feed or residue).

Competition, land productivity and gross value total

The competitive behavior of component crops in different sorghum/cowpea planting patterns were determined in the data in terms of land equivalent ratio (LER), gross value total (GVT), relative yield total (RYT), and percentage of land saved (LS%), of sorghum and cowpea by using the following formula.

Land equivalent ratio (LER): it measured the effectiveness of intercropping in using the the limited common resources compared to sole cropping. It was calculated according to Mead and Willey (1980)LER= (LER sorghum + LER cowpea), where LER sorghum = (Ysi/Yss), and LER cowpea = (Yci/Ycs), where Yss and Ycs were the yields of sorghum and cowpea as sole crops respectively, and Ysi and Yci were the yields of sorghum and cowpea as intercrops, respectively.

If LER is >1, the intercrop is more efficient in terms of land use and if it is < 1 the intercropping is not efficient.

Gross value total (GVT): the net production of Sorghum mono and intercropped crops were compared using GVT (Hauggaard-Nielsen, (2001) calculated as follows;

$$GVT = \frac{psIm + paIa + pbIb}{pmMm}$$

Where the prices of Sorghum (ps) and the companion crops (pa, pb) are included. RMV >1.0 indicates that the intercrop is advantageous compared with the mono-crop. The following market prices collected in January to March, 2019 at Fedis were used: sorghum = 12 ETB/kg and cowpea = 15 ETB/kg.

Percentage of land saved (LS%) were determined as described by Workayehu (2014) using the formula below; Land saved (%) =100− ($1/_{LER}$×100)

Statistical Analysis

Data were analyzed using the Statistical Analysis Software to perform ANOVA (SAS 9.1) in a randomized complete block design. Means of all treatments were calculated and the difference was tested for significance using the least significant difference (LSD) test at $p < 0.05$ (Gomez and Gomez, 1984).

Results and Discussion

Competition, Land productivity and Gross Value Total

The productivity of component crops in sorghum/cowpea varieties intercropping evaluated by calculated total land equivalent ratio (LER), relative yield total (RYT), percentage of land saved (LS%), and Gross Value Total (GVT). In Table (2), partial land equivalent ratio (LERp) and total land equivalent ratio (LERt) of sorghum and cowpea intercropping was more than unity (> 1), which showed that intercropping of sorghum and cowpea was advantageous than sole cropping. The value of LER was ranged from 1.21 to 1.36 when sorghum (Teshale) + cowpea (9334) and sorghum (Birhan) + cowpea (9333) were respectively used and overall mean was obtained 1.30 from the system. The mean total LER (1.30) indicates that the combination of 75% seed proportion sorghum and 25% seed proportion of cowpea gave a 30% yield advantage than planting Sorghum or Cowpea independently as sole crops. Thus suggested that cereal-legume intercropping systems are more resource complementary than legume-legume or cereal-cereal intercropping systems

This result was agreed with the report of Ahmed *et al*. (2013) where the LER of sorghum/cowpea intercrops ranged from 1.18 to 1.28. Similarly, Berhane *et al*. (2015) reported LER of (1.19) from sorghum-cowpea intercropping and Zamir *et al*. (2016) Sorghum + Cowpea in 70:30 seed proportion observed LER of 1.52. This showed that competitive performance of component crops in intercropping systems vary depending upon variety, type of intercropping, soil fertility and agro-climatic conditions.

Percentage of the land saved (LS): The percentage of land saved ranges for grain yields from 17.37% to 26.47% that was obtained from treatments of sorghum Teshale + cowpea genotypes (9334) to sorghum Birhan + cowpea genotypes (9333), respectively and for Biomass yield production accounts from 27.01% to 36.71% that obtained from treatment sorghum Melkam + cowpea (9333) and sorghum Birhan + cowpea (9334) respectively. Sorghum-cowpea intercropping could be attributed to less competition of growth resources

Table 2. Land productivity, percentage of land saved and gross value total of sorghum/cowpea intercropping system at Fedis station

	Partial (LER and RYT)				Total (LER&RYT)			
Trts	Sorghum		Cowpea				LS%	
	GY	ADBY	GY	ADBY	GY	ADBY	GY	ADBY
T1	0.87	1.13	0.34	0.39	1.21	1.52	17.36	34.21
T2	0.82	1.04	0.49	0.54	1.31	1.58	23.66	36.71
T3	0.95	1.06	0.36	0.37	1.31	1.43	23.66	30.07
T4	0.98	1.03	0.36	0.42	1.34	1.45	25.37	31.03
T5	0.87	0.85	0.49	0.51	1.36	1.36	26.47	26.47
T6	0.96	0.99	0.32	0.38	1.28	1.37	21.88	27.01
Mean	0.91	1.02	0.39	0.44	1.30	1.46	23.25	31.51

Trts =treatments, T1=Cowpea (9334) + Sorghum (Teshale); T2=Cowpea (9334) + Sorghum (Birhan); T3 = Cowpea (9334) +Sorghum (Melkam); T4 = Cowpea (9333) +Sorghum (Teshale) T5= Cowpea (9333) + Sorghum (Birhan); T6= Cowpea (9333) + Sorghum (Melkam); LER = land equivalent ratio; RYT = relative yield total; and LS = percentages of land saved

Gross value total (GVT): the net production of Sorghum mono and intercropped crops were compared. GVT was calculated. The result (1.03 > 1) showed that the intercropped was advantageous. RMV >1.0 indicates that the intercrop is advantageous compared with the mono-crop. Based on the following market prices collected in January to March 2019 at Fedis: sorghum price = 12 ETB/kg and cowpea price = 15 ETB/kg.

Chemical and Nutritional Quality Parameters of Cowpea-Sorghum Intercropping
Sorghum stover chemical composition and in vitro organic matter digestibility

There was a significant difference ($p < 0.05$) among the chemical composition content (Ash and NDF). But none significant of DM, CP and ADF) of sorghum stover due to the effect of cropping systems (under sole and intercropped sorghum-cowpea) and varieties of sorghum showed in (Table 3). The dry matter content was not significantly different ($P > 0.05$) in the stover obtained from the intercropping as well as sole sorghum varieties. However, in all treatments, the result of DM% that obtained higher than 92%, and average dry matter content was 93.04%. This result was indicated that high dry matter obtained when compared with 2012 feed composition table of sorghum stover of (87%) DM and also most “dry” feeds, such as grains and hays, often have a DM content of around 85% to 92%. “Wet” feeds, such as silage and wet distiller’s grains, typically have a DM content of 25 to 35 percent. Ash of sorghum Stover was significantly different ($p < 0.05$) under sole and intercropping of sorghum/cowpea and sorghum varieties (Table 2). The maximum Ash recorded by sole sorghum of Melkam [(T10, (13.02%) and followed by sole Teshale and sole Birhan (T9, 11.66% and T11 11.23%)] respectively. The minimum obtained from intercropped sorghum stover of Teshale (T4, 9.88%), (T1, 10.02%). Intercropping reduced the Ash content of the stover of sorghum. This was due to the additive effect of cowpea intercropping on total forage quality. The result of this finding is in conformity with the finding of Usman (2014) noted that which lablab intercropping increased the DM but decreased the ash content. The crude protein content was not significantly different ($P > 0.05$) in the stover obtained from the different treatments of sorghum varieties and intercropping. However, it showed in (Table 3) that numerically different among cropping systems and sorghum varieties. The maximum CP recorded by cowpea (9333) + sorghum Birhan (T5), cowpea (9334) + sorghum Birhan (T2) and sole sorghum Birhan T11); (6.81%, 6.68% and 6.26%) were followed by cowpea (9333) + sorghum Melkam (T6), cowpea (9334) + sorghum Melkam (T3) and sole sorghum Melkam (T10) (5.96%, 5.86% and 5.11%) respectively.

The minimum CP obtained from sorghum Stover of sole sorghum Teshale [(T9, (4.57%). In general CP that obtained from tested sorghum stover were classified under poor quality animal feeds according to General Forage Quality Standards for Livestock Diets classification, > 19% prime(the best quality feeds), QS(1)17-19%, QS(2)14-16%, QS(3) 11-14%, QS(4) 8-10% and QS(5) < 8% of CP indicated that the lowest quality. This indicates that when sorghum intercropping with forage cowpea; it numerically improves the quality of sorghum Stover mean under intercropped (6.03%) CP than sole sorghum stover (5.31%). This result agreed with the finding of Mergia (2012), the CP content of maize under sown with forage legumes was the higher ranging from 7.2 to 7.3%, while the CP content of Stover from pure stands was the lowest 6.9% or 69 g/kg/DM. Also, this result similar range with Sergio and Shelby (2016) Oregon State University stated that most forage has a range of 4% to 24% CP on a DM basis.

The fiber fractions; [acid detergent fiber (ADF), neutral detergent fiber (NDF) and acid detergent lignin (ADL)]; the NDF content was significantly different ($p < 0.05$) in the stover obtained from the intercropping and sole sorghum. The maximum NDF was recorded from sole sorghum Teshale (T9) whereas the minimum NDF of sorghum stover was obtained of sorghum Birhan + cowpea (9333). This may be due to free asses nutrients and solar radiation among the crops. The average NDF of sorghum stover; Birhan (59.16%) classified under QS (3), Melkam stover (64.66) under QS (4) and Teshale Stover (65.56) category under QS(5) or lower (poor) quality animal feeds. The ADF% of sorghum stover not affected by sorghum-cowpea intercropping and varieties of sorghum. Even if neutral detergent fiber represents the total fiber component of the feedstuff and value consists of all the cell wall contents plus the acid detergent lignin (ADL) contents ADF and ADL was not statistically affected. Also it includes cellulose, hemicelluloses, and lignin, but unlike ADF, it has no bearing on quality and digestibility. The ADF of sorghum stover of [(Birhan (37.54%) better than Melkam (40.35%) and Melkam (40.35) better than Teshale (41.86) averagely]. However, sorghum varieties was not affected sorghum stover and under different category based on "General Forage Quality Standards for Livestock Diets" i.e. prime < 40% (the best quality feeds), QS (1)40-46%, QS (2) 47-53%, QS (3) 54-60%, QS (4) 61-65% and QS (5) > 65% of NDF indicated that the lowest quality. Based on this description the result that obtained from varieties were low; because cereals are higher in lignin content than legumes, grass-legumes was decreased the neutral detergent fiber (NDF) and improve the crude protein content, which is important for production of quality forage. Thus lined with Iqbal *et al*. (2017) sorghum sown 15 days after Soybean in 2-2 row ratio intercropping decrease the neutral detergent fiber (NDF) and improve the crude protein content

Table 4. Chemical composition and *in vitro* dry matter digestibility of sorghum Stover grown in sole and under sorghum/cowpea intercropping system

Cropping system	Trts	DM (%)	Ash (%)	CP (%)	NDF (%)	ADF (%)	ADL (%)	IVOMD(%)
Intercropped	T1	92.64	10.02^{e}	5.07	65.56^{b}	38.42	4.35	51.29
Sorghum	T2	93.03	10.7^{cd}	6.26	59.62^{e}	37.79	4.48	51.32
	T3	92.39	10.65^{d}	5.56	63.54^{cd}	38.39	4.61	50.07
	T4	93.23	9.88^{e}	4.88	64.61^{bc}	43.25	4.71	53.12
	T5	93.7	10.79^{cd}	6.81	57.75^{f}	37.16	4.73	50.42
	T6	93.58	10.66^{d}	5.95	62.98^{d}	41.3	4.99	53.4
Sole Sorghum	T9	93.01	11.66^{b}	4.57	69.56^{a}	40.91	4.58	47.61
	T10	92.73	13.02^{a}	5.11	63.82^{cd}	41.38	4.59	49.48
	T11	93.07	11.23^{bc}	6.68	60.12^{e}	37.68	4.41	51.63
CV (%)		1.07	1.6	1.52	0.61	0.82	1.53	1.09
LSD (0.05)		NS	0.56	NS	1.12	NS	NS	NS

Trts = treatments, DM = dry matter, CP = rude protein, NDF= neutral detergent fiber; ADF = acid detergent fiber; IVOMD = in vitro organic matter digestible; NS = none significant. LSD = Least significant difference; CV = coefficient of variance.

***In vitro* organic matter digestibility** of sorghum stover: IOMD sorghum Stover was no a significant difference (p > 0.05) among sorghum varieties and cropping systems. However, numerically both cropping systems and sorghum varieties were affected sorghum stover of IVOMD. The highest IVOMD were recorded of T6 53.4% under intercropping of cowpea (9333) + sorghum melkam. The lowest IVOMD of sorghum Stover were recorded under sole cropping of sorghum of Teshale (T9) and Melkam (T10) (47.61% and 49.48%) respectively. This different was might be mainly due to the stage of maturity of sorghum, because as indicated intercropping was significantly increased days to maturity and reduced ADF among thus sorghum varieties. This was agreed the finding of Njoka *et al*. (2006) intercropping the grass with lablab there is an increase in crude protein and decrease in ADF and ADL, which increases the IVDMD of the Napier grass. Also this result was higher than the result that reported by Mekuanint and Girma (2017) on the cereal straw and major feed resource in Bale Zone; *In vitro* DM digestibility aftermath and wheat straw was 40.36 and 41.92% in Gasera district and 40.78 and 42.22% in Ginnir district, respectively

Forage cowpea chemical composition and *in vitro* organic matter digestibility

There was a significant difference (p < 0.05) of the chemical composition content CP and NDF among cropping systems and cowpea genotypes. The maximum CP obtained from cowpea (9334) intercropped with sorghum Teshale (T1) and sorghum Melkam (T3) 29.19% and 28.06% of dry matter basis; whereas the minimum CP obtained from under sole cowpea (9333) (T8, 24.38%) and cowpea (9334) (T7, 25.19%).This might be due cowpea not further exposed to solar radiation and sorghum hiding cowpea form sun shine and winds then decrease the stage of maturity and shattering of the leaves; increased CP. The maximum NDF obtained from sole cowpea (9333) and the minimum was obtained from T1; cowpea (9334) + sorghum Teshale. So intercropping of cowpea-sorghum increased the quality of forage cowpea by increased CP and decreasing fiber content as fiber is considered to be an anti-nutritional factor. This due to intercropping protected the shattering of leaves of cowpea and protein accumulation high in leaves than in steams. Thus result lined with Ahmad *et al*. (2007b) sorghum-cowpea and sorghum-sesbania produced better results in terms of green forage yield and quality. However, sorghum-cowpea intercropping and varieties of cowpea were not affected among chemical composition like; DM, ash, ADF and IVOMD of cowpea. In (Table 5) the result indicated that the mean was numerically different among cowpea (9334) (90.85%) and cowpea (9333) (91.73%). In general of forage cowpea in both under sole cowpea and intercropping of cowpea-sorghum of CP, NDF, ADF, ADL and IVOMD (25.89%, 44.6%, 24.43%, 2.92% and 61.09%) respectively. Thus result indicated that tested cowpea genotypes were categories under prime quality > 19% CP, 1^0 quality NDF 40-46%, prime quality ADF < 31% and 2^0 quality IVOMD 58-61% respectively according to "General Forage Quality Standards for Livestock Diets" so the result indicated that forage cowpea was highest quality forage.

This result disagreed with the result that reported by Solomon and Kibrom, (2014) Humera, Ethiopia Ash content of cowpea genotypes a mean of 14.2%, Crude protein a mean of 18.1%. *In vitro* dry matter digestibility 57.3%. This result average ADF content was 53% with the average NDF content was 58.1% among genotypes. ADL mean of 13.1%. This variation might be due to seasonal variation, soil types, and the difference between main crops and stages of the plants during the sample taken.

Table 5. Chemical composition and in vitro dry matter digestibility of forage cowpea grown in sole and under sorghum/cowpea intercropping system

Cropping system	Trts	DM (%)	Ash (%)	CP (%)	NDF (%)	ADF (%)	ADL (%)	IVOMD (%)
Intercropped	T1	91.6	8.93	29.19^{a}	40.95^{e}	24.15	2.73	60.78
Cowpea	T2	90.63	9.74	27.38^{bc}	42.65^{de}	24	2.99	61.47
	T3	90.65	9.1	28.06^{ab}	42.63^{de}	23.83	3.01	60.82
	T4	90.66	8.41	25.88^{cd}	45.51^{bc}	24.66	2.91	61.29
	T5	90.6	8.93	25.38^{d}	43.93^{cd}	24.15	2.73	60.78
	T6	90.55	8.91	25.44^{d}	44.13^{cd}	24.16	2.8	61.15
sole cowpea	T7	90.58	8.58	25.19^{d}	46.53^{ab}	26.32	3.35	60.72
	T8	90.65	6.83	24.38^{d}	47.89^{a}	24.14	2.84	61.71
CV (%)		1.52	1.96	2.24	2.79	2.53	0.96	1.21
LSD		NS	NS	1.73	1.87	NS	NS	NS

Key: Trts =treatments, T1=Cowpea (9334) + Sorghum (Teshale); T2 = Cowpea (9334) + Sorghum (Birhan); T3 = Cowpea (9334) +Sorghum (Melkam); T4 = Cowpea (9333) +Sorghum (Teshale) T5 = Cowpea (9333) + Sorghum (Birhan); T6 = Cowpea (9333) + Sorghum (Melkam), T7=Cowpea (9334) sole, T8=Cowpea (9333) sole, DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber, ADL= acid detergent lignin, IVOMD = in vitro organic matter digestibility; LSD = least significant difference; CV= coefficient of variation

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Integrated Management of Chocolate spot (*Botrytis fabae* Sard) through Host Resistance and Fungicide Application in the Highlands of Bale, Southeastern Ethiopia

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Abstract

Because of its nutritional value, Faba bean (Vicia faba L.) is one of the most important food legumes both as energy and protein source. It is among the most important pulse crops produced in Ethiopia in general and on the highlands of Bale in particular. Field experiment was conducted at Sinana Agricultural Research Center on-station using RCBD with three replications to study the integrated effect of fungicide (sprayed at various frequencies) and faba bean varieties to manage chocolate spot.. The experiment consisted of five (5) fungicide application frequencies and two Faba bean varieties (Gebelcho and Mosisa). Logistic model was used to calculate the disease parameters such as disease progress rate (r) and AUDPC. The partial budget analysis was carried out to assess financial profitability of fungicide application for the management of chocolate spot. ANOVA showed statistically significant difference ($P<0.05$) among the treatments for the disease parameters. The lowest chocolate spot severity (23.15%) and the best chocolate spot disease control were achieved from Gebelcho variety sprayed four times. Similarly, the lowest r (-0.00453 units/day) and AUDPC (823.1 %-days) were recorded from Gebelcho variety sprayed four times. Regarding yield and yield components, ANOVA showed significant differences ($P\leq0.05$) among the treatments. The highest number of pods per plant (15.28) was recorded from Gebelcho variety sprayed 2 times.Whereas, the highest TKW of 662.60 g was recorded from Gebelcho variety sprayed three times. The maximum grain yield of 3515.44 kg/ha was obtained from Mosisa variety sprayed four times followed by Gebelcho variety sprayed four times (3313.70 kg/ha). Partial budget analysis has shown the maximum marginal benefit of 41044.8 ETB ha^{-1} obtained from Mosisa variety sprayed four times at weekly interval while the second marginal benefit of 38624.4 ETB $ha^{-1}$was obtained from Gebelcho variety sprayed four times at weekly interval. The maximum MRR of 1726.11 % was obtained from Mosisa variety sprayed once and the second highest MRR (1592.84 %) was calculated from Gebelcho variety sprayed four times. Therefore, the recommendation is made depending on the results from the biological studies and partial budget analysis. For small scale farmers, it is recommended to produce Mosisa variety by spraying mancozeb 80% WP once to maximize the financial benefit from faba bean production. But, for small scale farmers who can afford, it is recommended to produce faba bean variety Mosisa sprayed three times by a fungicide mancozeb 80%. However, for large scale farmers who are producing faba bean for export market are recommended to produce faba bean variety Gebelcho sprayed four times at 7-10 days interval.

***Key words**: Chocolate spot, fungicide, host resistance, Integrated Disease Management*

Background and justification

Faba bean (*Vicia faba* L.) is among the most important pulse crops produced in Ethiopia covering about 459, 183.51 ha of land with a total annual production of 697, 798.39t yr^{-1} (CSA, 2011). The interest of farmers to produce faba bean in Ethiopia is growing because of the fact that its demand on the export market is increasing (Sahile *et al.*, 2008). It is also one of the most important food legumes due to its high nutritive value both in terms of energy and protein contents (24-30%) and also is an excellent nitrogen fixer. However, its average yield under smallholder farmers is very low, ranging from 1 to 1.2 t ha^{-1} (Agegnehu *et al*., 2006). Lack of or low adoption of high yielding cultivars, diseases, weeds and insect pests together with abiotic factors are the major constraints for Faba bean production (Yohannes, 2000). Chocolate spot (*Botrytis fabae* Sard.) is one of economically important diseases that damages all parts of the crop and reduces faba bean production globally (Torres *et al*., 2004). Similarly, it is one of the major faba bean yield limiting biotic factors for faba bean production in Ethiopia. Yield losses of up to 61% on a susceptible cultivar, and 34% on a tolerant cultivar were recorded in Ethiopia (Dereje and Yaynu, 2001; Sahile *et al*., 2012). For its management, there are a number of possible options such as the use of moderately resistant/tolerant varieties, application of fungicides, biological control, induced resistance and cultural practices (Agegnehu *et al*., 2006).

Host resistance is one of the most acceptable and economically profitable chocolate spot management options. However, host resistance alone is not a reliable management option of chocolate spot as faba bean varieties lack reliable resistance to the disease. Therefore, it is important to integrate faba bean varieties with fungicides and other cultural practices for the proper management of chocolate spot. The environmental conditions in the Faba bean growing areas of Bale highlands are conducive for chocolate spot development. A survey of chocolate spot disease in central Ethiopia showed 68% disease intensity (Dereje and Beniwal, 1988). As a result this disease need well developed management options. Sustainable management of chocolate spot needs epidemiological knowledge based management options based on fungicides, resistant cultivars and their integration with different cultural practices. Dereje (1993) indicated an option of early planting for the management of the disease. However, early planting may not be practical in regions where unreliable and erratic rainfall occurs frequently. Besides the importance of chocolate spot in Bale highlands, the effort towards the management of this disease is very minimal.

Materials and Methods

Field experiment was conducted during “bona” (main) cropping season at Sinana Agricultural Research Center (SARC) on-station and Agarfa sub-site for two consecutive years, 2017/18 and 2018/19 . SARC is located at 463 km away from the capital, Finfine to the south-east. Its geographic location is 07^o 07’ N latitude and 40^o 10’E longitude with an elevation of 2400 masl. The area receives an annual rain fall of 750–1000 mm and has an annual temperature range of 9-21 ^oC (Nefo *et al.*, 2008). The experiment was laid out in RCBD with 3 replications. Two faba bean varieties, Gebelcho (released from Holeta Agricultural Research Center in 2006 GC) moderately resistant to chocolate spot and Mosisa (released from Sinana Agricultural Research Center in 2013 GC) tolerant to chocolate spot were used in this experiment. A fungicide Mancozeb 80% WP was sprayed in five (5) frequencies (0 times, 1 times, 2 times, 3 times and 4 times) at a rate of 2.5kg/ha. The plot size was 2.4m ×3m which contains 6 seeding rows. Between row, plot and replication spacing was 0.4m, 2m and 1.5m, respectively. The seed rates of 125 kg ha^{-1} for small seeded (Mosisa) & 175-200 kg ha^{-1} for the larger seeded (Gebelcho). The fertilizer rate of 100 kg NPS/ha was applied as non-experimental variable. The disease development was rated using 1-9 scoring scale, where, 1= No disease symptoms or very small specks; 3= few small discrete lesions; 5= some coalesced lesions with some defoliation; 7= large coalesced sporulating lesions, 50% defoliation and some dead plant; and 9= Extensive lesions on leaves, stems and pods, severe defoliation, heavy sporulation, stem girdling, blackening and death of more than 80% of plants (Bernier *et al*., 1993). Disease scores were converted to percent severity index (PSI) (Wheeler, 1969).

Data collected

The field data such as disease (severity and incidence) data, number of pods per plant, number seeds per pod, number of seeds per plant and data from laboratory which are TKW and grain yield were collected at an optimal time for collection. The disease severity data collected based on scoring scale was converted to percent severity index for analysis. All the collected data were fed to computer, cleaned and subjected to SAS statistical package for analysis.

Data Management and Statistical Analysis

Logistic, [ln [(Y/1-Y)], (Vander Plank 1963) and Gompertz, -ln[-ln(Y)], (Berger, 1981) models were compared to estimate the disease parameters from each treatment. The logistic model was chosen based on the test of Goodness of the fit of the models using coefficient of determination (R^2). Therefore, variables for field experiment data under different treatments were analyzed using logistic model, ln[y/ (1-y)] with the SAS Procedure (SAS Institute, 1998). Mean separation was made based on List Significance Difference (LSD) technique at 5% probability level. AUDPC (Shaner and Finney, 1977) and disease progress rate I values were calculated for each plot using the formula indicated below. ANOVA was performed for disease severity index (Wheeler, 1969), AUDPC (Shaner and Finney, 1977), and rate of disease progress I. The association of disease parameters with yield and yield related parameters was assessed using correlation and regression analysis.

$$\mathrm{PSI} = \frac{\text{Sum of Numerical Ratings X 100}}{\text{Number of Plants Scored X Maximum Score on Scale}}$$

$$\mathrm{AUDPC} = \sum_{i-1}^{n-1} 0.5(x_{i+1} + x_i)(t_{i+1} - t_I)$$

Where, X_i= the PSI of disease at the i^{th} assessment

t_i= is the time of the i^{th} assessment in days from the first assessment date

n= total number of disease assessments

Cost-Benefit Analysis

The partial budget analysis was performed following the standard methodology, taking the variable costs in each treatment in to account (Table 3). The marginal rate of return (MRR) was computed for each treatment (Table 4). The total income from each treatment was obtained as sale revenue (SR) from the produced and sold faba bean in a rate of 12 ETB per kilogram of the product. The marginal cost (MC) is computed as a sum of all the variable costs incurred for the faba bean production and the marginal benefit (MB) is calculated as a difference of sale revenue and marginal cost (Table 3 and Table 4).

The production cost and benefit from each treatment was analyzed using partial budget analysis. Similarly, the marginal rate of return (MRR) was computed by considering the total variable costs incurred in each treatment. In this experiment the sum cost of fungicide, water, sprayer rental, labor for spraying, labor for water supply and labor for cleaning equipment were considered as variable costs. The MRR was used as major criteria which measures the effect of additional investment on net returns (CIMMYT, 1988). MRR provides the benefit value obtained as a function of the additional investment for the management of Chocolate spot in percentage.

$$\mathrm{MRR} = \frac{\mathrm{DNI}}{\mathrm{DIC}} \times 100$$

Where, MRR: Marginal Rate of Return; DNI-Difference in Net Income compared with control, DIC- Difference in input cost compared with control.

Results and Discussion

There was statistically significant difference (*P<0.05*) among treatments for all the disease parameters, Chocolate spot Disease Severity (%), AUDPC (%-days) and Disease Progress Rate I (units per day) (Table 1). On both varieties, there was not statistical difference between treatments for chocolate spot severity during the first two scoring periods. Dagne *et al.*, (2016) and Bouhassan *et al*., (2004) reported that there is no statistically justifiable difference between treatments regardless of the resistant level of faba bean varieties during the early stage of disease development. The maximum chocolate spot severity of 50 % was recorded from unsprayed susceptible variety Mosisa. The second highest chocolate spot disease severity of 48.15 % was recorded from Gebelcho variety with no fungicide spray whereas lower chocolate spot severity of 23.15% and 29.32 % were recorded from Gebelcho variety sprayed four times and three times, respectively. This result agrees with Shiferaw *et al.,* (2018) who have similarly reported that they recorded the highest disease severity from unsprayed susceptible local variety while the lowest disease severity was recorded from moderately resistant degage variety sprayed at seven days interval. For the variety Mosisa, the lowest disease severity recorded was 29.63% after spraying the fungicide four times while the highest severity of 50% was recorded from unsprayed plot (Table 1). This result is supported by Shiferaw *et al.*, (2018). Chocolate spot severity showed an increasing trend with time as fungicide application frequency was decreasing (Fig. 1). This trend was similarly reported by Dagne *et al*, (2016) and Shiferaw *et al.*, (2018).

ANOVA for chocolate spot disease progress rate I has shown statistically significant difference (*P<0.05*) between treatments. Higher disease progress rates I of 0.23360 units/day and 0.21370 units/day were recorded from unsprayed plots of Mosisa and Gebelcho varieties, respectively. On the other hand, lower disease progress rates of -0.00453 units/day and -0.00262 units/day were recorded from Gebelcho variety sprayed three times and four times, respectively. Similarly, Yekedem and Hassen, (2018) reported the suppression of the apparent disease infection rate in sprayed plots by about six (6) times over unsprayed plots.

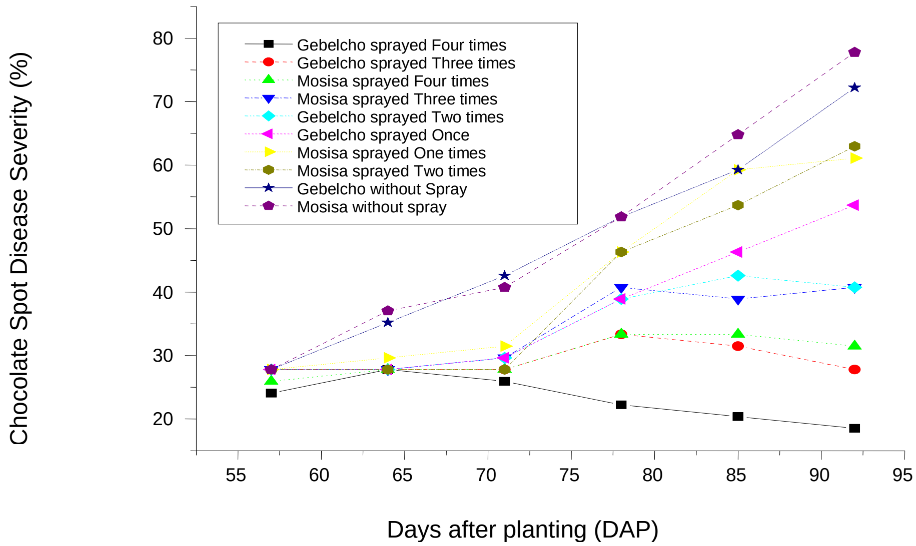

Figure 1: Influence of fungicide spray and varieties on chocolate spot development

The highest AUDP (1730.6 %-days) was recorded from unsprayed plot of Mosisa (susceptible) variety whereas the lowest AUDPC (823.1 %-days) was recorded from Gebelcho (moderately resistant) variety sprayed four times (Table 1). Similarly, Dagne *et.al.*, (2017) reported the highest AUDPC of 1817 %-days from susceptible faba bean variety which has not received any fungicide spray and the lowest AUDPC of 595 %-days from moderately resistant variety which has received fungicide spray at seven (7) days interval.

Table 1: Effect of Faba bean varieties and Fungicide application Frequencies on Chocolate spot Disease Severity (%), AUDPC (% days) and Disease Progress Rate I

Treatment	**Chocolate spot PSI (%)**	**R (units/day)**	**AUDPC (%-days)**
Mosisa No spray	50.00	0.23360	1730.6
Gebelcho No spray	48.15	0.21370	1672.2
Mosisa one time spray	42.59	0.04232	1477.8
Mosisa two times spray	41.05	0.07252	1406.5
Gebelcho one time spray	37.35	0.04293	1283.3
Gebelcho two times spray	34.57	0.00667	1212.0
Mosisa three times spray	34.26	0.00946	1199.1
Mosisa four times spray	29.63	0.00093	1050.0
Gebelcho three times spray	29.32	-0.00262	1037.0
Gebelcho four times spray	23.15	-0.00453	823.1
$LSD_{0.05}$	**7.88**	**0.10**	**273.44**
CV(%)	**18.36**	**14.35**	**18.29**

With regard to grain yield and yield components, ANOVA showed significant differences ($P \leq 0.05$) among the treatments for number of pods per plant (No. pod/plant), thousand kernel weight (TKW) and grain yield (grain yield (kg/ha)). The highest number of pods per plant (15.28) and the lowest number of pods per plant (11.17) were recorded from Gebelcho variety sprayed two times and 1 time, respectively. El-kohly, (2014) reported that the highest number of pods per plant was recorded from moderately resistant variety sprayed with a fungicide.

The highest and the lowest TKW of 662.60 g and 417.73 g were recorded from Gebelcho variety sprayed three times and Mosisa variety with no fungicide spray, respectively. Application of fungicide on moderately resistant faba bean variety increases thousand kernel weights (Ermias and Addisu, 2013; El-Kohly, 2014). Similarly, Dagne *et al.*, (2017), have also reported the reduction trend of faba bean TKW as the fungicide spray is decreasing.

Regarding grain yield, the highest grain yield of 3515.44 kg/ha was recorded from variety Mosisa sprayed four times whereas the lowest grain yield of 1705.5 kg/ha was recorded from Gebelcho variety with no fungicide spray (Table 2). The fungicide application frequency influences faba bean yield as faba bean grain yield shows a decreasing trend with decreasing fungicide application frequency (Ermias and Addisu, 2013). Similarly, Kohly (2014) and Dagne *et al.*, (2017) found that faba bean grain yield has decreased when the fungicide application decreases and they found the highest grain yield from plots which have received the highest frequency fungicide application. Host plant resistance is also one of the varietal factor which influences fungicide application frequency and faba bean grain yield. This study revealed that the effect of host plant resistance on faba bean yield. Mosisa variety is found to be susceptible and tolerant to chocolate spot disease while Gebelcho variety is moderately resistant to chocolate spot. At all level of fungicide spray, the highest chocolate spot disease severity was recorded from Mosisa variety. But, regardless of the disease severity scores of Mosisa variety, the highest grain yield was recorded from Mosisa variety at all frequencies of fungicide spray. This is because of the tolerance of the Mosisa variety to chocolate spot.

Table 2: The effect of varieties and fungicide application on disease severity, yield and yield components of faba bean

Treatment	**No. pod/plant**	**No. seed/plant**	**TKW**	**Grain yield (kg/ha)**
Mosisa No spray	13.78	14.06	417.73	2072.20
Gebelcho No spray	13.61	15.06	564.43	1705.50
Mosisa one time spray	12.50	16.11	435.17	2505.90
Gebelcho one time spray	11.17	13.72	639.27	1899.00
Mosisa two times spray	15.17	19.28	431.10	2513.5
Gebelcho two times spray	15.28	18.06	660.87	2090.70
Mosisa three times spray	12.83	15.22	442.43	3160.70
Gebelcho three times spray	13.94	16.28	662.60	2433.10
Mosisa four times spray	12.94	17.56	435.17	3515.40
Gebelcho four times spray	13.33	13.33	646.80	3313.70
$LSD_{(0.05)}$	**3.63**	**NS**	**62.02**	**914.29**
CV(%)	**23.29**	**15.36**	**10.02**	**32.57**

Partial Budget Analysis

Partial budget analysis has depicted the highest marginal benefit of 41044.8 ETB ha^{-1} from Mosisa variety sprayed with Mancozeb 80% WP four times at weekly interval and the second highest marginal benefit of 38624.4 ETB^{-1} was recorded from Gebelcho variety sprayed four times. The lowest marginal benefit of 20466 ETB ha^{-1} was obtained from unsprayed Gebelcho variety with no fungicide spray (Table 4). Similarly, the highest marginal rate of return (1726.11 %) was obtained from Mosisa variety sprayed once and the second highest marginal benefit of 1592.84% was recorded from Gebelcho variety sprayed four times using a fungicide mancozeb 80% WP. This indicated that for every 1.00 ETB invested to spray

Mancozeb 80% WP to produce faba bean, it gives a return of 17.26 ETB and 15.93 ETB from Mosisa variety sprayed once and Gebelcho variety sprayed four times, respectively. Therefore, partial budget analysis depicted that production of Faba bean variety Mosisa sprayed once with Mancozeb 80% WP for the management of chocolate spot optimizes the profitability from faba bean production under small scale agriculture/small holder farmers' condition and production of faba bean variety Mosisa with four times application of fungicide also gives high marginal rate of return (1419 %) and the highest marginal benefit of 41044.8 ETB ha^{-1}. For those farmers who produces faba bean for export market, production of Gebelcho variety sprayed four times with a fungicide Mancozeb 80% WP maximizes the benefit from faba bean production.

Table 3: Variable costs associated with fungicide application for the management of Chocolate spot for Faba bean production

No.	Treatment	Fungicide Rate (kgha^{-1})	Fungicide Frequency	Fungicide Cost (ETH Birr/kg)	Sprayer rent	Labor cost to spray	Labor cost for water supply	Cleaning equipment	Cost for water	Total variable cost
				List of items and activities as a source of costs (Ethiopian Birr)						
1	Mosisa No spray	0	0	0	0	0	0	0	0	0
2	Gebelcho No spray	0	0	0	0	0	0	0	0	0
3	Mosisa one time spray	2.5	1	200	25	25	20	5	10	285
4	Gebelcho one time spray	2.5	1	200	25	25	20	5	10	285
5	Mosisa two times spray	2.5	2	400	50	50	40	10	20	570
6	Gebelcho two times spray	2.5	2	400	50	50	40	10	20	570
7	Mosisa three times spray	2.5	3	600	75	75	60	15	30	851
8	Gebelcho three times spray	2.5	3	600	75	75	60	15	30	851
9	Mosisa four times spray	2.5	4	800	100	100	80	20	40	1140
10	Gebelcho four times spray	2.5	4	800	100	100	80	20	40	1140

Table 4: Cost-benefit analysis of fungicide applications against Chocolate spot for Faba bean production

No.	Treatment	Fungicide (kgha^{-1})	Yield (kgha^{-1})	SR (ETB ha^{-1})	MC (ETB ha^{-1})	MB (ETB ha^{-1})	MRR (%)
1	Mosisa No spray	0	2072.2	24866.4	0	24866.40	0.00
2	Gebelcho No spray	2.5	1705.5	20466	0	20466.00	0.00
3	Mosisa one time spray	2.5	2505.9	30070.8	285	29785.80	1726.11
4	Gebelcho one time spray	2.5	1899	22788	285	22503.00	714.74
5	Mosisa two times spray	2.5	2513.5	30162	570	29592.00	829.05
6	Gebelcho two times spray	2.5	2090.7	25088.4	570	24518.40	710.95
7	Mosisa three times spray	2.5	3160.7	37928.4	851	37077.40	1434.90
8	Gebelcho three times spray	2.5	2433.1	29197.2	851	28346.20	686.63
9	Mosisa four times spray	2.5	3515.4	42184.8	1140	41044.80	1419.16
10	Gebelcho four times spray	2.5	3313.7	39764.4	1140	38624.40	1592.84

SR = Sale revenue; MC = Marginal cost; MB = Marginal benefit; MRR = marginal rate of return

Conclusion and Recommendation

Faba bean (*Vicia faba* L.) is one of the most important pulse crops produced in Bale highlands. It is also one of the most important food legumes due to its high nutritive value terms of protein contents (24-30%) and also is an excellent nitrogen fixer. Regardless of the potential of the area to grow faba bean, there are numerous biotic and abiotic constraints limiting productivity of the crop. Chocolate spot disease is one of the major faba bean diseases limiting Faba bean productivity on the highlands of Bale. Chocolate spot epidemic occurs and causes significant yield losses in the highlands of Bale as most of the farmers are growing local cultivars.

The results from this experiment shown that the application of fungicide, Mancozeb 80% WP has resulted in significant disease severity reduction and subsequent increment in yield. Hence, Fungicide is one of the key production packages of faba bean on the highlands of Bale and similar faba bean growing agro-ecologies. The highest grain yield of 3515.4 kg/ha was recorded from Mosisa variety sprayed four times and the lowest grain yield of 1705.50 kg/ha was obtained from Gebelcho variety with no spray. Partial budget analysis has depicted the highest marginal benefit (MB) of 41044.8 ETB ha^{-1} and the lowest MB of 20466 ETB ha^{-1} from Mosisa variety sprayed four times and Gebelcho variety with no fungicide sprays, respectively. The highest marginal rate of return (MRR) of 1726.11% and the lowest MRR of 686.63% were obtained from Mosisa variety sprayed once and Gebelcho variety sprayed three times, respectively. The plot with the highest marginal benefit (41044.8 ETB ha^{-1}) has found to have the third maximum MRR of 1419.16%.

Based on the result from both biological study and partial budget analysis, the authors recommend small holder farmers to produce Mosisa variety aided by one time spray of a fungicide Mancozeb 80% WP to maximize the financial benefit from faba bean production. However, we recommend producing Mosisa variety supported by three times of fungicide spray to maximize the marginal benefit to 41044.8 birr/ha for those small holder farmers who can afford to spray a fungicide three times. For large scale farmers who are producing the crop for export market, it is wise to recommend variety Gebelcho with four times application of a fungicide mancozeb 80% WP for the management of chocolate spot which can give them a MRR of 1592.84 % as this variety is a large seeded variety and has high demand on international market because of its seed size.

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Multi-location evaluation of food barley genotypes for yield and yield related traits performance in western Oromia, Ethiopia

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Abstract

Barley is one of the founders of the old world agriculture and the first domesticated cereal crop. This experiment was conducted on fifteen barley genotypes along with checks at Haro Sabu Agricultural Research Center sub site from 2017 to 2018.The objective was to assess the magnitude of genotype by environment interaction & identify stadle high yielding genotypes adapted to western Oromia. The design was RCBD with three replications. Eleven agronomic traits and four disease reaction data were collected. Analysis of variance detected significant difference among genotypes for most observed traits both separated and combined analysis. Observation attained significant differences over years and locations for almost all traits. The combine analysis of variance (ANOVA) and the additive main effects and multiplicative interactions (AMMI) analysis for grain yield revealed the significant effect of the environments that hold 41% of the total variation. The genotype and genotype by environmental interation were significant and accounted for 10.46 % and 27.69 % respectively. Pricipal component 1 and 2 accounted for 15.74 % and 5.71 % of the GEI, respectively with a total of 21.45 % variation. In general, G2 (Acc. 220677) and G12 (Acc. 219307) were identified as the best genotypes in terms of yielding ability, stability & tolerant to diseases and thus will be used as parents in future breeding programs.

Key words: AMMI, food barley, GGEI, performance, stability

Introduction

Barley (*Hordeum vulgare* L) (2n = 2x = 14) is one of the most important staple food crops in the highlands of Ethiopia. It is a cool season crop, the most dependable and early maturing cereal grain with relatively high yield potential including in marginal areas where other cereal crops cannot have adapted (Harlan, 2008; Martin and Leonard, 2010). The major barley production areas of the world include: Europe, the Mediterranean fringe of North Africa, Ethiopia and the Middle East, former USSR, China, India, Canada and USA (Horsley and Hochhalter, 2004). Ethiopia is the second largest barley producer in Africa, next to Morocco, accounting for about 25 % of the total barley production in the continent (FAO, 2014). However, there is great yield gap between national average yield (2.11 t/ha^{-1}) (CSA, 2017) and world average yield (3.04 t/ha^{-1}) (Foreign Agricultural Service/USDA April 2017 Office of Global Analysis). This production limitation may be attributed to primarily the low yielding ability of farmers' cultivars, which are the dominant varieties in use; the influence of several biotic and a biotic stresses; and poor promotion of improved barley production package technologies (Bayeh and Berhane, 2011)

Environmental fulactuation and interaction is also the major limitation for food barley production and productivity. Genotype by environment interaction (GEI) is the differential responses of different genotypes across a range of environments (Horsley and Hochhalter, 2004). In breeding, genotype x environmental interaction (G x E) cause many difficulties, while the environmental factors such as temperature ,soil affect the performance of genotypes. Genotype x environment (GE) interaction reduces the genetic progress in plant breeding programs through minimizing the association between phenotypic and genotypic values (Comstock and Moll, 1963). Consequently, multi-environment yield trials are essential in assessing of genotype by environment interaction (GEI) and identification of superior genotypes in the final selection cycles (Kaya *et al*., 2006; Mitrovic *et al.,* 2012). Phenotypes are a mixture of genotype (G) and environment (E) components and interactions (G x E) between them. GxE interactions complicate process of selecting genotypes with superior performance. Therefore, multi-environment trails (METs) are widely used by plant breeders to evaluate the relative performance of genotypes for target environments (Delacy *et at.*, 1996).

The additive main effects and multiplicative interaction (AMMI) model have also led to more understanding in the complicated patterns of genotypic responses to the environment (Gauch, 2006).These patterns have been successfully related to biotic and abiotic factors. Yan *et al.* (2000) proposed another methodology known as GGE-biplot for graphical display of GE interaction pattern of MET data with many advantages. GGE biplot is an effective method based on principal component analysis (PCA) which fully explores MET data. It allows visual examination of the relationships among the test environments, genotypes and the GE interactions. The first two principle components (PC1 and PC2) are used to produce a two dimensional graphical display of genotype by environment interaction (GGE-biplot). If a large portion of the variation is explained by these components, a rank-two matrix, represented by a GGE- biplot, is appropriate (Yan and Kang, 2003).

The objective of this study was to assess genotype performances, the magnitude of genotype x environment interaction for grain yield and to evaluate the stability for grain yield and tolerant to diseases of food barley genotypes.

Materials and Methods

Description of locations: The experiment was conducted at three different rain fed locations in Kellem and west Wollega zones of Haro-sebu agricultural research center at Belem research sub site (altitude 1759 masl, 09° 02' N, 035° 104'E), Mata (altitude 2016 masl, 08° 34' N, 034° 44'E) and Badesso (altitude 2054 masl, 08° 40' N, 034°47'E) in western Oromia, Ethiopia, during the 2017 & 2018 main cropping season, that represent the varying agro ecologies of the barley growing areas of the zones.

Experimental materials: Fifteen food barley genotypes, together with two standard checks (Abdane and Dinsho) and one farmer’s cultivar were included in the trial (Table 1). The genotypes were selected based on average performance and agro-ecological adaptation.

Genotypes were obtained from Ethiopia biodiversity institute (EBI), Sinana Agricultural Research Center and from farmers for the farmers' variety.

Table 1: List of food barley genotypes evaluated in 2017-2018 main cropping season

No	Codes	Genotypes Acc.No	Sources
1	G1	242573	EBI
2	G2	220677	EBI
3	G3	Abdane	SARC
4	G4	202820	EBI
5	G5	237021	EBI
6	G6	219142	EBI
7	G7	241675	EBI
8	G8	Local	Farmer
9	G9	225176	EBI
10	G10	4560	EBI
11	G11	233028	EBI
12	G12	219307	EBI
13	G13	64260	EBI
14	G14	233030	EBI
15	G15	Dinsho	SARC

Key: G-genotype, Acc. No- accession number EBI- Ethiopia biodiversity institute, SARC- Sinana Agricultural Reaserch center

Experimental design and management: Randomized completed block design (RCBD) with three replications were used in all locations. Each experimental plot had 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 the same 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 DAP. All P_2O_5 and half of N were applied during planting, while the rest half splits were applied at tillering stages. A seeding rate of 85 kg ha^{-1} was used. First weeding was carried out 35 days after emergence and the second one at 30 days after the first weeding. Weeding was done up to four times for all locations. The data considered for analysis was from the candidates of the net plot, thus the four central harvestable rows. The harvested genotypes were sundried before being tested for moisture content where 12% was the preferred average moisture content using moisture tester. Grain yield data was then obtained by weighing the dried grain using a digital scale.

Data collection method: Ten plants were selected randomly before heading from each row (four harvestable rows) and tagged with thread and all the necessary plant based data were collected from these sampled plants.

Plot basis: The following plant parameters were determined: Days to heading (DH), Days to maturity (DM), Lodging percentage (LDG), Thousand seed weight (TSW), Grain yield (GY), and the four major economically important food barley diseases such as scald, septoria (SEP), stem rust (SR), and leaf rust (LR)

Plant basis: Plant height (PH), Productive tillers (PTR), Spike length (SL), Grain per spike (GPS), spike weight per plant (SWPP) and number of spike lets per spike (NSPS)

Statistical Analysis

Analysis of variance is calculated using the model:

Yij = µ + Gi + Ej + GEij

Where Yij is the corresponding variable of the i^{-th} genotype in j^{-th} environment, μ is the total mean, Gi is the main effect of i^{-th} genotype, Ej is the main effect of j^{-th} environment, GEij is the effect of genotype x environment interaction.

The AMMI model used was:

$$Y_{ij} = \mu + g_i + e_j + \sum_{1}^{N} \Lambda_k Y_{ik} \delta_{jk} + \varepsilon_{ij}$$

Where Yij is the grain yield of the i^{-th} genotype in the j^{-th} environment, μ is the grand mean, gi and ej are the genotype and environment deviation from the grand mean, respectively, ʎk is the eigenvalue of the principal component analysis (PCA) axis k, Yik and δjk are the genotype and environment principal component scores for axis k, N is the number of principal components retained in the model, and Ɛij is the residual term.

GGE-biplot methodology, which is composed of two concepts, the biplot concept. (Gabriel, 1971) and the GGE concept (Yan *et al.,* 2000), was used to visually analyze the METs data. This methodology uses a biplot to show the factors (G and GE) that are important in genotype evaluation and that are also the source of variation in GEI analysis of METs data (Yan ,2001).The GGE-biplot shows the first two principal components derived from subjecting environment centered yield data (yield variation due to GGE) to singular value decomposition (Yan *et al.*, 2000).AMMI Stability Value (ASV): ASV is the distance from the coordinate point to the origin in a two-dimensional plot of IPCA1 scores against IPCA2 scores in the AMMI model (Purchase,1997). Because the IPCA1 score contributes more to the GxE interaction sum of squares, a weighted value is needed. This weighted value was calculated for each genotype and each environment according to the relative contribution of IPCA1 to IPCA2 to the interaction sum of squares as follows:

$$ASV = \sqrt{[(SS_{IPCA1} \div SS_{IPCA2})(IPCA1score)]^2 + (IPCA2score)^2}$$

where, SS_{IPCA1}/SS_{IPCA2} is the weight given to the IPCA1-value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares. The larger the ASV value, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller ASV values indicate more stable genotypes across environments (Purchase, 1997). Genotype Selection Index (GSI): Stability is not the only parameter for selection as most stable genotypes would not necessarily give the best yield performance. Therefore, based on the rank of mean grain yield of genotypes (RYi) across environments and rank of AMMI stability value RASVi), genotype selection index (GSI) was calculated for each genotype as:

$$GSIi = RASVi + RYi$$

A genotype with the least GSI is considered as the most stable (Farshadfar, 2008). Analysis of variance was carried out using statistical analysis system (SAS) version 9.2 software (SAS Institute Inc., 2008). Additive Main Effect and Multiplicative Interaction (AMMI) analysis and GGE bi-plot analysis were performed using Gen Stat 15th edition statistical package VSN International (2012)

Results and Discussions

Combined analysis of variance

The mean square of analysis of variance (ANOVA) is presented in Table 2. Highly significant differences were detected among the main and the interaction effects ($P \leq 0.01$) for most of the parameters. The combined analysis of variance revealed that significant differences were recorded across location for all parameters except spike weight per plant. Year*genotypes effects were significant for most traits. Year*location *genotypes were significant for most traits such as days to heading, days to maturity, stem and leaf rust, spike length, grain per spike, thousand seed weight and grain yield. Likewise, Assefa (2003) reported that, barley landraces showed significant variations for many traits like thousand seed weight, spike length, heads per square meter, and grain yield per spike, days to heading, and days to maturity and plant height in Ethiopian barley landraces. Study by Oettler *et al*. (2009) showed significant differences among nine barley genotypes for grain yield, spikes/m^2, thousand seed weight, dry matter, days to heading and plant height.

Table 2: Analysis of variance (ANOVA) for grain yield and yield related traits of food barley genotypes evaluated in 2017-2018 main cropping season

Source	DF	DH	DM	PTL	Scald	SEP	SR	LR	LDG
rep	2	20.69	12.51	1.51	0.31	0.08	0	0.06	0.01
Geno.	14	163.17**	163.73**	2.20**	0.3	0.17**	0.34**	0.36**	0.66*
loc	2	371.83**	179.45**	24.35**	9.08**	8.81**	17.68**	20.38**	16.77**
yr	1	2881.20**	2.7	138.96**	3.91**	1.07**	2.22**	2.80**	47.71**
geno*loc	28	22.81*	33.77**	0.6	0.78**	0.08*	0.21**	0.21**	0.44
geno*yr	14	120.10**	104.67**	1.66*	0.25	0.04	0.09*	0.1	0.56*
loc*yr	2	124.34**	15.63	16.23**	3.91**	1.07**	2.22**	2.80**	1.17*
geno*loc*yr	28	28.30*	34.11**	0.61	0.25	0.04	0.09**	0.10*	0.38

Table 2: continue

Source	DF	PH	SL	SWPP	SPS	GPS	TSW	QTHA
rep	2	28.83	0.2	0.35	54.74	3.53	21.29	13.66
geno.	14	209.42**	2.06*	0.24	61.22**	126.71**	246.85*	823.16**
loc	2	4308.57**	2.60*	0.69	217.74**	119.41*	2933.84**	851.03**
yr	1	931.86**	0.02	0.4	84.90*	311.80**	8079.74**	9684.87**
geno*loc	28	51.28	0.99	0.42	18.95	48.69*	155.8	62.89**
geno*yr	14	133.98**	1.58*	0.39	36.70*	101.68**	139.09	81.29*
loc*yr	2	1603.92**	3.55*	0.94	88.44*	1264.39**	3855.68**	1132.38**
geno*loc*yr	28	79.04	1.46*	0.46	24.58	59.00**	176.35*	72.41*

Key: *, **: significant at 5% and 1% respectively, Loc *geno = location by genotype, Yr*Loc*geno = year by location by genotype, DF -degree of freedom, DH- Days to Heading; DM- Days to Maturity; PTL- productive tillers, SEP- septoria, SR-stem rust, LR- leaf rust, LDG- lodging, PH- Plant Height; SL- spike Length; SWPP-Spike Weight per plant, SPS-spike lets per spike, GPS-Grain per spike, TSW- Thousand Seed Weight, QTHA- Yield quintal per Hectare.

Yield performance of food barley genotypes across locations

Mean performance for grain yield across location and year presented in Table 3. Study by Tamene *et al.* (2013) indicated that, genotypes constantly performed best in some environments and fluctuating across some locations. Accordingly, the average grain yield ranged from the lowest of 19.33 Qtha^{-1} at Bedesso sub site in 2017 to the highest of 36.47 Qtha^{-1} at Bellem site in 2018 with grand mean of 29.29 Qtha^{-1}.The average grain yields across environments ranged from the lowest of 23.5 Qtha^{-1} for genotype G9 to the highest of 37.5 Qtha^{-1} for genotype G2. This wide variation might be due to the genetic potential of the different genotypes. Therefore genotypes G2 and G12 were constantly performed across the locations. The difference in yield rank of genotypes across the environments exhibited the high crossover type of genotypes x environmental interaction (Yan, 2001; Anandan *et al.*, 2009)

Table 3: Mean grain yield (Qtha^{-1}) of food barley genotypes evaluated at three environments

	Grain Yield in Qtha^{-1}						
	2017			2018			
Genotype	Bellem	Bedesso	Mata	Mata	Belem	Bedesso	**Com..mean**
G15	27.88bc	14.71fg	22.043fg	35.27b	31.92def	32.98b	27.5def
G1	31.23ab	16.56d-g	29.35b-e	31.69b	35.55cde	30.18b	29.1cde
G10	25.19b-e	20.17b-f	21.55fg	35.06b	33.59c-f	30.197	27.6def
G11	21.45def	23.03bcd	29.61b-e	28.92b	29.143ef	29.80b	27.0efg
G12	17.87fgh	26.85ab	30.81a-d	37.73ab	43.94abc	46.95a	34.0ab
G13	14.58gh	22.02b-f	23.38efg	29.74b	30.85def	31.43b	25.3gh
G3	7.79i	12.35g	36.94a	42.66ab	40.88a-d	37.21b	29.6cde
G14	34.60a	31.38a	29.41b-e	33.34b	24.87f	30.72b	30.7bcd
G2	23.07c-f	24.52abc	24.99def	49.86a	50.48a	51.89a	37.5a
G4	30.72ab	22.76b-e	31.54a-d	31.13b	31.72def	30.38b	29.7cde
G5	26.59bcd	15.10fg	34.74abc	31.95b	46.37ab	34.98b	31.6bc
G6	29.55ab	16.11d-g	35.31ab	30.75b	35.81cde	30.13b	29.6cde
G7	19.66efg	15.31efg	33.48abc	37.88ab	34.60c-f	29.66b	28.4c-f
G9	12.96hi	11.69g	16.58g	32.88b	39.10b-e	27.50b	23.5g
G8	14.36gh	17.47c-g	28.203c-f	36.48ab	38.19b-e	34.34b	28.2c-f
Mean	22.50	19.33	28.53	35.02	36.47	33.89	**29.29**
CV %	16.32	23.26	14.84	23.53	17.14	17.16	19.33
R^2	0.88	0.71	0.74	0.41	0.64	0.68	79.3
LSD 5%	6.14	7.52	7.08	13.78	10.46	9.73	3.724
F-test	**	**	**	ns	**	ns	**

Key: **G-genotype,** R^2, R-squire, CV- coefficient of variation, LSD- least significant different.

Agronomic performance

Combined mean grain yield and other agronomic traits are presented in Table 4. Genotype G12 was recorded medium days to heading, days to maturity, and plant height, indicated that, the possibility to develop lodging resistant variety. And also it recorded the highest productive tillers per plant, thousand seed weight and grain yield. Similarly, Genotype G2 was recorded medium days to heading, days to maturity, productive tillers and thousand seed weight and the highest spike length. These recommend great flexibility for developing improved varieties appropriate for different agro-ecologies with variable length of growing period and high in grain yield status. Moreover, these genotypes G12 and G2 were recorded the highest grain yield and they had 14.95 %, and 26.58 % yield advantage over the best standard check (Abdane) respectively.

Major disease reaction of food barley genotypes across environments

Most genotypes evaluated had significantly low scores with their corresponding economically important disease reactions. However, genotypes G1, G5, and varieties like Dinsho and Abdane were less tolerance to scald disease. Similarly, genotypes G11, G5, G7 and Abdane variety, were less tolerance to septoria and stem rust. On the other hand, genotypes (G12 and G2) were better tolerance to scald, septoria, stem and leaf rust (Table 5).

Table 4: Combined mean grain yield and other agronomic traits of food barley genotypes

Genotypes	**DH**	**DM**	**PTL**	**LDG**	**PH**	**SL**	SWPP	SPS	GPS	TSW	**QTHA**	**YLD AV**
G15	57.4cd	89.6de	3.5b-e	2.0ab	90.2a-e	8.4bcd	1.3b	17.38bcd	24.06cde	46.61ab	27.5def	-7.09
G1	54.3ef	89.0def	3.5b-e	1.9abc	90.6a-d	8.5abc	1.42ab	18.41a-d	25.96bcd	39.97bcd	29.1cde	-1.71
G10	55.8de	90.4cde	3.8a-d	2.1a	92.8a-d	8.0cd	1.56ab	18.96abc	24.87cde	37.08cd	27.6def	-6.67
G11	56.3cde	92.6bc	3.9abc	1.5cd	89.5b-e	8.9ab	1.35ab	19.69ab	22.13e	43.23bc	27.0efg	-8.81
G12	58.8bc	94.3ab	4.4a	1.7bcd	93.6abc	8.7ab	1.37ab	16.63cde	24.80cde	50.8a	34.0ab	14.95
G13	60.5b	96.4a	3.1e	1.9abc	89.5b-e	8.4bcd	1.4ab	20.86a	32.76a	40.78bcd	25.3gh	-14.42
G3	64.2a	96.5a	3.6b-e	1.5d	82.9f	7.9d	1.44ab	14.39e	28.96a	42.65bc	29.6cde	0
G14	54.9de	90.7cde	3.9abc	1.6cd	94.6ab	8.7ab	1.38ab	19.79ab	25.85bcd	42.68bc	30.7bcd	3.78
G2	57.2cd	93.2b	3.9ab	1.8a-d	90.3a-d	9.1a	1.41ab	16.03cde	22.49de	43.32bc	37.5a	26.58
G4	56.8cde	90.8cd	4.0ab	1.7bcd	91.0a-d	8.6ab	1.44ab	20.28ab	24.79cde	43.18bc	29.7cde	0.36
G5	55.4de	88.4ef	3.2de	2.0ab	87.7def	9.1a	1.28b	17.38bcd	24.71cde	44.24ab	31.6bc	6.84
G6	54.6e	90.2de	3.3cde	1.6cd	88.4cde	8.5bcd	1.71a	17.99a-d	24.58cde	40.94bcd	29.6cde	0.03
G7	56.8cde	86.9f	3.5b-e	1.6cd	94.8a	8.4bcd	1.36ab	15.88de	26.66bc	40.6bcd	28.4c-f	-3.94
G9	60.5b	93.3b	3.8abc	1.8a-d	85.0ef	8.4bcd	1.53ab	16.19cde	23.37cde	35.03d	23.5g	-20.77
G8	52.0f	87.1f	4.0ab	1.9abc	93.7ab	8.5abc	1.27b	17.82bcd	23.82cde	40.76bcd	28.2c-f	-4.82
M ± SEM	57.03±0.41	91.29±0.34	3.69±0.08	1.78±0.05	90.31±0.67	8.54±0.06	1.41±0.02	17.85±0.06	25.32±0.12	42.13±0.1	29.29±0.72	
CV%	6.76	3.74	25.01	31.54	8.78	10.75	40.87	25.17	22.08	25.31	19.33	
R^2 %	78	75	67	69	66	47	0.39	0.49	0.63	0.64	79.3	
LSD 5%	2.54	2.25	0.61	0.37	5.22	0.6	0.3804	2.95	3.68	7.01	3.724	
F test	**	**	**	**	**	**	ns	**	**	**	**	

Key: G-genotype, M-mean DH- Days to Heading; DM- Days to Maturity; PTL- productive tillers, LDG- lodging, PH- Plant Height; SL- spike Length; SWPP-Spike Weight per plant, SPS-spike lets per spike, GPS-Grain per spike, TSW- Thousand Seed Weight, QTHA- Yield quintal per Hectare, YAD- yield advantage, CV- Coefficient of variation,R^2-R-squere, LSD- least significant.

Table 5: Combined mean of disease reactions (1-5 scale) of food barley genotypes evaluated in 2017-2018 main cropping season.

Genotypes	SCALD	SEP	SR	LR
G15	1.6abc	1.3bcd	1.2f	1.3fg
G1	1.6a	1.3bcd	1.5abc	1.4ef
G10	1.3bcd	1.4bc	1.6a	1.6a-d
G11	1.2d	1.4ab	1.4de	1.5cde
G12	1.3d	1.2de	1.2f	1.3fg
G13	1.4a-d	1.3cde	1.4cde	1.5de
G3	1.6ab	1.4ab	1.6a	1.7ab
G14	1.3bcd	1.2e	1.4bcd	1.3g
G2	1.4a-d	1.4abc	1.4cde	1.4efg
G4	1.3a-d	1.3b-e	1.4de	1.5cde
G5	1.6abc	1.5a	1.5ab	1.8a
G6	1.4a-d	1.3b-e	1.3ef	1.6b-d
G7	1.3cd	1.4ab	1.4cde	1.4efg
G9	1.4a-d	1.3b-e	1.6a	1.6abc
G8	1.3a-d	1.3cde	1.6a	1.5de
Mean ± SEM	1.40±0.04	1.33±0.02	1.42±0.03	1.49±0.03
CV%	32.99	16.08	14.08	16.58
R^2 %	64	77	89	86
LSD 5%	0.3	1.97	0.13	0.16
F test	**	**	**	**

Key: G-genotype, CV- Coefficient of variation, LSD- least significant difference, R^2-R-Squere, SR-stem rust, LR-leaf rust, SEP-septoria, SEM- standard error of mean .1-5 scale where 1= resistant, 5= susceptible

AMMI analysis for grain yield

The additive main effects and multiplicative interaction analysis (Table 6) of grain yield showed that environment, and genotypes by environment interaction were highly significant ($P \leq 0.01$). This is similar to the report of Ntawuruhunga *et al*. (2001). This indicates that one of the basic factors that affect GEI could either be genotypic or environmental in nature (Debelo *et al.,* 2000; Anandan *et al.,* 2009) also reported that 74.3% of the interaction sum of squares was explained by IPCA1.

Table 6: Additive main effect and multiplicative interaction analysis of variances (AMMI) for grain yield of 15 food barley genotypes evaluated at six environments

Source of variation	DF	SS	EX.SS%	MS
Total	269	27580	100	102.5
Treatments	89	21830	79.15	245.3**
Genotypes	14	2886	10.46	206.1**
Environments	5	11308	41.00	2261.7**
Block	12	361	1.31	30.1^{ns}
GEI	70	7636	27.69	109.1**
IPCA 1	18	4340	15.74	241.1**
IPCA 2	16	1575	5.71	98.4**
Residuals	36	1721	6.24	47.8
Error	168	5390		32.1

Key: DF = degree of freedom, SS = sum of squares, MS = mean squares, IPCA = Interaction Principal Component Axis, EX. SS% = Explained Sum of square ns * ,** non-Significant ,Significant at the 0.5% and 0.1% level of probability respectively

The environment and genotype mean are presented in Fig.1 and Table 7. This bi-plot helped in the interpretation of the interaction effects among genotypes and environments; and in the assessment of the adaptability of genotypes. Genotypes G12 and G2 with a lower IPCA1 score were stable genotypes. Genotypes which are characterized by mean greater than grand mean and the IPCA scores nearly zero are considered as generally adaptable to all environment. However, the genotypes with high mean performance and with large value of IPCA scores are considered as having specific adaptability to the environments (Singh et al., 2009). Study by Bantayehu (2009) reported that the larger the IPCA scores, either negative or positive, the more specifically adapted a genotype is to a certain environments; yet the smaller the IPCA scores, the more stable the genotype is over all environments. Genotypes G14 and G4 had grain yield above the grand mean; and similar IPCA1 scores with locations Bedesso and Belem implying that their interactions were positive; the higher yields of these genotypes were found, particularly, at these locations. Hence, they were the best adapted genotypes for these locations.

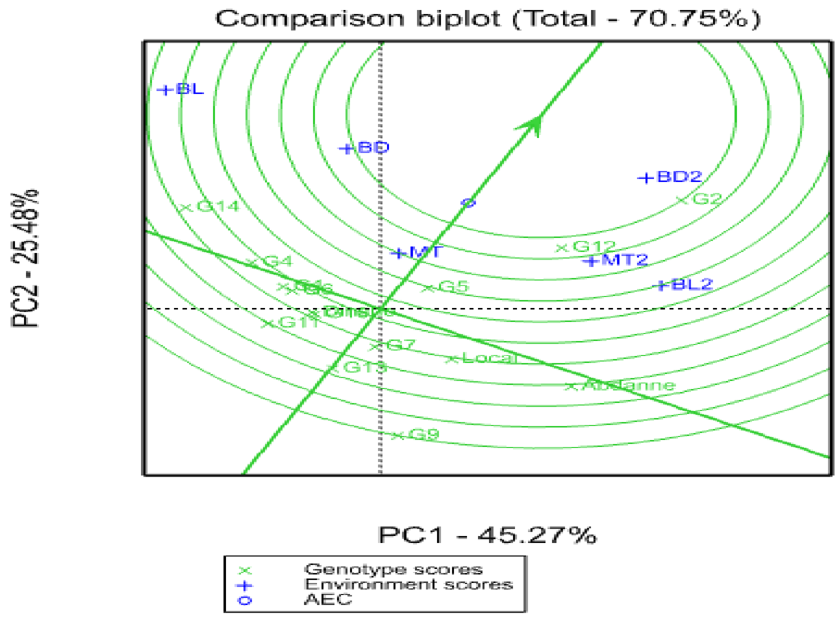

Figure: 1 GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability

Table 7: Mean grain yield (Qt ha^{-1}) per location and year from the AMMI additive GE model

Genotypes	BD1 (E1)	BD2 (E2)	BL1 (E3)	BL2 (E4)	MT1 (E5)	MT2 (E6)	Mean	IPCAg1	IPCAg2
G3	10.46	37.1	10.94	46.12	33.92	39.3	**29.64**	2.72	-1.89
G15	20.32	31.73	23.58	32.18	24.62	32.38	**27.47**	-0.66	0.69
G1	19.71	29.86	28	33.17	31.85	31.97	**29.09**	-1.32	-0.7
G10	21.38	32.55	23.63	32.07	23.29	32.83	**27.63**	-0.63	1.09
G11	19.14	29.32	25.11	30.93	26.77	30.67	**26.99**	-1.13	0.07
G12	23.97	43.49	20.55	44.63	28.26	43.24	**34.02**	1.55	1.06
G13	17.71	31.61	18.29	31.81	20.78	31.79	**25.33**	0.07	1.01
G14	29.28	30.95	37.27	28.11	27.12	31.59	**30.72**	-3.05	1.36
G2	28.39	50.62	19.86	49.83	27	49.11	**37.47**	2.52	2.14
G4	22.37	29.97	31.08	31.81	31.21	31.81	**29.71**	-1.88	-0.25
G5	16.82	33.99	23.64	41.12	37.43	36.75	**31.62**	0.25	-1.83
G6	17.56	28.93	28.15	34.82	36.19	32	**29.61**	-1.25	-1.75
G7	14.86	31.35	20.78	37.32	32.58	33.7	**28.43**	0.18	-1.36
G9	12.36	31.76	10.64	34.09	19.8	32.06	**23.45**	1.39	0.51
G8	15.69	35.14	15.98	38.99	27.14	36.11	**28.17**	1.24	-0.16
Environment									
Mean	**19.33**	**33.89**	**22.5**	**36.47**	**28.53**	**35.02**	**29.29**		
IPCAe1	-1.71	2.10	-4.34	2.81	-0.71	1.85			
IPCAe2	2.42	1.51	0.06	-0.89	-3.69	0.58			

Key: G- genotypes, E-environment, BD-bedesso, BL- Belem, MT- Mata, IPAg- interaction principal axis to genotypes, IPAe-interaction principal axis to environment, Number followed the lactations indicate the year (1=2017, 2= 2018)

Stability analysis for genotypic performance

AMMI Stability Value (ASV). In table 8 shows, AMMI stability values for grain yield. Considering the AMMI stability value (ASV) that takes into account the scores of the IPCA2, genotypes with least ASV scores are the most stable, whereas genotypes with high ASV score are unstable (Farshadfar, 2008; Bantayehu, 2009; Issa, 2009). Accordingly, genotypes (Dinsho, G11 and G13) were appeared to be among those showing low ASV and were the most stable. On the contrary, genotypes G14 and Abdane revealed the highest ASV and were thus considered to be unstable. Stability by itself should, however, not be the only parameter for selection, as the most stable genotype would not necessarily give the best yield performance (Mohammadi *et al.*, 2007). Therefore, the study indicated that, Dinsho, G11 and G13 were recorded the lower ASV (Table 8), but recorded lower yield (27.47, 26.99 and 25.33 Qtha^{-1} respectively) than the grand means (29.29 Qtha^{-1}). So if, Dinsho, G11 and G13 will be selected based on ASV per se, there will be a risk of yield reduction. The stable genotype was followed with mean grain yield above the grand mean and this result was in agreement with (Hintsa and Abay, 2013) who has used ASV as one method of evaluating grain yield stability of bread wheat varieties in Tigray and similar reports been made by Abay and Bjørnstad (2009), Sivapalan *et al*. (2000) in barley in Tigray and bread wheat using AMMI stability value. A genotype with the least of genotype selection index (GSI) is considered as the most stable genotype (Farshadfar, 2008). Accordingly, genotypes G2, G12 and G5 were more stable genotypes with the low of genotype selection index (GSI) and higher mean grain yield (Table 8).

Table 8: AMMI stability value, AMMI rank, Yield, yield rank and genotype selection index (GSI)

Genotype	ASV	**ASV RANK**	**YLD**	**YLD RANK**	**GSI**
G2	5.49	13	**37.47**	1	14
G12	3.12	10	**34.02**	2	12
G5	3.07	9	**31.62**	3	12
G14	5.54	15	**30.72**	4	19
G4	3.15	11	**29.71**	5	16
G3	5.50	14	**29.64**	6	20
G6	3.57	12	**29.61**	7	19
G1	2.48	8	**29.09**	8	16
G7	2.28	6	**28.43**	9	15
G8	2.08	4	**28.17**	10	14
G10	2.09	5	**27.63**	11	16
G15	1.59	1	**27.47**	12	13
G11	1.88	3	**26.99**	13	16
G13	1.68	2	**25.33**	14	16
G9	2.46	7	**23.45**	15	22

Conclusions and Recommendations

Although the GEI of grain yield partitioned in to different IPCAs using AMMI model analysis, the first principal component axis for interaction alone explains most of the interaction sum of squares. The sign and magnitude of IPCA scores showed the relative contribution of each genotype and environment for the genotype and environment interactions. It helps to summarize the pattern and magnitude of GEI and main effects that reveal clear insight into the adaptation of genotypes to environments. This shows that genotypes G2 and G12 are less contributors to the interaction effect and have consistent performances across locations. Whereas genotype G14 with higher ASV scores and unstable genotype. Therefore genotypes G2 and G12 were identified as the best genotypes in terms of yielding ability and stability, tolerant to diseases for advancement, release and use as parents in future breeding programs in the study areas and similar agro-ecologies.

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Genetic diversity study in sesame (*Sesamum indicum* L.) genotypes at Western Oromia, Ethiopia

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Abstract

Field experiment was conducted at Bako and Uke to evaluate the extent of genetic diversity in sesame (Sesamum indicum L.) genotypes for further improvement program. A total of forty nine sesame genotypes were evaluated during 2018 main cropping season including standared check. Combined analysis of variance showed highly significant differences among the test genotypes for all traits considered in the study. Result of cluster analysis grouped 49 sesame genotypes into four clusters. The highest inter-cluster distance observed between cluster three and four while the lowest was between cluster one and two. Principal Components Analysis (PCA) showed that, about 76.1% of the total variations among sesame genotypes were contributed by the first four PCAs with Eigen values greater than unity. Generally, the result of the study showed the existence of significant genetic diversity among tested genotypes. Therefore, simple selection of superior genotypes and crossing of highly divergent group to produce best heterotic offspring could be possible from the tested genotypes.

Keywords: Cluster analysis, Genetic divergence, Principal Component Analysis, Sesame (*Sesamum indicum* L.)

Introduction

Sesame (*Sesamum indicum* L.) is a self-pollinated crop containing 60 species organized into 16 genera (Zhang *et al.*, 2013). It is a diploid plant with chromosomes (2n = 26) and considered as the oldest oilseed crops cultivated by man (Kafiriti and Deckers, 2001). Hiltebrandt (1932) considered Africa as the original home of sesame, since this continent hosts higher number of wild species. The presence of weedy or wild forms of sesame (*S. alatum*; 2n=26 and *S. latifolium*, 2n=32) in Ethiopia show that it is indigenous and considered as the center of origin for sesame and the genetic diversity is high, serving as resources for further improvement of the crop (Daniel and Parzies, 2011). Sesame has been cultivated for centuries in India, Pakistan, Burma, Indo-China, China, Japan and Africa. In more recent times sesame has been introduced to Mexico, Central America, South America, and the U.S.A (Lalpantluangi and Shah, 2018).

Genetic diversity is an important tool of plant breeding in developing high yielding varieties and maintaining the productivity of such varieties by incorporating resistance genes for biotic as well as abiotic stresses (Kobayashi, 1990; Allard, 1999). Genetic distance is measured from the average genetic divergence between cultivars or populations and is defined as genetic divergence of two varieties as a function of their ancestry, geographic separation and adaptation at different environments. Here comes the importance of genetic divergence analysis in classifying genotypes into distinct genotypic classes and identifying parents for hybridization (Rao *et al*., 1981). However, little information has been generated as far as genetic diversity in sesame genotypes is concerned in Ethiopia. Hence, the present study was initiated to assess genetic diversity among advanced lines of sesame genotypes according to their genetic similarities based on the phenotypic traits using appropriate statistical tools.

Materials and Methods

Description of the Study Areas

The experiment was conducted at two locations viz. Bako Agricultural Research Center (BARC) and Uke sub site of BARC during 2018 main cropping season. BARC is located in Oromia Regional State at 250 kilometers West of Addis Ababa. BARC has a warm, humid climate with mean minimum and mean maximum temperatures of 13.97^{o}C and 29.80^{o}C, respectively. Relative humidity of BARC is 49.81% (BARC Agro metrology data, 2018).

Uke is located in East Wollega zone, Guto Gida district at about 365 kilometers away from Addis Ababa to the west on Nekemte-Bure-Bahir Dar main road and 34 kilometers away from Nekemte town. The area is located at altitude of 1383 m.a.s.l. and it is an area with high temperature and rain fall conditions. Major crops produced in the area include maize, sorghum, soybean, sesame and groundnut. Detail descriptions of the study sites are presented in Table 1.

Table 1. Site description of the study areas

Site	Rain fall(mm)	Longitude (E)	Latitude (N)	Altitude (m.a.s.l.)	Soil type	Soil PH
Bako	1161.7	37^{o} 09'E	09^{o}06'N	1590	Sandy-clay	4.9- 5.1
Uke	NI	036^{o} 31'E	09^{o}22'N	1383	Sandy-loam	NA

NA = Not Available

Experimental Materials

The experimental materials were consisted of 46 genotypes (pure lines) and three checks (Waliin, Chalasa & Obsa) (Table 2). These genotypes are progenies of the intra-specific cross of 11 morphologically diverse sesame genotypes through continuous maintenance of progenies up to the seventh filial generation (F7) through selfing using F2- derived pedigree breeding method at Bako Agricultural Research Center (Table 2). The original parental materials were collections from Western Ethiopia which includes; EW002, EW003, BG006, EW023 (2), EW006, EW003 (1), EW019, EW010 (1), Obsa, Dicho and Wama. These eleven parental materials were crossed in 11 x 11 diallel mating design, including reciprocals in 2011cropping season.

Table2. List of sesame genotypes used in this study

No.	Pedigree	No.	Pedigree
1.	EW002 X Obsa-1-1	26.	BG006 x EW023(2)-10-2-1
2.	EW002 X Obsa-16-1	27.	BG006 x EW010(1)-11-1-1
3.	EW002 X Obsa-22-1	28.	EW023(2) x Obsa-9-1-1
4.	Obsa x Dicho-19-1	29.	Obsa x BG006-2-2-1
5.	Obsa x Dicho-19-3	30.	Wama x Dicho-6-1-1
6.	Obsa x Dicho-27-1	31.	Obsa x EW023(2)-5-2-1
7.	EW002 x Dicho-1-1	32.	EW003(1) x EW002-4-1-1
8.	EW002 x Dicho-5-3	33.	Obsa x BG006-2-4-1
9.	EW002 x Dicho-12-1	34.	EW003 (1) x EW019-4-1-1
10.	EW002 x Dicho-17-2	35.	EW019 x Obsa-16-2-1
11.	EW002 x EW006-3-1	36.	EW003(1) x Obsa-2-1-1
12.	Dicho x EW006-9-1	37.	EW019 x Obsa-16-1-1
13.	Dicho x EW006-1-14-1	38.	Dicho x Wama-10-1-1
14.	BG006 x EW023(2)-11-2-1	39.	EW002 x EW019-1-2-1
15.	EW003 (1) x EW019-3-1-1	40.	EW019 x Dicho-8-2-1
16.	EW006 x EW003 (1)-4-1-1	41.	EW010(1) x EW003-1-1-1
17.	Dicho x EW006-2-1-1	42.	Obsa x EW019-6-3-1
18.	EW002 x BG006-4-1-1	43.	EW002 x Wama-6-1-1
19.	EW002 x BG006-7-2-1	44.	Dicho x Wama-11-1-1
20.	EW023(2) x EW006-11-1-1	45.	EW019 x Dicho-6-1-1
21.	EW002 x WAMA -2-1-1	46.	EW019 x Dicho-8-1-1
22.	Dicho x EW006-1-1-1	47.	Chalasa/EW023(2) (Parental check)
23.	EW006 x BG006-2-2-1	48.	Waliin (standard check)
24.	BG006 x EW010(1)-9-1-1	49.	Obsa (parental check)
25.	Obsa x EW023(2)-5-5-1		

Experimental Design and Trial Managements

The trial was laid out using 7 x 7 simple lattice design. Each genotype was planted in 4 rows in plot size of 6.4m^2 (4m row length, 40cm between rows and 10cm between plants within row and spacing of 1m between plots and 1.5m between blocks). The seeds were drilled by hand in each row at the rate of five kgha^{-1} and then covered by soil. The plant depth and soil compactions were kept at a minimum. Twenty days after planting, the plants were thinned to maintain the spacing between plants of 10 cm. Fertilizer was applied at the rate of 100 kgha^{-1} NPS at planting time whereas, 50 kgha^{-1} of Urea was applied two times at planting time and four week after planting. Other cultural practices were kept constantly for all experimental units.

Data Collection

All data were collected from the two central rows for both plant based and plot based data. The data were collected according to the International Plant Genetic Resources Institute (IPGRI, 2004) descriptor for sesame.

Plant based quantitative data collected

Plant height, Number of branches per plant, capsules per plant & Bacterial blight (%)

Plot based quantitative data collected

Days to 50% flowering, Days to maturity, 1000 Seed weight (g), Biomass yield per plot, Seed yield per plot, Biomass yield per hectare (kg ha^{-1}), Seed yield (kg ha^{-1}), Harvest index (%) & Oil content (%).

Oil content was determined by wide line nuclear magnetic resonance (NMR). Seeds were bulked per each plot and oven dried at 105 ^{0}C for 3 hrs and cooled for 30 minutes. Twenty two gram oven dried seed sample was used to analyze oil content using NMR. The NMR read oil content of the sample seed with reference to a standard of extracted sesame oil.

Data Analysis

The efficiency of simple lattice design over RCBD was checked and in most of the response variables, simple lattice design found to be more efficient than RCBD. Thus, ANOVA was computed based on simple lattice design. The quantitative data for each location was subjected to analysis of variance (ANOVA) and done using Proc lattice and Proc GLM procedures of SAS version 9.3 (SAS, 2012), according to simple lattice design. Before computing the combined analysis, homogeneity test for the error variance of two locations was done using Hartley`s test (1950) and checked by using F-test (ratio of the largest mean square error to the smallest mean square error in the set) according to Gomez and Gomez, (1984) and they were homogeneous. Hence, combined analysis was computed.

Cluster analysis

This analysis was done based on mean values of all yield and yield contributing traits. Clustering of genotypes were done into groups using the average linkage method by PROC clustering strategy of SAS 9.3 (SAS, 2012) and appropriate numbers of clusters were determined from the values of Pseudo F and Pseudo T^2 statistics (SAS, 2012).The dendrogram was constructed based on the average linkage and Euclidean distance used as a measure of dissimilarity.

Genetic divergence analysis

D-square statistics (D^2) developed by Mahalanobis (1936), was used to measure a group distance based on multiple traits of genotypes into different groups. Eleven quantitative traits were analyzed using the procedure Proc discrim of SAS version 9.3 facilities (SAS, 2012). The generalized distance between any two set of genotypes was defined as:

$$D^2_{ij} = (X_i - X_j)\, S^{-1} (X_i - X_j),$$

where, D^2_{ij} = the distance between cases i and j, Xi and Xj = vectors of the values of the variables for cases i and j and S^{-1} = the inverse of pooled variance covariance matrix. The D^2 values come from pairs of clusters were considered as the calculated values of chi-square (X^2) and tested for significance both at 1% and 5% probability levels against the tabulated value of X^2 for 'P' degree of freedom, where P is the number of traits considered (Singh and Chaudhary, 1996).

Principal component analysis

Principal component analysis (PCA) is one of the multivariate statistical techniques which is a powerful tool for investigating and summarizing the underlying trends in complex data structures (Legendre and Legendre, 1998). Principal component analysis reflects the importance of the traits with largest contributor to the total variation at each axis for differentiation (Sharma, 1998). Principal component analysis was computed by using SAS (SAS, 2012) computer software. In principal component analysis, eigenvalues greater than one were considered important to explain the observed variability.

Results and Discussions

Analysis of variance (ANONA)

The pooled analysis of variance showed highly significant ($P < 0.01$) difference among the test genotypes across locations for traits such as days to 50% flowering, days to maturity, plant height (cm), branches per plant, capsules per plant, biomass yield per hectare ($kgha^{-1}$), seed yield per hectare ($kgha^{-1}$), harvest index (%), thousand seed weight (g), oil content (%) and severity of bacterial blight (%) indicating that the presence of considerable variation in the genetic materials. This finding is in agreement with the reports of different researchers (Mohammed *et al.*, 2015; Iqbal *et al.*, 2018 and Singh *et al.*, 2018)

Cluster Analysis Based on Quantitative Traits

Cluster analysis grouped 49 sesame genotypes into four clusters with variable number of genotypes in each cluster (Figure 1**)**. The genotypes were distributed in such a way that 29 genotypes were grouped into cluster I (59.18%), 11 genotypes into cluster II (22.45%), 5 genotypes in the third cluster III (10.2%) and 4 genotypes in cluster IV (8.16%) (Figure 1). This indicated that there is moderate diversity among tested sesame genotypes. Similar results were also reported by Gadisa *et al.* (2015) where 64 sesame genotypes grouped into four clusters with different number of genotypes in each cluster. Besides, Kante (2017) reported similar findings, where 65 sesame genotypes were classified into four clusters with different number of genotypes per cluster and maximum number of genotypes were grouped in cluster I followed by cluster II, cluster III and minimum number of genotypes were grouped in cluster IV. Similarly Iqbal *et al.* (2018) were also reported related findings where 70 genotypes of sesame grouped into four clusters.

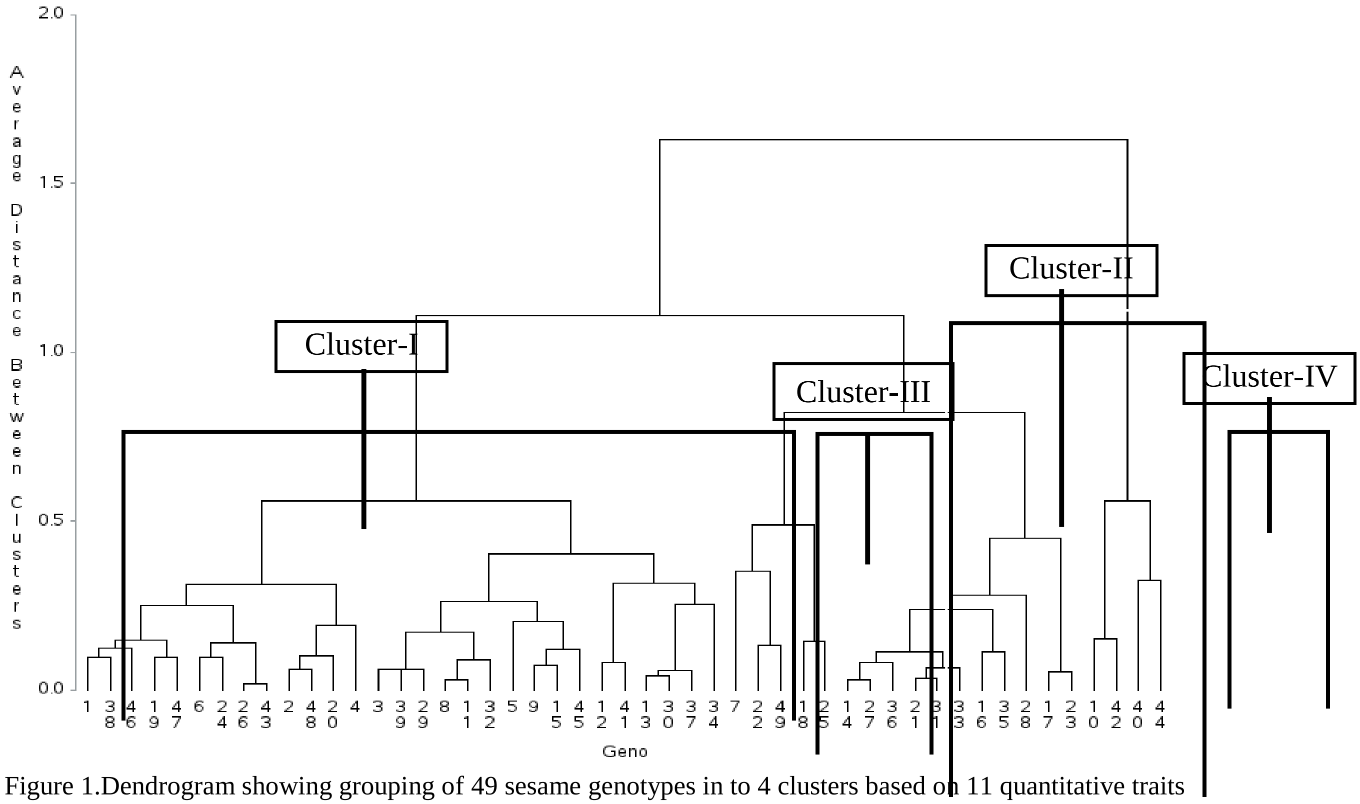

Figure 1.Dendrogram showing grouping of 49 sesame genotypes in to 4 clusters based on 11 quantitative traits

The mean value of the 11 quantitative traits in each cluster is presented in Table 3. The first cluster was characterized by medium flowering, late maturing, taller plant height, higher number of branches per plant, higher capsule per plant, higher biomass yield per hectare, higher seed yield per hectare and lower bacterial blight severity. The second cluster was characterized by late flowering, lowest number of branching and harvest index as well as the highest oil content. Cluster III consisted of 5 genotypes and characterized by early flowering and maturity, shortest plant height, lowest number of capsule per plant, biomass yield, seed yield, thousand seed weight and the highest severity of bacterial blight.

Cluster IV has 4 genotypes which are characterized by the highest in plant height, number of branches, number of capsule, biomass yield, seed yield, harvest index and thousand seed weight. Although, the lowest in oil content and severity of bacterial blight. Generally, cluster III had lowest mean values for most traits including seed yield and cluster IV has highest mean of most traits including seed yield. Crossing of genotypes grouped in cluster III with other all clusters cannot give as good yield performance. Therefore, these especial characteristics in clusters is important and would be considered in sesame variety development program through selection and hybridization including correlation and path coefficient analysis

Table 3. Mean value of 11 traits for the four clusters of 49 sesame genotypes evaluated at Bako and Uke in 2018 main cropping season

Traits	Cluster –I	Cluster -II	Cluster –III	Cluster –IV
Days to flowering	62.371	63.364**	61.650*	63.188
Days to maturity	113.241	112.182	111.650*	113.563**
Plant height	117.560	114.783	110.026*	121.415**
No. of branch/plant	6.529	5.435*	5.568	8.148**
No capsule/plant	99.131	82.589	81.736*	120.468**
Biomass yield/ha	3636.000	3068.482	2433.820*	4530.950**
seed yield/ha	1134.966	830.436	791.540*	1502.200**
Harvest index	31.210	27.212*	32.204	33.295**
1000 Seed weight (g)	6.336	6.455	6.120*	7.108**
Oil content	55.475	55.666**	55.568	55.443*
Bacterial blight %	17.832	21.600	22.900**	15.775*

*Key: *, **= represents lowest and highest cluster mean values, respectively*

Estimation of Inter-Cluster Square Distances (Genetic Distance)

The average inter-cluster distance (D^2) values of 49 sesame genotypes are presented in Table 4. The x^2- test for the four clusters indicated that there was a statistically significant difference between pairs of clusters except between cluster I and II. The highest average inter-cluster D^2 value was recorded between cluster III and cluster IV followed by cluster II and cluster IV indicating the presence of genetic variability between groups of tested genotypes (Table 4). Minimum inter-cluster distance was observed between cluster II and cluster III indicating little genetic diversity between these clusters. This signifies that, crossing of genotypes from these two clusters might not give higher heterotic value in F1 and narrow range of variability in the segregating F2 population.

Maximum genetic recombination is expected from the hybridization of the parents selected from divergent cluster groups (Singh *et al.*, 1987). However, the chance of getting segregants with a high yield level is quite limited when one of the clusters has a very low yield level (Samal *et al.*, 1989). Cluster III had the lowest mean performance in seed yield and other important traits. This indicates that the chance of getting segregants with high yield is limited between crosses of Cluster III with the other clusters. The selection of parents should also consider the special advantages of each cluster and each genotype within a cluster depending on specific objectives of hybridization (Singh, 2001; Chahal and Gosal, 2002).Thus, in the present result crosses involving Cluster VI with Cluster II and Cluster I are suggested to exhibit high heterotic and could result in segregants with higher seed yield.

According to Ghaderi *et al.* (1984) increasing parental distance suggests a great number of distinct alleles at the desired loci and cross of distantly related parents will be produce greater offspring and increases the opportunities for the effective selection for desired traits. Therefore, maximum recombination and segregation of the progenies is expected from crosses involving parents selected from cluster III and IV followed by II and cluster IV (Table 4), However any crossing program should be based on the breeder objectives, so that the breeder must specify his/her objectives in order to get best use of the traits those highly divergent.

Table 4. Average inter cluster divergence (D^2) values among 49 sesame genotypes evaluated at Bako and Uke in 2018 main cropping season

Clusters	Cluster –I	Cluster –II	Cluster –III	Cluster –IV
Cluster -I	0	13.439^{ns}	52.725**	30.295**
Cluster -II		0	20.647*	78.710**
Cluster -III			0	157.820**
Cluster –IV				0

*Key: * Significant at 0.05 (X^2) = 19.67 and ** Significant at P<0.01(X^2) =24.72*

Principal Component Analysis (PCA)

Principal component analysis reflects the importance of the traits with largest contributor to the total variation at each axis for differentiation (Sharma, 1998). Eigenvalues, percent of total variance and percent of cumulative variance for 11 quantitative traits in 49 sesame genotypes are presented in Table 5.

The result of the study showed that the first four principal components with eigenvalues greater than one have accounted for 76.1% of the total variation. The first two principal components PC1 and PC2 with values of 37.7 % and 16 %, respectively, contributed more to the total variation. Similar result was also reported by Akbar *et al*. (2011); Gadisa *et al.* (2015) and Kante (2017). According to Chahal and Gosal (2002), traits with largest absolute values closer to unity with in the first principal component influence the clustering more than those with lower absolute values closer to zero. Therefore, in this study, differentiation of the genotypes into different cluster was because of a cumulative effect of the number of traits rather than the contribution of specific few traits (± 0.06-0.722).

Table 5. Result of principal component analysis for 11 quantitative traits of 49 sesame genotypes evaluated at Bako and Uke in during 2018 main cropping season

Traits	PC1	PC2	PC3	PC4
Days to Flowering	0.071	0.485	0.503	0.174
Days to maturity	0.136	0.574	-0.167	-0.320
Plant height	0.249	0.351	-0.294	0.210
No. of branch per plant	0.401	0.078	0.068	0.387
No capsule per plant	0.427	-0.119	-0.058	0.253
Biomass yield per ha	0.423	0.012	-0.128	-0.088
seed yield per ha	0.460	-0.172	0.005	-0.045
Harvest index	0.295	-0.341	0.164	0.034
1000 Seed weight (g)	0.103	-0.331	0.352	-0.266
Oil content	0.062	0.180	0.674	-0.084
Bacterial blight (%)	-0.283	-0.060	0.059	0.722
Eigenvalue	4.149	1.754	1.403	1.059
Total variance explained (%)	0.377	0.160	0.128	0.096
Cumulative total variance explained (%)	0.377	0.537	0.664	0.761

The traits having relatively higher value in the first principal component (PC1) were number of branches per plant, number of capsule per plant, biomass yield and seed yield had more contribution to the total diversity and also the major contributor for the first PCA. Traits such as days to flowering, days to maturity, plant height, harvest index and thousand seed weight had contributed a lot for principal component (PC2), days to flowering, thousand seed weight and oil content had contributed in the PC3, days to maturity, number of branches per plant and bacterial blight severity were the major contributors in the fourth principal component (PC4) (Table 5). In general, traits contributing more to the variation should be more focused for sesame yield improvement through selection and hybridization.

Summary and Conclusion

Studying the extent and pattern of genetic diversity of sesame genotypes provide valuable information for plant breeders to design further breeding strategy. In order to generate such information, 49 sesame genotypes including standard checks were tested in 7 x 7 simple lattice design. The results showed that, there were highly significant differences among tested genotypes for all traits studied indicating the presence of high variability for yield and other related traits in the test genotypes. Generally, the analysis of variance results showed the presence of considerable variations among 49 sesame genotypes for all traits thereby suggesting possibility for further genetic analyses for all tested traits.

Cluster analysis grouped 49 sesame genotypes into four clusters based on their similarity. The highest inter-cluster distance occurred between clusters three and four while the lowest was between cluster one and cluster two. Principal components analysis showed that about 76.1% of the total variation among sesame genotypes through PC1 to PC4 and the total variation loaded largely by traits like branch per plant, capsule per plant, biomass yield and seed yield.
Generally, the present study showed existence of significant genetic diversity among tested genotypes indicating the presence of a huge opportunity for further improvement through selection and other breeding approaches using these sesame germplasm. Besides, hybridization which involves crossing of genotypes for selected traits of cluster VI with cluster I and II would result in heterotic progenies. Therefore, simple selection of promising genotypes and crossing of highly divergent group to produce best heterotic progenies were recommended from the studied sesame genotypes. As future direction, application of marker assisted selection along with phenotypic selection will be enhance the efficiency of selection and also helps to release superior varieties of sesame in a short period of time.

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Performance Evaluation and adaptability study of improved Sesame (*Sesamum indicum* L.) Varieties at Harari Region

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Abstract

Sesame (Sesamum indicum L.) is an important oilseed crop in the tropics and subtropics. Field trials were conducted during 2017 and 2019 main rainy seasons at Harari regional state of Kile kebele with objective to study the adaptability of released sesame varieties. Twelve improved varieties of sesame including standard check (Obsa) were used. The experiment was laid out in Completely Randomized Block Design (RCBD) with three replications. Analysis of variance showed that significant variation was observed among the varieties for days to flowering, days to maturity, number of branches per plant, number of pods per plant, plant height and grain yield. Accordingly, Chalasa, Srinka-2 Srinka-1and Hirhir varieties found to be best performing varieties among the test varieties and hence were recommended for further demonstration and scaling up in the study area and similar agro ecologies.

Key words: Adaptability, Sesame

Introduction

Ethiopian sesame is among the highest quality in the world, as seeds are naturally produced at near-organic levels (Fantaye *et al*., 2018). Sesame seed is branded as Humera, Gonder and Wollega types which are well known in the world market by their white color, sweet taste and aroma. The Humera and Gondar sesame seeds are suitable for bakery and confectionary purposes; on the other hand, the high oil content of the Wollega sesame seed gives a major advantage for edible oil production (Yamanura, 2008). The current sesame production in Ethiopia has many opportunities, such as highly market demand, large area with suitable environments for production (North western and South Western Ethiopia), growing in low moisture areas, presence of genetic diversity to improve production yield potential and export demanded very competitive world wide (Wijnands *et al*., 2007).

Survey of production constraints made by AGP-II project in the Harari region indicated that, sesame producing farmers in the area are not access to new and improved sesame varieties and rather they produce varieties that were released 7-10 years ago which are becoming susceptible and low yielder due to sesame diseases and other production constraints. . During the survey mission in the group discussion, the participant framers pointed out that lack of awareness on importance and utilization of sesame is common in the community. There is also the problem of late distribution of the seed for the farmers and also the seed distributed are poor both quality and quantity. Farmers of the districts noted that the shortages of improved varieties are the major problem. Generally, the number of improved sesame varieties released and introduced in study area is quite few and old and hence, introducing different recently released sesame varieties which are resistant and high yielder are needed to improve farmers access to different varieties in the area. Hence, introducing high yielder and disease resistant varieties for the sesame producing community of the area is quite important aspect to improve the production and productivity of this crop. Therefore, this experiment was conducted with the objective to evaluate different recetlt released sesame varieties for their adaptability in the study area for further scaling up activities.

Materials and Methods

Experimental Site

The study was conducted at Harari Regional state, Sofi disrict, Kile Kebele which is known for its frequent low moisture stress. Kile kebele is situated at the distance of about 20 km away from Harar city in the eastern direction. The experiment was conducted during 2017 and 2019 main cropping season.

Experimental Materials

The experimental materials were comprised of twelve released sesame varieties including one standard check (Obsa). Nine released sesame varieties viz. Srinka-1, Srinka-2, Setit-1, Setit-2, Humera-1, Gonder, Baha-Necho, Baha-Zeyit and Hirhir) were introduced from Humara Agricultural Research Center (HaRC) and two released varieties viz. Adi and Chalasa were introduced from Bako Agricultural Research Center (BARC).

Experimental Design

The trial was laid out in Randomized Complete Block Design (RCBD) in three replications. Each Variety was planted in a 6 rows of 40cm spacing between rows and 10cm between plants with row length of 3m.

Data Analysis

Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) was conducted using Statistical Analysis System (SAS) computer software program. Duncan Multiple Range Test (DMRT) was used to compare means of different treatments.

Results and Discussions

Results of analysis of variance showed that there is significant variation among the tested varieties for all considered parameters such as days to flowering, days to maturity, number of branches per plant, plant height, number of pods per plant, number of seeds per pod and Grain yield per hectare (kg/ha). Similarly, Fantaye *et al*. (2018) reported that sesame genotypes evaluated in the study were significantly ($p<0.01$) influenced by environment, genotype and genotype by environment interaction (GEI).

The variation was significant among tested varieties for the trait such as Days to flowering, Days to maturity, Number of branching per plant, Plant height, Number of pods per plant, Number of seeds per pod and grain yield. Humera-1, Setit-2, Srinka-1, Gonder, Setit-1, Baha-Necho and Chalasa gave higher number of seeds per pods than the standard check (Obsa). Maximum grain yield was harvested from Chalasa variety (787.6 kg ha^{-1}) followed by Baha-

Necho, Srinka-2, Srinka-1 and Hirhir; Similarly, Chalasa, Srilinka-1, Baha-Necho and Gonder-1 showed maximum number of pods per plant than the standard check, indicating that number of pods per plant has contribution for grain yield increment.

Table.1. Combined mean of grain yield and other parameters of sesame varieties tested over years (2017 and 2019)

Treatment	FD	MD	NB	PPP	PH	Grain y(kg/ha
Adi	53bc	99ab	4.35bc	72.07ab	65.4d	611.1abc
Gonder-1	48c	96b	4.95bc	58.17b	91.67a	568.9abc
Baha-Necho	51bc	112a	3.783c	68.88ab	77.02c	762.4a
Baha-Zeyit	53.33abc	118a	4.283bc	55.35b	83.4bc	609.5abc
Hirhir	54.67abc	96b	5.45abc	82.05ab	94.17a	708.8ab
Humera-1	57.33ab	97ab	5.05abc	58.85b	84.95bc	389.5c
Srinka-1	54.33abc	96b	6.6a	107.43a	90.1a	714.4ab
Srinka-2	59.83a	102a	5.15abc	67.63ab	90.6a	718.8ab
Setit-1	55.5abc	99ab	4.933bc	69.93ab	87.38ab	612.9abc
Setit-2	57.5ab	86ab	5abc	59.95b	88ab	487.9bc
Obsa	50.67bc	96b	4.833bc	65.43ab	89.77ab	581.5bc
Calasa	54.67abc	98ab	5.617ab	85.62ab	84.77bc	787.6a
CV (%)	9.8	3.8	24.6	26	10.4	26.1
LSD	6.115	4.341	1.420	37.67	10.42	262.4

Key: FD= days to flowering, DM= days to maturity, NB= number of branches, PH= plant height, PPP= pods per plant, GY=grain yield, CV= coefficient of variation and LSD= least significant differences

Conclusion and Recommendation

Analysis of variance showed that there is statistically significant different among the treatments for all the traits considered in this study. This showed the presence of great opportunity for sesame improvement by breeding for these traits. In terms of grain yield and yield related traits, varieties such as Chalasa, Srinka-2, Srinka-1 and Hirhir showed higher performance than the standard check. Accordingly, these varieties, Chalasa, Srinka-2 Srinka-1and Hirhir were recommended for further demonstration and scaling up in the study area and similar agro ecologies.

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Response of sesame seed and oil yield parameters to phosphorus fertilization in poor sesame growing soils of West Oromia

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Abstract

Field experiments were conducted during 2016 and 2017 cropping seasons at Ukke, and during 2017 at Chewaka sub-sites to study the effect of mineral phosphorus fertilizer on yield, its attributes, seed oil content and oil yield of three sesame varieties. Fifteen (15) treatments, factorial combinations of five levels of mineral phosphorus fertilizer rates; 0, 38, 58, 78 and 98 Kgha^{-1} P_2O_5 and three sesame varieties (Dicho, Obsa and Chalassa) were arranged in Randomized Complete Blok (RCBD) with three replications at both locations. The result of this study showed that application of different rates of phosphorus fertilizer rates differently affected the varieties at these two locations. Contrary to both Obsa and Dicho sesame varieties, variety Chalasa achieved its maximum number of branches (4.80) and pods (70.78) per plant when it was planted without phosphorus fertilization at Ukke. Obsa produced its maximum seed and oil yields when phosphorus fertilizer was applied at the rates of 78kg ha^{-1} P_2O_5 at both locations. The seed and oil yields of this variety at 78 kg ha^{-1} P_2O_5 phosphorus fertilizer rate were 13.7 and 14.5%; and 54.7 and 50% higher than the unfertilized plots at Ukke and Chawaka, respectively. On the other hand, sesame variety Dicho produced its maximum seed and oil yields under 38 and 98kg ha^{-1} P_2O_5 rates at Ukke and Chawaka respectively. Similarly, variety chalasa produced its best seed and oil yields under the application of 58 and 38kg ha^{-1} P_2O_5 rates at Ukke and Chawaka, respectively. Therefore, farmers at both locations and similar agro-ecologies can use those phophorus fertilizer rates that produced better sesame seed and oil yields specific to the variety and locations.

Key Words: Phosphorus, sesame varieties, seed and oil yields

Introduction

Sesame (*Sesamum indicum L*.) is an important annual oil seed crop grown especially in developing countries as a rich source of oil, protein, calcium and phosphorus. Among oil seed crops, sesame is the most ancient oil seed known and grown by humans according to archaeological records (Nayar 1984; Salunkhe*et al*., 1991). There are no definite findings on the origin of sesame, though Ethiopia is considered to be the center of cultivated sesame (Weiss, 1971). Despite its long history, sesame has recently attracted increasing interest as a source of good quality oil that is resistant to oxidative rancidity due to the presence of endogenous antioxidants such as sesamol, sesamolinol (Fukuda *et al*., 1984; Umezaki, 1997).

In Ethiopia, the production of sesame is both by small and large scale farmers; and it is an important crop and export commodity. The total area, production and productivity during 2013 were 0.299 million ha, 0.220 million tones and 0.735 t ha^{-1}, respectively; and the total area and production were increased by 61.23 % and 17.91 %, respectively. Whereas, the total productivity was decreased by 27.23 % when compared with 2008 cropping season (CSA, 2008; 2013). Sesame ranks first in total area and production from oil crops during 2013; and Tigray, Oromia, Amhara and Benshangul Gumuz regions are the major producers in Ethiopia. Due to its importance as a major export commodity, the area coverage and production has increased in the last few years in Ethiopia. The government is enhancing the investment in the oilseeds sector with an extended package of incentives.

In spite of the growing demand for sesame seeds and oil in Ethiopia, the productivity, production and oil extractions methods are traditional. Though Ethiopia is among the top five sesame seeds producers in the world, the potential benefit that could be obtained is below the optimum due to the use of traditional technologies and/or unavailable high-level sesame oil seed processing/refining industries in the country (Negash, 2015).

Application of phosphorous at the rate of 50 kg P_2O_5 ha^{-1}significantly enhanced seed yield, seed oil content and seed protein content increased pods per plant (Haggai, 2004), whereas Olowe*etal* (2000) reported significantly increased growth, yield and yield attributes in Nigeria with the application of 13.2 kg P ha^{-1}. Increased number of leaves per plant; number of seeds per pod and seed yield $ha^{-1}$with the application of 26.4 kg P ha^{-1} were reported by (Okpara*et al.*, 2007). An adequate amount of phosphorus in soils favors rapid plant growth and early fruiting or maturity and often improves the quality of vegetation (Martin *et al*., 1976). The general recommendation for a virgin soil is application of 30 $kgha^{-1}$ of both phosphorus and sulphur, traditionally applied as single superphosphate at 350 – 400 $kgha^{-1}$(Bennett *et al.*, 2003). Seed yield increased from 649 to 754 $kgha^{-1}$ with increasing Phosphorus rate (Deshmukh*etal*, 1990).

Growth and protein contents of shoots and roots increased with increasing P concentration (Muthusamy *et al*., 1999). Oil yield was increased by increasing Phosphorus rates up to 40 kg $P_2O_5ha^{-1}$, but it was not affected by Phosphorus source (Chaplot*et al*., 1991). Moreover, yields of sesame grain in India, were 0.65, 0.73 and 0.75 t/ha with 20, 40 and 60 kg P_2O_5/ha, respectively and unaffected by P source (Chaplot*et al*., 1992). Seed yields with 0, 40 and 80 kg $P_2O_5ha^{-1}$ were 725, 829 and 854 $kgha^{-1}$, respectively (Puste and Maiti, 1990). Seed yield was highest and it increased with rate of Phosphorus applicationof up to 45 kg ha^{-1}. Leaf area and dry matter yield per plant increased with rate of Phosphorus application (Behera *et al*., 1994). Maximum plant growth was achieved at 45 kg ha^{-1}rock phosphate. Higher rates of phosphate fertilizer didnot produce a significant effect on plant growth (Prakash *et al*., 2004). Seed yield due to Phosphorus rates was not significant even when 120 kg $P_2O_5ha^{-1}$ was applied to sesame (Shakoor, 1998). But, the effect of phosphorus fertilizer rates was not studied for western Oromia under acidic soils. Therefore, this study was proposed with the general objective of identifying phosphorus fertilizer recommendation that increases sesame productivity and seed oil yield; and with a specific objective of studying the effect of mineral fertilization of phosphorus on sesame seed oil yield improvement and the crop yield parameters.

Materials and Methods

Experimental Design and Locations

Field experiments were conducted during 2016 and 2017 seasons at *Ukke*, and during 2017 at *Chewaka* sub-sites to study the effect of mineral phosphorus fertilizer on yield, its attributes, seed oil content and oil yield of three sesame varieties. The experiment included 15 treatments which were the combinations of five levels of mineral phosphorus fertilizer rates; 0, 38, 58, 78 and 98 Kgha^{-1} P_2O_5 and three sesame varieties (*Dicho*, *Obsa* and *Chalassa*). The experimental design was Randomized Complete Blok (RCBD) in factorial arrangements with three replications.

Measurements of Yield and Yield Parameters

At harvest time, samples of five tagged plants were randomly taken from the inner ridges in each plot to estimate plant height (cm), number of branches and Pods per plant, and seed yield per plot. Seed yield (t ha^{-1}) was determined from the plants of the middle ridges in each plot and the yield per hectare was calculated. Seed oil content (%) was determined by using Soxhelt continuous extraction apparatus with petroleum ether as an organic solvent according to A.O.A.C. (1975) and oil yield (t ha^{-1}) was calculated by multiplying seed oil content (%) and seed yield (tha^{-1}). Analysis of variance (ANOVA) was computed for all collected data using SAS statistical software package. Treatment means were separated using fishery's protected least significant difference method (LSD) at 5% probability level for statistically different means.

Results and Discussion

Response of Sesame Growth Parameters to the Combination of Varieties and Different Phosphorus Fertilize Rates At ukke

Number of Branches and Pods per Plant, and Plant Height

The combined (over year) analysis of variance at *Ukke* showed that number of branches per plant and plant height were not affected by the main factors of variety and different phosphorus fertilizer rates, but significantly affected ($p<0.01$) by the interaction effect of the two main factors. Number of pods per plant was significantly affected ($p<0.001$) both by the main factors and their interactions (Table 1).

Table 1: Combined Analysis of variance for sesame growth and yield parameters, *Ukke* **(2016 – 2017)**

Source of Variations	DF	Mean Squares				
		No. of Branches/ Plant	**No. of Pods/Plant**	**Plant Height** *(cm)*	**Seed Yield** *(t ha^{-1})*	**Oil Yield** *(t ha^{-1})*
Season	1	7.569***	622.00***	6143.79***	0.39909***	0.07871***
Variety	2	0.35478^{NS}	306.00***	26.72^{NS}	0.19296***	0.05101***
P- Fertilizer Rates	4	0.33639^{NS}	534.65***	33.24^{NS}	0.01957^{NS}	0.00555^{NS}
Variety* P- Fertilizer Rates	8	1.15756**	1032.76***	199.47***	0.10470***	0.03357***

Significantly highest average number of branches (5.11) and pods (88.51) per plant were achieved by sesame variety *Obsa* that received 78 kg ha^{-1}P_2O_5, while variety *Dicho* reorded its average maximum number of branches (4.98) and pods (81.51) per plant at 38 kg ha^{-1}P_2O_5 appilication. Contrary to both *Obsa* and *Dicho* sesame varieties, variety *Chalasa* achieved its maximum number of branches (4.80) and pods (70.78) per plant when it was planted without phosphorus fertilizer (Table 2). The application of 38 kg ha^{-1}P_2O_5 to *Diccho* and 98 kg ha^{-1}P_2O_5 phosphorus to *Chalasa* resulted in the tallest (124.77 and 125.13cm) sesame plants, respectively. many authors reported that different sesame varieties respond differently to various phosphorus nutrient rates in their vegetative growth parameters (Chang *et al.*,2005; Okpara*et al.,* 2007).

Table 2: Sesame growth Parameters as affected by the interaction of varieties and different phosphorus fertilizer rates at *Ukke* (2016 – 2017)

Variety	**Phosphorus Fertilizer Rates** *(kg ha^{-1})*	**Number of Branches per plant**	**Number of Pods per plant**	**Plant Height** *(cm)*
Dicho	0 P_2O_5	4.00^{E}	54.86^{FGH}	121.63^{AB}
	38 P_2O_5	4.98^{ABC}	81.51^{B}	124.77^{A}
	58 P_2O_5	4.83^{ABCD}	63.00^{DE}	108.90^{E}
	78 P_2O_5	4.30^{DE}	60.26^{EF}	117.13^{BCD}
	98 P_2O_5	4.53^{ABCDE}	54.33^{FGH}	114.03^{CDE}
Obsa	0 P_2O_5	4.13^{E}	44.53^{I}	113.93^{CDE}
	38 P_2O_5	5.00^{AB}	64.23^{CDE}	117.83^{BCD}
	58 P_2O_5	4.43^{BCDE}	62.68^{DE}	121.20^{AB}
	78 P_2O_5	5.11^{A}	88.51^{A}	122.57^{AB}
	98 P_2O_5	4.31^{DE}	68.35^{CD}	119.83^{ABC}
Chalasa	0 P_2O_5	4.80^{ABCD}	70.78^{C}	116.53^{BCD}
	38 P_2O_5	3.93^{E}	63.16^{DE}	117.43^{BCD}
	58 P_2O_5	4.33^{CDE}	58.46^{EFG}	121.47^{AB}
	78 P_2O_5	4.43^{BCDE}	51.20^{HI}	113.07^{DE}
	98 P_2O_5	4.43^{BCDE}	52.81^{GH}	125.13^{A}
Mean		**4.50**	**62.58**	**118.36**
CV (%)		**12.62**	**9.54**	**4.45**
LSD (0.05)		**0.65**	**6.89**	**6.08**

Response of Sesame Seed and Oil Yields to the Combination of Varieties and Different Phosphorus Fertilize Rates

Sesame Seed and Oil Yields

Analysis of variance across growing seasons showed significant effects ($p<0.001$) of the main factor variety and its interaction with different rates of phosphorus fertilizer rates on sesame seed and oil yields. However, phosphorus fertilization rates did not show significant effects on sesame seed and oil yields (Table 1). The interaction of variety *Obsa* and phosphorus fertilizer rate at 78 kg ha^{-1} P_2O_5 achieved the highest average sesame seed (1.16 t ha^{-1}) and oil (0.63 t ha^{-1}) yields compared to the other varieties. The seed and oil yields of this variety at 78 kg ha^{-1}P_2O_5phosphorus fertilizer rate were 13.7% and 14.5% higher than the unfertilized plot, respectively. But, *Dicho* and *Chalasa* achieved the highest seed and oil yields at 38 and 58 kg $ha^{-1}P_2O_5$ applications, respectively. Increasing the phosphorus fertilizer rate from 0 to 38 kg $ha^{-1}P_2O_5$, increased sesame seed yield by 21.3% and its oil yield by 22.5% for *Dicho* variety, repectively compared to the unfertilized *Dicho*. Similarly, increasing the phosphorus fertilizer rate from 0 to 58 kg $ha^{-1}P_2O_5$, increased sesame seed yield by 18.7% and its oil yield by 20.4% for *Chalasa* variety, respectively compared to the unfertilized *Chalasa* (Table 3).

Similarly, Ali and Sakr, 2002; Shehu *et al.*, 2010 reported that sesame varieties could show better seed yields at different phosphorus rates. The increase in seed yield of sesame could be attributed to the importance phosphorus nutrient in enhancing the development of good root system (Russel, 1973) which inturn increases efficiency of the roots in absorbing various nutrients. This was evident in plant growth as expressed by plant height and number of branches per plant in response to Phosphorus applicatiom. Phosphorus stimulates photosynthesis, carbohydrate metabolism and synthesis of protein (Marschner, 1986) in turn increasing the amount of metabolites synthesized by sesame plants. Also, it plays important role in enhancing translocation of metabolites which might be the reason for the subsequent increases observed on seed yields of the varieties. Similarly, the increase in seed oil yield (tha^{-1}) by adding phosphorus fertilizer might be attributed to important role of phosphorus in metabolism of lipids (Marschner, 1986). The results are also in accordance with those reported by Ali and Sakr (2002).

Table 3: Sesame Seed and Oil Yields as affected by the interaction of varieties and different phosphorus fertilizer rates at *Ukke* (2016 – 2017)

Variety	**Phosphorus Fertilizer Rates** *(kg ha^{-1})*	**Seed yield** *(t ha^{-1})*	**Oil yield** *(t ha^{-1})*
Dicho	0 P_2O_5	0.94^{DE}	0.49^{DE}
	38 P_2O_5	1.14^{AB}	0.62^{AB}
	58 P_2O_5	0.91^{E}	0.49^{E}
	78 P_2O_5	1.12^{AB}	0.60^{AB}
	98 P_2O_5	0.99^{CDE}	0.53^{CDE}
Obsa	0 P_2O_5	1.02^{BCDE}	0.55^{BCD}
	38 P_2O_5	1.05^{ABCD}	0.55^{BCD}
	58 P_2O_5	0.98^{CDE}	0.53^{CDE}
	78 P_2O_5	1.16^{A}	0.63^{A}
	98 P_2O_5	1.13^{AB}	0.60^{AB}
Chalasa	0 P_2O_5	0.91^{E}	0.49^{DE}
	38 P_2O_5	0.93^{DE}	0.50^{DE}
	58 P_2O_5	1.08^{ABC}	0.59^{ABC}
	78 P_2O_5	0.67^{F}	0.36^{F}
	98 P_2O_5	0.96^{DE}	0.52^{DE}
Mean		**1.004**	**0.54**
CV (%)		**10.31**	**10.63**
LSD (0.05)		**0.11**	**0.06**

Response of Sesame Growth Parameters to the Combination of Varieties and Different Phosphorus Fertilize Rates at *Chawaka*

Number of Branches and Pods per Plant, and Plant Height

The analysis of variance at *Chawaka* showed that number of branches and pods per plant were significantly affected by the main factors of variety and different phosphorus fertilizer rates, and their interactions($p<0.05$). But, plant height was only affected significantly ($p<0.001$) by the main effect of variety (Table 4).

Table 4: Analysis of Variance for Sesame Growth and Yield Parameters at *Chawaka* (2017)

		MEAN SQUARES				
Source of Variation	**DF**	**Number of Branches per plant**	**Number of Pods per plant**	**Plant Height (cm)**	**Seed yield (t/ha)**	**Oil Yield (t/ha)**
Variety	2	1.18400^{**}	605.292^{**}	1082.75^{***}	0.62267^{***}	0.18287^{***}
Phosphorus Fertilizer rates	4	0.57467^{*}	827.599^{***}	114.83^{NS}	0.03785^{***}	0.01000^{**}
Variety *Phosphorus rates	8	0.37400^{*}	292.599^{*}	71.09^{NS}	0.32236^{***}	0.09227^{***}

Significantly highest average number of branches (5.4, 5.4 and 4.8) per plant were achieved by the application of 58kg P_2O_5 to *Obsa*, 38kg P_2O_5 to *Chalasa* and *Dicho* varieties, respectively. The maximum average number of pods per plant were achieved by *Chalasa* and *Obsa* (86.46 and 82.6) which received phosphorus fertilizer rates of 38 and 98kg ha^{-1} P_2O_5, respectively. However, variety *Dicho* produced its maximum average number of pods per plant (60.13 and 60.06) under 58 and 38 kg ha^{-1} P_2O_5, respectively (Table 5). Many reports show that different sesame varieties respond differently to various phosphorus nutrient rates in their vegetative growth parameters; increasing phosphorus fertilizer rates increased number of pods and branches per plant (Okpara*et al.*, 2007; Ahmad *et al.*, 2001; Malik *et al.*, 2003).

Table 5: Sesame growth Parameters as affected by the interaction of varieties and different phosphorus fertilizer rates at *Chawaka* (2017)

Variety	**Phosphorus Fertilizer Rates**(kgha^{-1})	**Number of Branches per plant**	**Number of Pods per plant**	**Plant Height** (cm)
	0 P_2O_5	3.93^{E}	41.60^{E}	115.93
	38 P_2O_5	4.80^{ABC}	60.06^{BCD}	119.87
Dicho	58 P_2O_5	4.33^{CDE}	60.13^{BCD}	123.00
	78 P_2O_5	4.60^{BCD}	48.86^{CDE}	118.73
	98 P_2O_5	4.13^{DE}	50.53^{CDE}	104.33
	0 P_2O_5	4.73^{BCD}	52.46^{CDE}	124.33
	38 P_2O_5	4.48^{ABC}	72.53^{AB}	128.67
Obsa	58 P_2O_5	5.40^{A}	44.26^{DE}	125.20
	78 P_2O_5	4.53^{BCDE}	57.53^{BCDE}	127.33
	98 P_2O_5	5.13^{AB}	82.60^{A}	116.93
	0 P_2O_5	4.40^{CDE}	55.93^{BCDE}	135.40
	38 P_2O_5	5.40^{A}	86.46^{A}	136.53
Chalasa	58 P_2O_5	4.53^{BCDE}	54.46^{CDE}	131.60
	78 P_2O_5	4.26^{CDE}	60.60^{BCD}	127.80
	98 P_2O_5	4.80^{ABC}	63.66^{BC}	135.40
Mean		**4.65**	**59.44**	**124.74**
CV (%)		**8.24**	**16.93**	**5.73**
LSD (0.05)		**0.64**	**16.83**	**NS**

Response of Sesame Seed and Oil Yields to the Combination of Varieties and Different Phosphorus Fertilize Rates

Sesame Seed and Oil Yields

Analysis of variance of the experiment at *Chawaka* showed that the main factors variety and different rates of phosphorus fertilizer rates significantly affected ($p<0.001$) sesame seed and oil yields. Similarly, the interaction of these main factors also significantly affected ($p<0.001$) both seed and oil yields (Table 4). Application of 98kg ha^{-1} P_2O_5 to variety *Dicho* resulted in the maximum seed and oil yields (Table 6). These seed and oil yields of variety *Dicho* were 27 and 27.4% higher than its seed and oil yields when produced with no phosphorus fertilizer application. *Obsa p*roduced its maximum seed and oil yields when treated with 78kg ha^{-1} P_2O_5 while increasing the phosphorus fertilizer rates beyond 38kg ha^{-1} P_2O_5 reduced both the seed and oil yields for variety *Chalasa* at *Chawaka.* The seed and oil yields achieved by *Obsa* at 78kg ha^{-1} P_2O_5 were 54.7 and 50% higher than the yields of no phosphorus fertilizer application. These results were also inline with the findings of (Muhammad Ibrahim *et al.*, 2014; Paga *et al.*, 2017) who reported that increasing the rate of phosphorus fertilizers from no application to different rates increased sesame seed and oil yields of different sesame varieties.

Table 6: Sesame Seed and Oil Yields as affected by the interaction of varieties and different phosphorus fertilizer rates at *Chawaka* (2017)

Variety	**Phosphorus Fertilizer Rates** (kgha^{-1})	**Seed Yield** (tha^{-1})	**Oil Yield** (tha^{-1})
Dicho	0 P_2O_5	1.15^{CD}	0.62^{CD}
	38 P_2O_5	1.22^{BC}	0.66^{BC}
	58 P_2O_5	0.90^{FG}	0.49^{FG}
	78 P_2O_5	0.58^{I}	0.31^{I}
	98 P_2O_5	1.46^{A}	0.79^{A}
Obsa	0 P_2O_5	0.84^{GH}	0.46^{FGH}
	38 P_2O_5	0.56^{I}	0.30^{I}
	58 P_2O_5	0.97^{EF}	0.52^{EF}
	78 P_2O_5	1.30^{B}	0.69^{B}
	98 P_2O_5	1.06^{DE}	0.56^{DE}
Chalasa	0 P_2O_5	0.82^{GH}	0.43^{GH}
	38 P_2O_5	0.83^{GH}	0.66^{BC}
	58 P_2O_5	0.54^{I}	0.28^{I}
	78 P_2O_5	0.76^{H}	0.41^{H}
	98 P_2O_5	0.38^{J}	0.20^{J}
Mean		**0.89**	**0.48**
CV (%)		**8.05**	**8.25**
LSD (0.05)		**0.12**	**0.06**

Conclusion

The study of the growth and yield responses of three sesame varieties, namely *Obsa, Dicho* and *Chalasa,* at *Ukke* and *Chawaka* revealed that different phosphorus fertilizer rates differently affected the varieties at these two different locations. It was concluded from the results that application of different phosphorus rates had significantly improved the seed and oil yields, and yield components of sesame varieties. Therefore, Farmers at Ukke and Chawaka can use those detrmined phophorus fertilizer rates that produced better sesame seed and oil yields specific to the variety they want to produce. It is important to further study the effects of the interaction between Sulfur (S) and Phosphorus (P) fertilizers as it was indicated by different researchers that thier interaction can further improve the yield and yield components of sesame varieties.

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Effect of Integrating Chickpea Varieties with Insecticides for the Management of Pod borer (*Helicoverpa armigera* Hubner)

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Abstract

Chickpea (Cicer arietinum L.) *is the world's second most important grain legume after common bean (Phaseolus vulgaris L.). Ethiopia is considered as a secondary center of genetic diversity for chickpea. The field experiment was conducted at Ginir district with the objectives to evaluate the effective management option against chickpea pod borer and to determine the optimum frequencies of the insecticide for the management of chickpea pod borer. The experiment was conducted using two chick pea varieties; Habru (more preferred) and Arerit (less preferred) and two insecticide* Highway 50% EC *(400 ml/ha) and* Nimbicidine *(3lt/ha). The result revealed that both insecticides are effective against pod borer even if they have slight percent larval reductions. The pod borer damage reduction ranged from 56.83% to 69.94% and on Highway 50% EC treated plots as compared to the control on Habru variety. On the variety Arerit, up to 76.30% larval reduction using Highway 50% EC treated plot was occurred as compared to control. The minimum 36.17% larval reduction was occurred on the plot treated with Nimbicidine on the variety Habru. The Maximum percent of seed yield (57.95% and 57.95%) increased over check was occurred by Highway 50% EC one and two times treaded plots on the variety Arerit, respectively. The plot sprayed one and two times with Highway 50% EC gave the maximum net return ETB 178,959.8 ha^{-1}and ETB 178,402 ha^{-1} on the variety Arerti and the unsprayed plot of the variety Arerti gave the minimum net returns ETB 15,054 ha^{-1}. It is recommended that these insecticides with specially Arerit variety are suggested to the growers for management of the pod borer population below economic threshold level under field conditions.*

Keywords*: Chickpea, Helicoverpa armigera, insecticide, Net return, Pod borer*

Backgroundand Justification

Chickpea *(Cicer arietinum* L.) is the world's second most important grain legumes after common bean (*Phaseolus vulgaris* L.) (Guar *et al*.,2012; FAOSTAT, 2012). Ethiopia is a secondary center of genetic diversity for chickpea; the wild relative of cultivated chickpea (*Cicer arietinum* L.), is found in Tigray region of Ethiopia (Yadeta and Geletu, 2002; Kanouni*et al*., 2011). India is the world's leading producer of chickpea followed by other major producer countries such as Pakistan, Turkey, Iran, Myanmar, Australia, Ethiopia, Canada, Mexico and Iraq. Ethiopia contributes about 2% of the global chick pea production (ICRISAT, 2004).

The total area covered by chickpea in Ethiopia is estimated at 239,512.43ha and from this a corresponding mean annual volume of 409,733.16 tons of chickpea is produced (CSA, 2012/13).Ethiopian chickpea production is predominated by the Desi type which accounts for about 95% of the total production. However, in recent years there has been an increase in the interest of farmers towards growing large seeded Kabuli type chickpea varieties due to their higher market price (Guar *et al*., 2005).

Chickpea is a rich source of dietary protein, providing as much as 17- 23 % protein as compared with cereals which provide only about8 – 10 %. Chickpea plays a significant role in improving soil fertility by fixing the atmospheric nitrogen; it can fix up to 60 kg N $^{-ha}$ per year. Chickpea has high potential for domestic and export market. In spite of its nutritional, market and other utilities, an average chickpea yield in Ethiopia on farmers field is usually below one ton per hectare, far below its potential yield of five tons per hectare (Jagdish *et al.*, 1995;Melese, 2005). This is due to several abiotic and biotic yield limiting factors: frost, low moisture stress , high moisture stress (water logging), poor agronomic and cultural practices, weeds, diseases and insect pests (Tilaye *et al.*, 1994; Bejiga *et al.*, 1994).

Chickpea is susceptible to a number of insect pests which attack roots, foliage and pods. Chickpea pod borer (*Helicoverpa armigera* Hubner) (*Lepidoptera: Noctuidae*) is a major field insect pest affecting chickpea production in several agro-ecological zones. It is also listed among pests, which are medium priority in research on chickpea, field pea and faba bean at national level. Besides pulse crops, pod borer also affects fiber crops, vegetables, cereals and oil crops in Ethiopia (Tadesse, 1989). This pest cause chickpea yield losses of up to 100% in spite of several rounds of insecticidal applications. . *H. armigera* is a highly polyphagous pest, feeding on a wide range of food, oil and fiber crops. Due to its wider host range, multiple generations, migratory behavior, high fecundity and resistance to insecticides; it has become a difficult pest to manage.

H. armigera selectively feeds upon growing points and reproductive parts of the host resulting in significant yield losses. In chickpea, it feeds on buds, flowers and young pods often resulting in poor yields. The pest status of this species has increased steadily over the last 50 years due to agro-ecosystem diversification by the introduction of host crops such as chickpea (Knights *et al.,* 1980; Passlow, 1986).Commercial chickpea crops are important sources of *Helicoverpa* species (White *et al.,* 1995). Sequeira *et al.,* (2001) reported chickpea is attractive to oviposition of *Helicoverpa* moths from as early as 14 days after planting and throughout the growth period. Typical of many chickpea growing areas of Ethiopia, pod borer heavily infests chickpea and other crops such as lentil in the major chickpea belt of Bale Zone, Ginner district. Therefore, this study was conducted in order to devise an integrated management option of pod borer on chickpea, essentially tolerant variety and insecticide at lower rate, and to determine the frequency of insecticide spraying.

Materials and Methods

Treatments and experimental design

The experiment was conducted in Ginner district of Bale Zone on farmer’s field using two chick pea varieties, namely Arerti which is less preferred by pod borer and Habru which is relatively more preferred by this pest. Two insecticides namely Highway which is synthetic and applied at the rate of 400 ml/ha and Nimbecidine which is botanical and applied at the rate of 3 lt/ha were used in the experiment with four insecticide frequencies of spraying i.e 0, 1, 2, 3 at 8 days intervals. The experiment was laid out in Randomized Complete Block

Design (RCBD) with three replications. The plot size was $5.4m^2$ (3m × 1.8m) with 6 rows spaced at 0.3m apart between block 1.5m and between plot 1.5m growth and 1.2m net. Recommended agronomic practices were followed for raising the crop. Insecticides were sprayed during the crop growing season following the incidence of pod borer and continued as found necessary.

Data to be collected

Data on pod borer population before and after insecticide application were recorded from 3 randomly selected plants in each plot at the seedling stage after the incidence of the pod borer was evident. The number of larval population per plant from 3 randomly selected plants in each plot before and after first spray of insecticides was recorded. The reduction percentage of larvae was recorded by counting the larval population after spraying. Such an exercise was repeated at 10 days interval. Data on pod damage (visual scoring) and grain yield were also recorded. At harvest, the data on pod damage due to pod borer from samples taken at random were recorded. The percentage pod damage was assessed for *Helicoverpa* damage visually based on the number of healthy and damaged pods and seeds per 10 plants to work out % pod damage at maturity. At maturity, data were also recorded on crop yield to observe grain yield per plot.

$$\%\boldsymbol{Pod\ damage} = \frac{\text{Total number of pod produced per plant} - \text{Number of undamaged pods X 100}}{\text{Total number of pods produced}}$$

$$\%\ \textbf{Larval reduction} = \frac{\text{Total number of larval population} - \text{Number of larval population after spray X 100}}{\text{Total number of larval population}}$$

Data were subjected to statistical analysis. Larval population, pod damage and yield data were analyzed separately. Data was subjected to the analysis of variance using GLM Procedure SAS software (SAS 2002). The mean was compared using Duncan's Multiple Range Test (DRMT) (Duncan, 1955) at 0.05 probability level. Insect counts and damage percentages was subjected to square root and arcsine transformation, respectively, before analysis as needed.

Results and Discussion

Larval Population

Results of the combined analysis revealed that both insecticides were found to be effective against pod borer though their efficacy varied in reduction of larval population. Generally, the larval population of Helicoverpa *armigera* ranged from 1.61 to 3.06 larvae per plant before spraying and 0.5 to 3.34 after spraying. The pest was active during December which coincided with the flowering and pod formation stage of the crop growth. Maximum mortality of pod borer, 79.75 and 64.48% were recorded on the plots of variety Arerit treated with Highway and Nimbicidine, respectively. On the other hand, no observable mortality was recorded on untreated plots on both varieties. These results are in conformity with the findings of Chandrakar and Shrivastava (2002) as well as that of Sonune *et al*., (2010) who reported the highest mortality of pod borer (94%) in pigeonpea when treated with profenofos. In contrast, Sreekanth *et al*., (2014) reported that the population of gram pod borer was found to be lowest in plots treated with flubendiamide, chlorantraniliprole, 171ehavior and indoxacarb followed by profenofos and emamectin benzoate. The result was also similar with the report of Dagne *et al*., (2018).

The population of *Helicoverpa armigera* ranged from 1.6 to 3.4 larvae per plant before spraying and 0.3 to 3.2 after spraying during the experimental season. The pod borer damage reduction ranged from 56.83% to 69.94% and on Highway 50% EC treated plots as compared to the control on Habru variety. For Highway 50% EC treated plots that were also planted to variety Arerit up to 76.30% larval reduction was achieved as compared to the untreated control. A minimum of 36.17% larval reduction was achieved on plot treated with Nimbicidine and planted to variety Habru. Therefore, the results of the current study show that both insecticides i.e Highway 50% and Nimbicidine were found to be effective in reducing the larval population of bod borer, of course with different levels of efficacy.

Table1.Combined Effect of Insecticides Application on larval population of pod borer (*Helicoverpa spp*) on chickpea in Ginner district, 2017- 2019 cropping season.

Varieties	**Insecticides**	**Frequencies**	**B spray**	**Mean after spray**	**% larval reduction**	**% Larval reduction over check**
Habru	Highway 50% EC	Control	1.88	1.83	-11.84	0
		1 time spray	1.88	0.58	62.48	68.30
		2 times spray	2.40	0.76	55.56	56.83
		3 times spray	2.26	0.55	44.83	69.94
	Nimbicidine	Control	2.00	1.88	11.09	0
		1 time spray	2.10	1.00	40.19	46.80
		2 times spray	1.95	1.20	29.02	36.17
		3 times spray	1.61	0.90	22.82	52.12
Arerti	Highway 50% EC	Control	2.21	2.11	7.75	0
		1 time spray	2.45	0.91	59.74	56.87
		2 times spray	2.81	0.50	79.75	76.30
		3 times spray	1.95	0.54	60.8	74.40
Arerti	Nimbicidine	Control	3.06	3.34	16.23	0
		1 time spray	1.95	0.89	45.20	73.35
		2 times spray	2.45	0.83	47.79	75.15
		3 times spray	2.11	0.77	64.48	76.94
CV (%)			55.63	98.62	119.09	
LSD($_{0.05}$)			0.49	0.47	19.37	

Grain Yields and yield components of Chickpea

The results of seed yield (Qt/ha) and yield advantage attained over untreated check is presented in table 2. From the combined analysis, plots that were sprayed with Highway 50% once and twice on variety Arerit gave maximum yield of 56.92 and 56.89 Q/ha, respectively. The minimum seed yield of 23.93 Q/ha was recorded from unsprayed plot of variety Arerit.
The maximum yield advantage over unsprayed check was attained by spraying Highway 50% once and twice on variety Arerit i.e 57.95% and 57.95%, respectively whereas the minimum (21.32%) was recorded on plots of variety Arerit three times sprayed with Nimbicidine. At crop harvest, the highest pod damage of 7.20% was recorded from untreated plots of variety Harbu.
The minimum percentage of pod damage (3.62%) occurred on the plot that was three times sprayed with Highway 50% EC. The results showed that some chickpea genotypes were

more attractive for Helicoverpa moths than the others. The preference or non-preference of chickpea genotypes for oviposition by female moth may be possibly due to different canopy structure of the plants. Another reason for these variations may be the variability in oviposition response of adult females due to chickpea foliar secretions containing high concentrations of malic acid (Rembold, 1981). The amount of foliar exudate and the concentration of malic acid depends on temperature and growth stage and have been shown to increase during the reproductive stages of the plant (Koundal & Sinha, 1981). When moths were drawn to chickpea in all growth stages, there was relatively less oviposition activity and damage in resistant cultivars that secreted high concentrations of malic acid (Rembold, 1981; Lateef, 1985; Reed *et al*., 1987).

Table 2. Combined Mean of Seed Yield and Yield Parameters of Chickpea varieties treated with different insecticides

Varieties	Insecticides	Frequencies	No. of Pod /plt	No. of pod damage	% pod damage	HSW	Yield (Qt/ha)	Percent yield increased over check
Habru	Highway 50% EC	Control	70.65	3.65	6.16	298.80	35.65	0
		1 time spray	62.45	2.72	4.85	284.00	47.23	24.51
		2 times spray	72.61	3.00	4.76	308.46	52.62	32.25
		3 times spray	62.16	2.45	4.47	316.03	53.95	33.92
	Nimbicidine	Control	57.78	6.95	13.55	305.26	28.86	0
		1 time spray	77.6	3.03	5.35	301.46	44.19	34.69
		2 times spray	62.28	2.72	4.45	312.06	52.44	44.96
		3 times spray	76.15	2.60	3.68	305.83	46.45	37.86
Arerti	Highway 50% EC	Control	72.50	3.40	5.00	247.00	23.93	0
		1 time spray	72.66	2.60	3.92	241.16	56.89	**57.93**
		2 times spray	75.11	2.50	3.74	244.13	56.92	**57.95**
		3 times spray	72.50	2.55	3.62	231.26	51.28	**53.33**
Arerti	Nimbicidine	Control	76.28	3.26	4.40	240.83	34.90	0
		1 time spray	79.66	3.05	4.12	249.26	46.64	25.17
		2 times spray	56.05	2.72	5.24	256.03	49.98	30.17
		3 times spray	76.90	3.12	4.23	207.60	44.36	21.32
CV (%)			**42.77**	**56.45**	**80.89**	**13.16**	**25.59**	
$LSD_{0.05}$			**12.29**	**0.72**	**1.68**	**14.64**	**4.75**	

Simple Regression Analysis between Pod borer larval populations and Yield

The estimated slope of the regression line obtained for the chickpea due to larval population was -3.68 and this shows that for each unit increase in mean larval population, there was a grain yield loss of 3.68 Qt/ha (Fig1). Also the estimated slope of the regression line obtained for the chickpea due to pod damage was -0.86 showing that for each unit increase in percent pod damage, there was a grain yield loss of 0.86 Qt/ha (Fig2).

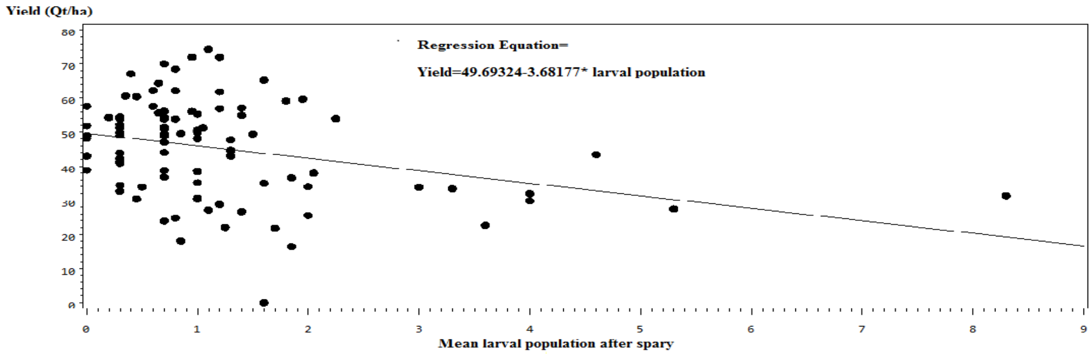

Figure1. Estimated Relationship Between Losses in Grain Yield with Mean Larval Population after spray at Ginir 2017/19 cropping season.

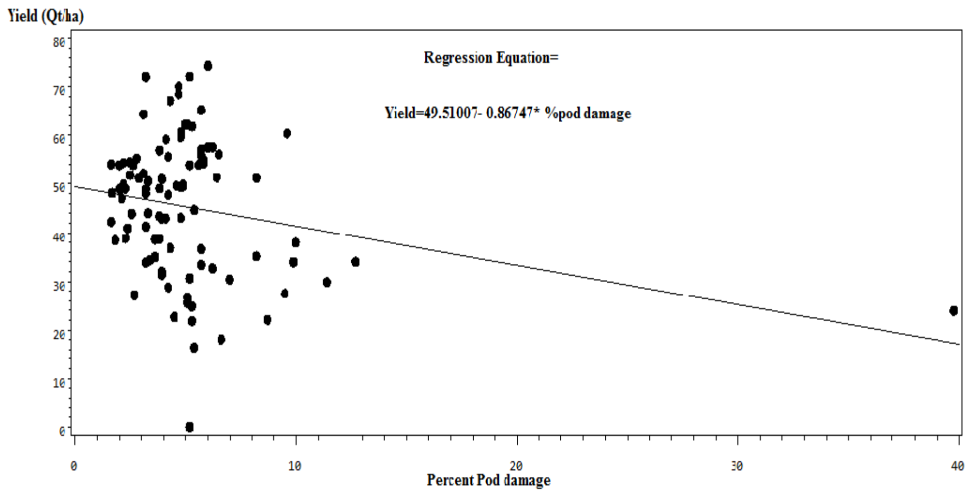

Figure2. Estimated Relationship Between Losses in Grain Yield with Percent pod damage at Ginir 2017/19 cropping season.

Return and Benefit Cost Ratio

The result showed that Highway 50%EC once and two times sprayed plot of variety Arerti resulted in the highest gross returns (ETB 194,666.4 $ha^{-1}$and ETB 194,563.8 ha^{-1}), respectively and the lowest gross return ETB 81,840.6 $ha^{-1}$was obtained from unsprayed check of variety Arerti(Table3). The plot sprayed once and two times with Highway 50%EC gave the maximum net return of ETB 178,959.8 $ha^{-1}$and ETB 178,402 ha^{-}1 on the variety Arerti and the unsprayed plot of the variety Arerti gave the minimum net returns ETB 15,054 ha^{-1}. The highest (ETB 714.36) marginal rate of return was obtained from variety Arerti when it was treated with Highway 50%EC once, followed by Arerti (ETB 237.45) treated with Nimbicidine once. In other words, for every ETB 1.00 investment in Highway 50%EC and Nimbicidine cost in spraying variety Arerit, there was a gain of ETB 7.14 and ETB 2.37, respectively (Table3).

Generally the highest chickpea grain yield, highest gross returns, and marginal rate of return were obtained from Highway 50%EC sprayed once on variety Arerit as compared to the other treatment combinations.

Table 3: Return and Benefit Cost Ratio of Treatment for the Control of Pod borer on Chickpea during 2017/19 Cropping Season at Ginir

Variety	Insecticide	Frequencies	Yield obtained (qt/ha)	Adjusted Yield (qt/ha)	Sale price (ETB/qt)	Total Variable Cost (ETB/ ha)	Gross Return (Price x Qt)	Net Return (GR-TVC)	MRR (NR-NR of Control /TVC)
Habru	Highway 50%EC	Unsprayed	35.65	32.085	3800	15561.6	121,923	106,361.4	0
		1 times	47.23	42.507	3800	16430	161,526.6	145,096.6	235.75
		2 times	52.62	47.358	3800	17187	179,960.4	162,773.4	102.84
		3 times	53.95	48.555	3800	17871	184,509	166,638	21.624
	Nimbicidine	Unsprayed	28.86	25.974	3800	15439.4	98,701.2	83,261.8	0
		1 times	44.19	39.771	3800	17165.4	151,129.8	133,964.4	33.54
		2 times	52.44	47.196	3800	18763.8	179,344.8	160,581	14.84
		3 times	46.45	41.805	3800	20106	158,859	138,753	-13.74
Arerti		Unsprayed	23.93	21.537	3800	14350.6	81,840.6	67,490	0
		1 times	56.89	51.201	3800	15604	194,563.8	178,959.8	714.36
	Highway	2 times	56.92	51.228	3800	16264.4	194,666.4	178,402	-3.43
	50%EC	3 times	51.28	46.152	3800	16823	175,377.6	158,554.6	-117.98
		Unsprayed	34.9	31.41	3800	14548.2	119,358	104,809.8	0
		1 times	46.64	41.976	3800	16209.4	159,508.8	143,299.4	237.45
	Nimbcidine	2 times	49.98	44.982	3800	17719.6	170,931.6	153,212	55.94
		3 times	44.36	39.924	3800	19068.4	151,711.2	132,642.8	-107.87

Conclusion and Recommendation

The present findings indicated that both insecticides (Highway 50% EC and Nimbicidine) were effective to manage pod borer on chickpea, up to seven days after treatment, where they are appreciably reducing larval population of the pest despite slight differences between the two in efficacy. Variety Habru was more preferred by the pod borer than Arerit. The result also showed that Highway 50% EC sprayed two times was enough for the control of pod borer than Nimbicidene that needed more frequency. This may be due to the fact that botanicals breakdown more rapidly than synthetic insecticides. Spraying with insecticides can control early instar larvae of pod borer but generally, as it holds true for all pest management recommendations, insecticides should be used as a last resort and as a component of Integrated Management where they may be used either at lower rates or reduced frequencies. Besides, as there are some differences among chickpea genotypes in their resistance to pod borer, the development of new varieties with better relative resistance needs to be conducted sustainably to lay a robust foundation for integrated management. The highest chickpea grain yield, highest gross returns, and marginal rate of return were obtained from Highway 50%EC one times treated variety Arerit. The variety Arerit sprayed one and two times were given higher yield. Therefore, it is suggested to the growers/farmers or other stake holders to produce Arerit variety for higher yield and to manage the pod borer population below economic threshold level under field conditions.

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Evaluation and Demonstration of Seedling Media for Hybrid Tomato Seedling Production at Dugda and Lume District

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Abstract

Tomato (Lycopersicon esculentum Mill), is one of the world's most popular vegetables. The objective of this study was to demonstrate and extend the locally available materials to substitute imported coco peat moss as a growing media for seedlings of tomatoes. ***.*** *The experiment was undertaken at Dugda and Lume under irrigation. Locally available Medias like red ash, termite tomb, Cow dung, course sand, compost of sugar cane were collected from nearby sources to make good soil of plant media in theory with a proportion of half solid and half pore space. All treatments were replicated three times in different experimental units to evaluate the performance of the seedling. For all treatments hybrid tomato variety (Venus) was used. The variety was selected based on its yield and market preference. To make the technology to be used by majority of end users before the beginning of the activity, training was given to representative farmers, DA's (development agents) and SMS (subject matter specialist) at both Dugda and Lume districts. Media mixing and plantation was made together with those two groups.The result indicate that, among the medias used, seedlings grown on near lake shore (seedling produced by lake shore soil) had more vigor, more thicker and longer stem and higher growth rate, which indicates better rate of photosynthesis.*

Key word: Coco peat, Seedling media, Tomato, Venus variety

Introduction

Tomato (*Lycopersicon esculentum* Mill), is cultivated both in backyard for home consumption and commercially for domestic market, processing plants and export. It is one of the World's most popular vegetables (FAO, 1989). Cultivation of tomatoes improves diet of the people, as they are a part of every salad in combination with leaf vegetables, green onions, cucumbers, peppers, and other vegetables. As a processing crop, it ranks first among all vegetables grown throughout the World. It also possesses valuable medicinal properties, an excellent purifier of blood and a rich source of vitamins like vitamin A and C than any other vegetables (Villareal, 1978). It is an important cash-generating vegetable crop to small-scale growers and provides opportunities for employment in the production and processing plants (Lemma, 2003). Its production is more attractive than any other vegetable crops for its multiple harvests, which results in high profit per unit area of land. Both fresh and processing tomato varieties are popular and economically important vegetable crops produced in the country (Geleta, *et al*, 1995).

In the tropics, tomato is mostly produced by transplanting. Good quality of seedling usually leads to higher yield and earlier maturity. Tomatoes that mature early not only could receive higher price on fresh market but also could reduce the risk involved in growing tomatoes in the tropics (AVRDC-TOP, 1987).The practice of germinating and raising hybrid vegetable seedlings is emerging as a professional and commercial activity in East Shoa. Previously, farmers produced seedlings of open pollinated varieties at a relatively low cost in their own nurseries. Despite their higher price, there is increasing demand for hybrid seeds in the zone. Initially, many farmers started raising seedlings of hybrid vegetables in traditional nursery beds but were unsuccessful. After the failure of first trial, most of the farmers in the study areas entered into an arrangement with Florensis Ethiopia to raise seedlings with imported media (Amenti Chali and Amare Haileslassie, 2015).

Smallholder growers therefore have to wait at least two months to submit their orders and a minimum of 19 days is required for the seedlings to be ready for transplanting. This supply delay has forced some farmers to pay about 2.80 Birr per seedling from farmers with excess seedlings grown at Florensis Ethiopia. Also, no attempt has been made so far to substitute the imported rooting media with locally available materials except a few research efforts at Adami Tulu Agricultural Research Centre (Amenti Chali and Amare Haileslassie, 2015). Therefore, screening of best media combination that best support the seedling for proper growth is paramount important to meet the demands of growers and to overcome the various production constraints such as poor water infiltration, ventilation, low yield, low quality, and susceptibility to different diseases/pests. Poor quality seedling will not be improved by any means of management after being transplanted to the field and the genetic inheritance of a given variety is revealed if supported by proper seedling management. So, in order to get quality seedling, it is paramount important to begin from proper and scientific seedling management practices (Abdissa *et al*, 2010). Therefore, this study was proposed to evaluate and demonstrate locally available materials to substitute imported coco peat moss as a growing media for seedlings of tomatoes**.**

Methodology

Description of the study area

The activity was conducted at Dugda and Lume under irrigation during 2019 off season. Lume district is located 70 kms South-East of Addis Ababa and cover 75,220.32 ha of land, where the lowland (Kolla) represent 25%, midland (Weyna dega) 45% and highland (Dega) 30% of land coverage of district. The district total populations were 117,415. According to Lume district 2015 report, from the total 75,220.32 ha of land, the total cultivated land of the district is 43,713 ha, for livestock grazing is 361.08 ha, for irrigation 6,497 ha, for forest 2,462.38 ha and unproductive land was 802.40 ha. The altitude is ranging from 1500 to 2300 m.a.s.l and the annual rainfall range from 500-1200 mm and temperature 18^{o} C-28^{o} C.

Dugda is located in mid-rift valley of Ethiopia on the main road from Addis Ababa to Awassa town 134 km apart from the capital city. The altitude of the woreda varies from 1600 masl (Ziway lake) and 2020 masl (Bora Mountain). More than 97% of the woreda represented by a flat land and 55% of the woreda lies in kola and the rest 45% fall in weynadega agro-ecology (WAO, 2014). Most of the soil of the area is sandy loam (59%) and clay loams (41%) which has been highly vulnerable to both wind and water erosion. The rainfall situation of the woreda is highly erratic with average annual rainfall of 671.8mm

Experimental design

There were four treatments evaluated for the study. The treatments designed for comparison against the commercial cocopeat media were cheap and locally available Medias like Red ash, Termite comb, Cow dung, Coarse sand and compost of sugar cane. The Medias were collected from nearby sources to make good soil of plant media in theory with a proportion of half solid and half pore space.Transparent plastic lath house was also constructed to prevent the seedling from strong wind. The seeds were then planted on a plastic tray which was purchased from local market.

The four Medias (Treatments) are prepared with the following ratios

T1= Re used Commercial cocopeat 100%

T2= Red ashes 12.5%: Course sandy 12.5%: Local peat soil 25% and fermented cow dung 50%)

T3= Local peat soil 25%, Compost of sugar cane 25%, Fermented cow dung 25% and Course sandy 25%

T4= Control or farmers practice seedling sown near lake shore

All treatments were replicated three times in different experimental units to evaluate the performance of the seedling and easy of management. For all treatments seed of tomato hybrids (Venus) variety was used based on its yield and market preference. Watering, weeding and other management practice were made as per the recommendation set for the crop.

Farmer's selection

The activity was carried out using FREG of smallholder farmers. Accordingly, FREGs with 15 members was established at Dugda and Lume Districts, respectively. One trial farmers was selected from each site for the tomato production based on the criteria including interest of the farmers in producing tomato.To make the technology to be used by majority of end users before the beginning of the activity, training was given to representative farmers, DA's (development agents) and SMS (subject matter specialist) at both Dugda and Lume districts. Media mixing and plantation was made together with those two groups.

Data Collected

Data were collected at 45 days of seed sowing in nursery (at the time of transplanting to permanent field). Date of germination, germination percentage, number of true leave and total input cost for seedling production were collected.

Seedling height: was measured from the soil surface to the apex of the plant

Number of leaves per plant: by counting the number of leaves of all sample plants and the average was recorded.

Greenness and seedling Vigor were collected using scores Greenness scored as (1= deep yellow; 2 = yellow; 3 = light yellow; 4 = green; 5 = very green) seedling.

Vigorous scored as (1 = very low vigor; 2 = low vigor; 3 = vigor; 4 = highly vigor; 5 = very highly vigor). The average leaf number per plant was counted.

Farmers' preferences and selection criteria

At 45th days when the seedling was ready for transplanting again representative farmers were invited and evaluated the stand performance of the seedlings based on their subjective judgment. The seedlings were demonstrated, evaluated by farmers and researchers based on the following selection criteria. The criteria were Earliness, Greenness, Seedling height, Disease tolerance and Seedling thickness. Each selection evaluation criteria were rated using the following rating scale; 1= Very poor, 2= Poor, 3= Fair, 4= Good and 5= Very Good.

Financial analysis

To assess the benefits derived from the application of each treatment, the simple partial budget technique was employed as described by (CIMMYT, 1988).

$$\text{MRR\%} = \frac{\text{Change NI}}{\text{Change TVC}}$$

Where: NI= change in net income, TVC= change in total variable cost, MRR= Marginal rate of return.

Gross field benefit: it was computed by multiplying farm gate price that farmers receive for the crop when they sell it.

Total cost: It includes the cost for the cocopeat media, seed purchase, media collection and media preparation costs. The cost of cocopeat and seed were20birr/kg and 2000 birr per 2000 seeds respectively. To produce 100 seedlings about 1kg cocopeat is needed and when it converted to hectare about 370kg of cocopeat was required. This means 7,400 Birr will be the cost for cocopeat medial to raise tomato seedlings required to cover a hectare. The cost of red ash, farm yard manure and sandy soil were labor cost paid for collecting them which were 600birr totally. The costs of Sugar cane compost were transportation and preparation costs, which were about 800birr. The cost of watering and guarding were assumed to remain the same among all the treatments. On farmer practice plot the costs considered were only inputs and production cost which was the same for all treatments about 200 birr.

Net benefit: was calculated by subtracting the total costs from the gross field benefit for each treatment.

Statistical analysis

The mean values of all the aforementioned parameters was subjected to analysis of variance (ANOVA) using the SAS. Least significant difference (LSD) procedure was used to compare differences between treatment means at p=0.05 whenever the treatment effects was significantly different.

Results and Discussion

Agronomic Parameters

Date of germination

From the current study date germination was highly affected by the treatments and it was statistically significant at $P < 0.05$ (Table 1). Cocopeat treated seed was germinated earlier (10.67days) then other seedlings. This was due to the lightness and more porosity of Cocopeat media. Here, seedling raised by mixing of Local peat soil 25%, compost of sugar cane 25%, fermented cow dung 25% and course sandy 25% also performs better (12.67days) than the rest. This might be due to the availability of sugar cane compost in the media. Among all, the check or farmers practice is late germinated do to the compaction of the soil that not mixed with any things.

Germination percentage

With this parameter, there is high statistical significant difference at $P < 0.05$ (Table 1). Here also Cocopeat treated seed was germinated by high percent (80%) than other Medias. This was due to the lightness and more porosity of Cocopeat media which is easy for seed sprouting. This is in agreement with Bustamante *et al*., 2008. Seedling raised by mixing of Local peat soil 25%, compost of sugar cane 25%, fermented cow dung 25% and course sandy 25% (77) also performs better than the rest, due to the availability of sugar cane compost in the media. Among all, check or farmers practice showed low germination percentage due to the compaction of the soil that not mixed with any things.

Seedling height, shoot length

With seedling height and shoot length, the highest significant difference occurs statistically among the treatments. Farmer practice indicates the higher seedling height (18cm). This is due to that the seedling bed was prepared along lake shore. This indicates that lake shore has high soil fertility which is appropriate for seedling growth. Previous studies showed a wide range of lake shores may be consisting of principal organic components (i.e. carbon-containing remnants or residues of life processes) (Peter *et al.*, 2015). Commercial media/Coco peat was reused so seedling height and other growth parameters were low except on germination date and percentage.

Among all treatment mixed with Red ashes 12.5%: course sandy 12.5%, local peat soil 25% and: fermented cow dung 50%) had lower seedling height due to low soil fertility. This indicated that it needs additional fertilizer application.

Number of true leave and seedling thickness

As opposed to the most parameters number of true leave and seedling thickness resulted statistically non-significant at ($P < 0.05$).

Seedling Vigorousity

There was a high statistically significant difference at $P < 0.05$ (Table 1) for seedling vigor parameter. Farmer practice resulted with the highest vigorousity (3.66) while the others performed similar to each other. Lake shore soil was the composting of commonly wood chips, vegetable scraps, paper products, sorted municipal solid waste (MSW), animal carcasses, manures and wastewater sludges (bio solids) have all been composted successfully (Peter B. S.*et al*., 2015)

Greenness

With this parameter, there is high statistical significant difference at $P < 0.05$ (Table 1). Farmer practice resulted with the highest greenness (4.22). Coco peat resulted with the lowest greenness (2.67). It was re-used so its fertility was declined.

Table1. Agronomic parameters of tomato seedling at Lume district

Treatments	Date of germination	Germination percentage (%)	seedling height (cm)	Shoot length (cm)	Leaf number (true leaf)	Seedling thickness	Vigorousity	reenness
Commercial cocopeat 100%	10.67c	80a	13ab	7.65a	4.33a	0.3a	2.3ab	2.7b
(Red ashes 12.5%: course sandy 12.5%, local peat soil 25% and: fermented cow dung 50%)	15ab	60b	10b	4.33b	3.6a	0.3a	2.6ab	3ab
Local peat soil 25%, compost of sugar cane 25%, fermented cow dung 25% and course sandy 25%	12.67b	77a	14ab	6ab	3.33a	0.4a	2.67ab	2.7b
Control or farmers practice (around lake shore)	14a	63b	18a	8a	4a	0.5a	3.66a	4.2a
CV	9.52	16.93	21	26	13.92	11.1	20	17.7

Farmer's evaluation on nursery

Participatory evaluation of seedling media was conducted at early transplanting stage by 10 farmers. The farmers agreed that earliness, greenness, seedling height, disease tolerance and seedling thickness were important for seedling growth. Accordingly, control/farmer practice was selected by them, because it looks green and strong. This is due to the fact that the soil along lake shore has important soil fertility (Bustamante *et al.,* 2008). Wet land, due to its appropriate physical properties, such as, low bulk density and high total porosity and its high nutrient exchange capacity constitute one of the main substrate components.

Table 2, Farmers selection result and their parameters

Treatments	Farmers parameters						Over all rank
	Earliness	Greenness	Seedling height	Disease tolerance	Seedling thickness	Rank index	
commercial cocopeat 100%	1	3	3	3	3	52	3
Red ashes 12.5%: course sandy 12.5%, local peat soil 25% and fermented cow dung 50%	3	2	4	4	4	68	4
Local peat soil 25%, compost of sugar cane 25%, fermented cow dung 25% and course sandy 25%	2	4	2	2	2	48	2
Control or farmers practice(around lake shore)	4	1	1	1	1	32	1

Financial analysis

In East Shoa zone, Ethiopia, farmers who produce hybrid tomatoes enter into contractual agreements with flower producing companies which produce high quality seedlings using imported cocopeat as a growing media. However, imported media is expensive and smallholder producers cannot afford to buy and use it. In addition, farmers have no access to buy the media and grow their own seedling because commercial importers are not available in Ethiopia.(Abad *et al.*, 2001). Use of peat for growing seedlings is however expensive. Results of the economic analysis are presented in (Table 3). Rising seedling with lake shore soil gave the highest net benefit per hectare with the highest marginal return rate. This was followed by Red ashes 12.5%: course sandy 12.5%, local peat soil 25% and: fermented cow dung 50%andLocal peat soil 25%, compost of sugar cane 25%, fermented cow dung 25% and course sandy 25, also the marginal return rate of from these treatments were highest than cocopeat media. The economic evaluation indicated that producing seedling near lake shore increased net benefit and marginal return rate.

Table3. Financial analysis of seedling Medias

Treatment	Germination (%)	Yield loss (%)	Price of one seedling in birr (Estimation)	Variable cost birr/ha	Gross return birr/ha	Net benefit birr/ha	Marginal return rate
Commercial cocopeat 100%	80	20	1.48	40,400	50,760	10,360	0.25
Red ashes 12.5%, course sandy 12.5%, local peat soil 25% and fermented cow dung 50%	60	40	1.4	33,600	41,880	8,480	0.26
Local peat soil 25%, compost of sugar cane 25%, fermented cow dung 25% and course sandy 25%	77	23	1.4	33,800	44,396	10,796	0.26
Control or farmers practice (around lake shore)	63	37	1.4	33,200	42,324	9,324	0.28

Conclusion and Recommendations

Growing media greatly influences quality of seedlings and this in turn affects the crop stand and eventually limits agronomic performance after transplanting. Based on the results of this study seedlings grown on near lake shore (seedling produced by lake shore soil) had more vigor, more thicker and longer stem and higher growth rate, which indicates better rate of photosynthesis. The result suggests that any small holders who are producing hybrid tomato can use produce hybrid tomato seedling near lake shore.

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Performance Evaluation of Onion Varieties at Biyo Awale Cluster in Diredawa Administration

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Abstract

Onion (Allium cepa L.) is an important crop worldwide. It is important in the daily Ethiopian diet. It is widely produced by small holder farmers and commercial growers throughout the year for local use and export market. No strong study has been conducted to evaluate the suitability of onion cultivation in Biyo Awale district of Diredawa. Hence, the present experiment was conducted to study the performance of improved varieties of onion for their suitability for cultivation in Biyo Awale district of Diredawa. The study was carried out during 2018-2019 cropping season to test the performance of onion varieties. Five high yielding onion varieties were planted in complete randomized block design with three replications including local check at farmer's field. The quantitative data on bulb yield, plant height, bulb size and number of leaves of onion varieties were collected. Harvesting was done and weighed when all onion varieties reach maturity (90% tops down). The results revealed that the tested onion varieties differ significantly for leaf length, leaf number, neck diameter, bulb diameter, average bulb weight and bulb yield. Among the varieties Bombay red and Melkam produced higher bulb yield (25.56 and 21.13 t ha^{-1}) and gave 140.68% and 98.96% yield advantage over local check varieties, respectively. Therefore, Bombay Red and Melkam varieties were recommended to the study area and similar agro-ecology.

Keywords: Bulb yield, Onion, Varieties

Introduction

Onion (*Allium cepa* L.), is an important vegetable belonging to family *Alliaceae* and widely grown herbaceous biennial vegetable crop with cross-pollinated and monocotyledonous behavior having diploid chromosomes number 2n=16 (Bassett, 1986). The production of fruits and vegetables has a comparative advantage particularly under conditions where arable land is scarce, labor is abundant and markets are accessible (Lumpkin *et al.*, 2005). The production of horticultural products offers opportunities for poverty alleviation, because it is usually more labor intensive than the production of staple food crops. Hence, the generation of additional employment opportunities in rural areas where labor is abundant is made possible. Increasing horticultural production contributes to commercialization of the rural economy and creates many off-farm jobs (Lumpkin *et al*., 2005). Vegetables took up about 0.98 % of the area under all crops at national level. Onion cultivated on 31,673.21 ha with a total production of 2,938,875.85 quintals (CSA, 2017). It is recently introduction and rapidly becoming popular among producers and consumers. It is widely produced by small farmers and commercial growers throughout the year for local use and export market. Onion is valued for its distinct pungency and form essential ingredients for flavoring varieties of dishes, sauces, soup, sandwiches, and snacks as onion rings. It is popular over the local shallot because of its high yield potential per unit area, availability of desirable cultivars for various uses, ease of propagation by seed, high domestic (bulb and seed) and export (bulb, cut flowers) markets in fresh and processed forms. The method of cultivation is via direct seeding or transplanting in the field growing. The weight of thousand seeds is about 3.6 g that can be produced by open Pollination via honey bees. Regarding seed production, it is necessary to plant maternal bulb in field in the due time. Otherwise, cold weather can influence seedlings which resulted in the induction of flowering. On the other hand, the proper time for planting maternal bulb is of value because of the optimum use of the land seed favorite production both quantitatively and qualitatively. Also, the bulb size is one of the most important factors in seed production (Nehra *et al*., 1988; Navab *et al*., 1998; Khodadadi, 2009). Therefore, planting bulbs with the proper diameter as well as high seed production, have been caused cost saving in the amount of consumption per hectare and, thus can be reduced the production cost (Basol *et al*., 1997).

Onion contributes substantially to the national economy, apart from overcoming local demands. Products like bulbs and cut flowers are exported to different countries of the world. Currently many farmers have changed their life in onion development program. With the growing irrigated agriculture in the country, there is a great potential for extensive onion seed and dry bulb in different production belt in the country. Unfortunately, some parts of the Diredawa ecology, particularly Biyo Awale cluster are unable to produce enough onion for local consumption due to non-availability of improved planting materials. The available local variety in production has low yield, with poor quality bulbs, short shelf life due to very high water content of the bulbs and high susceptibility to insect pest and diseases. However, the knowledge of the types of variety that will yield best in a given environment is important for good crop management decisions. Therefore, this paper was initiated with the objective to identify high yielding and disease tolerant variety of onion with a view of recommending it for Diredawa rural areas of Biyo Awale

Materials and Methods

Description of the Study Area

The experiment was conducted in Diredawa Administration Council at Adada and Bishan Baye village during the rainy season from early July to early November, 2017. Geographically, Diredawa Administration Council is located in the eastern part of Ethiopia between 9027'N and 9049'N latitude and 41038`E and 42019`E longitude. The mean annual temperature is about 24.8°C with a range of 31.4°C and 18.2°C average maximum and minimum temperatures, respectively. The rainfall pattern of the Administration has a bimodal characteristic. The small rainy season is from March to April; while the main rainy season extends from August to mid-September with average annual rainfall of the Administration is over 604 mm (Diredawa Administration Meteorological Station)

Experimental material and Design

Four improved varieties of onion introduced from Melkasa Agriculture Research Center, Melkam, Nafis, Bombay red, Adama red with local check collected from "Adada and Bishan baye" peasant associations were used in this study. The experiment was laid out in RCB design with three replications. The size of each experimental plot was 5.4m^2 (3m wide and 1.8m long). The onion varieties were randomly assigned to the experimental plots. The inter row spacing used was 20cm for bulb. Seeds of each onion variety were sown in rows of 15cm on well prepared seed bed of 1x5m and covered with light soil and mulching grasses until emergence. The beds were watered with watering can as supplementary irrigation. The seedlings were thinned at 3cm spacing within rows, followed by proper weeding and watering. Land preparation was done in advance to reduce diseases and insect pest incidence. Finally, hardened, healthy and uniform seedlings of pencil size were transplanted at an age of 30 days (MoARD, 2009). The transplanted seedlings were watered and inorganic fertilizers (NPS) and urea was applied at the recommended rate. All the phosphate fertilizer were applied at transplanting whereas nitrogen was given at two equal splits (at transplanting and 30 days after transplanting) as basal application (EARO, 2004). Plots were irrigated when there is insufficient rainfall as supplementary irrigation. Weeding, cultivation, watering, staking, chemical spray etc were done as recommended.

Data collected

Data for Bulb diameter, number of leaves per plant, leaf length, average weight of bulb, neck diameter, bulb yield, disease and insect pest were collected. Analysis of variance was carried out using GenStat discovery 15th edition software for the parameters studied following the standard procedures outlined by Gomez and Gomez (1984). The means were separated using the Fisher's Protected Least Significant Difference (LSD) test at 5% level of probability.

Results and Discussions

Analysis of variance (ANOVA) indicated that there was significance difference among onion varieties for leaf number, leaf length, Neck diameter, bulb diameter, average bulb weight and Bulb yield tested at 5% probability level. However, no significance difference was observed between varieties for days to maturity and plant height. This might be due to genetic makeup and environment. Similarly, Jilani and Ghafoor, (2003) reported that various cultivars of the same species grown in the same environment gave different yields as the performance of a cultivar mainly depends on the interaction of genetic makeup and environment.

Leaf Number, Leaf length and Neck Diameter

Analysis of variance revealed that there was significance difference ($P< 0.05$) among varieties for leaf number, leaf length and neck diameter (table 1). The highest leaf number (12.92) was recorded from Adama red variety, while the lowest (8.54) from Nafis. On the other hand the highest leaf length (40.02 cm) was recorded from Melkam varieties while the lowest (34.68 cm) from Nafis variety. The result also showed the highest neck diameter (1.72cm) gained from Nafis while the lowest (0.94cm) was from Bombay red variety.

Bulb Diameter and Average Bulb weight

Analysis of variance revealed that there was significance difference ($P< 0.05$) among varieties for bulb diameter and average bulb weight (Table 1). The bulb diameter was ranged between 5.99 and 4.75cm. The highest bulb diameter was recorded from Melkam (5.99) while the lowest was from Nafis (4.75cm). The current result also revealed the highest average bulb weight (92.79 g) was from Bombay red while the lowest (42 g) was from local cultivar.

Table: 1 The Mean of growth, yield and yield parameters for the onion varieties.

Variety	DM	PH(cm)	LN	LL(cm)	ND(cm)	BD(cm)	ABW(g)	BY(t/ha)
Bombay red	137.2	45.56	11.08[ab]	39.19[a]	0.94[d]	5.863[a]	92.79[a]	25.56[a]
Adama red	135.2	51.08	12.92[a]	38.63[ab]	1.69[ab]	5.48[a]	76.34[b]	16.32[bc]
Melkam	134.2	48.84	10.92[ab]	40.02[a]	1.45[bc]	5.99[a]	91.46[a]	21.13[ab]
Nafis	137.2	45.27	8.54[b]	34.68[b]	1.72[a]	4.75[b]	70.15[b]	13.23[c]
Local	139.5	49.43	9.54[ab]	37.30[ab]	1.38[c]	4.847[b]	42[c]	10.62[c]
LSD(0.05)	NS	NS	4.52	5.577	0.3581	0.8763	12.1	7.85
CV (%)	3.4	14.5	24.9	8.6	14.6	9.5	9.5	26.4

NB: Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; DM= Days to maturity, PH= plant height, LN=Leaf Number, LL=Leaf Length, ND=Neck Diameter, BD=Bulb Diameter, ABW=Average Bulb Weight, BY=Bulb Yield; LSD=Least Significant Difference; NS=Not significant; CV=Coefficient of variation

Bulb yield

Analysis of variance revealed that there was significance difference ($P < 0.05$) among varieties for bulb yield (Table 1). The bulb yield ranged from 25.56 t ha^{-1} to 10.62 t ha^{-1}. The highest bulb yield (25.56 t ha^{-1}) was obtained from Bombay red variety followed by the varieties Melkam (21.13 t ha^{-1}), Adama red (16.32 t ha^{-1}) and Nafis (13.23 t ha^{-1}) while the lowest yield (10.62 t ha^{-1}) was obtained from local check. Bombay red and Melkam gave 140.68% and 98.96% yield advantage over local check respectively. Statistically, significance difference was not observed among Adama red, Nafis and local check for bulb yield. The variation in bulb yield of the tested varieties showed the difference in adaptability of these varieties to the study areas. Similarly, Jilani and Ghofer (2003) & Kimani *et al*, (1993) reported that various cultivars of the same species grown in the same environment give different yields as the performance of a cultivar mainly depends on the interaction of genetic makeup and environment. In the contrary, Mitiku *et al*, (2017) reported that the onion varieties do not responded to the climatic conditions and reflected non-significantly to their productivity performance.

Conclusion and Recommendation

The two years experiment on onion adaptability trial at Diredawa, Biyo Awale area, varieties showed significant difference for leaf number, leaf length, neck diameter, bulb diameter, average bulb weight and bulb yield. Accordingly, Bombay red gaves the highest average bulb weight and bulb yield followed by Melkam as compared to local check and other varieties. Furthermore, Bombay red and Melkam varieties showed 140.68% and 98.96% yield advantage over the local check, respectively. Therefore, Bombay red and Melkam varieties were recommended to the study area and similar agro-ecologies.

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Evaluation of Improved Banana *(Musa paradisiacal Var. Sapiertum)* Varieties in Bale: The Case of Ginnir and Gassera Districts

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Abstracts

Adaptation trial of desert type banana varieties was conducted at Ginnir and Gassera districts of Bale zone. Seven desert type improved banana varieties and one local variety were planted at three PA's of Ginnir and Gassera districts. All varieties were performed well. However, there is significant variation among the varieties. Accordingly, Jiant Cavendish gives the highest number of finger per bunch (90.33) followed by Dwarf Cavendish (90), the longest and the heaviest finger. However, Poyo variety gives the lowest number of finger per bunch as well as lower yield comparative with local variety. On the other hand, Dwarf Cavendish and Jiant Cavendish gave higher yield than others and recorded 67.47%, 22.04% yield advantage. Jiant Cavendish recorded 64.48% & 14.87% yield advantage over local variety and national average productivity of the crop, respectively. Additionally, Grand Nain showed 60.82%, 6.09% yield advantage over local variety and national average productivity of the crop, respectively. Therefore, these three varieties (Dwarf Cavendish, Jiant Cavendish and Grand Nain) are well adapted, recorded maximum yield advantage over local and national average productivity of banana and thus recommended for banana producing community at study area & similar agro-ecologies.

Key words: Banana, Bunch, Finger, Sucker

Introduction

Banana (*Musa paradisiacal var. sapiertum*) is one of the most important tropical fruits and evolved in the humid tropical regions of South East Asia with India as one of its centers of origin. Banana represents the world's second largest fruit crop with an annual production of 129,906,098 metric tons (FAOSTAT, 2010). Banana is one of the most important fruit crops grown in Ethiopia. Local cultivars of banana were under cultivation in Ethiopia for long period of times. These local varieties are low yielder and less demand on market. As a result a number of high yielding banana varieties were introduced and adapted in the country. According to MoARD (2006), in Ethiopia there are seven dessert and five cooking type banana varieties released by the research system. Besides, different local varieties that are produced in almost all part of the country by small-scale farmers as garden crop mainly for home consumption and in some cases for sale in local markets. Banana provides a starch staple across some of the poorest parts of the world in Africa and Asia, while dessert bananas are a major cash crop in many countries. The all year round fruiting habit of bananas puts the crop in a superior position in bridging the 'hunger gap' between crop harvests. Banana therefore, contributes significantly to food and income security of people engaged in its production and trade, particularly in developing countries. In Africa they provide more than 25% of the carbohydrate requirements for over 70 million people (IITA, 1998).

Banana, especially the dessert banana is the major fruit crop in Ethiopia leading both in area and production. Dessert banana is the major fruit crop that is most widely grown and consumed in Ethiopia. It is cultivated in several parts of the country where the growing conditions are favorable. Especially in the south and southwestern as well as south eastern parts of the country, it is of great socioeconomic importance contributing significantly to the overall well being of the rural communities including food security, income generation and job creation (CSA, 2014). About 104,421.81 hectares of land is under fruit crops production in Ethiopia. Bananas contributed about 56.79% of the fruit crop area followed by avocadoes that contributed 17.26% of the area. More than 7,774,306.92 quintals of fruits were produced in the country. Bananas, Mangoes Avocados, Papayas, and Oranges took up 63.49%, 13.50%, 10.47%, 6.99% and 3.93% of the fruit production, respectively.

In Ethiopia about 59,298.19 ha is covered by Banana and 4,936,022.34 quintals are harvested annually. CSA (2011) also reported as the national yield potential of the crop is 83.24 quintals per hectare. On the other hand, in 2010 Meher cropping season 1,228,662 house holders was participated in banana production and about 13,156.6 hectares of land was covered with this crop, where 881,327.17 quintals were harvested annually in Oromia Regional state. The average yield potential of banana in Oromia regional state is 66.99 quintals per hectare and is lower than that of the national yield potential of the crop (CSA, 2017/18). However, improved varieties of banana can give higher yield than the mentioned yield potential. Banana is one of the most important fruit crops grown in Bale low lands viz… Dello Mena, Harena Buluk, Berbere, and some part of Ginnir, Gassera and Agarfa even if local cultivars of banana were under cultivation for long period of times. These local varieties are low yielder and less demand on market and planting material is mostly from local and they get low yield due to lack of high yielding and lack of sufficient quantity of suckers of improved Banana varieties. Hence, this experiment was conducted with the objective of evaluating the adaptability of improved desert type banana varieties to Ginnir and Gasera districts of Bale zone.

Material and Methods

The experiment was conducted at Ginnir and Gassera district. Seven dessert type banana varieties namely; *Williams-1, Grand nain, Robusta, Butazua, Poyo, Jiant Cavendish and Dwarf Cavendish*. Local Variety was used as local check for comparison. The experiment was laid out in randomized complete block design with three replications. Seven desert type and one local banana varieties were planted at Ginnir district at three PA's (Chancho, Dodo and Tullicha) and Gassera. All agronomic recommendations for banana production were kept constant for all varieties.

Data collection and analysis

All yield and related parameters of the crop were collected and inserted to GenStat 16th Edition computer software to determine the significant effects of treatments on the parameters. On the other hand, Least Significance difference was used for mean separation at 5% level of significance.

Result and Discussions

Analysis of variance showed that number of finger per bunch was significantly different at 5% level of significance due to variety. Accordingly, the highest number of finger per bunch (90.33) was recorded for Jiant Cavendish followed by Dwarf Cavendish varieties whereas the minimum number of finger per bunch (55.67) was obtained from Poyo variety. On the other hand, the average length of randomly sampled fingers showed that the longest finger (12.38 cm) was obtained from Jiant Cavendish variety whereas the shortest finger length (9.89 cm) was recorded for local variety which was used as local check.

Average weight of finger of banana was also determined and showed significant variation ($P<0.05$) among the varieties. Accordingly, the heaviest finger (0.3 kg) was obtained from Dwarf Cavendish variety whereas the lowest weight of finger (0.12 kg) was recorded for Robust variety. Likewise, average weight of bunch per plant was also determined. The maximum weight of bunch per plant was recorded for Dwarf Cavendish variety followed by Jiant Cavendish and Grand Nain. However, the minimum average weight of bunch per plant was obtained from Poyo variety and Local.

These varieties with high number of fingers per bunch, long finger, maximum weight of finger and maximum average weight of bunch per plant is preferable by farmers interims of yield performance. Incase Jiant Cavendish, Dwarf Cavendish and Grand Nain variety showed very good performance. On the other hand, Butazua, and William-I variety gives relatively good average weight of bunch per plant than Local and Poyo variety. On the other hand, the average yield of banana also determined and there is significant ($p<0.05$) difference among the mean of varieties. Accordingly, maximum yield was recorded from Dwarf Cavendish (106.77 qt ha^{-1}) followed by Jiant Cavendish (97.78 qt ha^{-1}) whereas the lowest yield was obtained from Local and Poyo variety. Dwarf Cavendish showed 67.47%, 22.04%, Jiant Cavendish 64.48%, 14.87% Grand Nain 60.82%, 6.09% Yield advantage over local variety and national average productivity of the crop (Table 1).

Table 1 Yield and yield parameters of banana varieties evaluated at Ginnir and Gassera district in 2018

S.N	Varieties	No of finger per bunch	Length of finger (cm)	Average Weight of finger (kg)	Average weight of bunch per plant	Total Yield (Qt/ha)
1	Jiant Cavendish	90.33	12.38	0.27	24.37	**97.78**
2	Dwarf Cavendish	90.00	12.04	0.30	26.69	106.77
3	Butazua	84.67	10.86	0.16	13.78	55.12
4	Grand Nain	83.00	11.83	0.27	22.16	88.64
5	Robust	76.67	10.35	0.12	9.33	37.32
6	Local	61.67	9.89	0.13	8.68	34.73
7	Williams-1	61.00	10.17	0.15	10.66	42.64
8	Poyo	55.67	10.17	0.15	8.46	33.84
	Mean	75.40	10.96	0.19	15.52	62.10
	CV (%)	19.40	4.80	14.1	21.60	21.60
Level of significance		25.56*	0.93**	0.05**	5.87**	23.48**

*Significant difference, * highly significant difference.

Conclusion and Recommendation

The study confirmed the existences of considerable variations among the tested varieties in terms of yield and yield components viz. mean number of finger per bunch, average length of fingers, fingers weight, weight of bunch per plant. The highest mean yield performance and yield advantage over local checks conclude that, Dwarf Cavendish, Jiant Cavendish, and Grand Nain, varieties are recommended for farmers producing banana at the study area and similar agro-ecology

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Inputs-outputs Marketing System Efficiencies of Maize and Tomato Production of Bako Tibe and Guto Gida Districts of West Shewa and East Wollega Zones, Ethiopia

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Abstract

The study is to describe the marketing system of inputs and outputs; identify weather there is marketing system inefficiencies and integration in inputs and outputs of maize and tomato marketing system in Bako Tibe and Guto Gida districts. From the result there is information gap within & among producers, DAs, Input suppliers, traders and consumers. Majority of the producers preferred union/coops to sell their products and there is poor enabling environment in the study areas. According to producers' reported disease, low price of grain, poor market linkage, shortage of chemicals and unlicensed traders were the major challenges in both maize and tomato production. Shortage of inputs, farmers reluctant to buy inputs, high competition unlicensed traders, weak government support and shortage of storage were the main challenges in input supply while low quality with poor awareness, low supply, unlicensed traders, brokers and demand fluctuations were also major challenges in trading systems. Enhancing the technical knowledge and skill of farmers, DAs, suppliers and traders on input-output marketing efficiency system by providing training to provide effective enabling service to increase market efficiency among the actors. Besides, build the capacity of farmer's cooperatives/unions in value chains of inputs-outputs, considering market-oriented extension service and improving enabling environment in promoting competition in agribusiness across emerging marketing efficiency.

Key words: input-output, maize, marketing system efficiency and tomato

Introduction

Maize is a staple food in Ethiopia particularly in the study areas and strategic crop. Over half of all Ethiopian farmers grow maize 0.8 ha, mostly for subsistence, with 75 % of all maize produced being consumed by the farming household. It is believed that the consumption of maize has significantly increased over the years, as maize is the cheapest grain for farmers in food deficit rural areas and low-income households in the urban areas (Berhanu *et al.*, 2007; Dagnachew *et al*., 2018). Improving smallholders' tomato production would contribute to enhancing food security and alleviating poverty (Ambecha *et al.*, 2012; Eyob *et al.*, 2014). Farmers in the study areas produce maize along with tomato mostly to support their livelihood and increase their income.

Even though, both crops are contributed a vital role in farmers and others actors livelihood and income sources in the areas the crops are characterized by low production and productivity high price of inputs (fertilizers and seeds), limited modern agricultural technologies, poor and biased agricultural policies and lack of knowledge on limited resources while high volatility of crops prices even from week to week were fluctuated, lack of transportation and limited market information (FAO and WFP, 2012). Farmers in these areas perceive that inputs and output marketing system in their areas are not efficient, especially the pricing mechanizes of inorganic fertilizer, maize improved varieties and grain of outputs (Dagnachew *et al*., 2018).

A marketing system is a network of individuals, collection of actors, channels, intermediaries, business activities, and institutions which facilitate the physical distribution and economic exchange of goods (Roger 2007). It can also be regarded as a multi-layered sequence of physical activities and of transfers of property rights from the farm-gate to the consumer. A channel of distribution of marketing system is path traced in the direct or indirect transfer of the title to a product as it moves from a producer to ultimate consumer.

Input and output marketing system efficiency play key roles in adoption of technologies and increasing production and productivity from improved agricultural technologies (Singh 2008; Denning *et al.*, 2009; Jack, 2013). Market development was recommended for such marketing system insufficiencies by various authors to increases the competitiveness of selected agricultural sub-sectors that target national, sub-regional and international markets thereby contributing to agricultural growth. Before market development and other short and long term interventions are going to realized, areas of marketing system effectiveness and inefficiencies should have to be identified for both inputs and output marketing. If farmers do not have efficient input and output markets, they resist investing in new and more productive technologies.

Therefore, there is a need to understand what is wrong in marketing system of inputs and outputs marketing system of some selected AGP crops to discover some solution for such problems and to inform policy makers decisions with the following objectives: to describe the marketing system of inputs and outputs in the study areas; identify weather there is marketing inefficiencies and integration in inputs and outputs marketing system and to give policy direction in input-output marketing system in the study areas.

Research Methodology

Description of the Study Areas

The study was conducted in Guto Gida and Bako Tibe districts of east Wollega and west Shewa zones, respectively. Both districts are selected purposively based on maize and tomato production potential and market access. Bako Tibe is located in Western Oromia at about 251 km from Addis Ababa and 80 km East of Nekemte, the zonal capital East Wollega Zone. Out of the total area of the 104,452 ha, crop land accounts for 37,906 ha and the remaining land is allocated for community land, forest and other purposes. Geographically, the study area is located 370 3' 27" E longitude and 090 07' 12" N latitude and categorized into three agro-ecology like as lowland (51%), midland (37%) and highland (12%). The annual rainfall of the study area ranges of 1200-1300 mm and has an annual temperature range of 13.8-27.8oc. The study area has total population 136,829 of which 47.1% are male and 52.9% are female. Guto Gida district is located at about 328 kilometers distance from Finfinnee to the western direction possessing a total area of 901.80 km2. The district is divided in to three distinct geographical areas with different proportion; namely, highland (0.26%), midland (46.74%) and lowland (53%).

Data collection and Sampling

Both primary and secondary data were employed for this study. Primary data were collected from maize and tomato producers, traders and input suppliers using a semi-structured questionnaire during 2017/18-2018/19 cropping season. Secondary data was collected by reviewing the required documents from inputs suppliers, government and non-government offices, traders credit sources in the business of inputs and outputs marketing system, which related to this study to rational conclusion. A sample design is an exact plan for obtaining a sample from a given population before data is collected (Kothari, 2004). Three sampling stage were employed to identify sample households. In the first stage two districts Bako Tibe from west Shewa zone and Guto Gida from east Wollega zone districts were selected purposely based on maize and tomato production extent and suitable agro-ecology for crops. In the second stage, seven kebeles (four from Bako Tibe district and three from Guto Gida district) were selected purposely considering high potential of maize and tomato production. Finally, in every selected kebele, probability to proportional size sampling was also used to identify 161 households for surveyed.

Traders and input suppliers were selected based on numbers of traders and inputs suppliers in the areas. Accordingly, 26 traders (16 from maize traders and 10 tomato traders) were selected randomly based on probability proportionality to size while 13 inputs suppliers were selected purposively based on inputs they supplied.

Methods of Data Analysis

The data was analyzed using descriptive statistics such as mean, standard deviation, percentage, frequency and ranking to make sound conclusion for a given survey information. Chi-square test for discrete variables and independent sample t-test for continuous variables were applied to identify variables that vary significantly between the study areas.

Results and Discussion

Sample Households Characteristics

A combination of different descriptive statistics was performed on the sample households' characteristics of both districts. The average age of sample household heads was 38.1 years. Age of household heads across the districts were significantly different at 10% probability level. The average household size across the surveyed was 6.5 with 6.7 Bako Tibe and 6.2 Guto Gida districts which is greater than national average family size which is 4.6 (UN, 2010). The majority of the household heads (80.1%) were found to have at least a year education level. The sample household attend on average 6.4 years' education level.

The difference between the two districts respect to family size and education level were insignificant. About 4.3% of the surveyed households were female headed with 5.9% in Bako Tibe and 1.7% in Guto Gida districts. Over 93.2% of sample households were married with 90.1% in Bako Tibe and 98,3% in Guto Gida districts. The marital status was significantly different at 10% probability level and the gender of households was insignificant (Table 1).

Table 1. Descriptive statistics of sample household characteristics

Continuous variables		Bako Tibe (101)		Guto Gida (60)		Total (N=161)		t-value
		N	Mean	N	Mean	N	Mean	
Age of household head		101	36.2 (10.3)	60	41.3 (13.6)	161	38.1 (11.9)	2.7*
Family size		101	6.7 (2.5)	60	6.2 (2.3)	161	6.5 (2.4)	-1.1
Education level household		88	6.5 (2.8)	41	6.1 (2.7)	129	6.4 (2.8)	0.9
Maize experience		101	18.5 (10.1)	60	12.5 (8.5)	161	16.2 (9.9)	-3.8***
Tomato experience		98	4.7 (3.5)	57	5.0 (3.2)	155	4.8 (3.4)	0.5
Nearest market distance (min)		101	36.7 (22.5)	60	63.6 (55.6)	161	46.7 (40.3)	4.3***
FTC distance (min)		101	28.0 (20.5)	60	22.0 (14.6)	161	25.7 (18.7)	-2.0
Average land (ha)		98	1.5 (1.1)	59	2.6 (3.9)	157	1.9 (2.6)	2.5*
Average livestock (TLU)		101	8.5 (5.3)	57	7.7 (8.4)	158	8.2 (6.6)	-0.7
Discrete variables		N	%	N	%	N	%	$\chi 2$
Marital status	Married	91	90.1	59	98.3	150	93.2	4.0*
	Single	10	9.9	1	1.7	11	6.8	
Household gender	Male	95	94.1	59	98.3	154	95.7	1.7
	Female	6	5.9	1	1.7	7	4.3	

Key: ***, **, and * indicate statistically significant at 1%, 5% and 10% probability levels, respectively and figure in the parenthesis are standard deviation.

The study also required to establish farmers' experiences in growing maize and tomato crops. The result show that farmers had the longer experience in growing maize with over 16.2 years and growing tomato 4.8 years. The maize growing was significantly different at 1% probability level where as tomato growing was insignificant (Table 1). The sample households were on average walk a distance 25.7 minutes with 28 minutes at Bako Tibe and 22 minutes at Guto Gida districts to access extension services. Extension service is the more effective in encouraging fast adoption than subsidies (Lohr and Salomonsson, 2000). The sample households on average walk a distance 46.7 minutes with 36.7 minutes at Bako Tibe and 63.6 minutes at Guto Gida districts to access nearest market center which was statistically significant at 1% probability level (Table 1). In economic transformation of rural livelihoods market improvement linkages along the value chain is critical which is increases opportunities and choices of rural farmers and reduces fluctuations between household consumption and income. Efficient integrated value chains, access to markets and other infrastructure help reduce transaction costs thus raising incomes of the rural poor.

In terms of land and livestock holding sizes were analyzed. The average land holding by sample households were 1.9 hectares with 1.5 and 2.6 hectares in Bako Tibe and Guto Gida districts, respectively. There is a significantly difference in land holding between districts at 10% probability level. Regarding to livestock holding about 8.2 Tropical Livestock Unit per households owned with 8.5 and 7.7 TLU in Bako Tibe and Guto Gida districts, respectively. On average land holding by surveyed households were 1.9 hectares with 1.5 and 2.6 hectares in Bako Tibe and Guto Gida districts, respectively (Table 1). In contrast to crop production, outputs from livestock are season independent and benefits stream in throughout the year.

Maize and tomato land allocative trends over the last three years

The study looked at land tenure and how land under farmer's control was utilized in both commodities. The result shows that an average of 1.43-1.62 hectares were allocated to maize during 2015/16-2017/18 cropping season by rain fed while few farmers were applied irrigation for maize while 0.33-0.5 hectare was allocated to tomato by irrigation. This revealed that over the last three years the land allocated for both commodities were increased.

Table 2. Maize and tomato area allocated over the last three years

Production seasons		Bako Tibe (N=101)				Guto Gida (N-60)				Total (N=161)			
		Maize (ha)		Tomato (ha)		Maize (ha)		Tomato (ha)		Maize (ha)		Tomato (ha)	
		N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
2015/16	Rain fed	98	1.04	6	0.22	53	2.14			151	1.43	6	0.22
	Irrigated	5	0.28	51	0.32	13	0.27	37	0.27	18	0.27	88	0.30
2016/17	Rain fed	100	1.09	7	0.23	53	2.18			153	1.46	7	0.23
	Irrigated	9	0.51	63	0.39	17	0.36	48	0.24	26	0.41	111	0.33
2017/18	Rain fed	101	1.25	6	0.54	59	2.27			160	1.62	6	0.54
	Irrigated	8	0.40	83	0.47	14	0.48	33	0.64	22	0.45	116	0.52

Farmers in Guto Gida district had better maize farm size (2.14-2.27 hectares) during the survey period where as 1.04- 1.25 hectares of farm were operated in Bako Tibe district. In Bako Tibe few farmers were produced tomato by rain fed while in Guto Gida no farmers produced tomato by rain fed (Table 2).

Maize and tomato input used over the last three years and sources

Adoption of improved varieties has effect of raising farm incomes as it allows multiplier effects to take root, raising the general welfare of the farmer. The results of this analysis for the varieties grown during 2015/16-2017/18 cropping season were presented in table 3. Among the maize varieties both Bako hybrid (BH-660, BH-661 and BH-540) and pioneer (Limu and Shone) were widely grown in both districts. Over the last three years Bako hybrid varieties users were decreased while pioneer varieties users were increased. Tomato producers were widely used Galilea and Koshoro varieties. Over the last three years Galilea variety users were increased and cochoro users were decreased due to high yielders, better color and size.

Sample households obtain their inputs (seeds, fertilizers and chemicals) from farmers' union and private dealers. Farmers union/cooperative formed the highest source of fertilizers with about 85.3% and 80.1% of farmers were reported in Bako Tibe and Guto Gida districts, respectively while few of private and others* were supplied. This implies that inorganic fertilizers were monopolized by cooperative without clear price methodology, only distributed with one channel and price negotiating. As a result, these unclear supply systems implicate market inefficiency or market imperfection. Maize and tomato seed and chemicals were supplied by private dealers in both districts. About 69.1% and 75.8% of farmers were gotten maize seed from private suppliers in Bako Tibe and Guto Gida districts, respectively (Table 3). According to the sample households reported the price of maize and tomato seed increased from time to time than other inputs due to input speculation and shortage of seed. This finding result shows that there is maize seed market inefficiency due to input speculation (Andrew *et al.,* 2010).

Table 3. Input used and sources by sample households for the last three years

Production Seasons	Bako Tibe (N=101)											Guto Gida (N=60)							
	Maize seed (%)								Tomato seed (%)			Maize seed (%)					Tomato seed (%)		
	N	BH-661	BH-660	BH-540	BH	Limu	Shone	Pioneer	N	Galilea	Cochoro	N	BH-540	Limu	Shone	Pioneer	N	Galilea	Cochoro
2015/16	86	7.0	5.8	38.4	51.2	34.9	14.0	48.8	42	38.1	61.9	53	41.5	9.4	49.1	58.5	25	20.0	80.0
2016/17	89	6.7	3.4	20.2	30.3	51.7	18.0	69.7	58	62.1	37.9	56	33.9	12.5	53.6	66.1	22	27.3	72.7
2017/18	101	6.9	3.0	26.7	36.6	51.5	11.9	63.4	83	78.3	21.7	60	35.0	3.3	61.7	65.0	33	27.3	72.7

Input sources of sample households during 2017/18 cropping season

Sources	Bako Tibe (N=101)								Guto Gida (N=60)							
	Maize (101)		Tomato (83)		Fertilizer (101)		Chemicals (101)		Maize (60)		Tomato (33)		Fertilizer (60)		Chemicals (60)	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Own			15	18.1							5	15.2				
Private suppliers	70	69.3	60	72.3	4	3.9	70	69.3	18	30	25	75.8	8	13.3	44	73.3
Farmers union	15	14.9			86	85.2	20	19.8	19	31.7			48	80.0	13	21.7
Others*	16	15.8	8	9.6	11	10.9	11	10.9	23	38.3	3	9.0	4	6.7	3	5.0

Note: Others* are research centers, BoANR and NGOs for research purpose.

Institutional Services

Institutional services are services which institutions performs in the marketing process of any else product and add utility to the product (Williamson, 2009). These institutions were those who perform the activities necessary to transfer goods from the producer to consumer and inputs from its production areas to product producers, because of the benefit of specialization and scale that exist in marketing. In the study areas; service provider, institutions provide services like products production extension services, marketing information services, credit services and improved agricultural inputs supply services which presented in table 4, 5, 6 and 7.

Agricultural extension service: agricultural production extension service in Ethiopia is mainly given by public institutions for analyses different sources of information available and success rate of each in speeding up technology adoption (Diederen *et al.,* 2003). This service is mainly provided in the country in generally and in the study areas in specific by the office of agriculture and natural resources through its development agents at kebele level. The government policy of Ethiopia on agricultural development has started to emphasize the transformation of subsistence agriculture into market orientation as a basis for long term development of the agricultural sector (Berhanu *et al.,* 2006).

The study from the two districts revealed that about 78.8% and 56.9% of sample households reported that they received on agricultural production management and post-harvest handling extension services on maize and tomato, respectively from different resources (Table 4). Majority of respondents were received extension services from Bureau of Agriculture and Natural resource (DAs) mainly focused on crop production managements. Few of respondents were received extension service on marketing system especially on production market oriented without quality, transport, upgrading, demand situation, price and standardization. This poor extension service brings market imperfection or inefficiency (Ramon, 20005).

Credit: we analyzed credit needs of farmers to adopt high yield inputs (seed, fertilizers and chemicals. Results presented in table 4 indicate that 86.3% and 69.8% of the farmers who accessed credit for maize and tomato production, respectively. About 41.7% and 12.3% of farmers were utilized credit for purchasing fertilizer and seed (84.5%), chemicals purchase (34.5%) and market utility (39.7%) for maize production and tomato producers utilized only for purchase or rent water pump. The result indicates that there is a big gap between credit access and utilized among the producers. Microfinance (Oromia credit and saving S.C) was the major credit source who provided credit to the farmers.

Table 4. Extension and credit services of sample household

Description		Bako Tibe (N=101)				Guto Gida (N=60)				Total (N=161)			
		N	Maize	N	Tomato	N	Maize	N	Tomato	N	Maize	N	Tomato
Received extension service (%)		82	81.2	42	50.6	47	78.3	24	72.7	129	78.8	66	56.9
Contact frequency			4.1		3.4		3.3		2.7		3.8		3.2
Sources	MoANR (%)	79	96.3	42	100	47	100	24	72.7	126	97.7	66	100
	NGOs (%)	14	17.1	9	21.4	2	4.3	3	9.1	16	12.4	12	18.2
	Research center (%)	12	14.6	6	14.3	3	6.4	1	3.0	15	11.6	7	10.6
Information areas	Production (%)	80	97.6	42	100	46	97.9	23	69.7	126	97.7	65	98.5
	Post-harvest (%)	46	56.1	22	52.4	27	57.4	9	27.3	73	56.6	31	47.0
	Marketing (%)	22	26.8	12	28.6	22	46.8	6	18.2	44	34.1	18	27.3
Credit service of sample households													
Description		Bako Tibe (N=101)				Guto Gida (N=60)				Total (N=161)			
		N	Maize	N	Tomato	N	Maize	N	Tomato	N	Maize	N	Tomato
Access credit service		92	91.1	62	74.7	46	76.7	19	57.6	139	86.3	81	69.8
Received credit service		36	39.1	8	12.9	22	47.8	2	10.5	58	41.7	10	12.3
Purpose	Purchase fertilizer and seed	30	83.3			19	86.4			49	84.5		
	Chemicals	15	41.7			5	22.7			20	34.5		
	Marketing utility	16	44.4			7	31.8			23	39.7		
	Purchase/rent water pump			8	12.9			2	10.5			10	12.3

Market Aspects: crop marketing forms an integral part of famer's production decisions. Though most of the subsistence farmers are net buyers of crop produce like maize selling the produce is necessary for the fulfillment of short-term needs (Denning *et al.*, 2009). In this study, we characterized markets used by farmers to sell their produce, sale methods outputs, buyers with behaviors, price decision and market information of the commodities in the study areas.

Table 5. Characteristics of maize and tomato market aspects of sample households

Description		Bako Tibe (N=101)				Guto Gida (N=60)				Total (N=161)			
		N	Maize	N	Tomato	N	Maize	N	Tomato	N	Maize	N	Tomato
Farmers sale (%)		99	98	83	100	60	100	33	100	159	98.8	116	100
Sale (%)	Direct to buyers	94	94.9	17	20.5	54	90	27	81.8	144	90.6	54	46.6
	Through broker	6	6.1	46	55.4	4	6.7	5	15.2	10	6.3	51	44.0
	Both	7	7.1	10	12.0			1	3.0	7	4.4	11	9.5
Buyers (%)	Collectors	37	37.4	11	13.3	17	28.3	6	18.2	54	34.0	17	14.7
	Cooperative	35	35.4			20	33.3			55	34.6		
	Wholesalers	38	38.4	52	62.7	19	31.7	23	69.7	57	35.8	75	64.7
	Retailers	8	8.1	7	8.4	6	10.0	14	42.4	14	8.8	21	18.1
	Consumers	7	7.1	10	12.0	5	8.3	19	57.6	12	7.5	29	25.0
Preferred (%)	Collectors	21	21.2			7	11.7			28	17.6		
	Cooperative	42	42.4			29	48.3			71	44.7		
	Wholesalers	21	21.2	59	71.1	14	23.3	21	63.6	35	22.0	80	69.0
	Retailers			2	2.4			11	33.3			13	11.2
	Consumers			5	6.0			5	15.2			10	8.6

Results in table 5 show that about 98.8% and 100% of maize and tomato producers were sold their products, respectively. This implies that majority of producers were supply maize to the market while all tomato producers were supply to market through brokers during harvesting period. Collectors (34%), cooperative (34.6%) and wholesalers (35.8%) were the major maize buyers take lion share and preferred by producers due to better price, had potential, available in the areas whereas wholesalers (64.7) and consumers (25%) were the main tomato buyers and wholesalers are preferred due to had potential to buy and available in the areas. From these results we analyzed there is lack of competition in tomato marketing, inadequate market facilities and poor policy formulation and implementation especially on tomato.

The results presented in table 6 shows that about 27.7% and 81% of respondents were reported there is a buyer's problem in areas on maize and tomato sold, respectively due to inaccessibility (road), lack of market information and demand situation. This implies that the farmers are sale oriented, accepted any price violation, presence of many unlicensed traders and risk takers for market failures. Besides, price of the product decides by buyers it lead maize and tomato producers to market imperfection/inefficiency.

Table 6. Market accessibility and decision of sample households

Description		Bako Tibe (N=101)				Guto Gida (N=60)				Total (N=161)			
		N	Maize	N	Tomato	N	Maize	N	Tomato	N	Maize	N	Tomato
Difficulty to finding buyers		35	35.4	70	84.3	9	15	24	72.7	44	27.7	94	81
Reasons	Inaccessibility	6	17.1	34	48.6	3	33.3	15	62.5	9	20.5	49	52.1
	Shortage of information	11	31.4	47	67.1	4	44.4	10	41.7	15	34.1	57	60.6
	Demand and supply situation	13	37.1	29	41.4	7	77.8	7	29.2	20	45.5	36	38.3
Price decision	Sellers	11	11.1	9	10.8	5	8.3	7	21.2	16	10.1	16	13.8
	Buyers	88	88.9	74	89.2	52	86.7	17	51.5	140	88.1	91	78.4
	Supply and demand situation	13	13.1	6	7.2	6	10	11	33.3	19	11.9	17	14.7

Market information is critical in reducing market imperfection with choices type of market to sell their products. Results presented in table 7 shows that about 79.4% and 58.6% farmers were received market information only on sale orientation (what farmers sold) on maize from DAs (22.2%), farmers (74.6%) and traders (34.1%) and tomato from DAs (27.9%), farmers (64.7%) and traders (41.2%), respectively. This sale orientation information with farmer's source indicates that farmers were failed to decides sale place, time, reduce marketing risks, limit market participation, lack demand driven or market oriented and lack of effective competition.

The results indicated that due to inadequate market information majority of respondents were supplied their products to village and district markets. About 71.1% and 26.4% of respondents were supplied maize grain to village and district markets while about 44.8% and 36.2% of respondents were supplied tomato to village and district markets, respectively (Table 7). With these limitations of the market mechanism the producers failed to this market imperfection or inefficiency and inequality situation.

Table 7. Market information of sample households

Description		Bako Tibe (N=101)				Guto Gida (N=60)				Total (N=161)			
		N	Maize	N	Tomato	N	Maize	N	Tomato	N	Maize	N	Tomato
Received information (%)		87	87.9	53	63.9	39	65	13	39.4	126	79.2	68	58.6
Sources	DA (%)	16	18.4	15	28.3	12	30.8	4	30.8	28	22.2	19	27.9
	Farmers (%)	70	80.5	33	62.3	24	61.5	11	84.6	94	74.6	44	64.7
	Traders (%)	20	23	23	43.4	23	59	5	38.5	43	34.1	28	41.2
Sale Market	Village (%)	59	59.9	21	25.3	54	90	31	93.9	113	71.1	52	44.8
	District (%)	33	33.3	35	42.2	9	15	7	21.2	42	26.4	42	36.2
	Finfinnee (%)	13	13.1	18	21.7	6	10			19	11.9	18	15.5

Challenges and Opportunities of Producers

The key challenges that producers generally faced include high unlicensed traders, disease, poor extension service, shortage of chemicals (especially for different maize and tomato diseases), poor market linkage, poor infrastructure (road), shortage of credit, low price of grain, shortage of improved seed and lack of coordination among producers and stakeholders. Among these challenges disease, low price of grain when compare to input prices, poor market linkage, shortage of chemicals and high present of unlicensed traders were the top five majors' challenges in maize and tomato producers in production and marketing system (Table 8). These challenges indicate that input-output market system in the areas laid market inefficiency due to poor enabling environment like regulation on traders, market linkage system on grain price and inputs like chemicals and inadequate awareness of the technologies and marketing skills which contribute to low productivity and profitability.

Availability of high yielding maize and tomato varieties with access, suitable agricultural development policies with good condition of production, better price of maize grain than previous (increase trend of maize grain from time to time) and better available of inputs than previous were the majors' opportunities which can help offset some of the challenges with appropriate policy measures for producers.

Table 8. Major challenges and opportunities of sampled producers

Challenges	Maize (161) %	Maize (161) Rank	Tomato (116) %	Tomato (116) Rank	Opportunities	Maize %	Maize Rank	Tomato %	Tomato Rank
Unlicensed traders	53.4	5	72.5	5	Technology adoption	88.2	2	61.6	3
Disease	80.1	1	98.6	1					
Shortage of chemicals	56.5	4	78.0	3	Access new varieties	89.4	1	64.6	2
Poor extension service	36.6	8	61.9	6					
Poor market linkage	68.6	3	72.7	4	Better price of grain than previous	56.5	4	31.4	5
Poor infrastructure	47.2	6	45.7	10					
Shortage of credit	8.7	10	51.8	7	Better availability of inputs	47.2	5	43.9	4
Low price of grain	78.3	2	93.5	2					
Shortage of improved seed	34.2	9	51.1	8	Good condition for production	83.2	3	72.6	1
Lack of coordination	39.1	7	47.8	9					

Challenges and Solutions of Input Dealers

The key challenges reported by both commodities inputs suppliers include shortage of inputs, farmers reluctant to buy inputs with high price, high competition with unlicensed traders, shortage of storage, shortage of capital, weak government support, shortage of transportation and poor infrastructure (road). Among these challenges shortage of inputs, farmers reluctant to buy inputs, high competition unlicensed traders, weak government support and shortage of storage were the top five majors' challenges reported by inputs suppliers.

Table 8. Major challenges and solutions of sampled input dealers

Challenges	N	%	Rank	Solution
Shortage of inputs	13	100	1	Search alternative
Farmers reluctant to buy inputs	9	69.2	2	Awareness creation
Much competition with unlicensed traders	8	61.5	3	Regulation
Shortage of storage	6	46.2	5	Rent and construct
Shortage of capital	3	23.1	8	Access credit
Weak government support	7	54.8	4	Attention
Shortage of transportation	4	30.8	7	Facilitation and linkage
Poor infrastructure	5	38.5	6	Construct

Solutions were identified by sample households' inputs suppliers such as search alternative inputs sources, awareness on altitude of farmers for inputs used as recommended, awareness and regulation on unlicensed traders, access credit to solve capital shortage, government must give attention for inputs suppliers as others actors and establish inputs supply system were reported for the challenges identified.

Challenges and Solutions of Traders

The key challenges of traders which presented in table 10 include low supply of product, grain price fluctuation, low quality of product, poor infrastructure (road), poor awareness especially on quality, shortage of capital, high unlicensed traders, brokers interference especially tomato, supply fluctuation (high during harvesting and low in others) and demand fluctuation. Among these challenges low quality, demand fluctuation, high present of unlicensed traders, low supply and shortage in maize while supply fluctuation, high unlicensed traders, poor awareness on quality, brokers interference and demand fluctuation shortage in tomato were the top five majors' challenges marketing system.

Table 9. Major challenges and solutions of sampled traders

Challenges	Maize (N=16)		Tomato (N=10)		Solutions
	%	rank	%	rank	
Low supply	81.3	4	50	8	Increase productivity using appropriate inputs
Price fluctuation	68.8	6	60	6	Awareness and price regulation
Low quality	100	1	40	9	awareness creation and regulation
Poor Infrastructure	50	9	30	10	Construct road
Poor awareness on quality	56.3	8	90	2	awareness creation
Shortage capital	75	5	60	6	Credit availability and time of repayment
High unlicensed traders	87.5	3	90	2	Regulation and awareness creation
Brokers interference	43.8	10	80	4	
Supply fluctuation	62.5	7	100	1	Contractual agreement and awareness
Demand fluctuation	93.8	2	70	5	

Increase productivity using appropriate inputs to balance demand and supply situation, awareness creation on trade system and strengthens regulation on unlicensed traders and brokers, construct road to solve (transportation and price fluctuation), credit availability and time of repayment to solve shortage of capital and contractual agreement signed with awareness creation of contractual agreement were reported as solutions for the challenges identified.

Conclusions and Recommendations

Even though maize and tomato contributed a vital role to farmers and others actors in the study areas, the crops are characterized by low production and productivity due to different factors including inputs and outputs price violating, lack of transportation and limited market information. Input and output marketing system efficiency play key roles in adoption and increasing production and productivity of improved agricultural technologies. The study is to describe the marketing system of inputs and major outputs in the study areas; identify weather there is marketing inefficiencies and integration in inputs and outputs marketing system and to give policy direction in input-output marketing system. Both primary and secondary data collected from different sources to derive comprehensive conclusion using a semi-structured questionnaire. The collected data were analyzed by descriptive statistical include mean, standard deviation, frequency, percentage, Ch-square test, t-test and rank.

The result was described the information links and approaches of input and output marketing systems. From the sample household used maize Bako hybrid decrease from time to time due to information gaps among producers, DAs, Input suppliers, traders and others. Therefore, enhancing the technical knowledge and skill of farmers, DAs, suppliers and traders on maize hybrid and input-output marketing efficiency system by providing training to provide effective enabling service to increase market efficiency among the actors.

Majority of the producers preferred union/coops to sell their products and better opportunities integrating inputs-outputs marketing system but the cooperative have poor capacity to serve farmers through the year so, build the capacity of farmer's cooperatives/unions in value chains of inputs-outputs to improve farmers profit margin with available equal opportunities for all actors, technical backup (awareness on market system efficiency) and adequate credit facilities. From the analysis we understand: the integration of input and output marketing system of producers, suppliers and traders relevant in enhancing agricultural production and productivity were poor. Hence, market-oriented extension services should be considered with improving enabling environment include market information (inputs &outputs), services access (credit and extension), rules and regulation (inputs &outputs) and others importance enabling by public and private sectors must play complementary roles in promoting competition in agribusiness across emerging marketing efficiency.

Disease, low price of grain, poor market linkage, shortage of chemicals and unlicensed traders are the major challenges in both maize and tomato production. Shortage of inputs, farmers reluctant to buy inputs, high competition unlicensed traders, weak government support and shortage of storage are main challenges in input supply while low quality with poor awareness, low supply, unlicensed traders, brokers and demand fluctuations are also major challenges in trading systems. Thus, in order to exploit the benefits of the two commodities given the existing positive environment; private and public institutions in the supply of improved and supply of quality outputs more vital to improve input-output marketing system efficiency.

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LIVESTOCK

Phenotypic characters of Nile tilapia (*Oreochromis niloticus* L.) in three Ethiopian Rift Valley lakes (Chamo, Danbal and Koka)

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Abstract

Nile tilapia (*Oreochromis niloticus* L.) is indigenous species to Ethiopia and constituted major proportion in the country's fishery production. In an attempt to select better performing strains for aquaculture development, tilapia populations from different Ethiopian Rift Valley Lakes showed different growth performances in pond culture. The current study was made to investigate phenotypic characters of the tilapia in three isolated Ethiopian Rift Valley Lakes (Chamo, Danbal and Koka). A total of 450 adult tilapias of commercial catches were sampled from the three lakes and their phenotypic characters analyzed. Twenty six morphometric character indices, eight meristic counts, total length, standard length, total weight and Fulton's condition factor were considered in the analysis. The results revealed significant differences ($p \leq 0.05$) in most of the morphometric character indices, meristic counts, mean length and weight and Fulton's condition factor among the three tilapia populations. Chamo tilapia population were found to have highest mean values of total weight, total length and standard length while Koka population have highest mean value of Fulton's condition factor as characters desired in aquaculture. Further research is required to investigate that the fish populations could maintain those characters in pond cultures.

Key words: morphometric, meristic, nile tilapia, phenotypic characters

Introduction

Nile tilapia (*Oreochromis niloticus* L.) is cultured worldwide and currently ranked second only to carps in global farmed food fish. The fish is indigenous species to Ethiopia and constituted major proportion (65%) in the country's fishery production (Hussein, 2015). In the aquaculture development of Ethiopia, wild *O. nilotcus* were collected from natural environments, especially from the Ethiopian rift valley lakes and stocked in to ponds. In an attempt to select better performing strains for aquaculture, tilapia populations from different Ethiopian Rift Valley Lakes showed different growth performances in pond culture. Daba *et al.* (2017) evaluated growth performances of four *O. nilotcus* populations of Ethiopian rift valley lakes (Awassa, Chamo, Danbal and Koka) in pond culture at Batu where the Chamo population found to grow significantly faster than others. Similar studies were conducted to evaluate the growth performances of the tilapia populations of Ethiopian rift valley lakes in pond culture at different times for different experimental periods and found variation in growth performances (Kassaye and Gjoen, 2012; Daba *et al.* 2014) whereby the Koka and

Danbal tilapia populations were mentioned as promising candidate populations for aquaculture development in Ethiopia.

The three lakes, Chamo, Danbal and Koka are geographically isolated (figure 1); situated in different drainage basins: Abaya-Chamo, Danbal-Shala and Awash basins, respectively, within the Ethiopian Rift Valley (Tenalem, 2009). Chamo has more diversified ichtyo fauna than other lakes in Ethiopia except Lake Abaya. There are six important fish species for fishery in Chamo, namely, Nile perch (*Lates niloticus*), Nile tilapia (*Oreochromis niloticus*), labeo (*Labeo horie*), African catfish (*Clarias gariepinus*), Bagrus (*Bagrus docmak*) and Barbus (*labeobarbus intermedius*) (LFDP, 1997). The *O. niloticus, L. niloticus and C. gariepinus* were numerically the three dominant species in the fish landings (Zerihun, 2008). Indigenous fish species such as Nile tilapia (*Oreochromis niloticus*), Barbus (*Labeobarbus intermidus),* straightfin barb (*Barbus paludinosis*) and Garra (*Garra dembecha),* and exotic fish species such as African Catfish (*Clarias gariepinus*), Crucian carp (*Carassus carrassus*), Common carp (*Cyprinus carpio*) and Tilapia zillii (*Coptodon zilli*) are found in lake Danbal (Megerssa *et al.*, 2015). Among these species, Nile Tilapia, African Catfish, Crucian carp and Common carp are commercially important ones. According to Megerssa *et al.* (2015), the current annual fish production from Lake Danbal is declining, particularly the population of the Nile tilapia declined tremendously.

Koka harbors three commercially important fish species: Nile tilapia (*Oreochromis niloticus),* common carp (*Cyprinus carpio)* and African catfish (*Clarias gariepinus)* where *O. niloticus* were found in healthy state, *C. gariepinus* shown signs of growth overfishing and *C. carpio* shown under exploitation (Gashaw and Wolff, 2015). Aquatic environment of the three lakes in terms of their basic morphometric features, altitude, water quality parameters and fish species diversity are different (Brook and Hayal, 2016). Under these different environmental conditions of the three lakes, tilapias are expected to develop different phenotypic and genetic characters. Characterization of the tilapia population helps in utilization of the resource in aquaculture, and further contribute to protect the population in their natural environment. Hence the objective of the present study was to investigate desired culture characteristics of *Oreochromis niloticus* of rift valley in order to improve their productivity in aquaculture system with specific objective of characterizing the *Oreochromis niloticus* populations of Chamo, Danbal and Koka lakes based on their phenotypic characters.

Materials and methods

Description of the study areas

The fish were sampled from three Ethiopian rift valley lakes: Chamo, Danbal and Koka lakes from May, 2018 to March 2019. These water bodies were selected for their targeted Nile tilapia (*Oreochromis niloticus* L.) populations to be used in the development of aquaculture in Ethiopia.

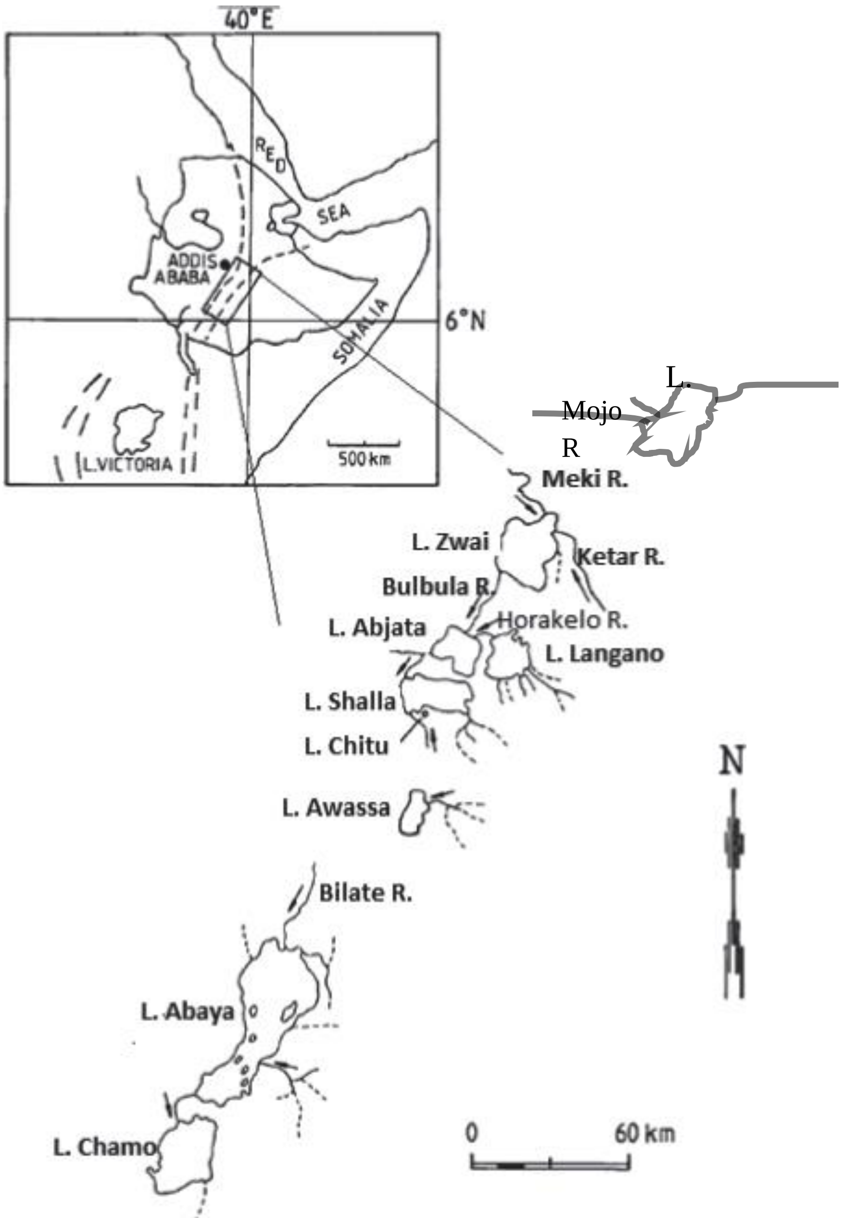

Figure 1. Location of the Ethiopian rift valley lakes (modefied after Kebede *et al*. 1994)

Lake Chamo is situated in South most part of the Ethiopian rift valley lakes. The lake was reported to have an area of 551 km^2 (Amha and Wood, 1982; LFDP, 1997) and it was the third widest lake in Ethiopia next to Tana and Abaya. However, according to Seleshi *et al*. (2007), the surface area of the lake declined to about 335 km^2 owing to high rate of water evaporation and diversion of feeder river, Kulfo for irrigation.

Lake Danbal (also known as Lake Ziway) is located in the Ethiopian rift valley between 7^0 52' to 8^0 8' N and 38^0 40' to $38^0$56' E at an altitude of 1636 m a.s.l. with maximum length of 32 km and maximum width of 20 km (LFDP, 1997). The Lake is the second largest lake is 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, and has one outlet river in its South part, the Bulbula river, which seasonally flows into Abijata Lake.

Lake Koka is a manmade reservoir located at about 90 km Southeast of Addis Ababa between 8° 18′ 57″ to 8° 28′ 21″ N and 39° 0′ 0″ E to 39° 9′18″ E 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 surface area of about 255 km^2 with a maximum and mean depth of 14 m and 9 m, respectively (LFDP, 1997).

Phenotypic characterization of the *Oreochromis niloticus*

Phenotypic variation is wide in organisms spread in nature, and often involves ecologically relevant behavioral, physiological, morphological and life historical traits. Phenotypic plasticity can be inclusively defined as the production of multiple phenotypes from a single genotype, depending on environmental conditions (El-Zaeem, 2012).
Morphometric characters and meristic counts (table 1) were recorded within each population from at least 50 fish per study sites as described in El-Zaeem (2012).

Table 1. Morphometric and meristic characters of *O. niloticus* populations of the three lakes

A. Morphometric analysis			
Characters	**Acronyms**	**Characters**	**Acronyms**
Total length	TL	Caudal peduncle length	CPL
Standard length	SL	Caudal peduncle width	CPW
Head length	HL	Caudal peduncle depth	CPD
Body depth	BD	Pectoral fin length	Pec FL
Body width	BW	Dorsal fin base length	DFBL
Head width	HW	Pelvic fin base length	Pel FBL
Abdomen length	AL	Length of longest dorsal fin spine	LLoDFS
Orbit diameter	OD	Length of last dorsal fin spine	LLaDFS
Pre-orbital length	Pr-OL	Length of longest dorsal fin ray	LLoDFR
Post-orbital length	Po-OL	Length of last dorsal fin ray	LLaDFR
Trunk length	TrL	Length of longest anal fin spine	LLoAFS
Pelvic fin length	Pel FL	Length of first anal fin spine	LFiAFS
Anal fin base length	AFBL	Length of longest anal fin ray	LLoAFR
Caudal fin length	CFL	Length of last anal fin ray	LLaAFR
B. Meristic analysis			
Characters	**Acronyms**	**Characters**	**Acronyms**
Dorsal fin spines count	DFSC	Pectoral fin rays count	Pec FRC
Dorsal fin rays count	DFRC	Anal fin spines count	AFSC
Pelvic fin spines count	Pel FSC	Anal fin rays count	AFRC
Pelvic fin rays count	Pel FRC	Caudal fin rays count	CFRC

Along with the morphometric measurements, weight (TW) of each specimen was measured to the nearest 0.1g. At least 150 fishes per lake were assessed. Condition factor of each fish was measured using the following equation:

$$K= 100 (TW/TL^3) \text{ (Lagler, 1956)}$$

Where, k = Fulton's condition factor

TW = total weight in grams

TL = total length in centimeter

The fish were characterized based on the morphometric and meristic parameters. Values for the quantitative traits of the populations were expressed as mean and standard deviation as mean ± SD. Differences in mean values of the traits between the populations were analyzed in one-way analysis of variance (ANOVA) at significance level of $p \leq 0.05$ using Tukey's mean separation method.

Results and discussion

In this phenotypic characterization, morphometric character indices, meristic counts, total weight, total length, standard length and fish condition factor were analyzed from a total of 450 samples: 150 fish samples for each of the populations (table 2). Nile tilapia population of Chamo were characterized b,y highest mean weight (412.24 ± 218.21 g), total length (27.81 ± 4.79 cm) and standard length (22.56 ± 4.17 cm), which differed significantly ($p \leq 0.05$) from that of Koka and Danbal populations' parameter values. The current mean total length of the Chamo population is within the range of 19-43 cm length reported by Zerihun (2008). The Chamo population have also scored highest morphometric character indices of BD/SL, CPD/TL, Po-OL/HL, PelFBL/SL, LLoDFS/SL, LLaDFS/SL, LLaDFR/SL, FiAFS/SL, LLoAFR/SL and highest record of meristic character in PecFRC in which all the characters differed significantly ($p \leq 0.05$) from the mean values scored by the Koka and Danbal populations. However, the Chamo population scored significantly ($p \leq 0.05$) lowest mean values of BW/SL, TL/SL and LLaDFR/SL morphometric indices, and DFSC and AFRC meristic characters (table 2).

Generally, Chamo *O. niloticus* population were found to be larger in total length and weight (figure 2), shorter at trunk region with respect to their standard length, dorso-vetrally deep, laterally compressed in body form (figure 3) as compared to other populations. They also had longest pre-orbital region, dorsal and anal fins as indicated in their morphometric indices (table 2). Nile tilapia populations of Koka scored mean weight of 259.17 ± 87.65 g, mean total length of 23.90 ± 2.63 cm and standard length of 19.17 ± 2.22 cm; values which were significantly ($p \leq 0.05$) lower than that of Chamo population but higher than that of Danbal population. A mean total length that a fish of a given stock would reach if they were to grow indefinitely ($L\infty$) was estimated to reach 44.5 cm for the *O. niloticus* population of Koka (Gashaw and Wolff, 2015) and 28.1 cm for the *O. niloticus* population of Danbal (Gashaw, 2006). The size differences between the population means in the current result agrees with the reports.

Highest mean score of Fulton's condition factor (K) was obtained in the Koka population (1.83) and the value differed significantly ($p \leq 0.05$) from that of Chamo (1.78) and Danbal populations (1.75). The average K values of *O. niloticus* were reported to vary over time; 1.87

for Koka population (Gashaw and Zenebe, 2008) and 1.89 (Zenebe, 1988) and 1.81 (Gashaw and Zenebe, 2008) for Danbal and 2.35 for Chamo (Yirgaw and Demeke, 2002). The Koka population scored highest morphometric character indices of AL/SL, TL/SL, DFBL/SL, CPW/TL, PelFL/SL and LLaAFR/SL but lowest mean values of HL/SL, BD/SL, CPL/TL, PecFL/SL, PelFBL/SL, LLoDFS/SL, LLaDFS/SL, LLoAFS/SL, and LFiAFS/SL which were significantly different ($p \leq 0.05$) from that of Chamo and Danbal populations (table 2). As compared to Chamo and Danbal populations, the Koka *O. niloticus* population were generally found to have longer trunk region, laterally wide (fat), not dorso-ventrally deep, with shorter head and fin spines (figure 3).

The tilapia population of Danbal were significantly ($p \leq 0.05$) lower in their mean total weight (115.13 ± 47.14 g), mean total length (18.44 ± 2.46 cm) and standard length (14.94 ± 2.06 cm) than the Chamo and Koka populations. The population had also lowest morphometric character indices of LLoDFR/SL, AFBL/SL, LLoAFR/SL and lowest meristic counts of dorsal and pectoral fin rays which were significantly ($p \leq 0.05$) different from mean values observed in that of Chamo and Koka populations. However, the population scored highest mean value of OD/HL morphometric character index and highest mean caudal fin ray count and differed significantly from Chamo and Koka. Generally, Danbal *O. niloticus* populations were relatively smaller in size, have shorter dorsal fin rays and wider orbit diameter with respect to their head length (figure 3).

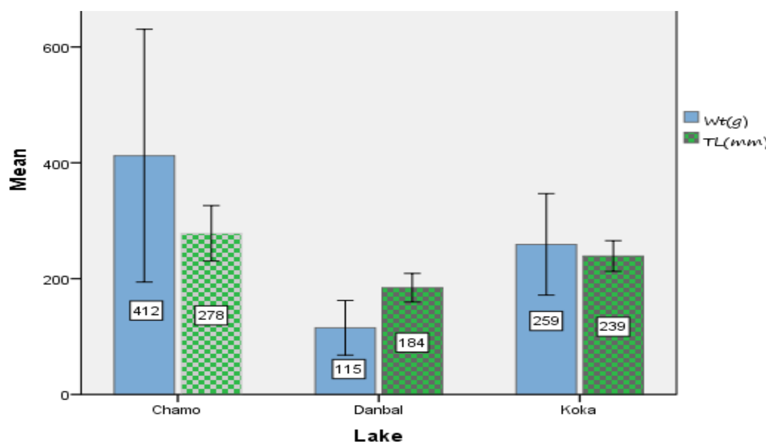

Figure 2. Mean total weight (gm) and TL (mm) of Nile tilapia (*O. niloticus*) populations of the three Ethiopian Rift Valley lakes

Aquatic environment of the Chamo, Danbal and Koka lakes in terms of their basic morphometric features, altitude, water quality parameters and fish species diversity are different (Brook and Hayal, 2016). The *O. niloticus* populations of the three lakes are accordingly isolated genetically and developed different morphometric characters (table 2) to adapt to their corresponding environmental conditions.

Morphometric characters in fish have been demonstrated to be influenced by environmental factors (Robinson and Wilson, 1995). Fulton's condition factor (K), which indicates the nutritional level and status of the fish over time, might be greatly influenced by environmental factors. The higher Fulton's condition factor (K), observed in *O. niloticus* of Koka population in the current study perhaps resulted as a function of better feed availability in artificial reservoirs than in natural lakes. Though the degree vary from lake to lake, anthropogenic impacts such as pollution due to silt and nutrient load from watershed areas, municipal waste, industries (tannery, flower culture), water level fluctuation and fishing pressures have directly or indirectly affected the fish community in the lakes (Lemma, 2016). Floodplains associated with the reservoirs are generally known to be most productive aquatic ecosystem. The K value of *O. niloticus* population of Chamo, Danbal and Koka varied over time based on environmental changes (Zenebe, 1988; Yirgaw and Demeke, 2002; Gashaw and Zenebe, 2008).

Phenotypic adaptations of fish to their environment do not necessarily cause a change in genetic constitutions of the population (Allendorf, 1988) and hence the phenotypic differences among the populations cannot usually be taken as evidence of genetic differentiation. However, in genetic analysis using total mtDNA digestions, Seyoum and Kornfield (1992) grouped *O. niloticus* of Ethiopia into different subspecies: *O. n. cancellatus (*Awash basin), *O. n. filou* (Sodore hot springs), *O. n. taita* (Tana population). Later, Agnese *et al.* (1997) using allozyme, clustered natural populations of *O. niloticus* in the Ethiopian Rift Valley (Lakes Danbal, Awasa, Koka and Sodore hot springs) in one group and populations of Tana, Nile, Kenya in another group. The authors considered the subspecies classification made by Seyoum and Kornfield (1992) were premature. According to the species clustering of Agnese *et al.* (1997), the *O. niloticus* of Lake Chamo can be related to the Kenyan and Nile group since the Abaya-Chamo basin connects down to the Chew Bahir and Turkana lake in northern Kenya.

Table 2. Means and standard deviations of quantitative phenotypic traits based on morphometric character indices and meristic counts

Characters	Population		
	Chamo	Koka	Danbal
Morphometric indices			
HL/SL	0.324 ± 0.02^{a}	0.312 ± 0.01^{b}	0.324 ± 0.02^{a}
BD/SL	0.392 ± 0.02^{a}	0.360 ± 0.02^{c}	0.370 ± 0.02^{b}
BW/SL	0.158 ± 0.01^{b}	0.170 ± 0.01a	0.167 ± 0.02^{a}
HW/HL	0.550 ± 0.03	0.559 ± 0.03	0.553 ± 0.10
AL/SL	0.302 ± 0.02^{b}	0.314 ± 0.03^{a}	0.304 ± 0.02^{b}
OD/HL	0.209 ± 0.03^{b}	0.220 ± 0.03^{b}	0.249 ± 0.09^{a}
Pr-OL/HL	0.320 ± 0.03	0.287 ± 0.03	0.312 ± 0.24
Po-OL/HL	0.497 ± 0.03^{a}	0.493 ± 0.03^{a,b}	0.484 ± 0.09^{b}
TrL/SL	0.681 ± 0.03^{c}	0.710 ± 0.02^{a}	0.690 ± 0.06^{b}
PelFL/SL	0.257 ± 0.02^{b}	0.273 ± 0.05^{a}	0.263 ± 0.02^{b}
AFBL/SL	0.194 ± 0.01^{a}	0.195 ± 0.01^{a}	0.182 ± 0.01^{b}
CFL/TL	0.200 ± 0.01	0.201 ± 0.01	0.203 ± 0.11
CPL/TL	0.119 ± 0.01^{a}	0.113 ± 0.01^{b}	0.120 ± 0.01^{a}
CPW/TL	0.040 ± 0.00^{b}	0.044 ± 0.01^{a}	0.040 ± 0.01^{b}
CPD/TL	0.105 ± 0.01^{a}	0.098 ± 0.01^{b}	0.096 ± 0.01^{b}
PecFL/SL	0.365 ± 0.02^{a}	0.342 ± 0.04^{b}	0.359 ± 0.02^{a}
DFBL/SL	0.598 ± 0.03^{b}	0.622 ± 0.06^{a}	0.601 ± 0.03^{b}
PelFBL/SL	0.056 ± 0.01^{a}	0.052 ± 0.01^{c}	0.055 ± 0.01^{b}
LLoDFS/SL	0.156 ± 0.01^{a}	0.141 ± 0.02^{c}	0.149 ± 0.01^{b}
LLaDFS/SL	0.156 ± 0.01^{a}	0.141 ± 0.02^{c}	0.149 ± 0.01^{b}
LLoDFR/SL	0.250 ± 0.03^{a}	0.224 ± 0.03^{b}	0.217 ± 0.02^{c}
LLaDFR/SL	0.077 ± 0.01^{b}	0.082 ± 0.01^{a}	0.080 ± 0.01^{a}
LLoAFS/SL	0.151 ± 0.01^{a}	0.138 ± 0.02^{b}	0.149 ± 0.02^{a}
LFiAFS/SL	0.064 ± 0.01^{a}	0.050 ± 0.01^{c}	0.056 ± 0.01^{b}
LLoAFR/SL	0.226 ± 0.02^{a}	0.221 ± 0.03^{b}	0.215 ± 0.01^{c}

LLaAFR/SL	0.075 ± 0.01^{b}	0.081 ± 0.01^{a}	0.076 ± 0.01^{b}
Meristic counts			
DFSC	16.59 ± 0.49^{b}	16.82 ± 0.39^{a}	16.85 ± 0.37^{a}
DFRC	12.29 ± 0.49^{a}	12.21 ± 0.41^{a}	12.09 ± 0.46^{b}
Pel FSC	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00
Pel FRC	5.00 ± 0.00	5.00 ± 0.00	5.00 ± 0.00
Pec FRC	13.06 ± 0.35^{a}	12.63 ± 0.51^{b}	12.42 ± 0.56^{c}
AFSC	3.00 ± 0.00	3.00 ± 0.00	3.00 ± 0.00
AFRC	9.29 ± 0.47^{b}	9.53 ± 0.54^{a}	9.48 ± 0.51^{a}
CFRC	17.46 ± 0.88^{b}	17.23 ± 0.98^{c}	17.93 ± 0.61^{a}
TW(g)	412.24 ± 218.21^{a}	259.17 ± 87.65^{b}	115.13 ± 47.14^{c}
TL(mm)	278.15 ± 47.89^{a}	239.00 ± 26.35^{b}	184.43 ± 24.61^{c}
SL(mm)	225.63 ± 41.73^{a}	191.74 ± 22.26^{b}	149.44 ± 20.59^{c}
Condition factor	1.78 ± 0.16^{b}	1.83 ± 0.22^{a}	1.75 ± 0.14^{b}

In a study of phylogenetic differentiation of wild and cultured Nile tilapia populations based on phenotype and genotype analysis, El-Zaeem *et al.* (2012) reported that phenotype analysis based on a large number of morphometric character indices and meristic counts can be used to discriminate fish populations up to the intraspecific level with the same results as the genotype analysis based on random amplified polymorphic DNA (RAPD) fingerprinting. Hence, the differences observed in phenotypic characters of the three *O. niloticus* populations in the present study based on the analysis made using 26 morphometric character indices, 8 meristic counts and four other morphometric characters indicates that the differences have also genetic bases.

Figure 3. *O. niloticus* samples of Chamo (upper), Koka (middle) and Ziway (lower) populations.

Conclusion

Based on the parameters considered for characterization, Nile tilapia (*O. niloticus*) populations of Chamo, Koka and Danbal differed in many phenotypic characters in their natural environments. As a desired character in aquaculture production, tilapia population of Chamo had higher mean weight and length than population of Koka followed by population of Danbal. The phenotypic characters are governed by genetic and/or environmental factors. Thus, it is important to confirm that the populations maintain these characters when grown under controlled environments.

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Integrated Fish - Poultry- Horticulture - Forage and Fattening Production System in Ada'a District, East Shoa Zone

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Abstract

Integrated fish-poultry-horticulture-fattening and forage farming is based on the concept that 'there is no waste', and waste is only a misplaced resource which can become a valuable material for the production of other products. A study was made to assess the production performance of the system in Ada'a district, East shoa zone. Chicken started to laying eggs at 20 weeks of age with the mean egg production of 76.7 percent per day. Fingerlings of *Oreochromis niloticus* stocked in the pond and reached table size with an average weight of 226 gram within six months. Vegetable yields obtained from Potato, Gurage cabbage and Ball-head cabbage were 36,666; 5,500 and 28,333 kg ha^{-1} respectively. Forage varieties of *Medicago sativa*, *Pennisetum pedicellatum* and *Pennisetum purpureum* were planted on the top of the dike for fattening of bulls. The study confirmed that the technology is highly profitable and needs to be promoted as one of the strategies that can be adopted by small holder farmers of the country to increase farm returns per unit area of land.

***Key words**: Fattening, fish, forage, horticultures, poultry and poultry litter*

Introduction

Providing adequate food for a rapidly increasing human population is one of the greatest challenges in the world. The problem is particularly acute in countries like Ethiopia where, besides population explosion, natural and man-made calamities have aggravated the problem. In addition to increasing food production from agricultural land, it is necessary to sustainably exploit the aquatic ecosystems. By virtue of their high productivity these ecosystems can highly contribute towards the effort of food security. Ethiopia's fish resources could undoubtedly offer one of the solutions to the problem of food shortage in the country.

The ecological diversity and climatic variation of the country is to a large extent explained by its highly variable topography. These altitude extremes imply that Ethiopia is a country of enormous habitat diversity. Ethiopia, with its different geological formations and climatic conditions, is endowed with considerable water resources and wetland ecosystems, including river basins, major lakes, many swamps, floodplains and man-made reservoirs. Hence, the water bodies support a diverse aquatic life including more than 200 fish species (Redeat, 2012). In reality, however, all these capitalized potentials and praises ended in vain contributing little to the well being of the country. While, capture fisheries is very common in most parts of the country, as a result fish production is highly exploited as the resource has been an open access. To alleviate this problem aquaculture technology must be an option that needs to be intensified.

Aquaculture is a part of agriculture, which deals with rearing of aquatic organisms, plants and animals including fish under controlled condition. Fish culture can be integrated with livestock and agronomy, especially vegetables using waste from one production as an input for the other and enabling the production of organic products. Pond management with fish, poultry and vegetables proved to be an excellent approach for sustainable production, income generation and employment opportunities for the resource poor rural households (Lemma, 2013). Addition of organic fertilizers like poultry litter to a fish pond, that is integrating poultry farm with fish, increases the water nutrients for better production of fish by resolving the problem of fish feed faced in aquaculture.

Currently, there is a need to find a suitable agricultural system to meet the increasing demand for food, and also maximizing the utilization of available limited resources without much wastage. In integrated farming system, waste from one component is used as an input for the next component. In this case, waste from poultry is used to fertilize the fish pond substituting feed supplements for the fish, and also improve the nutrient content of the water which is used to irrigate the horticulture during the water exchange. Hence, based on the potential advantages of such integration technology, a research was conducted to find a better approach of fish pond culture that can be practiced among farmers as a strategy for poverty reduction, ensuring nutritional security and diversifying income. The general objective of the activity was therefore, to maximize aquaculture-agriculture production on the same piece of land by way of creating synergistic interactions among different components.

Materials and Methods

Description of the study area

The activity was conducted in Ada'a district of Esat Shoa zone Oromia region. The district is located in the Great Rift Valley and bordered on the south by Dugda Bora district, on the west by the West Shoa Zone, on the northwest by Akaki, on the northeast by Gimbichu district, and on the east by Lume district. The district has an altitude ranging from 1500 to 2250 meters above sea level (CSA, 2005). The minimum and maximum temperatures are 13^0C and 25^0C respectively (DZARC, 2017 unpublished data). The farming system of the district is characterized by mixed agricultural production system. Irrigation is mainly practiced with the main water source from "Wodecha" river.

Site and farmer selection

A number of formal and informal discussions were conducted with the beneficiaries, development agents and local government officials to select site and farmers. Various factors were considered in selecting farmers. Some of these factors were attention to physical factors, including environmental conditions of the farm area (availability of continuous source of water, water quality, soil types, weather condition, etc.), adaptability of commercial fish species and different horticultural crops to the area, existence of beef and poultry breeds, availability of local materials/inputs for the integration and market accessibility.

Design of the integration

Design of the integrated farming system is described in figure 1.

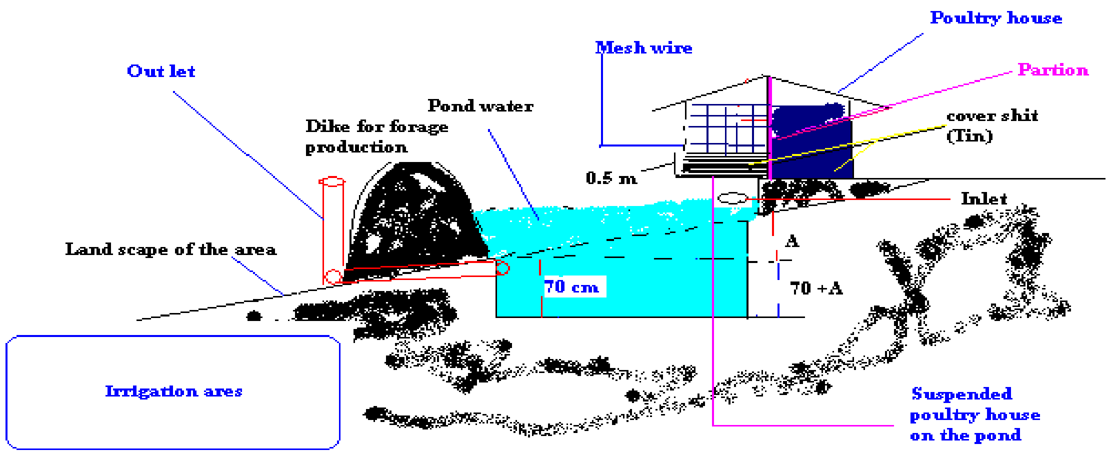

Figure 1: Design of the integrated farming system

Poultry house construction and production

Poultry house was constructed from locally available materials after the fish pond was excavated. Walls of the house were built from eucalyptus wood and plastered by mud (Fig 2). The roof of poultry house was covered by iron sheet. The house had two compartments. The first half of the house which is 1.5 m x 6 m lying on ground and used for a nighttime resting place for the chicken and also used as a place to lay egg (Fig.2b). The second half of the house with area 1.5 m x 6 m is open to air and light, hanging over part of the fish pond and used as feeding and drinking place for the chicken during day time (Fig.2a). This part of the house lying over the pond is covered by mesh wire to protect chickens from different predators.

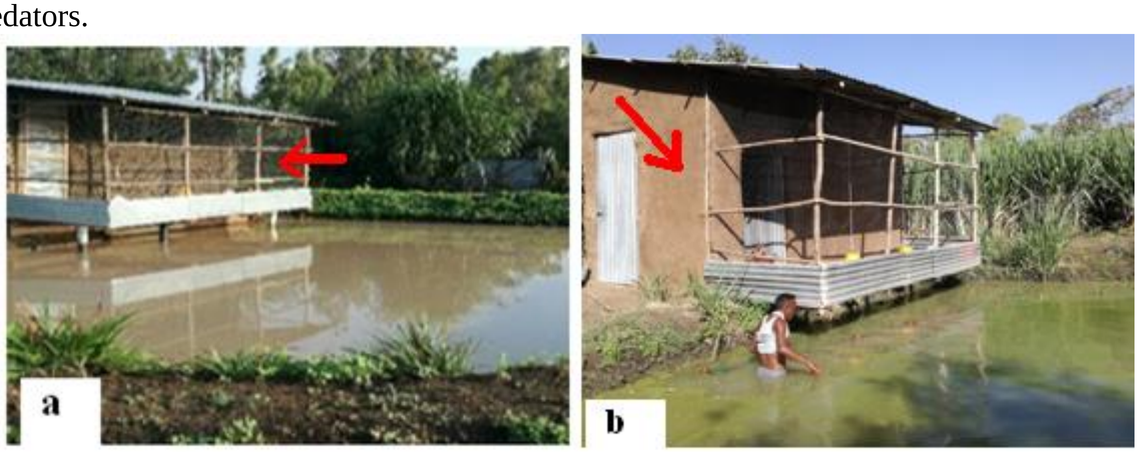

Figure 2: Constructed poultry house used for feeding and drinking during day time (a) used as a place to lay egg (b)

After the house was constructed, 30 Rhode Island Red (RIR) breed of poultry with three months of age were purchased and stocked in to the house part which is suspended on the top of the pond for egg production. The chickens are also used for the production of litter as the main feed for fish in the pond and as fertilizer for horticulture when the water is exchanged. Information on the volume of poultry litter per animal and the relation between fish and litter load is available. For this relation the reference of Hopkins and Cruz (1982) was used.

As a management, the chickens were fed with an adlib amount of commercial feed purchased from animal feed processing company in Bishoftu town. Grower phase for the chicken ranged from 9 to 20 weeks whereas the Layer phase was greater than 20 weeks. Health inspection was monitored daily throughout the experimental periods. The chicken started laying eggs at the age of 5 months. The eggs were collected every day, stored for sell, and used for household consumption in the family. Finally, aged hens were sold for meat at the local market.

Fish pond construction and production

Earthen pond of 99 m^2 surface area with 1.5 m depth and 5% slope was constructed. The pond was stocked with 500 *Oreochromis niloticus* fingerlings with stocking density of five specimens/m^2. Sizes of the stocked fingerlings were ranged from 5-6 cm total length (TL) and 3-4 g total weight (TW). The fish were grown in pond under integration farming system with the necessary management practices (environmental monitoring as well as health inspection) for six months. The litter coming out from the poultry house and dropped in to the pond are diluted with water and used as fed for the fish. The fish also used natural feed like phytoplankton and zooplankton from the pond. Finally, those fish that reached table size were harvested and used for home consumption and supplied for market as income generation for the farmer.

Horticulture production

Horticulture production activities were carried out a week after the fish and poultry were stocked. This was for the enhancement of nutrient in the pond for the production of horticulture that is directly integrated with the system. The horticulture species were Potato (*Solanumtu berosum*), Gurage cabbageand Ball-headcabbage (*Brassica oleraceavar. capitata)*. The horticulture verities were selected based on market demand, earliness of maturity and high yield performance in the area.

Procedurally the land was cleared, ploughed and then prepared for planting the horticulture at different phases on the total area of 600 m^2 for each crop. The horticultural crops were grown by water coming out of the fish pond and without adding any additional fertilizer. Management of the horticultural crops throughout the experimental period was done according to the earlier recommendations for each crop. Finally, the horticultural crops were harvested and made ready for local market and for home consumption. The remaining by-products of the crops were also used as feed for beef production.

Forage and beef production

The livestock feed Alfaalfa (*Medicago sativa*), Desho (*Pennisetum pedicellatum)* and Napier or Elephant grass (*Pennisetum purpureum)*) were planted at the edge (Dike) of the pond. The livestock feeds were also selected based on their adaption and yield performance in around the study area. Other managerial activities of the forages were conducted throughout their growing period (up to harvesting).

One cross breed bull (Holstein Frisian crossed with local breed) with an age of four years was purchased from the surrounding local market and treated for external and internal parasites with Accarcide and Albendazole, respectively.

A preliminary feeding period of 21 days was given to allow the bull adjust to the environment followed by 90 days of fattening period. The feed resources used were from the forages planted around the dike and from by-products from the horticultures. The feeds were provided adlib.

Cost of production

Major cost items incurred on poultry, fish, horticulture, forage and beef in the integrated farming system are described in Table 1.

Table 1. List of items for integrated farming system

Items	Integrated components				
	Poultry	**Fish**	**Horticulture**	**Forage**	**Beef**
Fixed cost	House Construction Feeding trough Watering trough	Pond Construction Fishing gear	Land	-	Feeding and watering trough
Variable costs	Chicken (Layer) Feeds Vaccines Labour Transport	Fingerlings Lime Labour Transport	Seeds Labour Pesticides Transport	Seeds Labour	Bull Medicament

Fixed costs: Fixed costs in the component of integrated farming system consists of those costs incurred for the construction of poultry house and fish pond, land, feeding and watering troughs as well as fishing gears as described in Table 1.

Variable costs: Variable costs were incurred for the purchase of animals, feeds, labour payment and other inputs, etc. (Table 1). Since, small-scale farmers employ only family labour for production activities cost of labour did not form an important variable cost. Transport costs were other variable costs which can be quite high if the producer lives far away from the input suppliers and the market where his products could be sold. However, this was not the case in the study area due to its proximity to the market in Bishoftu town. While feed is the major variable cost item in pond culture alone, this was not the case in the integrated system as there were no supplementary feeding for fish except poultry.

Data analysis

Fish growth performance was expressed in terms of daily growth rate using length - weight data taken monthly during the experimental period. The fish growth performance was presented in graphs. Fish, egg, horticulture, forage and fattening production data were analyzed using EXCEL and presented using tables.

Results and Discussions

Egg production
With the aim of improving poultry productivity, Rhode Island Red breed was imported to Ethiopia since 1950's (Haftu, 2016). A total of 30 pullets of 90 days of age were purchased and stocked from the local market. In the system chicken started laying eggs at the age of 20 weeks. On average a hen was laid 23eggs (76.7%) per month.
The study showed that egg laying becomes uneconomical after the chickens reach the age of 15 months (Fig.3). The production was decreased due to the physiological change of the hen.

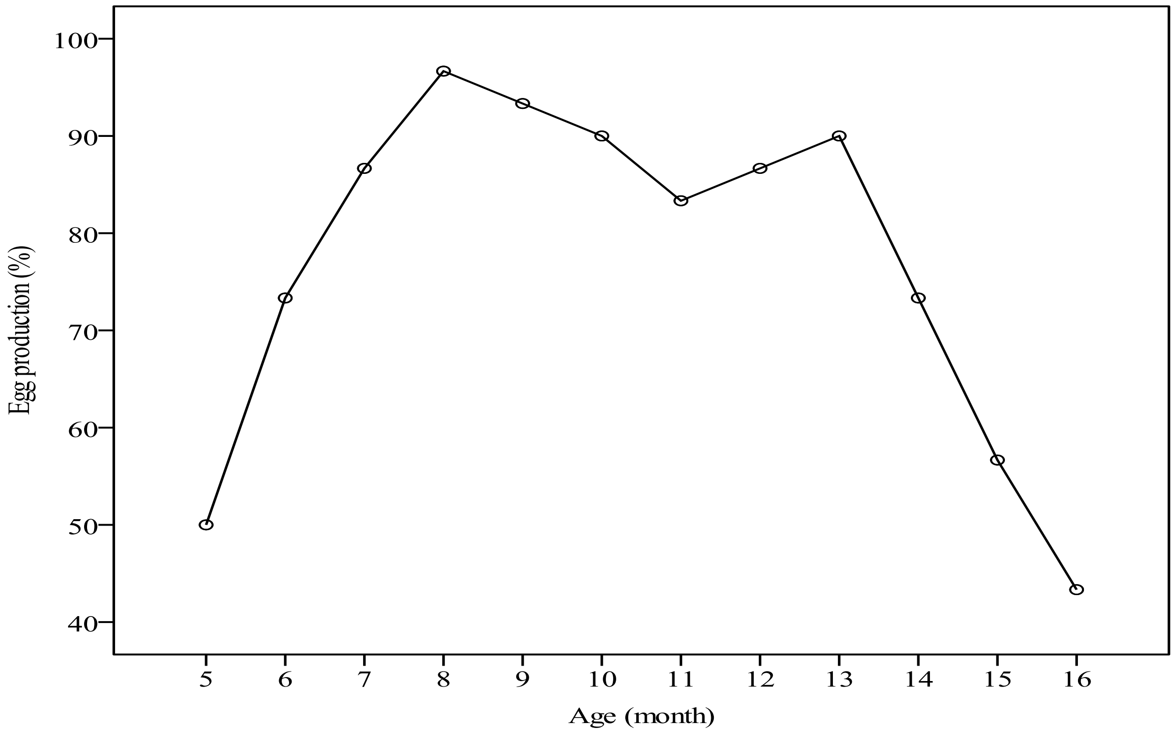

Figure 3: Trends of egg production in relation to age of the chicken

Chemical composition of the poultry litter was nutrient-rich and used as input/feed for fish production in aquaculture especially in integrated farming system with agriculture and aquaculture. The amount of poultry litter which was dropped to the fish pond contains more calcium and phosphorous which is also used for the production of horticulture as layers produce more excreta (Lemma, 2013).

Fish production
In this study, fish production totally depended on the recycling waste in the integration without the need for providing any supplementary feed. Initially 500 fingerlings of *O.niloticus* with a total initial weight that ranges from 3-4 gram were stoked. Finally the fish attained weight ranging from 110 to 305 gram, with an average of 226 gram within six months (Table 2 and Figure 4).

Table 2. Summary of fish growth performance

Initial weight range (in gram)	Final weight range (in gram)	Average weight (in gram)	Fish Daily Growth Rate (in gram)
3 - 4	110 - 305	226	0.71

The mean daily growth rate was 0.71 gram which is comparable with the work of Daba, *et al*., 2017); Negisho *et al.*, (2017), and Megerssa, *et.al*., 2016).

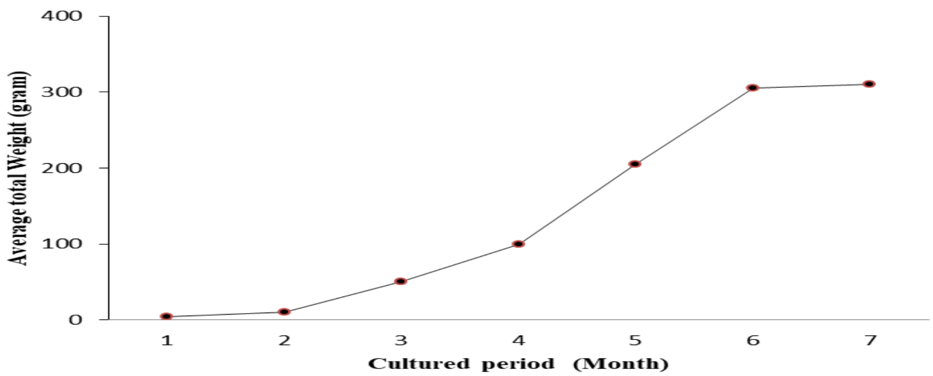

Figure 4: Average growth performance of *Oreochromis niloticus* in the system

On the other hand, the growth performance of the fish in this study was faster than the fish culture with in a pond only that reached table size in more than six months. Poultry litter has short digestive tract, 80% of chicken manure represents undigested feedstuffs (Chen, 1989). The litter was also used as fertilizer with the aim of promoting pond productivity of phytoplankton and zooplankton. In integrated poultry-fish farming, the protein rich chicken dropping was made available to the fish either directly or indirectly via the primary producers in the aquatic food web (Oladosu *et al*., 1990), which in most cases reflects the productive capacity of the ponds. It also contains non-digested feed metabolic excretory products and residues resulting in microbial synthesis which can be utilized to replace reasonable parts of feed stuff used in conventional fish production cost (Falayi, 1998; Fashakin*et al.*, 2002).

Horticulture production

The yield obtained from Potato, Gurage cabbage and Ball- head cabbage were 2200, 330 and 1700 kg /600 m^2 respectively (Table 3). The yield obtained from Potato, Gurage Cabbage and Ball- head cabbage that integrated with fish were also separately analyzed and swap over to the yield per hectare. Productivity of potato in this activity was 36,666 kg ha^{-1} (Table 3), which was higher than the national productivity of 7.2 ton ha^{-1} (Bereke, 1994). Production of Gurage Cabbage was 5,500 kg per hectare (Table 3), and the production of cabbage in this study was much higher than the production in previous studies 4400 kg ha^{-1} (Megerssa Endabu *et al.*, 2016) and 2210 kg ha^{-1}(Lemma, 2013).

Table 3. Yield of different variety of horticulture

Type of Vegetable	Plot area (in m^2)	Estimated yield (in kg)	Estimated yield (in kg ha^{-1})	Sale (in Eth. Birr)
Potato	600	2200	36,666	11,000
Gurage Cabbage	600	330	5,500	4,455
Ball- head cabbage	600	1700	28,333	5,950

The total yield of 28,333kg ha^{-1} obtained from Ball-head cabbage was less than the production of 33,800 kg ha^{-1} in previous studies (Demoz, 2016).

Forage and fattening production

All forages were grown on the top of the dike with the moisture that they get from the pond. The dry matter yield of the forages (*M. sativa*, *P. pedicellatum* and *P.purpureum*) summarized in the Table 4.

Table 4. Yield of different variety of forage

Type of forage	Plot area (m^2)	Estimated yield (kg)	Estimated yield (kg ha^{-1})
Medicago sativa	152	120	14,000
Pennisetum pedicellatum	152	141,36	9,300
Pennisetum purpureum	37.5	82.5	22,000

In general, in Ethiopia low productivity of livestock is mainly because of poor feed quality (FAO, 2010). To combat the livestock feed shortage, the use of indigenous forage plants as a feed source is recommended. The total production of *M. sativa* harvested for hay by cutting at 6 cm height at first flowering stage (Fig.5a) and the total production performance was about 14 ton/hectare dry matter per year from seven cuts. *Pennisetum pedicellatum* was harvested on 3 months after planting, that the grass reached about one meter high and yields was 22 tones (dry matter) per hectare per year (Table 4).

Figure 5: *Medicago sativa* (a), *Pennisetum pedicellatum* (b) and *Pennisetum Purpureum* (c) on the top of the dike

Pennisetum pedicellatum grass is also serves for land rehabilitation around the pond dike in addition as fodder for fattening in the integration (Figure 5b). *Pennisetum purpureum* was a fast growing; deeply rooted perennial grass that grows up 3.5 meters tall in the study area (Figure 5c). The grass is an important fodder plant in the cut-and-carry system for fattening in the area. The grass also takes many nutrients from the soil (Lukuyu *et al*., 2007). The dry matter yield of *M. sativa*, *P. pedicellatum* and *P. purpureum* were 14,000, 9,300 and 22,000 kg ha^{-1} respectively. Forage production from the integration and the byproducts of the horticulture were used as feed for beef production and the farmer can get huge profit without adding any other cost for supplementary feed (Table 5).

Partial budget analysis

The products from the integrated farms were sold to local market and also consumed at home by the family members. The monetary values of consumed products were also estimated to obtain the estimated the profitability of the farms as a source of income. Production cost and revenue generated from the products are presented in Table 5.

Table 5. Summary of partial budget analysis of fish - poultry - fattening - horticulture and forage production in the study area

Parameters	**Production cost (in birr)**	**Revenue**		**Profit (Birr)**
			Amount (in birr)	
	Fish production			
Fingerling purchase	250			
Estimated labor cost	150			
Fishing net depreciation	200			
Pond depreciation cost	300			
Total	**900**	Fish selling (120 birr/kg x 88.3Kg)	**10,596**	**9,696**
	Poultry (egg) production			
Pullets purchasing	3600	Revenue from egg production(25*30*12*3.5)	31,500	
Poultry feed purchase	13,800	Estimated value of poultry at the end of the trial (Cull out hen)	4,500	
Poultry feeders & equipment	750	Estimated value of equipment	350	
Estimated labor cost	4,800			
Poultry house depreciation	600			
Total	**23,550**		**36,350**	**12,800**
	Horticulture production			
1. Land preparation, weeding, harvesting etc for potato	1,140	Selling of potato	11,000	
Purchase of potato seed	600			
Total	**1,740**		**11,000**	**9,260**
2. Land preparation, weeding, harvesting g etc for Gurage Cabbage	900	Selling of Gurage Cabbage	4,455	
Purchase of Gurage Cabbage seedling	500			
Total cost	1,400		4,455	3,055
3. Land preparation, weeding, harvesting etc for Ball- head cabbage	1,050	Selling of Ball- head cabbage	5,950	
Purchase of Gurage Ball- head cabbage seedling	800			
Total	**1,850**		**5,950**	**4,100**
Over whole cost for horticulture	**4,990**		**21,405**	**16,415**
	Forage production			
Medicago sativa	350	Includes seed production	3000	
Pennisetum pedicellatum	150		2500	
Pennisetum purpureum	100		1000	
Total	**600**		**7500**	**6900**
	Fattening			
Bull purchase	4,000	Selling of bull	11,000	
Estimated labor cost	1,000			
Total	**5,000**		**11,000**	**6,000**
	Total cost of the whole integrated farming system			
For the whole integration	**35,040**	From the whole integration	**86,851**	**51,811**

The total farm area occupied for the whole integration system was used 1040.5 m^2 (around 0.1 hectares). The total estimated costs of fish, poultry, horticultures, forage production and for fattening were 900; 23,550; 4,990,600 and 5,000 Birr, respectively. The revenue obtained from the harvested fish, poultry, from harvested all horticultural crops, forage and from fattening were 10,596; 36,350; 21,405; 7500 and 11,000 Birr, respectively (Table 5). In general, the total cost that required to establish the farming system was 35,040 Birr and revenue generated from the system was 86,851 Birr and the total profit was 51,811 Birr (Table 5).

From the survey conducted in the the study area, the farmer didn't get more than 5,000 Birr profit from the traditional farming practice and before the technology was introduced. The huge difference in the profit was due to the fact that, in the integrated system, the waste from one commodity was used as an input for the other. Results in this study concur with the previous study undertaken using integration of three commodities, namely fish, horticulture and poultry (Lemma Abera, 2013 and Daba Tugie, *et al*., 2017)

Conclusions and Recommendations

Integrated fish farming system entails increasing the productivity of water, land and associated resources while contributing to increased fish production. This maximizes land utilization within a specific area, as it also utilizes land which would have otherwise been idle. It also makes one system of farming to benefit from the other. Fish convert plant and animal waste into high quality protein and simultaneously enrich pond mud for use as fertilizer on horticulture land.

From the study, it was concluded that the integration of different commodities (Fish, poultry, fattening, horticulture, and forage) results in the use of a waste from one component as an input for the next part so that the farming system could be an economical and viable one for improvement of the livelihood of smallholder farmers. Hence, the technology recommended that it further promoted as it was found to be one of the strategies that can be adopted by small holder farmers of the country to increase farm returns from per unit area of land.

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Adaptation Trial of Elephant Grass (*Pennisetum purpureum*) in Harari Region and Dire Dawa

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Abstract

The experiment was conducted to evaluate the biomass yield and adaptability of five accessions of Elephant grass (*Pennisetum purpureum*) at Harari Region and Dire dawa. The accessions evaluated were Acc. No. 16836, 16798, 16788, 15743 and local check in a Randomized Complete Block Design (RCBD) with three replications. The biomass yield, plant height, number of tillers, number of nods, interned length and leaf to stem ratio (LSR) were measured at 3 months of plant growth during 2017/18 and 2018/19 cropping seasons. The combined analysis result indicated in Table (1) showed that there was highly significant (P<0.01) variation among the Accessions in survival rate, plant height, dry matter yield, number of tillers and LSR across location. The results indicated that biomass yield of the accession No. 16836 (15.5ton ha^{-1}) was higher (p<0.05) than accessions No.16798 (13.77 ton ha^{-1}), 16788 (12.01 ton ha^{-1}) and local (10.25 ton ha^{-1}). The results showed that leaf to stem ratio of accession No.16836 was higher (p<0.05) than accessions No.15743, 16798, 16788 and local at Dire dawa (Adada Peasant Aassocation). At Harari Region (Harawe and Qile PAs) analyzed results indicated that biomass yield of accession No 15743 (15.12 ton ha^{-1}) was higher (p<0.05) than accessions No.16798 (13.11 ton ha^{-1}) and local (10.39 ton ha^{-1}) but similar to accession No.16788 (14.51 ton ha^{-1}) and16836 (14.50 ton ha^{-1}).The results indicated that LSR of accession No. 15743(1.94) was higher (p<0.05) than accessions No. 16836(1.74), 16788(1.55), 16798(1.36) and local(1.26) at Harari Region. It was concluded that the accessions No.16836 and 15743 were found promising to be demonstrated along with the previously adapted local accessions in Dire Dawa (Adada PA) and under climatic conditions similar to Dire Dawa. Also, it was concluded that the accessions No. 15743, 16788 and 16836 were found promising to be demonstrated along with the previously adapted local accessions in Harari Region and under climatic conditions similar to Harari Region (Harawe and Qile PAs).

Keywords: *dry matter yield, elephant grass accession, leaf to stem ratio*

Introduction

Livestock in Ethiopia is mainly of smallholder farming system with an animal having multi-purpose use and contributes about 16.5% of the national Gross Domestic Product (GDP) and 35.6% of the agricultural GDP (Sintayehu, 2017). It also contributes 15% of export earnings and 30% of agricultural employment (Behnke, 2010, Sintayehu, 2017). Ethiopia has large livestock population and diverse agro ecological zones suitable for livestock production. However, livestock production has mostly been subsistence oriented and characterized by low reproductive and production performance. This is mainly attributed to shortage of feed in quality and quantity (Malede, 2013).

The main feed resources for livestock in Ethiopia are natural pasture and crop residues, which are low in quantity and quality for sustainable animal production (Alemayehu, 2004). This results in low growth rates, poor fertility and high mortality rates of ruminant animals (Odongo *et al*., 2002). A large proportion of livestock feed resources in Ethiopia are natural pastures, crop residues and aftermath grazing (Adugna, 2008; Getnet, 2012). These feed resources cannot support higher animal productivity due to their nutritional limitations. The major constraint to such low productivity is shortage of livestock feeds in terms of quantity and quality, especially during the dry season (Ahmed *et al*., 2010). 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 (Kahindi *et al*., 2007; Tessema *et al*., 2010a, b)

Different strategies were used to correct the nutritional limitations of these feed resources. One of such strategies that has been receiving recognition and considered as the best option is the use of improved forage species. The integration of improved forage crops in agricultural systems has many advantages including soil conservation, weeds, pests and diseases control besides to their primary use as high quality animal feeds (Getnet, 2012). Forages are essential in animal production systems hence the most important feed as a substitute for concentrates normally used for feeding livestock. In fact, forages were certainly known as a cost effective feed rather than commercial concentrate. The substitution of forage to concentrate from 30 to 70% in dairy cattle diet could reduce up to 30% cost of production (Sanh *et al*., 2002). The ideal pasture and fodder species were high yielding and palatable, and contain adequate levels of highly digestible nutrients to satisfy the requirements of livestock (Kisitu, 2010). Elephant grass originates from sub-Saharan tropical Africa (Clayton *et al*., 2013) and has been introduced in most tropical and subtropical regions worldwide as forage. Elephant grass also called merker grass, Napier grass, Uganda grass and by several other names in different parts of the world. It carries the name Napier grass to recognize the contribution of Colonel Napier of Rhodesia who first wrote to the Rhodesian Agricultural Department to make them aware of the value of this plant.

Characteristically, Napier grass is vigorous and highly productive forage, which can withstand long periods of drought (Lowe *et al*., 2003; Tessema, 2005). Although little or no growth takes place during these drought periods, it rapidly recovers with the onset of rains (Mwendia *et al*., 2006; Wijitphan *et al*., 2009) and can survive in drought for more than five years (Woodard *et al*., 1991). It is a tall, stout and deep rooted perennial bunch grass well known for its high yielding capability and value as forage for livestock with good agronomic practices (Woodard *et al*., 1991). Moreover, Napier grass is an erect and tall perennial grass up to 5m heights with prolific tillering ability after cutting or grazing and adaptive to well-drained fertile soil. Napier grass is superior to other tropical grasses in terms of dry season growth and forage quality (Odongo *et al*., 2002; Wijitphan *et al*., 2009) and can support large tropical livestock units per hectare (Muia *et al*., 2001). It also performs well in low, mid and highland areas of Ethiopia (Tessema, 2005, 2008). Elephant grass (*Pennisetum purpureum*) has become by far the most important species due to its wide ecological range of adaptation (from sea level to over 2,000 meters), high yield and easy of propagation and management (ILRI, 2010a; ILRI, 2013).

Napier grass can provide a continual supply of green forage throughout the year and best fits i n intensive small scale farming systems with appropriate management practices in Ethiopia (T essema, 2005, 2008; Tessema *et al*., 2010b). Napier grass (*Pennisetum purpureum*) has been the most promising high-yielding fodder, giving dry matter yields that surpass most other tropical grasses (Ansah *et al*., 2010). The objective of this work was to select the high biomass yield, high quality and most adaptable elephant grass accessions to the study areas.

Materials and Methods

Description of the study area

The study was done on farm at Harari Regional state and Dire Dawa administration town which are far 518 km and 510 km from Addis Ababa respectively which is 1500 m.a.s.l and annual rainfall 650-900mm. Layout system is randomized complete block design (RCBD) with three replications.

Data Collection and Measurement

- Survival rate
- Plant height
- Number of tillers per plant
- Number of nods
- Nod length (inter nod length)
- Biomass yield (Dry matter bases)
- Leave to stem ratio

Source of Planting Materials and Experimental Design

Four accessions of Elephant grass (*Pennisetum purpureum*) were brought from Fadis Agricultural Research center and one local were planted at Harari Region (Harawe & Qile PAs) and Dire Dawa (Adada PA) for performance evaluation. The Elephant grass accessions used as treatments were Acc. No.16836, 16798, 15743, 16788 and local check with Randomized Complete Block Design (RCBD) with three replications. Local check was the previously adopted at farmer's conditions and used as a control to compare the performance of other accessions in the study area. The plot size was 2.5mx3m with four accessions (5) of elephant grass. A single plot of 2.5m x 3m (7.5m^2) containing 6 rows, each row 0.5m apart and plant spaced 0.5m within rows. The spaces between replications and plots were 1.5m and 1.0m respectively and the total area of experiment was 10.5m x 19m (199.5m^2).

Land Preparation and Planting

A total area of 10.5m x 19m (199.5m^2) plot was ploughed and harrowed with Oxen. The field was divided in to fifteen (15) plots with each plot measuring 7.5m^2. The parent plants were cut into stems with three nods per cutting for planting. The cuttings were planted one and half nods in the soil at an angle of about 40°C. Plant population per plot were 42 (3m/0.5m*6 rows) and plant population per accessions were 126 (42 plants*3reps).

Dry Matter Yield Determination

An area of 1.5m^2 (1mx1.5m) was randomly selected and harvested with a sickle at a height of 15cm above the ground. The total harvest per plot of fresh forage was weight and about 500g of sub samples taken from each plot and chopped in short lengths (2-4cm) for dry matter determination using AOAC (1990) procedure. This involves drying in an oven at 105°C overnight. The dry matter (DM) yield of each accession at each plot was calculated on dry matter basis by multiplying the percentage dry weight of the sub-samples from the whole fraction to the fresh weight of the respective accessions at each plot per $1.5m^2$ and converted to hectares.

Height and Leaf to Steam Ratio (LSR) Determination

The height of plant at each plot was measured by measuring all the samples harvested for DM yield determination and the average height of all the plants was taken as a height of plant at each plot. LSR of Napier accessions at each plot was measured by the fraction of weight of leaf of plants sampled for herbage yield determination to the weight of stem of plants sampled for herbage yield determination.

Statistical Analysis

Data were analyzed using the Statistical Analysis Software (GenStat 15th Ed.) in a randomized complete block design. Means of all treatments were calculated and the difference was tested for significance using the least significant difference (LSD) test at $p < 0.05$ (Gomez and Gomez, 1984).

Results and Discussion

Effect of Accessions on survival rate, Plant height, Biomass Yield, Number of Tillers and LSR

The result of combined analysis indicated that there was highly significant (P<0.01) variation among the accessions in survival rate, plant height, dry matter yield, number of tillers and LSR across location (Table 1). The analysis was performed separately for the two locations and interpreted separately.

Table1. Morphological characteristics of Napier grass accessions harvested at three (3) months of grown in Harari Region (Harawe & Qile PAs) and Dire Dawa (Adada PA) from 2017/18-2018/19 cropping seasons

Source of Variation	Mean squares							
	df	SR (%)	PHt(cm)	Dm yield	NT	NNP	NL	LSR
Year	1	4392.31*	565.6ns	78.76*	95.63*	27.92*	6.80ns	0.02ns
Location	2	722.67**	11839.2**	16.70**	117.23**	26.48**	124.92**	0.45**
Trt	4	1673.7**	1681.2*	52.84**	11.76**	17.136**	30.9**	1.35**
Rep	2	41.5ns	290.9ns	3.24ns	0.04ns	0.58ns	1.167ns	0.07ns
Interaction (Trt*Loc*year)	4	496.01**	1874.0*	7.0**	8.65*	12.25**	10.60*	0.40ns
Error	48	25.1	612.2	0.74	2.63	1.76	2.81	0.02
Total	74							

Key: **=highly significant,*=significant, ns=non significant, df=degree of freedom, Trt= treatment, Rep= Replication, Loc= Location, DM=dry matter, SR=survival rate, PHt=plant height, NT=number of tillers, NNP=number of nod per plant, NL=nod length, LSR=leave to stem ratio

Table 2. Means of Biomass yield (DM bases), Survival rate, Plant height, No of tillers, No of nods, Nod length and LSR obtained from Elephant grass Accessions during 2017/18 and 2018/19 Cropping season at Dire Dawa (Adada PA)

Treatments	SR (%)	PHt(cm)	BMY/ton	NT	NNP	NL	LSR
16836	85.07b	81.77ab	15.5a	12.20a	4.63ns	11.69b	2.21a
15743	92.53a	96.10a	14.7ab	11.38ab	5.33ns	10.10c	1.86b
16798	76.83c	75.44b	13.77b	10.33ab	4.69ns	11.04bc	1.70b
16788	96.02a	88.28ab	12.01c	11.58ab	6.31ns	10.66bc	1.30c
Local	72.83c	90.5ab	10.25d	9.25b	6.73ns	13.05a	1.22c
CV (%)	**6.7**	**15.6**	**7.1**	**18.2**	**29.3**	**8.8**	**8.4**
LSD (0.05)	**9.79**	**23.07**	**1.61**	**3.41**	**2.78**	**1.71**	**0.24**

Key: ns = non significant, DM=dry matter, SR=survival rate, PHt=plant height, NT=number of tillers, NNP=number of nod per plant, NL=nod length, LSR=leave to stem ratio

Table 3. Means of Biomass yield (DM bases), Survival rate, Plant height, No of tillers, No of nods, Nod length and LSR obtained from Elephant grass Accessions during 2017/18 and 2018/19 cropping season at Harari Region (Harawe & Qile PAs).

Treatments	SR (%)	PHt (cm)	BMY/ton	NT	NN	NL	LSR
15743	77.32b	71.36b	15.12a	8.83a	2.37c	10.25b	1.94a
16788	88.21a	116.27a	14.51a	8.58ab	5.31a	14.09a	1.55c
16836	85.37a	74.76b	14.5a	9.78a	2.81c	11.21b	1.74b
16798	85.71a	97.33ab	13.11b	7.39b	4.07b	13.75a	1.36d
Local	56.89c	89.22ab	10.39c	5.56c	4.89ab	14.56a	1.26d
CV (%)	**5.9**	**32.8**	**6.2**	**17.1**	**28.8**	**15.7**	**9.4**
LSD (0.05)	**5.83**	**36.72**	**1.04**	**1.71**	**1.396**	**2.499**	**0.18**

Effect of Accession on Biomass Yield: The DM yield of the accession No. 16836 was higher ($p<0.05$) than accessions No. 15743, 16798, 16788 and local check. Also, accessions No. 15743 was higher ($p<0.05$) than accession No. 16788 and local check. Accession No.16788 was higher ($p<0.05$) than local check but lower dry matter yield than the improved accessions. Accession No.16836 recorded highest (15.5 ton ha^{-1}) and local recorded the lowest (10.25 ton ha^{-1}) biomass yield respectively.

Effect of Accession on Survival Rate, Plant Height and Leaf to Stem Ratio: The height of accession No.15743 was higher ($p<0.05$) than accession No.16798 but similar to accession No. 16788, 16836 and local check at three months of harvesting (Table 2). In the present study, the minimum height was found in accession No. 16798 (75.44 cm) while the maximum height was found in accession No. 15743 (96.1cm) which was statistically similar to accession No. 16788, 16836 and local but numerically different. This result was different from Getnet (2003) that reported at 2 months of age all Napier grass accessions attained the optimum plant harvesting stage (1-1.5m) for forage which might be due to varietal difference and the work performed in the highland areas (moisture content).
The survival rate of accession No.16788 was higher ($p<0.05$) than accession No.16836, 16798 and local check but similar ($p>0.05$) with accession No.15743 (Table 3).The highest and lowest result was recorded from accession No.16788 (96.02%) and local check (72.83%)

respectively in survival rate. The LSR of Napier grass accession No. 16836 was higher ($p<0.05$) than accessions No. 15743, 16798, 16788 and local check. This indicating that accession No.16836 contained higher nutrients than others and the performance of animals is closely related to the amount of leaf in the diet because leaf is generally of higher nutritive value than stem (Tudsri *et al.*, 2002). In the present study, the LSR ranging from 1.22 (local check) to 2.21 (accession 16836) were different from the range of ratios reported by Deribe *et al*. (2017) who reported that 0.31 to 1.01 was might be due to varietal differences of Napier grass.

Conclusion

Elephant grass (*Pennisetum purpureum*) is vigorous and highly productive forage, which can withstand long periods of drought. Elephant grass has become by far the most important species due to its wide ecological range of adaptation (from sea level to over 2,000 meters), high yield and easy of propagation and management. The Elephant grass accession No.16836 and 15743 were performed better in terms of biomass yield (dry matter bases) and leaf to stem ratio in Dire Dawa (Adada PA). In Harari Region (Harawe & Qile PAs) Elephant grass accession No. 15743, 16788 and 16836 were out performed than other accessions and local check in terms of biomass yield (dry matter bases), leaf to stem ratio and other parameters. With its performances by considering parameters in field at Harari Region accessions No. 15743, 16788 and 16836 were selected as candidate to be further distributed for local farmers but at Dire Dawa accessions No.16836 and 15743 were performed better than other tested accessions and selected as candidate to be further distributed for farmers.

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Adaptation Trial of Improved Forage Legumes: The case of cowpea and Lablab

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Abstract

The experiment were conducted by Fadis Agricultural Research Center in 2017/18 and 2018/19G.Cconsecutive years on-farm in Harari (Qile Peasant Association) and Dire Dawa(Adada PA) with three cowpea[(V.unguiculata (L.check), V.unguiculata (9334) and V.unguiculata (9333)] and three lablab(Gebis-17, Beresa-55 and Local check)selected varieties that introduced from Bako Agricultural Research Center and local checks obtained from farmers which were laid out in a randomized complete block design with three replications based on the objective of selected and recommended high quantity and better yielding and adaptable varieties to the area and the same agro-ecologies.The analyzed result showed in above ground dry biomass and grain yields of cowpea were a significant different ($p < 0.05$) over locations and over year among varieties.The highest above ground dry biomass of cowpea (9334) (6.42 t ha^{-1}) during 2017/18 at Harari (Qile PA) and the minimum was obtained from T3 (0.89 t ha^{-1}) during 2018/19at Dire Dawa (Adada PA).There was statistically significant difference ($p<0.05$) among varieties of lablab dry matter herbage yield at Harari (Qile PA) and at Dire Dawa(Adada PA). During the first and second growing years, highest dry matter herbage yield of 19.44 t ha^{-1}, 9.74 t ha^{-1} which was obtained from variety lablab Beresa-55 (T3) at Harari (Qile PA) and Dire Dawa respectively.

Keywords: cowpea, forage legumes, lablab, quantity forage

Background and Justification

In many developing countries, livestock play an important role in most small-scale farming systems. They provide traction to cultivate fields, manure to maintain crop productivity, and nutritious food products for human consumption and income-generation (Sere et al 2008). For instance, livestock production is an important component of the Ethiopian economy with an overall contribution of about 20% to the gross domestic product (GDP) and 40% to the gross value of annual agricultural output.

Agriculture dominates the economies of developing countries and in these countries the livestock sector is the fastest growing agricultural sector (3.77% for livestock *vs.* 2.71% for crops in last decade). In 2020, consumers in developing countries will eat 87% more meat and 75% more milk than they do today making livestock production the largest share of the value of global agricultural output (FAO 2005)**.** Animal feeding systems in Ethiopia are mainly based on grazed native pastures, which are deteriorating in production and quality, which vary seasonally resulting in poor animal performance. Despite the importance of livestock, inadequate livestock nutrition is a common problem in the developing world, and a major factor affecting the development of viable livestock industries in poor countries (Sere et al 2008).

Legumes are the most important forage plants that substantially improve the feed available for livestock as they can provide the essential protein for animals, improving soil fertility food crop production and household nutrition through a more reliable supply of milk and meat (Alemayehu, 1997

Grain legumes provide food and feed and facilitate soil nutrient management. Herbaceous and tree legumes can restore soil fertility and prevent land degradation while improving crop and livestock productivity on a more sustainable basis. Thus the adoption of such dual-purpose legumes, which enhance agricultural productivity while conserving the natural resource base, may be instrumental for achieving income and food security, and for reversing land degradation. In particular the integration of legumes into cereal-based systems can provide services such as high quantity and quality fodder production, soil erosion prevention, and soil fertility restoration. Enhanced availability of livestock feed can reduce degradation of grazing lands. The demand for forage and the opportunities for diffusion of forage technology may be high where livestock response to improved feed technology and profitability from livestock enterprise is high. Farmers are responsive to the amounts of economic incentives provided by the new technology (Stevens and Jabara 1988).

Cowpea (*Vigna unguiculata*) is a leguminous forage crop. This could be grown in relatively infertile sandy soils. It is a fast growing, drought resistant crop, which also improves soil fertility by fixing atmospheric nitrogen. Cowpea forage is usually superior to other forage legumes in terms of both quantity and quality. Cowpea crop is grown as a green manure and also a cover crop to increase soil fertility, retain moisture and reduce soil erosion (Koralagama, K. D. N. et al. 2002). Cowpea is among the most widely used legumes in the tropical world. They can incorporate into cereal cropping system to address soil fertility decline and cereals to provision of better legume/Stover to cereal (Cook et al., 2005).

Food production systems, particularly in cropping systems with limited external inputs, this may be due to some of the potential benefits for intercropping systems such a high productivity and profitability (Yildirim and Guyenc, 2005), and there is a big market for the sale of cowpea grain and fodder in West Africa. A farmer who cut and store cowpea fodder for sale at the peak of the dry season Cowpea can be grown under rain fed conditions as well as by using irrigation or residual moisture along river or lake flood plains during the dry season, provided that the range of minimum and maximum temperatures is between 28 and 30°C (night and day) during the growing season. Cowpea performs well in agro ecological zones where the rainfall range is between 500 and 1200 mm/year (Madamba et al., 2006).
Lablab (*L. purpureus*) is an herbaceous, climbing, and warm season annual or short-lived perennial with a vigorous tap root. It has a thick, herbaceous stem that can grow up to 3 feet, and the climbing vines stretching up to 25 ft from plant (Valenzuela and Smith, 2002).
Objective: To select and recommend high quality and quantity yielding and adaptable legumes (cowpea & lablab) varieties

Materials and Methods

Description of the study area

The study were conducted on farm at Harari Regional state and Dire Dawa administration town which are far from 518 km and 510 km Addis Ababa respectively which is 1500m.a.s.l and annual rainfall 650- 900mm.

The experiment was laid out in randomized complete block design (RCBD) three replications. The plot size is 3x2m^2 was used three (3) varieties of cowpea and three (3) varieties of lablab.

A seed rate of 30kg/ha was used by keeping 40cm row-to-row spacing and 20cm between plants. Fertilizer NPS (19% N, 38% P_2O_5 and 7% S) and Urea (46% N) each at the rate of 100 kg ha^{-1}. NPS during planting and Urea after plants emerged 2-3 leaves were used.

Data Collection and Measurement

Days of emergency
Days of 50% flowering
Plant Height
Pod per plant
Seed per pod
Green fodder yield
Grain yields

Statistical Analysis

Data were analyzed using the Statistical Analysis Software (SAS 9.1). Means of all treatments were calculated and the difference was tested for significance using the least significant difference (LSD) test at $p < 0.05$ (Gomez and Gomez, 1984).

Results and Discussion

Days to Flowering, Maturity and biomass Yield (Drymatter bases) of Cowpea

Days to flowering and days to maturity obtained from the cowpea varieties sown during the consecutive two years were presented in Table 2were found significant ($p<0.05$) deferencein different location in different years except in 2018/19 at Dire Dawa (Adada PA) for Df 50% and at Harari (Qile PA) in both years for days to maturity. The late Days flowering obtained under cowpea 9334(T2) and T3 at Harari (Qile PA) (94 days) and days to maturity (132.99 days) were cowpea 9333(T3) at Harari in 2018/19 year. The early flowering (40.87days) and maturity (125 days) cowpea 9333(T3) in 2018/19 at Adada location

Table 1: Analysis of variance (ANOVA) of Cowpea varieties

Source of Variation	DF	Mean squares						
		plt h(cm)	Df (50%)	Dm	AGBY t/ha	P/P	Dry wt(t/ha)	s/p
Year	1	3882.12*	225.0*	294.69*	55752.96**	54.67ns	94.12**	40.48ns
Loc	1	11685**	11165.44**	5064**	1729.59**	440.72*	22.67**	13.94*
Trt	2	1085.1ns	248.86**	200.03*	43.48*	659.98**	0.678	20.04ns
Rep	2	1116.18ns	13.36ns	10.03ns	166.06ns	40.47ns	2.13ns	7.36ns

Table 2: Mean of fresh biomass yield, plant height, dry grain yields obtained from the cowpea varieties sown during the consecutive two yearsat kile and Adada

Harari (Qile PA)2017/18								
Treatments	plt h(cm)	Df (50%)	Dm	AGBY t ha^{-1}	P/P	Dry wt(t ha^{-1})	s/p	Gy
T1	65.00ab	90.67a	124.22	23.35b	22.99	2.54b	9.87b	9.89
T2	71.67a	88.00b	124.1	34.07a	31.56	3.92a	11.2a	10.12
T3	59.00b	87c	123.99	18.71b	26.11	1.92b	10.93a	8.79
CV (%)	11.75	2.24	0.93	29.22	25.79	28.5	2.88	12.64
LSD (0.05)	9.56	2.84	Ns	9.25	Ns	0.99	0.38	Ns
Dire Dawa (Adada) 2017/18								
T1	38.33b	64.33c	105.67b	4.89b	18.91	0.99b	6.64	7.67
T2	50.00a	83.33a	123.33a	9.77a	15.12	1.56a	6.87	7.33
T3	31.67b	71b	108.67b	3.55b	14.64	0.89b	5.99	6.67
CV (%)	21.18	3.95	4.62	18.16	16.12	12.67	13.6	18.15
LSD (0.05)	10.57	3.59	6.49	3.92	Ns	0.41	Ns	Ns
Harari (Qile)2018/19								
T1	96.57b	91.33b	134.22	40.22b	19.99b	4.85b	9.87b	10.89
T2	100.58a	94a	130.1	44.89b	21.56a	6.42a	11.2a	11.34
T3	94.43b	94a	132.99	50.53a	19.11b	5.09b	10.93a	12.79
CV (%)	25.72	1.66	1.93	21.34	12.56	21.52	2.88	12.64
LSD (0.05)	3.56	2.64	Ns	5.25	1.66	1.32	0.38	Ns
Dire Dawa(Adada) 2018/19								
T1	50.4b	60	125	40.09	14.67	4.04c	10.2	8.77
T2	57.78a	65	125	33.49	18.33	4.84a	8.93	9.43
T3	40.87c	60	125	36.8	12.67	4.44b	9.13	7.62
CV (%)	8.21	3.95	4.62	17.59	16.12	17.66	9.29	22.15
LSD (0.05)	5.08	Ns	6.49	3.92	Ns	0.41	Ns	Ns

Means with the same letter in the same column are not significantly different ($p<0.05$), Df= days to 50% flowering, plth(cm) = plant height, T1 = cowpea (local check), T2=cowpea(9334), T3=cowpea(9333), Dm=days to maturity, FBY(t ha^{-1})=fresh biomass yield, P/P=no of seed per pod, Dry wt(t ha^{-1})= dry weight, s/p=seed per pod, Gy (q ha^{-1}) = grain yield quntal per hectar

The dry matter yield of cowpea was significantly different ($P<0.05$) for the first and second growing years. During the first growing year, highest dry matter yield of 3.92 t ha^{-1}, 1.56 t ha^{-1} which was obtained from variety cowpea (9334) (T2) at Harari (Qile PA) and Dire Dawa respectively. During the second growing year, cowpea (9334) (T2) produced highest dry matter yield of 6.42 t ha^{-1} and 4.48 t ha^{-1}at Harari (Qile PA), and Dire Dawa (Adada PA) respectively. In all the two consecutive growing years, 9334 was found outstanding in dry matter yield in (Table 2). The grain yield across all the experimental years varied between 6.67 and 12.79 quintal ha^{-1} with a mean of 9.28 quintal ha^{-1}, but was not significant differences ($p>0.05$) among varieties of cowpea and location.

Days to Flowering, Maturity and Dry Biomass yield of Lablab

Days to flowering and days to maturity obtained from the lablab varieties sown during the consecutive two years were presented in Table 4 were found significant ($p<0.05$) deference in different location at Dire Dawa (Adada PA) for Df 50% and at Harari (Qile PA) but non-significant among planting years for days to maturity and flowering. The late Days flowering obtained under lablab Beresa-55 (T3) at Harari (Qile PA) (105 days) flowering and days to maturity (185 days) were lablab Beresa-55 (T3) at Harari, at Dire Dawa lablab Beresa-55 (T3) (109 days) flowering and days to maturity (171.83 days). The early flowering (85.67days) and maturity (15583 days) local check (T1) at Adada PA of Dire Dawa location

Table 3: ANOVA of lablabvarieties that show the mean squares of factorials'

Source of Variation	Mean squares					
	DF	plt h (cm)	Df (50%)	Dm	AGBY (t/ha)	Dry wt(t/ha)
Year	1	17147.47**	4761.00**	3.36ns	534.09ns	8.12ns
Loc	1	64219.16**	10138.78**	3461.36**	12385.83**	250.80*
Trt	2	634.95ns	2070.58**	41.58ns	1518.5*	55.21*
Rep	2	324.16ns	52.00ns	158.33ns	1470.55ns	51.67ns

Table 4: Mean of fresh biomass yield, plant height, dry grain yields obtained from the cowpea varieties sown during the consecutive two years at kile and Adada

Harari(kile PA) in2017/18 and 2018/19					
Treatments	plt h(cm)	Df (50%)	Dm	FBY t/ha	Dry wt (t/ha)
T1	181.67b	105	185.00a	84.38b	13.19c
T2	186.67ab	102.25	176.67c	106.6a	16.22b
T3	203.33a	105.33	178.33b	116.31a	19.44a
CV (%)	**12.56**	**2.24**	**0.93**	**13.82**	**15.04**
LSD (0.05)	**20.16**	**Ns**	**0.69**	**10.7**	**2.04**
Dire Dawa(Adada PA)2017/18 and 2018/19					
T1	64.06b	85.67b	155.83b	28.25b	5.95b
T2	92.10a	107.50a	170.17a	43.34a	9.07ab
T3	92.49a	109.00a	171.83a	48.63a	9.74a
CV (%)	**19**	**3.95**	**5.35**	**25.16**	**26.67**
LSD (0.05)	**13.11**	**16.74**	**6.49**	**17.74**	**3.76**

Means with the same letter in the same column are not significantly ($p<0.05$) differentFBY=fresh weight biomass yield ton per hectare, T1=Lablab (L.check), Gebis-17, T2=T3=Beresa-55

The dry matter herbage yield of lablab was significantly different ($P<0.05$) at Harari (Qile PA) and at Dire Dawa (Adada PA). During the first and second growing years, highest dry matter herbage yield of 19.44 t ha^{-1}, 9.74 t ha^{-1} which was obtained from variety lablab Beresa-55 (T3) at Harari (Qile PA) and Dire Dawa respectively. Lowest dry matter herbage yield of 13.19 t ha^{-1} and 5. 95 t ha^{-1} was obtained from local check of lablab (T1) at Harari (Qile PA) and Dire Dawa, respectively.

Plant height oflablab was significant ($p < 0.05$) different across location and during cropping consecutive years. The maximum plant heights were recorded from lablab (Beresa-55) (T3)203.33cm at Harari region, Qile PA and Gebis-17 (92.10cm), Beresa-55 92.49cm at DireDawa. The minimum was recorded from Lablab (Local check (181.67 cm) and 64.06 cm at Harari and Dire Dawa locations respectively.

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Demonstration of cattle fattening and related initiatives at Bako Tibe, Guto Gida and Wayu Tuka districts, West Oromia, Ethiopia

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Abstract

Ethiopia has the largest livestock population in Africa. Despite the huge cattle population in the country, most of the beef is produced under an extensive low input system, in conjunction with crop and small ruminant production. In Ethiopia, there is no specialized beef production system; rather beef is a by-product of the pastoral and mixed crop-livestock production systems. The average Ethiopian beef yield per animal of 135 kg is by far less than 146 kg for Africa, and 205 kg for the whole world. Ethiopians remain slightly below the average meat intake of all low-income countries and consume on average eight kg of meat per capita annually. To alleviate these situations much work is required and the present work was implemented to contribute to the development of the livestock meat sector in Ethiopia. However, instead of demonstrating the fattening technologies only initiatives associated with cattle fattening were also demonstrated. Hence, the present work was executed to achieve two objectives: (1) to demonstrate cattle fattening technologies and highlight associated issues for future considerations in Bako Tibe, Wayu Tuka and Guto Gida districts of western Oromia region and (2) to document existing practices in the area of biogas production and use of the slurry as bio-fertilizer. The kebeles and specific villages within the three districts were Bako Tibe district: Sadan kite kebele, Jage village; Guto Gida district: Madda Jalala kebele, zone six villages; Wayu Tuka district: Wara babo kebele, Guliso village. The fattening technologies demonstrated were supplementation of concentrate feeds that included ground maize grain as energy sources, noug cake as protein sources and table salt as mineral sources with the proportion of 49.5%, 49.5% and 1%, respectively. The highest total revenue was obtained from Wayu Tuka district followed by Guto Gida. The net profit per animal per fattening cycle was calculated to be ETB 1300.00 assuming equal variable costs for all the study sites. The net profit realized in the current work was smaller than the findings elsewhere and all possible corrections should be done. At the time of writing this paper, about 90% of the biogas construction was completed and it is recommended to discuss with respective districts dealing with these issues to finalize them.

Keywords: bio-fertilizer, biogas, cattle fattening

Introduction

Meat is an important part of the human diet worldwide with strong implications on health, environment and socio-economy (Dario et al., 2016). It is a highly nutritious food, particularly in terms of supplying high quality protein (essential amino acids), minerals (especially heme iron and zinc) and vitamins (De Smet and Vossen, 2016). In Ethiopia, meat plays a vital role in daily human nutrition, and its cultural symbolic weight is markedly greater than most other foods (Semeneh et al., 2013). However, Ethiopians remain slightly below the average meat intake of all low-income countries and on average consume eight kg per capita annually (Tafere and Ibrahim, 2012; Eyob and Zewudu, 2016). Accordingly, the Ethiopian livestock development master plan and strategy are aiming at stimulating meat consumption by increasing meat production in the country by expanding commercial supply. The forecasted annual per capita consumption of red meat for Ethiopia, for 2020, is between 14.5 kg and 19.1 kg whereas production is presumed to be enhanced by 52% (Shapiro et al., 2015). In line with this, the country's second Growth and Transformation Plan (GTPII), primarily focuses on red meat (beef, goat, and sheep) production as one of the priority intervention areas within the current five years' plan (LMP, 2015). The plan considers that investment in red meat production on family farms offers opportunities to enhance nutritional security, job creation for youth, industrial output and export earnings.

Pastoral, agro-pastoral and mixed crop-livestock production systems accounted for more than 99% of cattle production system practiced in the country (Negassa *et al*., 2011). In Ethiopia, there is no specialized beef production system (Mengistu et al., 2016). Beef is a majorly the products of pastoral production system and by-product of the mixed crop-livestock production systems as cattle are primarily kept for milk and traction, respectively. Cattle are usually slaughtered in poor body condition when they are culled from dairy purpose or too old for draught purpose (Mengistu et al., 2016).

In both rural and urban areas, smallholder cattle fattening is emerging as an important source of income. In rural Ethiopia, cattle fattening is based on locally available feed resources (Takele *et al.,* 2009; Harko, 2015). The mixed crop-livestock production system is based on limited communal and/or private grazing areas and the use of crop residue and stubble. The pastoral production system is based on extensive communal grazing while agro-pastoralists are characterized by a combination of both pastoral and mixed crop-livestock production (Takele *et al.,* 2009).

Ethiopian market provides about 45% of all domestic meat consumption with small surplus, which generates export income mainly from the sale of live animals. However, the earning from export of live animals and processed meat is very small as compared to the potential of the country. Ethiopia has the largest livestock population in Africa with 59.5 million cattle, 30.70 million sheep, 30.2 million goats and 59.5 million poultry (CSA, 2017). Despite the huge cattle population in the country, the benefit in terms of beef is minimal as most of the beef is produced under an extensive production system in conjunction with crop and small ruminant production with low input (SPS-LMM, 2011; Gezu *et al*., 2014).

Cattle fattening practices in Ethiopia are categorized into three major fattening systems, namely, traditional system, by-product based system and the Hararghe fattening system (MOA, 1997; Teshager *et al*., 2013). The average Ethiopian beef yield per animal is 135 kg, which is by far less than 146 kg for Africa, and 205 kg for the whole world (Negassa *et al.*, 2011; Yesihak and Webb, 2015; Zekarias, 2016). Ethiopians consume about eight kg of meat per capita annually, which is far less than what is consumed in developing countries (Sebsibe, 2008; Yesihak and Webb, 2015). To improve this scenario, looking for different best feeding practices for local bulls in different parts of Ethiopia in general and in Oromia in particular has paramount important to attain the desired market weight and carcass quality at an earlier age.

Instead of demonstrating a cattle fattening technology alone, additional technologies are believed to have links with the cattle fattening and were planned to be demonstrated. For instance, biogas and bio-fertilizer technologies were proposed to be demonstrated with the cattle fattening technology in Bako Tibe district.

Biogas is a flammable gas produced when organic materials are fermented under anaerobic condition. It contains methane and carbon (IV) oxide with traces of hydrogen sulphide and water vapor. It burns with pale blue flame and has a calorific value of about 30 J/m^3 depending on the percentage of methane in the gas. Digester is high quality organic fertilizer (nutrients, humus). One of the renewable energy sources is biogas. These gases are derived from a wide range of organic wastes such as biomass waste, human waste, animal waste through the process of anaerobic digestion and it can be used as energy (https://www.britannica.com/technology/biogas).

Organic compounds decompose under anaerobic condition to yield biogas. Research results showed that differences in the production of biogas to a large extent depend on the nature of the substrate. Compared to the other sources of biogas, cow dung is the most common one. Methane generation has been applied to meeting the energy needs in rural areas. In developed and also some developing countries, there has been considerable interest in the process of anaerobic digestion as an approach to generating a safe clear fuel as well as source of bio-fertilizer (https://www.britannica.com/technology/biogas).

Therefore, the present work was designed to explore and demonstrate the cattle fattening technologies and related initiatives (use of cow dung as biogas and the slurry as bio-fertilizer) in selected AGP-II districts of western Oromia including *Bako Tibe* district of West Shoa and *Wayu Tuka* and *Guto Gida* districts of East Wolllega Zone. Although the initial plan was to report the full package performances, the latter two components lagged behind the plan because of various reasons, which were included in the current report.

Materials and methods

This work was an integrated project where three main activities were planned to be demonstrated, namely, biogas technologies, fattening technology and the soil fertility improvement technology. Bako Tibe, Wayu Tuka and Guto Gida were the AGP-II implementing districts. To realize the planned activities, about five farmers, who can prepare their own oxen (two oxen per farmer), were identified from three districts, with the help of respective district livestock and fisheries resource development bureaus. The kebeles and specific villages within the three districts were *Sadan kite* kebele, *Jage* village from Bako Tibe district, *Mada Jalala* kebele, *zone six* village from Guto Gida districtand *Wara babo* kebele, *Guliso* village from Wayu Tuka district. The project was initiated by meat research team at Bako agricultural research center (BARC) and was implemented by the initiating team and the energy research team from Bako agricultural engineering research. The soil research team of BARC was also the implementing team. Farmers were selected based on the following preset criteria:

- having enough land to be used for backyard forage development and oxen rearing,
- having enough oxen,
- able to construct simple shade,
- having interest,
- having interest to share information, and
- fattening experience, if any.

Results and discussion

Age of animals to be fattened

There could be different ways of deterring the age of an animal; the actual being records from farm. When recording is not there, the dentition of the animals, counting pairs of permanent incisors, particularly for ruminants could help to estimate the age of the animals. From the total number of oxen prepared, from the three fattening villages, it was seen that the age of farmers' oxen had dentition four pairs of permanent incisors. In the course of determining the age of ruminants, one, two, three and four pairs of permanent Incisors indicates that the animal reached one, two, three and four years of age, respectively. When the pairs of the permanent teeth starts to erupt, it indicates that the age of animal is already more than four years; it is difficult to tell the age of the animal once the animals started erupting their permanent teeth.

Although it is advisable to fatten young bulls from meat quality viewpoint, it was known from the recent work that farmers could prepare only animals of old age. The farming system of the current study is mixed crop-livestock system. Crop production in such system highly depends on livestock mainly for land preparation, which signifies the importance of oxen in the area. This may indicate that the farmers reserve the young bulls for farm land plough instead of engaging them in fattening, which should be born in mind while working in such production systems.

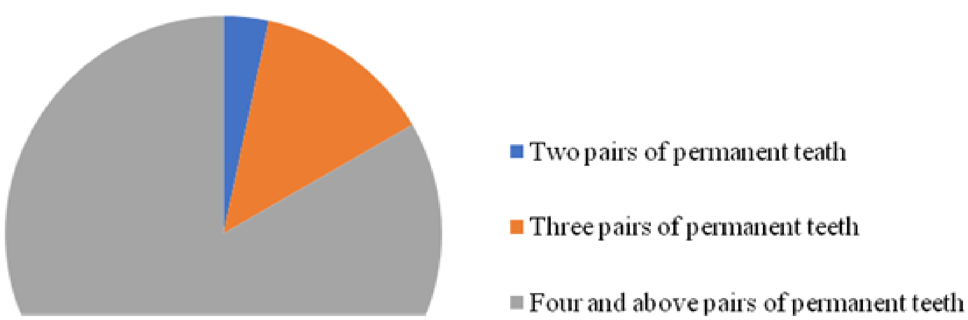

Figure 1: The age of oxen screened for fattening (total number of oxen was 30) from the three villages

Preconditions for cattle fattening

Various preconditions are required for cattle fattening, including identification of the right animal, preparation of sufficient basal and supplementary feeds, preparation of fattening lots, de-worming and disinfestations for internal and external parasites, respectively, and provision of clean water on ad libitum. Before the commencement of the current work, these all preconditions were ensured. The animals identified for fattening should be the one that has high potential of converting the feeds into meat. In order to ensure the anticipated weight gain, the internal and external parasitic load was avoided through treating the animals using the right medications.

In order to quantify the realized weight gain, initial body weight was taken to be compared with the final one. These could have been done by weighing scales; but it was not available in the country side where the study was conducted. Therefore, the linear body measurement (heart girth) was used to measure the progresses in our current work and it fairly indicated the progresses of oxen under the fattening experiment.

Investments and returns of cattle fattening in the study area

The total revenue of cattle fattening from the three villages is indicated in Figure 2. The total variable costs per animal per fattening periods were almost the same for the three areas. The highest total revenue was realized in Wayu Tuka district where the smallest was from the Bako Tibe district. The net profit per animal per fattening cycle was ETB 1300. When compared with reports from the other works (Temesgen and Tesfaye, in press), the current net profit realized was small. However, if all possible procedures could be adhered, more net profit could be realized from cattle fattening.

Figure 2: The gross profit per animal per fattening cycle was promising for the first-round fattening

Preparation of biogas infrastructures

Preparation of the biogas infrastructure was done at the three villages and their status was more than 90% at the time of compiling this paper. The infrastructures including building the concrete silo, installation of pipes from the silo to each of the participating farmers' home and installation of the biogas lamps at each of the house of the farmers were performed by the professionals.

Even though the progress of implementation of the biogas infrastructure is promising, the final light was not yet seen. Hence, it is important to discuss with the nearby respective districts working on this issue and enable the farmers enjoy the light from the biogas system.

Conclusion

The highest total revenue was obtained from Wayu Tuka district followed by Guto Gida. Assuming equal variable costs for all the study sites, the net profit was calculated to be ETB 1300.00. The net profit realized in the current work was smaller than the findings elsewhere and all possible close follow-up should be done. The functionality of the constructed biogas needs critical concerne/follow-up and discussion with the respective district Ethiopian Electric power authority.

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NATURAL RESOURCE MANAGEMENT

Participatory Demonstration and Evaluation of Integrated Maize-Forage Production and Soil Conservation through Forage Legumes under Sowing and Grass Strips on Soil Bunds.

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Abstract

Dire Dawa and Harari are one of the area that are subjected to soil erosion and require immediate soil and water conservation measure. To implement this activity, farmlands that are prone to soil erosion were selected in the study area in close collaboration with DAs and farmers. Two FRGs consisting three trial farmers at Harari and two FRGs, with 6 trial farmers at Dire Dawa were established. The trial was conducted using RCBD on three farmers' fields, where farmers are used as replication. Soil bunds extending 20m across contour were constructed on each farm. The design of structure was based on the slope of the land which encompasses bund height 70cm and bund width 50cm to protect over toping of flood and increases water retention in the soil. Training was given for farmers, DA's, and woreda experts. Farmers appreciate the integrated physical and biological soil and water conservation measures in terms of design, space and highest. The result indicated that, maize yield, fresh weight of elephant grass, pigeon pea and maize stock biomass data shows an increasing trend across the year. Soil laboratory analysis also shows increasing trends across yrears especially in the terms of organic matter, available p and total nitrogen. Because of the good bund spacing, and well stabilized soil bund both maize grain and fresh elephant grass and pigeon pea biomass shows an increasing trend across the year.

Key words: *Soil bund, Elephant grass, Pigeon pea*

Introduction

Low productivity of crops due to soil fertility depletion and livestock feed shortage are among the major factors limiting agricultural production in eastern Ethiopia. In the region, because of the undulating topography and low vegetation cover, vast areas of farmland are suffering soil degradation. The problem of soil degradation is exacerbated by deforestation, continuous cropping, crop residue removal, and soil pulverization to create fine seedbed. Particularly important in this respect is the decrease in soil organic matter which is the basis for soil fertility in agricultural systems due to its multiple physical, chemical, and biological functions. In addition, shortage of feed is the key limiting factor for livestock production in the region, and the possibility of producing forage as sole cropping is impractical due to severe shortage of land. As a result, livestock are mostly fed with crop residues. This practice, on top of depleting soil fertility, it supplies livestock with low nutrients and results in low productivity. Hence, to improve the nutritive value residues it is important to supplement with forage legumes as fresh or conserved hay. Apart from their feed values, forage legumes fix atmospheric nitrogen and improve soil fertility. Hence, the shortage of feed could be alleviated through integrating forage production with the existing cropping system. On the other hand, to conserve soil and moisture, farmers usually construct soil bunds along the contour on the farm land. The ever-increasing land use change is aggravating the rates of soil erosion, soil fertility reduction, crop yield decline, and food insecurity (Haregeweyn et al., 2005; Tsegaye et al., 2012).To combat land degradation at a national level, environmental conservation and land rehabilitation effort was started in 1970 s, with a particular focus on the construction of physical structures (bunds, terraces etc.) in the fast deteriorating highland areas of Ethiopia (Abinet, 2011). The intention of these efforts is to reduce soil erosion, restore soil fertility, rehabilitate lands, improve microclimate, and boost agricultural production and productivity. Integration of biological practices with physical structures is highly contributed for the improvement soil fertility and crop production (Abay, 2011; Zenebe et al., 2013). Biological practices are enhancing the overall and cheaper than physical structures, compassionate to rehabilitation lands, protect land from further degradation, and stabilize physical structural for long period (Abinet, 2011; Terefe 2011).Therefore, there is high possibility of integrating food and forage crops production, and soil and water conservation practices to alleviate feed shortage and improve productivity of soil. In this innovation, forage legumes (pigeon pea) are sown under maize in between the soil bunds and grass (elephant grass) is planted on the soil bunds along the contour.

Materials and Methods

Description of the study area

This participatory evaluation and demonstration of integrated physical and biological soil and water conservation technology was conducted in (Agricultural Growth Program-II) nationally selected districts of Dire Dawa administration and Harari Region. Dire Dawa Administration is located on distance of 515km from capital city Fin fine in direction of county's Eastern part; it is bordered by Somali, and Oromia regions in all directions. Dire Dawa Administration has both urban and rural set governance system. The climatic condition of Dire Dawa is almost dry land with the maximum and minimum temperature 38^{0c} and 25^{0c} respectively (TVO broadcasting on metrology allocated time). Harari regional state is located on distance of 526 kms from capital city Finfine in direction of country's eastern part; it is all in all bordered by Oromia region and hosts one capital town of Oromia Regional state's zone that is East Hararghe. The climatic condition of the region includes highland, midland and lowland; the soil type exist in the region is different in different ecologies of the region that is clay, loam, sandy and black vertysol types. These selected districts where the potentiality of the program will be succeeded in consideration of residents' problems, potential succession of the technologies these fit problems and solve; including the outcomes prevailed in AGP-I.

Site and farmer's selection

To implement this activity, farmlands that are prone to soil erosion was selected in the study area in close collaboration with DAs and farmers. Dire Dawa administration and Harari regional district were purposively selected by AGP-II. PAs were selected purposively based on the potentiality, appropriateness of the area by considering lodging, slope land escape, access to road, suit for repeatable monitoring and evaluation in progress of sowing to harvesting. One district from Harari region (Sofi) and two district from Dire Dawa administration (Wahile and Biyo awale) selected by AGPII. Kile from Sofi were selected purposively. Farmers were selected purposively based on their interest, innovation he/she has, land provision for this participatory evaluation and demonstration, interest in cost-sharing, willingness to share experiences for other farmers, and studying their profile with the participation of DAs and community leaders. The selected farmers were grouped in form of Farmers Research Group (FRG) with the member of 15 farmers per PAs in consideration of gender issues (women, men and youth). In the form of establishing FRG in each two study areas total of 4 FRGs (FRG/ PAs- from one PA 15 farmers and a total of 60 farmers were grouped in 4 FRG). In the FRG 4 farmers was trial farmers per PAs (3 male trial farmers and 2 female trial farmers) and 10 farmers will work with trial farmers.

Table 1: Summary of selected site and farmers with area coverage of the experiment

Measures	Farmers (NO of FRG)		Area Coverage (m^2)
	Total established	4	
Soil bund (daaga biyyoo)	2, at Dire Dawa	2, at Harar	10mx20 m for each plot
Grass for stabilization Pigeon pea for soil nutrient replenishment		Over bund	60cm width and 70cm height of bund and extending 20m for each (the L of one bund.

Table 2: Summary of selected site and farmers with area coverage of the experiment

District	Pas	No. of trial farmers	FTCs	Area covered
Dire Dawa	Wahil	3	1	20mx 10m for each plots
Sofi	Kile	4	1	
Biyo awale	Adada1	4	1	
	Total	11	3	

Technology evaluation and demonstration methods/technique

Participatory evaluation and demonstration of the trial was implemented on farmers' fields to create awareness about the integrated soil and water conservation. The evaluation and demonstration of the trials were followed process of demonstration approach by involving FRGs, development agents and experts at Different growth stage of the crop and during construction of soil bund. The activity was jointly monitored by FRGs, researchers, experts and development agents.

Data Collection

Both quantitative and qualitative data were collected through personal field observation, individual interview, Focus Group Discussion by using checklist and data sheet tools. Types of collected quantitative data were number of farmers participated in FRG, grain and biomass yield performance, number of stakeholders participated in training and field days while qualitative data were farmers' perception toward the new technology, awareness created and farmers' technology selection criteria.

Data analysis

Quantitative data was summarized using simple descriptive statistics (Mean, average, Frequency and Percentage) while the qualitative data collected using group discussion and key informant interviews, field observation and oral histories was analyzed using narrative explanation or PRA (Participatory Rural Appraisal) tools and argument. Finally, data from different sources was triangulated to get reliable information.

Soil analysis

Soil samples before and after were collected and taken to ziway and Bedele soil laboratory and physical and chemical parameter was analyzed.

Table 3. Soil data of 2016 and 2017

Experimental site	Parameters						
	PH H_2O (1:2.5)	EC Mmhos/cm	CEC meq/ 100g	Av.p (ppm)	Total nitrogen	Total carbon result %	%OM
site1	8.01	0.202	41.15	29.18	0.04	0.99	1.71
site2	7.57	0.500	55.682	24.13	0.028	1.65	2.84
site3	8.32	0.391	42.452	4.23	0.057	1.56	2.68
site4	8.740	0.412	44.14	6.10	0.07	1.10	2.03
site5	8.95	0.449	43.648	11.17	0.04	0.79	1.71
site6	8.55	0.177	39.73	0.33	0.042	1.03	1.78

Table 4. Soil data of 2018

Experimental site	Parameters						
	PH H_2O (1:2.5)	EC mhos/cm	CEC meq/ 100g	Av.p (ppm)	Total nitrogen	Total carbon result %	%OM
site1	8.01	0.202	22.15	29.18	0.071	1.09	1.88
site2	7.57	0.500	25.682	24.13	0.088	1.95	3.37
site3	7.32	0.391	28.452	4.23	0.097	1.86	3.21
site4	8.740	0.412	34.14	6.10	0.087	1.18	2.04
site5	7.150	0.449	31.648	11.17	0.094	0.99	1.71
site6	7.55	0.177	39.73	0.33	0.092	2.03	3.51

According to the table above, soil parameter analysis shows an increasing trend especially in terms of, total nitrogen, organic matter and to some extent available p which are the indicator of soil fertility improvement. This finding is also agree with Mulugeta and Karl (2010) who are reported that the land with physical SWC measures have high total nitrogen as compared to the non-conserved land. This result also coincides with Million (2003) found that the mean total N content of the terraced site were higher than the average total N contents in the corresponding non-terraced/conserved sites.

Design of implementation

The trials for evaluation and demonstration of improved integrated maize-forage production and soil conservation were implemented on the farmers' fields in the target areas. The trial was conducted following the procedure of RCBD on three farmers' fields at each site where farmers are used as replication. Soil bunds extending 20m across contour were constructed on each farm of three farmers at Harari and Dire Dawa respectively. The design of structure was based on the slope of the land which encompasses bund height 70 cm and bund width 50 cm to protect over toping of flood and increases water retention in the soil. Elephant grass planted on the structures for the stabilization purpose. Besides stabilize the structure, grass is provided as fodder for livestock and improving soil fertility. Maize sown between the grass strips (soil bunds) and the legumes (pigeon pea) under sown at 3-4 leaf stage of maize. Distance between the strips was kept at 6 m wide. The grass planted densely at 15 cm between slips at start of the rainy season for better establishment. The alleys between the strips is equally divided into 3 parts (plots) planted to the legumes along with control. The evaluation and demonstration was followed process of demonstration approach by involving FRG farmers as well as other stakeholders. The activity was monitored jointly and followed up by FRG farmers, researchers, district experts and development agents.

Result and discussion

Two FRGs consisting three trial farmers at Harari and two FRGs, with 6 trial farmers at Dire Dawa were established respectively. The trial was conducted following the procedure of RCBD on three farmers' fields at each site where farmers are used as replication. Soil bunds extending 20m across contour were constructed on each farm of three farmers at Harari and Dire Dawa respectively. The design of structure was based on the slope of the land which encompasses bund height 70cm and bund width 50cm to protect over toping of flood and increases water retention in the soil. Training was given at both Harari and Dire Dawa for farmers, woreda's experts DA's, and management officials were participated. Farmers appreciate the technology and decide to practice it and some of them are already started it. This training mainly based on the importance of technology (land saving, increases production and productivity of both land and livestock), construction of the soil bund, spacing, height etc. Mini filed day was organized and local community; Das, Management officials and woreda's experts were participating and share the experience.

Table 5. Yield and biomass data of maize and forage at both dire dawa harari 2016

No	Site Name	Average Maize yield (kg/ha)	Maize Stock/ha	Average Eg(Kg/ha)	Avrg Fresh ppbiom (kg/ha)	Pa's
1	Adada1	3375	1950	15000	7200	PA1 Dire D
2	wahil	2250	1850	12000	8400	PA2DireD
3	kile	1716.6	1150	19200	9000	PA1Harari
4	Average	2447.2	1650	15,400	8200	

The variation in both grain yield and biomass data are mainly due to soil textural distribution and pervious soil fertility level. The highest record for both grain and biomass yield of maize was taken from site1 (adad1). This is due to the existence of previous good soil depth and fertility status of the filed. The lowest yield was recorded from 2nd site. This is because of shallow soil depth and also to some extent the availability of termite

Summary of yield and biomass data of planting year 2017

Table 6. Grain and fresh weight biomass yield data at Harari.

No	PA's and kebeles.	grain yield of maize(kg/ha)	Maize stock(kg/ ha)	Average biomass of elephant grass(kg)/4m	Average biomass of pigeon pea(kg)/4m	Site name
1	PA#1	28000	2543	19800	10,200	kile
2	PA #2	3,466.7	1550	18,900	8880	Ada1
3	PA#3	3,133.4	2900	11220	9780	wahil
4	Average	3311.13	2331	6150	9620	

According to the table 6 highest Maize grain yield per ha, average fresh weight of elephant grass and fresh weight of pigeon pea biomass was collected from PA1 and the lowest data was collected from the 3thrd PA. This variation of data from PA to PA is because of the soil textural distribution and water holding capacity of soil. Water holding capacity, improved soil aggregation, stabilized soil bund and good bund spacing, are the main factor an increment of both grain and biomass yield. The highest record for both grain and biomass yield of maize was taken from Dire Dawa PAs. This is because of the degree of soil excavation/disturbance of soil during bund construction in the field and the extent to which the bund is maintained or stabilized and conserves the necessary amount of moisture. It also depends on the initial soil depth. On the other hand, the lowest yield was recorded from Harari PAs. This is because of soil textural distribution that affects water holding capacity and also the degree that soil aggregation is improved.

Table 7. Maize yield and forage biomass data at both harari and dire dawa2018

No	Site Name	Average Maize yield (kg/ha)	Maize Stock (kg/ha)	Average Eg (Kg/ha)	Avrge Fresh ppbiom (kg/ha)	Pa's
1	Adada1	3975	2588	20,400	12000	PA1 Dire D
2	wahil	3817	2383	19200	14400	PA2DireD
3	kile	3633	5556	21,000	15000	PA1Harari
4	Average	3808.66	3509	20200	13800	

According to the collected data, the highest maize yield and fresh biomass data of animal feed was obtained at dire dawa location. But at kile, the highest elephant grass fresh weight biomass and pigeon pea fresh weight biomass was recorded. This is because of well stabilized soil bund and good bund width and height. Thus why, both maize grain and fresh weight biomass of elephant grass and pigeon pea shows an increasing pattern.

Training

Training was given at both Harari and Dire Dawa. Farmers, woreda's experts, DA's, and Dire Dawa management officials were participated. This training mainly based on the importance of technology (moisture and soil conservation, land saving, increases production and productivity of both land and livestock), construction of the soil bund, spacing, height etc. Farmers appreciate the technology and decide to practice it and some of them who are outside of established FRG's already started to practice it. Farmers appreciate the technology in terms of land saving, animal feed provision and decided to implement it in a large scale on their own farm land. Mini filed day was organized and local community; DAs, Management officials and woreda's experts were also participated and share the experience.

Table 8. The established FRG and training given in 2016

No	AGP-II Woreda	kebele	Number of FRG	member of FREGs			Type and number of tech. demonstrated	plot size per variety (for crop and forage)	Mini filed visit participants	
				Men	Women	total			M	F
1	Sofi	Kile	2(four trial farmers	32	13	45	1	20m*10m	30	19
2	wahile	Dujuba	1(three trial farmers)	11	9	20			18	10
3	Total		2	43	22	65	1	$200m^2$	77	

Table 9: Type of profession and number of participants during the training at two districts 2017 and 2018

		Kile		Wahil	Adada1		
No.	Participants	Male	Female	Male	male	female	Total
1	Farmers	45	20	40	72	20	217
2	Das	9	1	5	6	5	26
3	District experts	4	1	3	4	1	13
4	Journalist	1	0	0	1		2
	Total	59	22	48	83	26	258

Source: Own computation 2016, 2017/18.

Table 10: Ranks of the practices based on farmers' selection criteria.

Types of technology	Farmers rank	Reasons
Integrated physical and biological swc	1st	Good bund width that is suitable for forage production over the bund, water holding capacity, land saving Good bund height for protection of run of destruction. Improve soil depth.
Soil bund farmers practice	2nd	Poor water holding capacity, shallow soil depth, un appropriate design.

Table 13: Pair-wise ranking matrix result to rank improved swc measures.

Code no.	Parameter of selection	width	height	Soil depth	Water holding capacity	Bulb skin color	Seed set
1	Bund width		2	3	1	1	1
2	Bund height			3	2	2	2
3	Land saving				3	3	3
4	Water holding capacity					4	4
5	Erosion control capacity					5	5
6	Maize yeild					6	6
7	Total fresh biomass harvested						7
8							

Conclusion

Integrated physical and biological soil and water conservation measure is one of climate smart agriculture that alleviates land degradation and enhances soil fertility. Not only conserve soil and moisture but also integrated soil and water conservation measures can address the problem of land shortage, especially for the country that its population grow radically. Leguminous forage crop especially like pigeon pea, is very important to replenish soil nutrient and componset nutrient completion with crop.

Recommendation

Farmers practice integrated physical and biological soil and water conservation measures to cop up the climate change problem specially those farmers who live in arid area. Research extension should go for pre-scaling up and scaling up of the technology to reach for pastoral society specially. Office of agriculture and natural resource create awareness further about integrated soil and water conservation for both arable and degraded land.

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Effects of Straw Mulch and Manure on Moisture Conservation, Yield and Yield Components of Maize (*Zea Mays* L.) in the Mid Rift Valley of Oromia, Ethiopia

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Abstract

*Water shortage is one of the major problems limiting crop productivity in arid and semi-arid regions. Suitable soil and water conservation measure that can be easily integrated into the existing farming operations while enhancing in-situ moisture conservation by reducing the direct impact of raindrops, maintaining soil infiltration, increasing surface storage and affecting soil temperature, and increasing nutrient is crucially needed. A field experiment was conducted under rainfall conditions in the mid rift valley in 2018 cropping season to investigate the effects of straw mulch and farmyard manure on soil water-nutrient status and sustainable productivity of maize. Twenty-seven experimental plots each with 3 m * 3 m area were used to conduct the experiment. The experimental design used RCBD with nine treatments and replicated three times. The results revealed that there was highly significant difference (P≤0.01) between the treatments regarding their effect on yield and yield components of maize while the amount of moisture conserved through growth stages show significant differences (P≤0.05). The moisture conserved through growth stages was increased more due to combined effect of straw mulch with manure up to 60 cm depth of the soil from emergence to maturity stages. The results showed that application of straw mulch and farmyard manure could increase the soil moisture content by 16 - 28% in the three soil depths in relation to the control. Also, the highest grain yields (11.8 tons ha^{-1} and 11.2 tons ha^{-1}) were obtained from the combined application of treatments. These results indicated that retaining crop residue and application of farmyard manure in the field could be used as soil moisture conservation measure for sustainable improvement of maize production under the low moisture stress and rainfall conditions of the study area.*

Key words: Farmyard manure, Growth stages, Moisture content, Soil depth, Straw mulch

Introduction

Water shortage is one of the major problems limiting crop productivity in arid and semi-arid regions. Crop productivity could be greatly influenced by even a small change in soil water storage (Liu *et al.,* 2010). In the integrated and ecological agriculture systems more attention is being paid to the longest possible period of soil coverage with plant mulches and mulches from straw left after cereal grain harvest (Borowy and Jelonkiewicz, 1999; Pabin *et al*., 2006). Mulch also reduces the depletion of water within the root zone because it suppresses evaporation. Straw mulch covers to be more effective at increasing infiltration than incorporation of organic matter (Adekalu *et al*., 2007).

Straw mulch has been carried out in arid and semi-arid region to improve crop yields (Liu *et al*., 2010; Cai *et al*. 2011; Li *et al*. 2012); however, the effects of straw mulch on soil water storage, maize yield and water use efficiency are not well documented. Even though wheat and maize account for approximately 70% of the world cereal production, their yields are significantly limited by the availability of water, especially in arid and semi-arid regions (FAO, 2015).

Addition of organic matter to soil improved both soil water infiltration and water holding capacity, through incorporation of plant residues or manures (Celik *et al*., 2010; Parija and Kumar, 2013). The farm-yard manure (FYM) improves soil physical, chemical and biological properties (Khan *et al*., 2010). Improvement in the soil structure due to FYM application leads to a better environment for root development (Prasad and Sinha 2012), and improves soil water holding capacity (Dejene and Lemlem, 2012). 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 manure typically mineralized within only a few cropping seasons to obtain a sustainable and stable increase in yield. Therefore, organic manure should be applied for consecutive years (Uzoma *et al*., 2011; Molina *et al*., 2014). In the area of arid and semi-arid climate region, where maize (*Zea mays L*.) is one of the most common crops, erosion occurs in top soil by water and wind, and evaporation of water from surface and subsurface (Li *et al.*, 2013). Mulching regulates the farm environment and enhances crop production by affecting soil temperature, leaching, evaporation, soil moisture content and nutrient loss due to run off (Shah *et al*., 2013). It also increases yield by improving soil physical conditions. Wheat straw mulch reduced evaporation by 50% under winter wheat, and saved about 80 mm of water during wheat growing season (Wang *et al*., 2017).
Consequently, consecutive organic manure input improved soil water uptake in more than 150 cm soil profile and maintained stable soil water conservation in the depth of 0-50 cm and below 150 cm (Wang *et al*., 2017). It was likely that organic manure improved the soil permeability (Liu *et al*. 2014; Zhao 2014) and stimulated root physiological function and adjusted soil water distribution for higher water penetration (Zhou *et al.*, 2012; Mkhabela and Materechera, 2013).

In the study area maize is widely produced by small scale farmers using rain-fed system and use as basic cereal crop for providing food and as cash crop for the market. However, the productivity of maize in the area has been decreasing from year to year due to moisture deficit and depletion of soil nutrients. The rainfall came late in the cropping season or earlier offset before maturity of the crop. Even in the normal onset and offset season, the rainfall had no uniformity in intensity and frequency. On the other hand, most of the community produce the crop under required dose of chemical fertilizers for their land size, while few of the farmers produce without any fertilizer, because chemical fertilizers were costly to apply to their farm lands.

However, the combination of organic manure and chemical fertilizer increased the sustained supply of soil nutrients, while reduced the nutrient enrichment of synthetic fertilizer in soil environments (Wang *et al*., 2017). Many research findings have showed that neither inorganic nor organic fertilizers alone can result in sustainable productivity (Tadesse et al., 2013). Research on mulching and farmyard manure application was conducted separately in different agro-ecological conditions, especially in the area of high rainfall at different time. However, there were a limited number of researches conducted on mulching and farmyard manure integrated with inorganic fertilizers in the low moisture stress area of the mid rift valley of the country. Therefore, this study was initiated to evaluate the effects of wheat straw mulch and farmyard manure on soil moisture content at different growth stages of maize, and to determine the effects of wheat straw mulching and farmyard manure on maize yield and yield components for sustainable productivity and production of maize in the Mid Rift Valley of Oromia, Ethiopia.

Materials and Methods

Description of the Study Area

Adami Tulu Agricultural Research Center (ATARC) is geographically located between 7° 50' 30" to 7° 51'30" N latitude and 38° 42'0" to 38° 43'0" E longitude and at altitude of 1600 m.a.s.l. It is found in Adami Tulu Jido Kombolcha District of East Showa Zone of Oromia. The center is 7 km far from Batu (Zeway) town on the Hawassa main road and 167 km to the south of Addis Ababa.

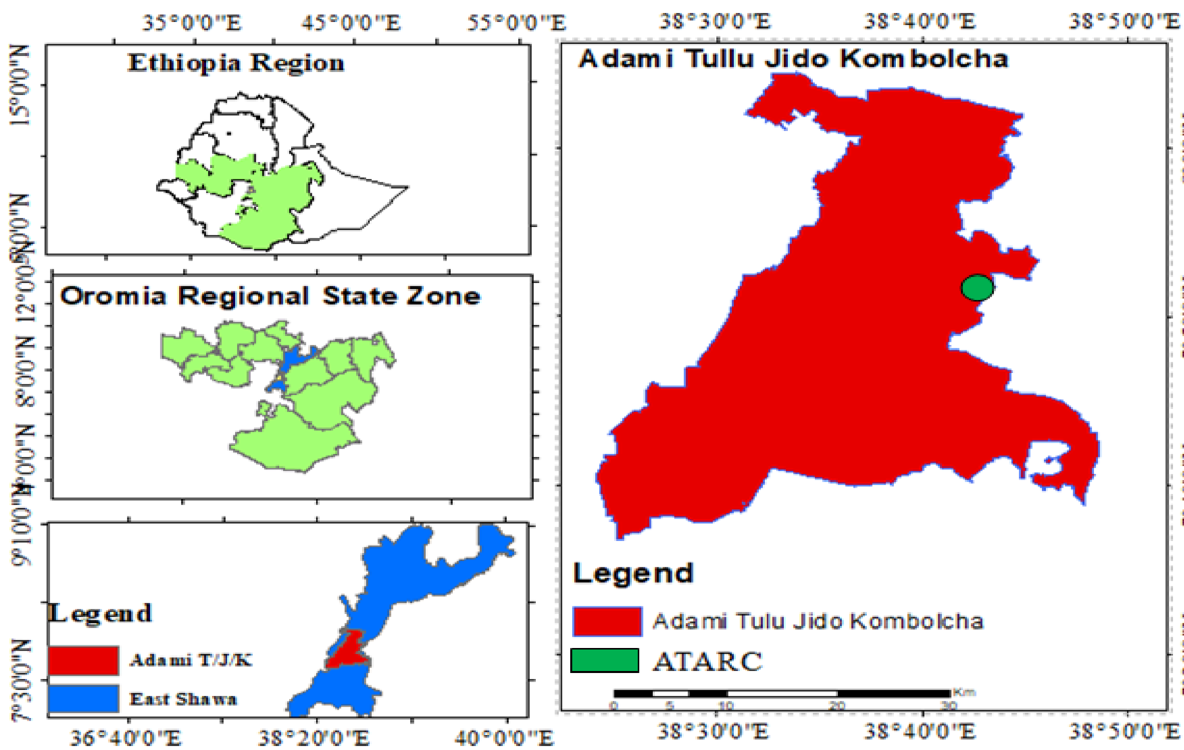

Figure 1. Map of Adami Tulu Agricultural Research Center

Most of the land of Adami Tulu District is topographically flat. The total coverage area of the district is about 1487.60 km^2 (Gemechu, 2016). The major soil type in the study area is Andosol. The major crops produced in the area are maize, wheat, teff, haricot bean, barley, sorghum, onion, cabbage, potatoes and tomatoes. Among the crops maize is the dominant one by area coverage and yield produced. It is the first and basic crop providing food in all households.

The study area is characterized by lowland and dry agro-climatic zone with a mean annual rainfall ranging from 619 to 750 mm for the last fifteen years. It exhibits bi-modal rainfall pattern with erratic condition and insignificant mean monthly precipitation. Rainy season is April to October and, the dry seasons cover other months. The solar radiation in the dry season was considerably high (>25 MJ m^{-2}) and reduced during rainy season, and most of the day time is sunny. The daily mean relative humidity was less than 50% in the dry and increased up to 80% in the rainy season. The temperature of the area ranges from 17 to 21°C during the rainy seasons and exceeds to 27°C during the dry seasons with an annual temperature ranging from 20 to 25°C (ÀTARC, 2017).

Treatments and Experimental Design

The experiment was conducted at ATARC in 2018/19 cropping season on twenty seven experimental plots. The experiment was consisted of nine treatments: T_1(3 tons ha^{-1} wheat straw mulch), T_2 (5 tons ha^{-1} wheat straw mulch), T_3 (3 tons ha^{-1} of farmyard manure), T_4 (5 tons ha^{-1} of farmyard manure), T_5 (3 tons ha^{-1} wheat straw mulch plus 3 tons ha^{-1} farmyard manure), T_6 (3 tons ha^{-1} wheat straw mulch plus 5 tons ha^{-1} farmyard manure), T_7 (5 tons ha^{-1} wheat straw mulch plus 3 tons ha^{-1} farmyard manure), T_8 (5 tons ha^{-1} wheat straw mulch plus 5 tons ha^{-1} farmyard manure) and T_9 (Control/farmer practice) were applied by a randomized complete block design (RCBD) with three replications. The size of each plot was 3 m x 3 m with spacing between row of maize 75 cm and 25 cm between plants. Space between each plot was 1 m and between blocks was 2 m and 1 m from the borders.

All experimental plots were tilled three times by hand before plating of the maize variety, BH-540 and sown in rows based on the recommended space between rows and plants. This hybrid was selected due to its tolerance to low moisture stress, high yielding and most widely grown in the area. Fertilizers (urea and DAP) were applied to T_1-T_8 by the half of the blanket recommended rate per hectare. Treatment nine (T_9) without mulching and FYM plot received a full dose of inorganic fertilizer as usual practice by the local farmers.

Soil Sampling and Moisture Determination Methods

Soil samples were collected throughout the growth stages from surface and subsurface during the 2018 to 2019 cropping season and its moisture content was determined. Moisture contents of the soil at different crop growth stages were determined by taking soil samples from 60 cm depth by 20 cm intervals from the middle of the plots at four growth stages of maize (2, 4, 8 and 10 weeks from sowing date), and the wet soil sample was weighted and oven dried at temperature of 105°C for 24 hours. Then its gravimetric water content was determined using the expression:

$$\theta dw = \frac{Wws - Wds}{Wds} x100$$

Where, Wws = weight of wet soil (g), θdw = water content expressed on a weight basis (%)

Wds = weight of dry soil (g)

Meteorological and Agronomic Data Collection Methods

Meteorological data of the study area

Different meteorological data of the study area in the experimental year were collected from ATARC meteorological station nearby the experimental site. The collected data included rainfall, evaporation, air temperature, sun shine, relative humidity and soil temperature at 5, 10, 50 and 100 cm depths. The amount and distribution of the rainfall at the study area in the cropping seasons were compared with results obtained due to the effects of the treatments on the nutrient content, soil moisture conservation and yield and yield components of maize.

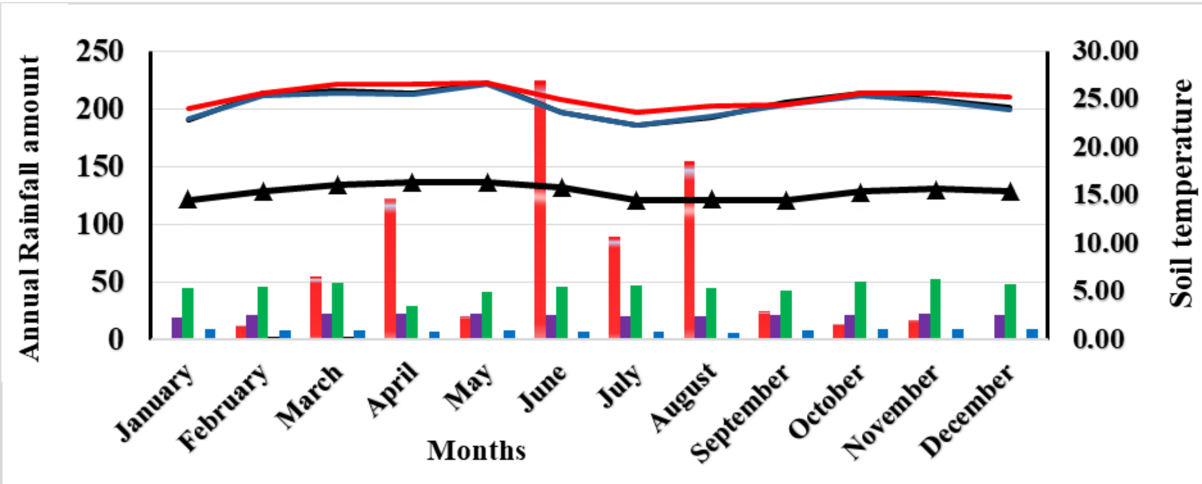

Figure 2. Distribution of climatic factors and soil temperature data of the study area

Growth parameters, yield and yield components of maize

Important agronomic data on maize such as growth parameters (plant height, days to 50% flowering and 50% physical maturity) yield and yield components (number of ear per plant, number of seeds per ear, thousand grain weight and total grain yield) were collected.

Data Analysis

The collected data were subjected to analysis of variance (ANOVA) in Randomized Complete Block Design (RCBD) replicated three times using statistical analysis systems (SAS) software (SAS, 2004 Version 9.1.2). General linear model (GLM) was employed and treatment means were compared using Duncan's Multiple Range Test at $P \leq 0.05$ significance level.

Results and Discussion

Rainfall Amount and Distribution during the Cropping Season

The daily rainfall distribution for the cropping months (May to October) of the year 2018 to 2019 at the study area was recorded. The total rainfall (636.3 mm) recorded over the period of the cropping season was generally within the normal range (619 to 750 mm) in the study area but could not be considered as optimum for crop growth in the area provided that it was erratically distributed. The length of the growing period of the cropping season was long and matched with the cropping season of Maize (160 days) as compared to what experienced with local farmers (Gemechu, 2016). However, there was a serious shortage of rainfall at flowering and physiological maturity which highly affected the grain filling of the crop.

In addition to less amount of rain at the onset of cropping season and generally lower total seasonal rainfall, the distribution of rainy days within the duration of the cropping season was not uniform either no or very small amounts of rains were recorded in the month of May 1 to 18 and 25 to 31, between August 1 to 8 and October 1 to 15. On the contrary, except for the on and off rain, considerable amounts of rainfall were received from early 1st to 16th of June (Figure 2). Therefore, it could be inferred that the erratic and insufficient rainfall and the resultant limited availability of soil moisture coupled with the exceptional risks of prolonged dry spells could be the major constraints for crop production in Adami Tulu area.

Soil Moisture Contents as Affected by Wheat Straw Mulch and Farmyard Manure Application

Effects of straw mulch and manure on soil moisture content at different growth stages

Soil moisture content in 2nd weeks (Emergence to vegetative stage)

The data on the soil moisture content at the first two weeks after sowing (Table 1) and analysis of variance revealed that there were highly significant ($p\leq0.01$) differences due to the application of two levels of straw mulch and manure as compared to control in the soil depth of 0-20 and 20-40 cm, whereas a significant ($p\leq0.05$) changes observed in the 40-60 cm soil layer. In the case of 40-60 cm depth the maximum moisture content (19.89%) was obtained from plots treated with 5 tons ha^{-1} of straw mulch plus 5 tons ha^{-1} of FYM, while the minimum (13.14% and 12.81%) was from the 3 tons ha^{-1} and 5 tons ha^{-1} of FYM treatments. This might be due to shortage of time for making a better soil structure by decomposing the manure through microbial activities and the production area was exposed to evaporation. The research finding reported by Cai1 *et al*. (2015) revealed that under 4.5 tons ha^{-1} of wheat straw mulch, the storage of soil water provided more soil moisture in sowing, which would be beneficial for the maize seeding and for promoting the emergence and survival rate of the maize.

Table 1. Gravimetric soil moisture content (%) in the second weeks at different soil depths

Treatments (tons/ha)	**Soil depths (cm)**			
	0-20	20-40	40-60	Mean
Control	16.52^{f}	16.36^{d}	15.38^{cd}	19.09^{d}
3 WSM	21.62^{cd}	23.14^{b}	19.22^{ab}	21.33^{bc}
5 WSM	25.95^{ab}	24.98^{ab}	19.15^{ab}	23.36^{ab}
3 FYM	17.17^{ef}	15.64^{d}	13.14^{d}	15.32^{d}
5 FYM	20.18^{de}	19.51^{c}	12.81^{d}	17.50^{d}
3WSM + 3 FYM	24.06^{bc}	22.70^{b}	15.95^{bcd}	20.91^{c}
3 WSM +5 FYM	23.39^{bcd}	25.44^{ab}	19.27^{ab}	22.70^{bc}
5WSM + 3 FYM	24.54^{bc}	26.19^{a}	17.49^{abc}	22.74^{abc}
5WSM + 5FYM	28.31^{a}	27.07^{a}	19.89^{a}	25.09^{a}
LSD $_{(0.05)}$	3.52	2.89	3.36	2.36
CV (%)	9.07	7.47	11.48	6.63

Treatment values within a column followed by the same letter are not significantly different at $P\leq0.05$, 3WSM = 3 tons per hectare of wheat straw mulch, 5WSM= 5 tons per hectare of wheat straw mulch, 3FYM= 3 tons per hectare of farmyard manure, 5FYM= 5 tons per hectare of farmyard manure, CV=coefficient of variation, LSD $_{(0.05)}$ = least significant difference 5%

In general, it could be concluded that from Table 2 soil moisture content decreased with an increase in the soil sampling depth from 0-20 to 20-40 to 40-60 cm. This could be due to the occurrence of high rainfall during the first sampling time, resulting in infiltration into the soil and moisture through the soil profile but had no uniformity through the soil profiles. On the other hand it might be due to the depth of water table of the area. Further, it may be contented that the soil moisture retained in the deeper horizon is not important for plant growth because plant roots in the first stage are able to use only the water stored in shallow soil depth.

Soil moisture content in 4th weeks (Development stage)

A perusal of the data on the soil moisture content at the development stage demonstrated that application of both straw mulch and manure at 3 and 5 tons ha^{-1} had influence to increase moisture contents of the soil at three soil depth intervals compared to the control. The analysis of variance showed that there was highly significant difference ($P \leq 0.01$) between the treatments in 20-40 cm soil depth. This might be due to relatively high rainfall received by the study area and the rain was percolated down into subsoil as the soil was sandy loam but it could not infiltrate more down up to 60 cm during the week of the gravimetric soil moisture determined because of erratic or lack of continuity of rainfall. Li *et al*. (2013) reported that soil mulched with wheat straw conserved 106.9 mm water in the 0-200 cm soil layer during the maize growth stage.

Table 2. Gravimetric soil moisture content (%) in the fourth weeks at different soil depths

Treatments (tons/ha)	**Soil depths (cm)**			
	0-20	20-40	40-60	Mean
Control	17.06	13.68^{c}	12.23	14.88^{c}
3 WSM	19.78	16.92^{ab}	12.45	16.38^{bc}
5 WSM	19.95	19.83^{a}	16.25	18.68^{ab}
3 FYM	17.24	13.97^{bc}	13.31	14.84^{c}
5 FYM	18.20	16.99^{ab}	13.89	15.81^{bc}
3WSM + 3 FYM	20.85	17.50^{a}	16.13	18.16^{ab}
3 WSM +5 FYM	20.48	18.12^{a}	13.82	17.47^{abc}
5WSM + 3 FYM	23.09	19.17^{a}	16.80	19.69^{a}
5WSM + 5FYM	22.73	19.94^{a}	17.34	20.00^{a}
LSD $_{(0.05)}$	4.35	3.03	4.48	2.90
CV (%)	12.61	10.09	17.63	9.68

Treatment values within a column followed by the same letter are not significantly different at $P \leq 0.05$; 3WSM = 3 tons per hectare of wheat straw mulch, 5WSM = 5 tons per hectare of wheat straw mulch, 3FYM = 3 tons per hectare of farmyard manure, 5FYM = 5 tons per hectare of farmyard manure, CV = coefficient of variation, LSD $_{(0.05)}$ = least significant difference at 5%

Soil moisture content in 8th weeks (Flowering stage)

From the analysis of variance soil moisture contents determined at this stage showed highly significant ($p \leq 0.01$) difference among the evaluated treatments in 0-20 and 40-60 cm soil depths. However, the soil moisture content was significantly ($P \leq 0.05$) affected in the 20-40 cm depth as treated by the straw mulch and farmyard manure. Also looking at the surface soil layer (0-20 cm), the soil moisture was increased from 14% to 19.82% due to the impact of straw mulch.

Table 3. Gravimetric soil moisture content (%) in the eighth weeks at different soil depths

Treatments (tons/ha)	Soil depths (cm)			
	0-20	20-40	40-60	Mean
Control	14.01^{c}	15.04^{d}	10.25^{b}	13.10^{e}
3 WSM	17.68^{ab}	18.16^{abc}	11.42^{b}	15.75^{bc}
5 WSM	19.82^{a}	18.79^{abc}	11.58^{b}	16.73^{abc}
3 FYM	15.45^{bc}	16.30^{cd}	9.85^{b}	13.87^{de}
5 FYM	19.13^{a}	16.92^{bcd}	9.97^{b}	15.34^{de}
3 WSM + 3 FYM	18.65^{a}	17.45^{bcd}	12.48^{b}	16.19^{bc}
3 WSM +5 FYM	17.43^{ab}	17.63^{bcd}	12.48^{b}	15.85^{bc}
5 WSM + 3 FYM	19.50^{a}	19.57^{ab}	12.67^{b}	17.25^{ab}
5 WSM + 5 FYM	18.52^{a}	20.82^{a}	16.34^{a}	18.56^{a}
LSD $_{(0.05)}$	2.81	2.92	2.86	1.85
CV (%)	9.13	9.44	13.91	6.72

Treatment values within a column followed by the same letter are not significantly different at P≤0.05; 3WSM = 3 tons per hectare of wheat straw mulch, 5WSM = 5 tons per hectare of wheat straw mulch, 3FYM = 3 tons per hectare of farmyard manure, 5FYM = 5 tons per hectare of farmyard manure, CV = coefficient of variation, LSD $_{(0.05)}$ = least significant difference at 5%

The moisture contents enhanced by 5 tons ha^{-1} of straw mulch plus 5 tons ha^{-1} of the farmyard manure were found as 20.82% and 16.34% in 20-40 cm and 40-60 cm depths, respectively. Cover with crop straw mulch on soil surface is important to promoting soil moisture content (Li *et al*. 2012), improving crop yields and water use efficiency (Wang *et al*. 2009).

Apparently, in this growth stage, the minimum soil moisture was recorded in manure treatments next to the control through the three soil depths. This might be because of the major part of the rain water was forced to infiltrate due to the mulch applied and soil type. Once infiltrated the opportunity of back evaporation was less in mulched plots as compared to the manure and control treatments. Similar trends were observed in the mean of soil moisture at 60 cm as in the case of three soil depth intervals, the maximum moisture content was obtained in plot treated with 5 tons ha^{-1} of straw mulch plus 5 tons ha^{-1} of farmyard manure.Under the traditional practices represented by the control plots (uncovered), the water is lost as runoff and evaporation, hence not used for crop production. This result was parallel with Wang *et al*. (2018) report, compared without straw mulch, soil gravimetric water content was improved in the 0-200 cm profile by straw mulch, due to the deep underground water supply was ignored, the more water loss in without straw mulch was consumed by evaporation in surface.

Soil moisture content in 10th weeks (Maturity stage)

The analysis of variance revealed that the soil moisture content was more affected due to application of farmyard manure (Table 4). The soil moisture content at first and the third soil depths did not show significant effect due to the surface management practices evaluated compared to the control. Soil moisture content was highly significantly ($p \leq 0.01$) influenced (Table 4) due to the uses of straw mulch and farmyard manure in 20-40 cm soil depth and the maximum moisture storage was resulted due to application of 5 tons ha^{-1} of farmyard manure. This might be as a result of manure capacity to hold moisture within the soil that was infiltrated to the root depth through the growth stages sequentially. Manure had improved soil moisture holding capacity at the tasseling and grain filling stages, and decreased evaporation at the jointing–big trumpet and tasseling–grain filling stages (Wang *et al*. 2018). Soil moisture content was increased in the maturity stage due to the soil water holding capacity improved slowly after the manure decomposed by microbial activities (Li *et al*. 2012), and the straw mulch also decomposed and incorporated into the soil. Therefore, as soil structure and bulk density (soil aggregate) improved, the infiltration and water holding capacity (moisture content) increased by the increases of straw mulch and farmyard manure levels.

Table 4. Gravimetric soil moisture content (%) in the ten weeks at different soil depths

Treatments (tons/ha)	**Soil depths (cm)**			
	0-20	20-40	40-60	Mean
Control	11.74	10.85^{de}	13.55	12.04^{c}
3 WSM	12.81	12.49^{cde}	15.17	13.93^{bc}
5 WSM	13.11	13.31^{bcd}	15.82	14.08^{bc}
3 FYM	10.36	9.91^{e}	15.24	11.84^{c}
5 FYM	18.12	16.91^{a}	16.29	17.11^{a}
3WSM + 3 FYM	13.34	14.03^{abc}	16.29	14.55^{abc}
3 WSM +5 FYM	11.23	13.45^{bcd}	16.75	13.81^{bc}
5WSM + 3 FYM	15.13	15.90^{ab}	16.27	15.77^{ab}
5WSM + 5FYM	15.78	16.74^{a}	16.49	15.88^{ab}
$LSD_{(0.05)}$	4.60	3.02	4.53	2.75
CV (%)	19.67	12.71	16.61	11.10

Treatment values within a column followed by the same letter are not significantly different at P≤0.05; 3WSM = 3 tons per hectare of wheat straw mulch, 5WSM = 5 tons per hectare of wheat straw mulch, 3FYM = 3 tons per hectare of farmyard manure, 5FYM = 5 tons per hectare of farmyard manure, CV = coefficient of variation, LSD $_{(0.05)}$ = least significant difference at 5%

Effect of Moisture Conservation on Crop Phenological Development, Yield and Yield Components of Maize

Soil moisture and nutrient content variability have a remarkable effect on crop growth habit. In this regards the effects of different soil moisture and nutrient contents from straw mulch and farmyard manure on different growth parameters and yield of maize are described below. Effect of moisture conservation on crop phenological development

Days to 50% flowering and physiological maturity

Analysis of variance indicated that means of days to flowering were highly significant ($p \leq 0.01$) as a result of straw mulch and farmyard manure applied; also, days to 50% physiological maturity showed very highly significant ($p \leq 0.001$) among the evaluated moisture conservation practices. The number of days to 50% flowering and physiological maturity was decreased as the impact of the combined application of the treatments. This might be due to the availability of adequate amounts of nutrient and soil moisture that may favor the plant to grow faster and mature earlier, in addition to the crop variety (tolerant to mid rift valley weather conditions). So, the minimum number of days to flowering (60 and 59 days) and days to physiological maturity (98 and 99 days) were observed from the plots treated with 5 tons ha^{-1} of straw mulch plus 3 tons ha^{-1} of FYM and 5 tons ha^{-1} straw mulch plus 5 tons ha^{-1} of manure, respectively.

Table 5. Growth parameters of maize as affected by straw mulch and farmyard manure

Treatments (Tons/ha)	**Parameters**		
	NFD	DPhM	Plant Height (m)
Control	67^{a}	108^{ab}	2.14^{c}
3 WSM	64^{ab}	105^{b}	2.52^{b}
5 WSM	63^{bc}	107^{ab}	2.53^{b}
3 FYM	67^{a}	109^{a}	2.40^{bc}
5 FYM	63^{abc}	105^{b}	2.51^{b}
3 WSM+3 FYM	65^{ab}	107^{ab}	2.34^{bc}
3 WSM+5 FYM	63^{bc}	106^{b}	2.51^{b}
5 WSM+3 FYM	60^{cd}	98^{c}	2.83^{a}
5 WSM+5 FYM	59^{d}	99^{c}	2.85^{a}
Mean	63	105	2.51
LSD(0.05)	3.75	4.28	10.26
CV (%)	3.41	2.36	5.89

Treatment values within a column followed by the same letter are not significantly different at P≤0.05, NFD = days to 50% flowering, DPhM = Days to 50% physiological maturity, CV = coefficient of variation and LSD = Least significant difference (5%)

However, the maximum days (delay to flowering and physiological maturity) were observed from plots treated with 3 tons ha^{-1} of manure (67) for days to flowering and 109 days to physiological maturity, respectively (Table 4). This result indicates that improving the soil moisture content and nutrient availability by using the integrated straw mulch and manure with inorganic fertilizers, the maize variety delays to flowering and physiological maturity could be reduced by 11 to 13% and 10 to 11% correspondingly, and this may save the crop from the offset of rainfall before maturity in the mid rift valley of low moisture stress area. According to Lee (2007), the decrease of maize production happens when the crops experience low water stress in flowering phase and during the pollination period.

When the maize entered flowering stage, the crop experienced moisture stress, especially on the non- mulch treatments (Sahindomi *et al*., 2013). Days to physiological maturity can illustrate the response of plants whereby growing under unfavorable condition tried to make adjustments to the environment through modification of their normal physiological growth, development processes and morphological behavior under non-conducive conditions in order to assure and maintain the survival of the species that was long/late maturity crop phases high yield reduction. The growth parameter and maize yield components significantly reduced due to soil moisture deficits and delayed flowering due to water stress (Abayomi, 2012).

Plant height

Statistical analysis revealed that there was highly significant (p≤0.001) difference in plant height among the effects of wheat straw mulch, farmyard manure and their combinations compared to the control. The tallest plant height (2.85 m) was measured from plots treated with 5 tons ha^{-1} of straw mulch with 5 tons ha^{-1} of farmyard manure and followed by 5 tons ha^{-1} of straw mulch with 3 tons ha^{-1} of farmyard manure (2.83 m), 5 tons ha^{-1} of straw mulch (2.53 m), while the shortest (2.14 m) was measured in control plots which was lower by about 33% from the tallest plant (Table 5).

Application of the combinations of straw mulch with farmyard manure by integrating with chemical fertilizers promoted plant growth (height, weight, flowering, etc.) compared to mineral fertilized Sheikha (2016) and combination of 8 tons ha^{-1} of wheat straw mulch with the sowing system increased the plant height from almost 5 to 13% (Shah *et al.*, 2015). The potential mechanism of straw mulching can help to improve maize yield and yield components because it can effectively improve soil nutrient availability, increase plant growth (Fang *et al*. 2011), and influence soil physical and chemical properties. Plant height was positively correlated with average soil moisture content measured at flowering and maturity growth stages. It showed a linear relation with average soil moisture content measured in both growth stages (Figure 3). This indicates that soil with higher soil moisture content had tallest plant height at flowering and physical growth stages.

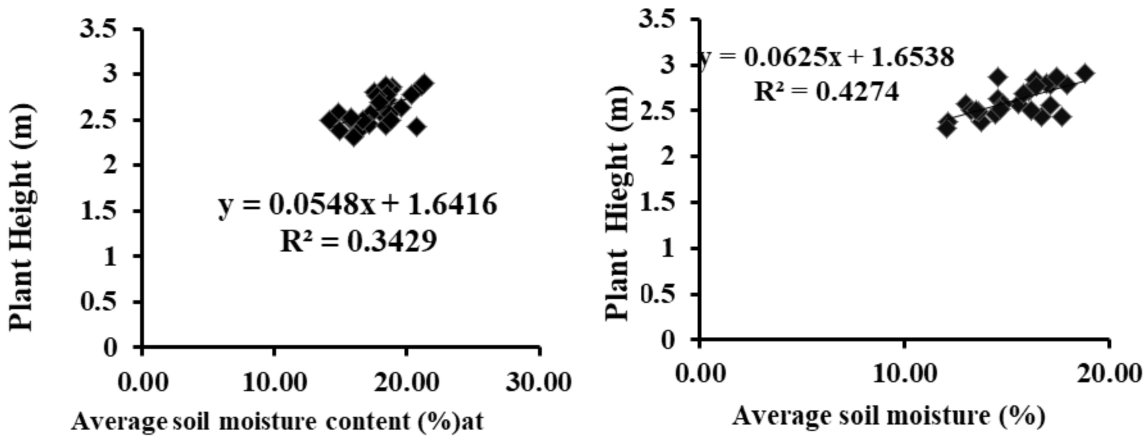

Figure 3. Relation of plant height with average soil moisture content at flowering and maturity stages

Effects of soil moisture conservation on yield and yield components of maize
Since this study was conducted in the low moisture stress area, the crop obtained adequate moisture in the cropping season for growth and high yield production. The grain yield and yield components were increased significantly according to the availability of moisture in the treatments. This was in agreement with the previous studies of Muhammad *et al*. (2015) and Kho-darahmpour (2011).

Number of seeds per ear
The analysis of variance showed that the combined and sole application of wheat straw mulch and farmyard manure had highly significant ($p \leq 0.01$) effects on the number of seeds/ ear. The maximum number of seeds (686) per ear was counted from the plots received 5 tons ha^{-1} of wheat straw mulch plus 5 tons ha^{-1} of farmyard manure and followed by 5 tons ha^{-1} of wheat straw mulch plus 3 tons ha^{-1} of farmyard manure (674) while the minimum number of seeds (364) per ear counted in the control plots which indicated reduction of about 89% and 85%, respectively. This might be due to the synergistic effects of treatment combinations that improved soil moisture conservation, nutrient use efficiencies and normal development of maize with increasing number of seeds/ear, ear per plant and thousand seed weights. The study conducted by Tolessa et al. (2015) discussed that application of mulches brought the higher number of seeds per ear obtained from the maize.

Table 6. Yield and yield components of maize as affected by straw mulch and farmyard manure

Treatments (tons/ha)	Parameters			
	NEPP	NSPE	THGW (g)	GY (tons ha^{-1})
Control	1.00	364[c]	282.40[d]	5.397[c]
3 WSM	1.33	419[bc]	346.07[cd]	6.463[bc]
5 WSM	1.67	549[ab]	408.67[bc]	8.313[b]
3 FYM	1.00	404[bc]	354.33[bcd]	5.587[c]
5 FYM	1.67	432[bc]	360.20[bc]	6.797[bc]
3WSM+3FYM	1.33	412[bc]	427.00[b]	8.073[b]
3WSM+5FYM	1.67	665[a]	404.07[bc]	8.523[b]
5WSM+3FYM	2.00	674[a]	537.00[a]	11.157[a]
5WSM+5FYM	2.00	686[a]	539.17[a]	11.837[a]
LSD $_{(0.05)}$	NS	157.33	77.386	2.310
Mean	1.5	512	406.55	8.016
CV (%)	27.62	17.76	10.99	16.65

Treatment values within a column followed by the same letter are not significantly different at P ≤0.05; NEPP= number of ears per plant, NSPE=number of seeds per ear, THGW=thousand grain weight, GY=grain yield, CV=coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% and NS=non-significant

Thousand grain weight

The analysis of variance revealed that thousand seed weight was very highly significantly (P≤0.001) influenced by the application of moisture conservation practices (Table 6). The soil with suitable amount of moisture content had brought maximum number of seeds and had an implication for seed weight. Similarly, the seeds, which were supplied with adequate moisture, matured well to have heavier seed weight than those exposed to low moisture stress like planting with only inorganic fertilizer (Shah *et al*., 2013).

Similar to the number of seeds/ ear, the maximum thousand seed weight was obtained from plots treated with 5 tons ha^{-1} of straw mulch plus 5 tons ha^{-1} of manure (539 g), followed by 5 tons ha^{-1} of straw mulch plus 3 tons ha^{-1} of manure (537 g) that increased about 90.92% and 90.16%, respectively, over the control. The increased in thousand grain weight might be due to the better integration of organic fertilizers with inorganic fertilizer for better growth and grain filling of maize in addition to the moisture availability as a result of combined surface management practices. The improvement in yield and yield components due to the management practices was related to the enhanced water availability during the grain filling stage due to increased infiltration and the nutrient availability that has resulted in increased individual grain weight and number of grains per plant (Admasu *et al*. 2014).

Grain yield

The mean grain yield was increased very highly significantly (p≤0.001) under moisture conservation system (Table 6). This result showed that the combined effect of 5 tons ha^{-1} of straw mulch with 5 tons ha^{-1} of farmyard manure and 5 tons ha^{-1} of straw mulch with 3 tons ha^{-1} of manure treatments were improved total grain yield to (11.8 tons ha^{-1} and 11.16 tons ha^{-1}), respectively, which enhanced the yield by 119.3% and 106.7%, respectively compared to the control (5.4 tons ha^{-1}). Water deficit causes a decrease in maize yield potential of 50-60% and decrease of 40% when the water deficit in the flowering phase (Bruce *et al*. 2002), yield decrease of 40% in tasselling phase and yield decrease of 66-93% when water deficit in ear formation (Cakir, 2004). Almost every plant process affected directly and indirectly by the availability of water in the soil. Cover with crop straw mulch on soil surface is important to promoting soil moisture content improving crop yields and water use efficiency (Wang *et al*., 2016).

In addition, study by Zhao *et al*. (2014) found that farmyard manure application with chemical fertilizer causes higher yield in maize, total N, soil organic matter, and available P compared with those found under mineral fertilizer treatment. The research reported by Misganaw (2014) revealed that the highest grain yield (8.159 tons ha^{-1}) was obtained in the treatment 4 tons ha^{-1} of farmyard manure plus 0.075 tons ha^{-1} N and 0.060 tons ha^{-1} of P compared to alone inorganic fertilizers and high dose of farmyard manure applied.

Conclusions and Recommendations

Generally, results of this study indicated that application of the combination of wheat straw mulch with farmyard manure had enhanced the productivity of maize by affecting soil moisture content at different growth stages in low moisture stress area of the mid rift valley of the country. The farmers are advised to use 5 tons ha^{-1} of straw mulching with 3 tons ha^{-1} of farmyard manure and/or 5 tons ha^{-1} of straw mulching with 5 tons ha^{-1} of farmyard manure for better effectiveness and higher yield of maize in the area. To come up with actual conclusive generalizations of soil moisture holding status and maize productivity from the applied treatments, this experiment should be repeated on the same area at least for three years and economic analysis is required for provision of appropriate recommendations.

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Evaluation of Combined and Sole Effect of Application of Gypsum and Compost for Soil Salinity Management at Small Scale Irrigation Farm in Dugda District of East Shewa Zone, Oromia, Ethiopia

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Abstract

This experiment was conducted in Dugda district of East Shoa Zone of Oromia, Ethiopia from 2018 to 2019 with the aim to evaluate the effect of sole and integrated application of Gypsum ($CaSo_4.H_2o$) and compost as soil salinity amendment. Onion variety (Adama red), the most commonly produced crop by farmers, was used as the test crop. Three levels of compost (0, 2.5, 5 tons ha^{-1}) and three levels of Gypsum (0, 50%, 100% Gypsum requirement (GR)) were factorial combined and arranged in RCBD design with three replications having an area of 3mx4m plot each. It was identified that the integration of 100%GR and 5 tons ha^{-1} compost produced economically optimum yield (320 qt ha^{-1}). The effect of Gypsum integrated with compost in reducing soil sodicity indicators such as ESP(exchangeable sodium percentage), Na^+ concentration, and EC were highly significant ($p<0.05$). Sole application of Gypsum was also significantly affect ($p<0.05$) the level of ESP, Na^+, Ca^{2+} and EC. ESP is very high at the control treatment (40.7 meq/100g) and showed a decreasing trend from 25.12-12.97 meq/100g as the level of Gypsum requirement increases from 50% to 100%. The main effect of compost significantly affected ($p<0.05$) the level of pH showing a decreasing trend (8.62-7.41) as the level of compost was increased from 2.5-5 tons ha^{-1}. Crop yield was increasing as the level of compost and gypsum application level were increasing indicating that both materials are very determinant for improvement of production and productivity of land affected by salinity problem. Therefore, considering its economical importance and positive effect in soil salinity amendment potential, the results of the study indicated that 100%GR integrated with 5 tons ha^{-1} compost as the best strategy in reclamation of salt affected soil.

Keywords: Compost, Gypsum, Reclamation, small scale Irrigation, Soil salinity

Introduction

In many areas of the world, salinity is one of the principal environmental causes of soil degradation, and consequently, a source of reduction in the biomass (Tejedor *et al.,* 2003; André *et al*., 2004; Warrick 2004). According to certain estimates, approximately 7% of soils all over the world suffer from this phenomenon (Ziad *et al*., 2004, Jassogne et al., 2006). These types of soils appear mainly in arid and semi-arid areas where precipitations are insufficient to drain the soluble salts contained in the soil profile (Caitlin, 2003). Salinity affects agricultural soils by destabilizing their structure, affecting microbial life with consequent declines in porosity. It also affects plants by decreasing the available water for plant growth, reducing mineral uptake and causing physiological stress.

In Ethiopia, soil salinity is the major problems in irrigated areas of arid and semi-arid region where there is a high evapotranspiration rate in relation to precipitation (Tenalem, 2008). According to Sissay (2003), in Ethiopia, about 9% of the population lives in the areas affected by salinity. This study also revealed that about 44 million ha (36% of the country's total land areas) are potentially susceptible to salinity problems. In addition, it was reported that in Ethiopia, there are over 11 million hectares of unproductive naturally salt affected wastelands (Tadele, 2003). The rift valley of Ethiopia is one of the regions where soil salinity problem is highly pronounced due to higher evapo-transpiration rates in relation to precipitation in the region (Tamire, 2004). Small-scale irrigation activities are very common in mid rift valley areas for addressing chronic food security vulnerability in the rural communities to which they have been providing relief assistance for decades. However, In the rift valley areas of Ethiopia, an expansion of irrigated agriculture is greatly contributing to the build up and spread of salinity problems. According to the study by Kasahun *et. al*. (2015), about 75% of the farmers in Dugda, Lume and Bora districts have been using ground water for irrigation that were found sodic based on FAO classification of salt affected soil and water. This study revealed that pH > 8.5, EC < 4ds/m, and ESP >31 in these districts at the farmers who have been using ground water as source of irrigation.

Soil salinity management interventions usually vary from place to place depending on the availability of the materials and awareness on soil salinity management practices. In Egypt, Gypsum is commonly used for the reclamation of saline-sodic and sodic soils to remove the Na^+ from the soil columns to form neutral salt $NaSO_4$ (Mohamed*et.al.* ,2012).

$$\mathbf{CaSO_4 + Na_2CO_3 = Na_2SO_4 + CaCO_3}$$

The addition of organic material in to salt affected soil has been successful in improving soil properties of sodic soils (Dalal, *et. al.,* 2009). However, the effectiveness of integration of both organic material and Gypsum for soil salinity treatment was not identified. Therefore, this trial was conducted to evaluate the effect of sole and integration of gypsum and compost for soil salinity reclamation, and to determine the best combination of soil salinity reclamation materials for the small scale irrigation farmers.

Material and Methods

The study was conducted in Dugda District of East Shewa Zone of Oromia where small scale irrigation is the main economic activity for many farmers. The district is generally characterized by dry low land agro-climate with the altitude ranging from 1576-1750 m.a.s.l. The rainfall pattern is erratic, insignificant mean monthly precipitation and higher potential evapo-transpiration as compared with precipitation. Mean daily temperature is 25^oC during the rainy season. Sandy loam is the dominant soil texture identified during the soil salinity assessment and characterization (Kasahun *et. al.,* 2015). As far as vegetation is concerned, mid rift valley in general and Dugda district in particular is characterized by scattered acacia wood lands.

Farmers Selection and Treatments

Two farmers who are using ground water for irrigation were purposively selected depending on their interest for evaluation of different soil salinity management interventions. In this trial three levels of Gypsum requirement (0, 2 and 4 tons ha^{-1}) were factorial combined with three levels of compost (0, 2.5 and 5 tons ha^{-1}). The level of Gypsum requirement was determined by the initial level of CEC, ESP initial, plan of ESP at final and 1.72t Gypsum which is the amount of Gypsum required to reduce a unit of sodium in the soil (Mohamed, 2012).

Therefore, Average CEC at initial was 13 meq/100gm, ESP initial = 30%, ESP final (required to be reached by reclamation) = 10%, GR (Gypsum requirement) = (ESPi SPf)/ 100*CEC *1.72ton = (30-10)/100*13*1.72 = 4 tons ha^{-1}

The level of compost was determined based on the amount of nitrogen fertilizer that the farmers are currently applying and the quality of conventional compost in terms of total nitrogen content. Accordingly, on average the farmers were using 100kg urea (46kg N/ha) for onion. The quality of compost was determined after laboratory analysis; accordingly, it contained1% total nitrogen. Therefore, about 4.6ton which is nearly 5 tons ha^{-1} compost can supply or substitute 46kg N (100kg urea). About 200kg/ha NPS was used based on the farmers practice that was applied uniformly for all plots at all trial sites.

Treatmets

1. Control (without compost and gypsum)
2. 2.5 tons ha^{-1}Compost
3. 5 tons ha^{-1} Compost
4. 50%GR
5. 100%GR
6. 2.5 tons ha^{-1} Compost+50%GR
7. 2.5 tons ha^{-1} Compost +100%GR
8. 5 tons ha^{-1} Compost +50%GR
9. 5 tons ha^{-1} Compost+100%GR

Onion variety (Adama red), which is one of the major vegetable crops produced by the farmers in the area, is used as the test crop. The treatments were replicated three times having $12m^2$ (3m*4m) area for each plot and arranged using RCBD. Site management (weeding, pesticide application, monitoring and watering) was done uniformly for all plots and experimental sites

Soil Sampling and Data Collection

Soil samples were collected from each plot before application and after harvesting to the depth of 20cm and were sent to soil laboratory for soil physiochemical analysis. The extent of salinity before and after intervention were identified based on four main parameters such as EC (electrical conductivity), pH, ESP (exchangeable sodium percentage), SAR (sodium adsorption ratio) because these values are used in the guidelines for classification of salt affected soil by different authors and organizations (FAO, 1988; Qadir & Schubert 2002;

Gonzalez *et al.,* 2004). In addition, soluble cations such as CEC, Calcium, Magnesium, Sodium, and Potassium were analyzed. Crop yield was also taken and recorded to evaluate the effect of the treatments on total onion yield.

Table1: Guidelines for classification of salt affected soil and water (FAO, 1988)

Soil classification	EC DS/m	SAR	ESP	PH
Sodic	<4	>13	>15	>8.5
Saline	>4	<13	<15	<8.5
Saline sodic	>4	>13	>15	<8.5

Sodium percentage was calculated as:

$$ESP = \frac{[Na+] * 100}{CEC}$$

Data Analysis: Data were analyzed using SAS 9.0 version, SPSS version 20 and R-software were used.

Results and Discussion

Main and Interaction Effect of Gypsum and Compost on Onion Yield

The main effect of compost significantly affected ($p<0.05$) crop yield and similarly, main effect of gypsum and its interaction with compost were significantly affected ($p<0.05$) the crop yield (Table 2). Maximum crop yield (320.61Q/ha) was obtained 5 tons ha^{-1} compost combined with 4 tons ha^{-1} Gypsum followed by 2.5 tons ha^{-1} compost combined with 4 tons ha^{-1} gypsum (300.4Q/ha) (Figure1 & Table 2).

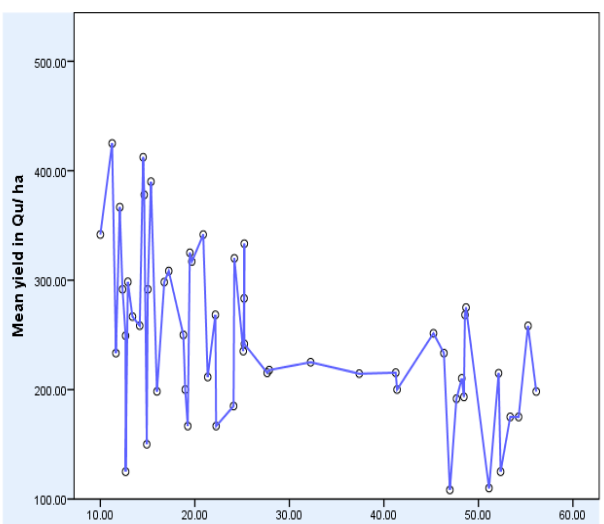
Table 2: Effect of compost integrated with Gypsum on onion yield

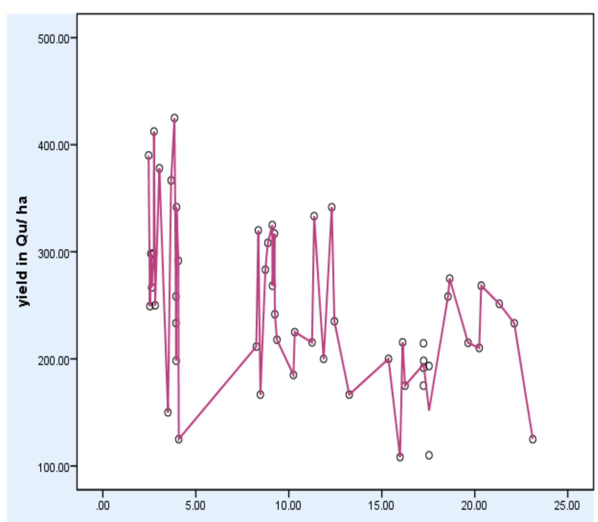
No.	Treatment	Mean yield Q/ha	Std. Error	Minimum (Q/ha)	Maximum (Q/ha)
1.	Control	217.75^{f}	22.59	110.00	258.22
2.	2.5 tons ha^{-1} Compost	225.05^{f}	12.96	166.66	241.66
3.	5 tons ha^{-1} Compost	253.74^{de}	12.42	125.00	298.23
4.	50%GR (2 tons ha^{-1})	243.01^{e}	29.89	108.33	251.42
5.	100%GR (4 tons ha^{-1})	260.55^{d}	14.25	191.66	275.00
6.	2.5 tons ha^{-1} Compost+50%GR	276.01^{c}	13.55	200.00	283.33
7.	2.5 tons ha^{-1} Compost +100%GR	300.4^{b}	4.86	308.33	341.66
8.	5 tons ha^{-1} Compost +50%GR	295.55^{b}	10.15	233.33	298.45
9.	5 tons ha^{-1} Compost+100%GR	320.61^{a}	12.4280	341.667	425.000
LSD		15.65			
P-value		<0.0001			
CV		16.85			

Other similar studies by Joachim *et al.* (2007) and Hanay *et al.* (2004), indicated that integrated application of gypsum and compost on salt affected soil significantly increased maize yield in Tanzania for two consecutive years. Gypsum and compost applications to paddy saline soil is an effective remediation procedure not only in terms of improving the physical, chemical and biological properties of the soil but also used to enhance the growth and development of rice crops prior to grain harvesting (Mitchell et al.,2000; Hanay et al., 2004; Tejada et al., 2006; Wong et al., 2009). On the other hand, a sole application of compost is ineffective in remediating saline soil (Amanullah, 2008; Qadir et al., 2008).

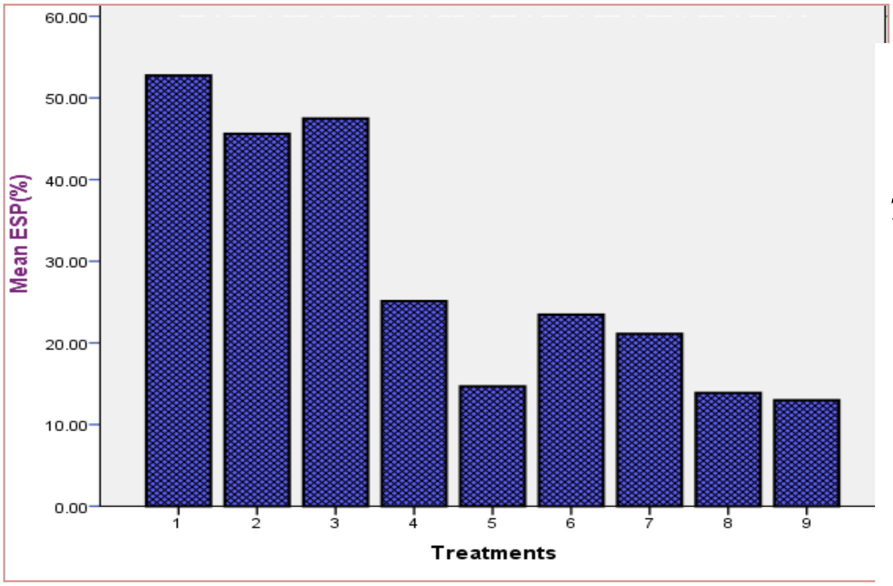
Effect of Gypsum and Compost Interaction on Soil Salinity Management

Sodicity is measured by calculating the exchangeable sodium percentage (ESP) and/or the sodium adsorption ratio (SAR). ESP is the percentage of soil exchange sites occupied by Na^+, and is calculated by dividing the concentration of Na^+ cations by the total cation exchange capacity (Qadir et al., 2008). Exchangeable sodium percentage was highly significantly different ($p<0.05$) among the treatments. ESP was very high at the control treatment (40.7 meq/100g) where there was no application of Gypsum and compost as compared with other treatments. ESP value showed a decreasing trend from 25.12-12.97 meq/100g as the level of Gypsum requirement increases from 50% to 100% (Table 3). However, the main effect of compost did not significantly affect ($p<0.05$) the ESP in the first three treatments that received 0, 2.5 and 5 tons ha^{-1} compost. Main effect of gypsum and its interaction with compost were significant ($p<0.05$) for the ESP (Table 3). As the levels of gypsum requirement (GR) and compost increased, the levels of ESP were decreasing indicating that application of gypsum integrated with compost could be used to reduce the soil salinity problem associated with high concentration of sodium in the soil (Figure 3). The effect of ESP on crop yield also indicated that as the level of sodium concentration in the soil (ESP) increases, the onion yield showed a decreasing trend indicating that high sodium concentration in the soil was a problem to onion production (Figures.1 & 2).





Figures1&2: Effect of ESP and Exchangeable sodium on Onion yield



Treatments

1. *Control*
2. *2.5 ton/ha Compost*
3. *5t/ha Compost*
4. *50%GR (2ton/ha)*
5. *100%GR (4ton/ha)*
6. *2.5t/ha Compost+50%GR*
7. *2.5t/ha Compost +100%GR*
8. *5t/ha Compost +50%GR*
9. *5t/ha Compost+100%GR*

Figure 3: Trends of ESP dynamics with the application of treatments

Reclaiming sodic and saline-sodic are done by replacing excess Na^{+} from the exchange site by another cation, namely Ca^{2+} or Mg^{2+}. This is done by adding an amendment that either directly or indirectly releases exchangeable Ca^{2+} or Mg^{2+}. Because Ca^{2+} and Mg^{2+} have a stronger charge than Na^{+}, they will replace Na^{+} on exchange sites, causing Na^{+} to be released to the soil solution and be susceptible to removal by leaching (Abbas et al., 2016). Other similar studies also indicated that use of gypsum integrated with organic material like water hyacinth compost and rice straw compost reduced ESP of saline-sodic soils as compared to their individual use (Mikanova et al., 2012; Shaaban et al., 2013). The result is also supported by previous findings that application of gypsum with organic amendments decreased the soil salinity and sodicity indicators related to high accumulation of sodium concentration in the soil (Nan et al., 2016; Qadir et al., 2017). Studies also indicated that application of 50% GR+ 20t ha-1 compost at 20t/ha were successful to increase wheat yield by 219% over the control (Zaka et al., 2003, Mahdy, 2011). Beneficial effect of compost on crop growth and yield has been reported by many researchers (Islam et al., 2017). However, combination of chemical amendments (gypsum) with compost is more beneficial to cut short the reclamation period and for achieving rapid rehabilitation (Ameen et. al., 2017).

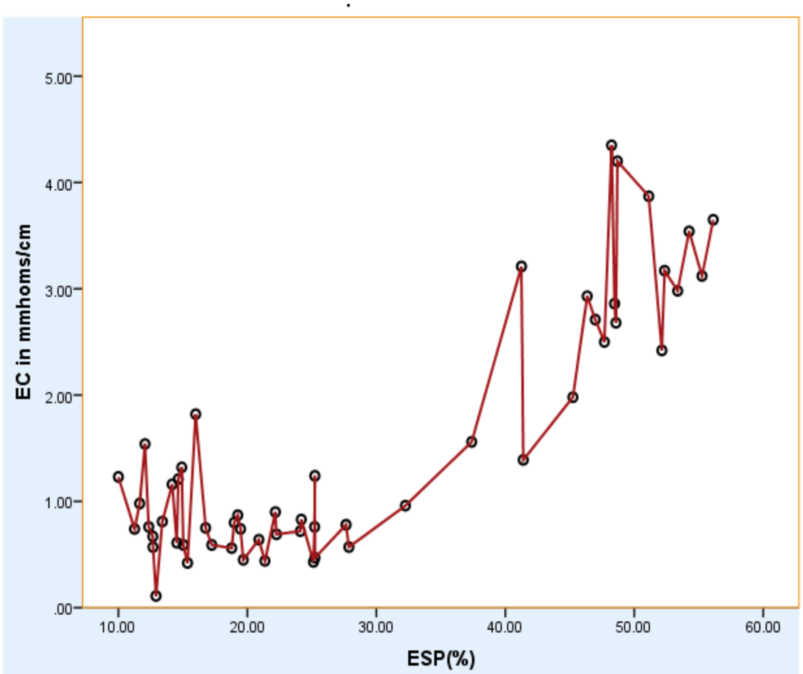
Effect on Electrical Conductivity

Soil EC is very important parameter that indicates an overall estimate of soluble salts. It is of prime importance in water relation of plants as well as nutrient uptake (Munns et al., 2006). Electrical conductivity was highly significantly different ($p<0.05$) among the treatments. It was very high at the control treatment (3.52 mmhos/cm), where there was no application of gypsum and compost, as compared with other treatments. EC showed a decreasing trend from 3.52 mmhos/cm to 0.96 mmhos/cm as the levels of gypsum requirement was increasing from 50% to 100% (Table 3). The main effect of compost did not significantly affect ($p<0.05$) the levels of EC in the first three treatments However, main effect of gypsum significantly affected ($p<0.05$) the levels of EC.

Table 3: Effect of compost and gypsum application on soil chemical properties

Treatment	pH	EC mmhos/cm	ESP (%)	Ca (me/100g)	Na(me/100g)
Control	8.62a	3.52a	40.74a	12.92c	18.99a
2.5 tons ha^{-1} Compost	8.40ab	2.64a	35.60a	12.67c	17.41a
5 tons ha^{-1} Compost	7.96c	2.69a	34.47a	11.91c	18.9a
50%GR (2 tons ha^{-1})	8.55a	0.75b	25.12b	21.08b	10.47b
100%GR (4 tons ha^{-1})	8.39ab	0.25c	14.67c	31.70a	3.23c
2.5 tons ha^{-1} Compost+50%GR	8.31ab	0.65b	23.45b	24.09a	9.97b
2.5 tons ha^{-1} Compost +100%GR	8.20ab	0.73b	13.88c	33.29a	3.35c
5 tons ha^{-1} Compost +50%GR	7.82bc	0.75b	21.12b	22.00b	9.87b
5 tons ha^{-1} Compost+100%GR	7.41c	0.16c	12.97c	34.60a	3.29c
LSD	1.2	0.46	6.54	15.35	3.12
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
CV	4.09	26.36	12.17	10.50	15.66

Application of 5 tons ha^{-1} compost integrated with 100%GR resulted in significantly lower EC (0.16 mmhos/cm) though not significantly different from sole application of 100% GR (0.25 mmhos/cm). Generally, EC showed the decreasing trend as the level of GR was increasing indicating that sole application of gypsum significantly reduced the electrical conductivity of the soil due to reduced concentration of dissolved sodium as a result of gypsum application. The amount of EC of the soil also depends on the concentration of sodium or exchangeable sodium percentage (ESP). The higher ESP of the soil is the higher EC (Figure 4).



Treatments

1. *Control*
2. *2.5 ton/ha Compost*
3. *5t/ha Compost*
4. *50%GR (2ton/ha)*
5. *100%GR (4ton/ha)*
6. *2.5t/ha Compost+50%GR*
7. *2.5t/ha Compost +100%GR*
8. *5t/ha Compost +50%GR*
9. *5t/ha Compost+100%GR*

Figure 3: Change in soil EC with the application of treatments Figure 4: The relationship between ESP and EC

The result was also highly complemented with the study by Muhammad et.al. (2018) which indicated that EC of the soil reduced from 8.52 dS m^{-1} to 3.0 dS m^{-1} (critical limit 4.0 dS m^{-1}) due to integrated application of gypsum application at 100 % GR plus compost at 5 tons ha^{-1}. The integrated application of compost and gypsum reduced EC by 31% as compared with sole application of compost (Niazi et al.2001). The result suggested that combined ameliorants were superior to either one alone in their effect to decrease EC. The reduction of EC might be due to leaching of soluble salts (Na^+) into the drainage systems or into the deeper layers of the soil profile (Hanay et al., 2004).

Effect on Soil pH

Soil pH was highly significantly different ($p<0.05$) among the treatments. pH was very high at the control treatment (8.62), where there was no application of gypsum and compost, as compared with other treatments (Figure 4). The main effect of compost significantly affected ($p<0.05$) the levels of soil pH. Soil pH showed a decreasing trend (8.62-7.41) as the level of compost was increased from 2.5-5 tons ha^{-1} (Table 3). This is mainly due to the fact that application of compost can significantly reduce soil pH as a result of organic acids released during decomposition of compost (Abbas et al., 2016). Interactions of compost and gypsum application also significantly affected the levels of soil pH. However, main effect of gypsum was not significant–for the levels of soil pH as the GR increased from 50-100%. This is mainly due to an increased in concentration of calcium from gypsum application has little influence in reducing soil pH as a result of high calcium carbonate content (Brady and Weil, 2002). Other similar studies also indicated that compost decreased pH by 9.5%, gypsum by 3.9%, pH was lowered by 14.7% when compost and gypsum were combined as compared with the control treatments (Niazi et al. 2001).

Effect of Compost and Gypsum Application on Concentration of Sodium and Calcium

Sodium concentration was relatively very high (18.99 meq/gm soil) and highly significantly different ($p<0.05$) for the control treatment as compared with other treatments. It was very low (3.29 meq/gm soil) at treatment received 100% GR (Figure 5). The main effect of compost did not significantly affect ($p<0.05$) the levels of sodium concentration in the soil. However, interaction effect of gypsum with compost and main effect of gypsum were highly significant ($p<0.05$) for sodium concentration (Table 3). Crop yield also showed a decreasing trend as the amount of Ex. Na was decreasing (Figure 5).

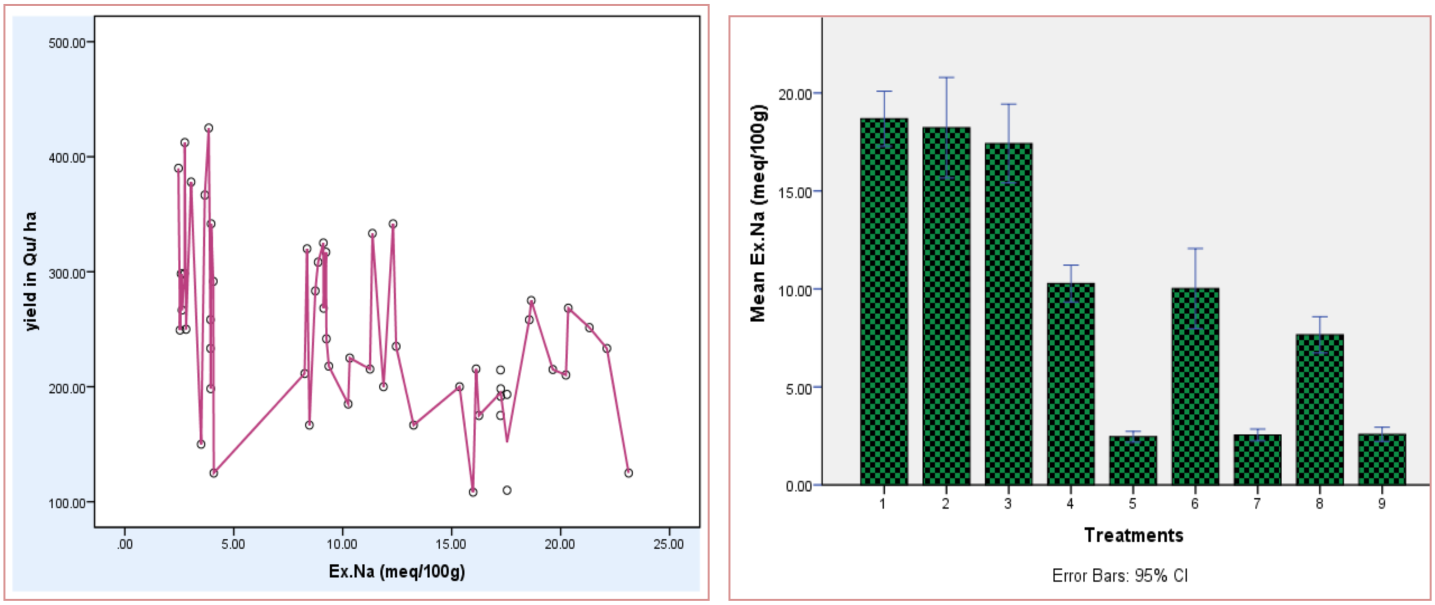
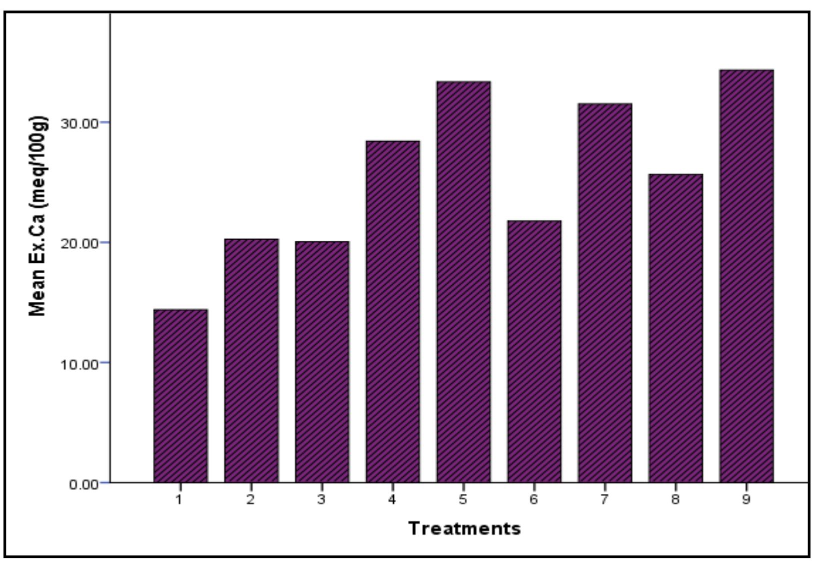


Figure 5: Effect of Ex.Na on crop yield and its variation between the treatments

Calcium concentration varied negatively with the sodium concentration in the soil. It was very low at the control treatment (12.92 meq/gm soil) where no gypsum and compost were applied. It was very high (34.60 meq/gm soil) at the treatment received 100% GR (Figure 6). The main effect of Compost was not significantfor the levels of calcium concentration. However, compost interaction with gypsum was significant ($p<0.05$) for the levels of calcium concentration in the soil. Similarly, the main effect of gypsum was highly significant ($p<0.05$) for calcium concentration (Table 3).



Treatments

1. *Control*
2. *2.5 ton/ha Compost*
3. *5t/ha Compost*
4. *50%GR (2ton/ha)*
5. *100%GR (4ton/ha)*
6. *2.5t/ha Compost+50%GR*
7. *2.5t/ha Compost +100%GR*
8. *5t/ha Compost +50%GR*
9. *5t/ha Compost+100%GR*

Figure 6: Variation of calcium concentration among the treatments

Similar studies by different authors also indicated that the increase in Ca^{2+} occurred due to direct application of gypsum (Wright et al., 2008). This Ca^{2+} replaced Na^+ on exchange sites that was leached down during continuous irrigation so that there was net increase in Ca content and very high decrease in the amount of Na from the soil solution (El-Sanat et al., 2017).

Economic Analysis

The economic analysis was done to select the most economically important soil salinity amendments that were evaluated using detail field trial. Accordingly, the maximum net benefit (560,800Birr) was obtained by treatment 5 tons ha^{-1} Compost + 100% GR followed by 2.5 tons ha^{-1} Compost + 100%GR (528,480Birr) and 5 tons ha^{-1} Compost +50%GR eight (516,280Birr). The maximum yield advantages (47.2%) followed by (38%) and (35.7%) were obtained from the mentioned treatments respectively compared with the control treatment. However, the lowest net benefit (370,980Birr) was obtained at the control treatment (Table 4). The net benefit showed an increasing trend as the level of compost and gypsum application was increasing. Similar studies by Wienhold and Trooien (2005) and Abdel-Fattah (2012) reported that gypsum ($CaSO_4 \cdot 2H_2O$) amendment is the most economical amendment used on sodic soils.

Table 4: Economic analysis for onion yield

Treatments	Mean yield in Q/ha	Input cost /ha (Birr)	Labor costs /ha (Birr)	Total variable cost/ha (Birr)	Market price of Onion/Q (Birr)	Gross income/ha In Birr	Net income/ ha in	MRR (%)
Control	217.8	36500.00	28020.00	64520.00	2000.00	435500.00	370980.00	0.00
2.5 tons ha^{-1} Compost	225.1	36350.00	30520.00	66870.00	2000.00	450100.00	383230.00	18.31
5 tons ha^{-1} Compost	253.7	36200.00	33020.00	69220.00	2000.00	507480.00	438260.00	97.19
50%GR (2 tons ha^{-1})	243.0	42100.00	28020.00	70120.00	2000.00	486020.00	415900.00	64.06
100%GR (4 tons ha^{-1})	260.6	47700.00	28020.00	75720.00	2000.00	521100.00	445380.00	98.25
2.5 tons ha^{-1} Compost+50%GR	276.0	41950.00	30520.00	72470.00	2000.00	552020.00	479550.00	149.81
2.5 tons ha^{-1} Compost +100%GR	300.4	41800.00	30520.00	72320.00	2000.00	600800.00	528480.00	217.78
5 tons ha^{-1} Compost +50%GR	295.6	41800.00	33020.00	74820.00	2000.00	591100.00	516280.00	194.19
5 tons ha^{-1} Compost+100%GR	320.6	47400.00	33020.00	80420.00	2000.00	641220.00	560800.00	236.03

Conclusions and Recommendations

Soil and plant health can be adversely affected by the presence of excessive salts in soils. Understanding how salt-affected soils develop and identifying their characteristics is crucial to managing salt affected areas. Choosing which management techniques to employ to salt-affected soils will depend on the nature and extent of the problem, cost and available resources. An effective reclamation procedure for saline-sodic soils is removal of undesirable Na^+ concentration in the soil by application of some Ca^{2+} source like gypsum. Accordingly, the combination of compost + gypsum proved to be the best soil amendment for reducing soil pH, ESP and EC in these soils. In addition, with increasing rate of the application of gypsum and compost used in reclamation process, the more decrease in soil salinity. The finding derived for farmers and other beneficiaries from this study was that they could effectively reclaim their salt affected soils by applying gypsum at the full rate (100% GR) integrating it with compost (2.5 to 5tons ha^{-1}).

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Adaptation and Growth Performance Evaluation of Agroforestry Tree Species under Dire Dawa Administration and Harari People Regional State Condition, Eastern Ethiopia.

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Abstract

Tree growth is a function of the genetic potential of the species and environmental conditions. Hence, before introducing any species to a given agro ecology there is always a need for a well conducted field trial for matching species to a particular site. A study was conducted to evaluate adaptation and growth performance of five agro forestry tree species at Dire Dawa Administration; Adada2 and Harari Region; Erer dodota for three years (June 2016 - June 2019). Five agroforestry tree species (Sesbania sesban, Moringa oliefera, Gravilea robusta, Azadarichta indica and Leuceana leucocephala) were compared in randomized complete block design with three replications. Data on growth parameters, diameter, plant height and survival rate were measured and recorded at interval of three months. Results revealed that there were highly significant ($p<0.05$) variations among tree species in height growth, root collar diameter development, diameter at breast height and survival rate at both study areas. This could be due to environmental factor and/or genetic potential of the species, which generally govern the growth of a given species. Among the species tasted, Moringa oliefera showed the highest performance followed by Azadarichta indica, Sesbania sesban and Leuceana leucocephala in terms of height growth, root collar diameter and diameter at breast height at both Dire Dawa Administration and Harari Region. After three years of establishment, Moringa oliefera, Azadarichta indica, Sesbania sesban and Leuceana leucocephala showed the highest mean survival rate at both study areas. Hence it can be inferred that the conditions of Dire Dawa Administration and Harari Region matched with the environmental requirement of those tree species. On the other hand, species of Gravilea robusta showed lowest performance at both study areas. Thus, the long dry season, which extended from eight to ten months in the study area, clearly explains the poor survival and growth response in some of the species. Generally, these findings may help forest and agroforestry managers to properly allocate species into the site that grow and adapt well. Further testing of provenances of the best performing species is recommended to select the most adaptable ones for such areas for future agroforestry practices at wider scale; on which success of agroforestry practices and forest plantations depend.

Keywords*: Agroforestry, diameter at breast height, height growth, root collar diameter*

Introduction

Land degradation in Ethiopia is a major problem due to a number of factors. One of the important causes is the removal of forest and vegetative cover as a result of increased human population leading to high demand for forest products and land for expanding the agricultural activities (Demel *et al.*, 2001). Consequently; these areas are now characterized by loss of soil fertility and soil erosion problems. Eastern Ethiopia particularly, East Hararghe high land is well known by vegetation cover and most of the surrounding area is covered by forests comprised of a rich mixture of woody species (Abebe *et al.*, 2000). In spite of the importance of forest ecosystem to the livelihoods of the people in the area, the forest is dwindling from time to time due to high exploitation of woody and non-woody products. Rapid deforestation caused by an escalating demand for fuel wood expansion for agriculture has brought an ever-increasing pressure on native woodland species (Mebrate *et al.*, 2004). If no remedial action is taken, this will cause severe impact on agricultural productivity leading to energy poverty and environmental degradation. Frequent and severe droughts often present a serious threat for millions of lives (Brockerhoff, 2008), which have occurred once in a decade in the 1970s and 1980s. Shortages of animal feed and biomass energy are also such an unsustainable use of natural resources Currently, biomass energy constitutes 88.7% of all energy consumed in Ethiopia which is mainly derived from the woody biomass resources (forests, woodlands, shrub lands, planted trees, agro forests). Agro forestry system has much potential for supplying fodder, poles, farm equipment, fuel wood and agricultural improvements (Abebe, 2000).

Multipurpose tree and shrubs species (MPTS) play a considerable role in addressing such multifaceted demands in the mixed crop-livestock production system (Betre *et al.*, 2000). They have the ability to fit into the farming system to be used as a source of manure, mulch, soil conservation, forage, fuel wood, farm implements and other like shade and shelter (Kahsay *et al*., 2001). However, each/shrubs species has its own biotic and abiotic factors in which it performs to its maximum potential. It has specific edaphic and climatic requirements (Abebe *et al.*, 2000). Some possible research needs include soil-plant interactions, soil fertility and N-fixation studies on wide range of species, crop tree yield studies and optimum tree density, socioeconomic studies, and species selection and screening including seed tests, establishment, and management. In Babile district, farmers practice on farm and homegarden for economic, social and environmental benefits (Getahun *et al.*, 2014). These traditional agroforestry practices could be intensified by using fast growing multipurpose tree species (MPTS) to satisfy the demands of the growing population. Thus, before introducing any species to a given agro ecology, there is always a need for a well conducted field trial for matching of the species/provenance to a particular site (Mebrate *et al*., 2004). The first trial should be a species screening trial that will test the survival and early growth of the species in one to three years. Deciding what species to plant in any agroforestry system to meet the intended objectives require a well- conducted field trial to match a species to a particular site.
Many species screening experiments have been conducted in different parts of country (Betre Alemu *et al.*, 2000). However, information is scarce at Dire Dawa Administration and Harari Region to recommend promising multipurpose tree and shrubs species for use in agro forestry practices. Hence, there is a need to investigate adaptable and promising tree and shrubs species in the areas. Therefore, this experient was designed to evaluate the adaptation and growth performance of five agroforestry tree species to Dire Dawa Administration; Adada2 and Harari Region: Erer Dodota conditions and sites of similar agro-ecology.

Materials and Method

Description of the study area

The experiment was conducted in Dire Dawa Administration, Biyyo Awalle Cluster in Adada2 on farmer land and Harari People Regional State, Erer Waldea District in Erer Dodota on Farmers Training Center (FTC). The study area geographically lies at an altitude of 1300-1800 m. a. s l which is lowland. The area was characterized by very short rainy season of 3 to 4 months (single quarter of the year), with all its intermittent condition and erratic distribution which may affect the growth and performance of trees. The soil is clay loam in texture and medium in organic matter content and high in exchangeable potassium. Generally, the pH of the soil (7.94) is in the optimum range for growth of most plants. The experiment was also conducted at Dire Dawa Administration; Biyyo Awalle cluster; Adada2 Peasant Association (PA) which is located at $41^0$51'E longitude, $9^0$31'N latitude and an altitude of 1160 m a. s. l. It is situated in the semi-arid tropical belts of eastern Ethiopia at the middle of the eastern Hararghe mountain chain. The area experiences a bimodal type of rainfall with the mean annual precipitation of 556.5 mm. The mean annual maximum and minimum temperatures vary from 28.3^0C to 34.9^0C and 15.1^0C to 22.7^0C, respectively. Soil type of the experimental site is clay loam. The area is classified under semi-arid climate (Adnew, 2005).

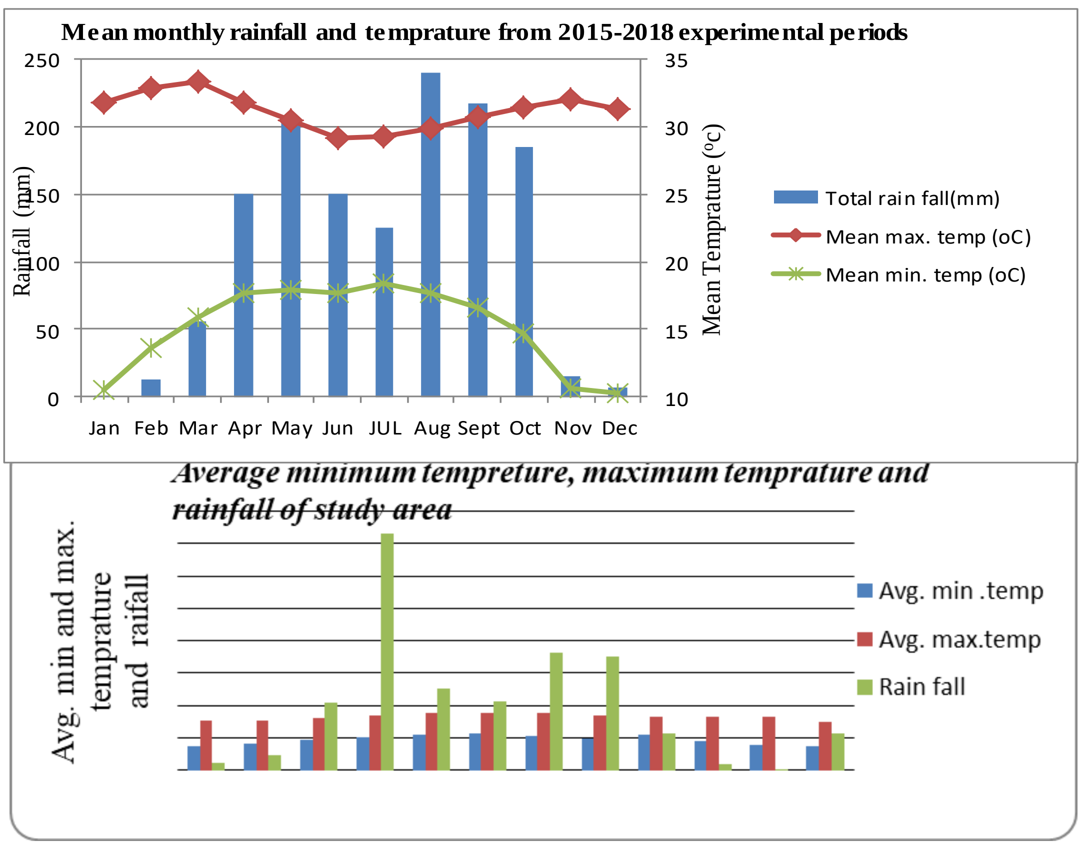

Figure 1: Mean monthly rainfall and temperature during experimental period at Harari Region and Dire Dawa Administration respectively based on meteorological data nearest to the study areas.

Seeds source

Seeds of five agroforestry tree species were obtained from Central Ethiopian Environment and Forestry Research Center.

Table 1. Details of tree species used in the adaptation trial

Tree species	Family name	Seeds source
Sesbania sesban	Leguminosae	CEFRC
Leuceana leucocephala	Leguminosae	CEFRC
Moringa oliefera	Moringaceae	CEFRC
Azadarichta indica	Meliaceae	CEFRC
Gravilea robusta	Proteaceae	CEFRC

Key: CEEFRC: Central Ethiopian Environment and Forestry Research Center

Treatments and experimental design

Seedlings of tree species *(Sesbania sesban, Gravilea robusta, Azadarichta indica, Leuceana leucocephala and Moringa oliefera*) were raised directly into polythene tubes at Adada2 and Erer nursery sites with the recommendation of nursery activities. Seedlings with the same age of these tree species were planted in the field in June, 2016 at both experiment sites using a randomized complete block design with three replications. Each replication had five experimental plots, representing five tree species of nine seedlings each. The spacing between blocks and plots were 2.5 m and 2 m; respectively and the space between trees in a plot was 2 m. After planting, the sites were protected from grazing and human interferences. Plantation plots were neither irrigated nor fertilized. Survival rate, plant height (from ground level to the tip of the plant), diameter at breast height (DBH) and root collar diameter (RCD) were recorded every three months from June 2016 - June, 2019.

Data Collection

In order to fit the given objectives, data were collected on growth and adaptation parameters such as Plant height, root collar diameter, diameter at breast height and survival rate for the three years at interval of three months. Root collar diameter were collected only up to the tree reaches 1.3 meters in height and diameter at breast height were collected after tree reaches 1.3 m whereas plant height and survival rate were up to the end of the period of the activity. Height growth was determined by using measuring tape and root collar diameter and diameter at breast height by digital caliper.

Data Analysis

Analysis of variance was computed using Genstat software (18^{th} edition) package to test the significant difference among tree species. Least significant different (LSD) test was employed to separate statistically different means using the software package at 0.05 level of probability.

Results and Discussion

Survival rate

Among tree species, differences were highly significant ($p<0.05$) for survival rate as well (Table 2 and 3). After three years of establishment, *Moringa olifera* demonstrate the highest survival rate at both experiment sites. Yitebitu, 2004 also reported that *Moringa* species are quite drought resistant species which is similar to the observation of the present study. This can be attributed to the moisture stress experienced, which as Kozlowski *et al.* (1991) also stated can affect the growth, survival and distribution of forest trees. *Azadarichta indica, Sesbania sesban, Leuceana leucocephala* demonstrated the good survival rate at both Dire Dawa (Adada2) and Harari (Erer Dodota) respectively. Hence, it can be inferred that the condition of Dire Dawa and Harari matched well with the environment requirement of these species. *Gravilea robusta* on the other hand, showed lowest survival rate at both study areas. The long dry season, which extended from seven to nine months in the study areas, clearly explains the low survival of the *Gravilea robusta* seedlings during the experimental period. In the present study, the mortality was subjectively attributable to abiotic factors such as drought and moisture stress during the initial growth from October to June, although biotic problems like termites were also experienced during the assessment period at both study area. Thus, the environmental condition of Dire Dawa and Harari not suitable for *Gravilea robusta.* Soil and below ground competition are also other factors that influence the growth and survival rate (Casper and Jackson, 1997). On the other hand, *Moringa oliefera, Azadarichta indica, Sesbania sesban* and *Leuceana leucocephala* were found to be highly resistance to moisture stress in the both Dire Dawa Administration, Adada2 and Harari Region, Erer Dodota. Highly significant variations was among the tree species in survival rate ($p<0.05$) was recorded at all three years of age after transplanting.

Table 2: Mean survival rate (%) of agroforestry tree species planted in Biyyo Awalle; Adada2, over three years (2016/17- 2018/19)

Tree species	Stages age of seedling after transplanting		
	Year (2016/17)	Year (2017/18)	Year (2018/19)
Sesbania sesban	86.67[a]	85.00[a]	76.67[a]
Azadarichta indica	89.00[a]	88.33[a]	83.33[a]
Leuceana leucocephala	89.67[a]	80.00[a]	76.67[a]
Moringa oliefera	95.00[a]	90.00[a]	85.00[a]
Gravilea robusta	65.00[b]	42.33[b]	37.00[b]
LSD (0.05)	9.86	12.00	12.67
CV (%)	6.2	8.3	9.4
Mean	85.1	77.1	71.7
P value	<.001	<.001	<.001

N.B. Means in columns with the same letters are not significantly difference using LSD, CV=Coefficient of Variation, LSD= Least Significant Difference

Table 3: Mean survival rate (%) of agroforestry tree species planted in Erer Dodota; Harari Region over three years (2016/17 - 2018/19)

Tree species	Stages age of seedling after transplanting		
	Year (2016/17)	Year (2017/18)	Year (2018/19)
Sesbania sesban	85.67[a]	81.00[a]	72.33[a]
Azadarichta indica	86.67[a]	86.33[a]	79.33[a]
Leuceana leucocephala	88.33[a]	78.33[a]	72.00[a]
Moringa oliefera	92.67[a]	89.00[a]	81.33[a]
Gravilea robusta	64.00[b]	41.33[b]	34.33[b]
LSD(0.05)	9.97	12.80	11.09
CV (%)	6.3	9.0	8.7
Mean	83.5	75.2	67.9
P value	<.001	<.001	<.001

NB: Means in columns with the same letters are not significantly difference using LSD CV=Coefficient of Variation, LSD= Least Significant Difference

Height growth

Analysis of variance revealed that variations in height among tree species were highly significant ($p<0.05$) after three years of age at both study areas. Height growth trend (Table 4 and 5) showed that *Azadarichta indica* and *Moringa oliefera* were the tallest trees , followed by *Sesbania sesban, Leuceana leucocephala* but *Gravilea robusta* showed the shortest tree at both Dire Dawa and Harari Region's environmental conditions. Result on growth performance also showed that *Azadarichta indica* and *Moringa oliefera* were higher than the other species at both study areas. *Sesbania sesban* and *Leuceana leucocephala* also showed good growth performance at both study areas. Similarly, Raebild *et al*. (2003) also stated that apart from indicating productivity, height may also be seen as a measure of the adaptability of trees to the environment as tall trees usually being better adapted to the site than short trees (Cossalter,1987). *Moringa* species could also play a great importance in the rehabilitation process especially during periods of drought or in areas where nutrient resources are not available. Several similar studies also showed that fast growth of seedling is an important indicator in terms of determining the situation of growth response especially in the first growing period and it is commonly assumed that the early fast growth rates of tropical trees reflect productivity status of the trees (Baris and Ertenkin, 2010).

Diameter Growth

As depicted in Table 4 and 5, there is significant variation among tree species in diameter growth at both study areas. Diameter growth trend (Table 4 and 5) shows that the highest root collar diameter was recorded for *Azadarichta indica* followed by *Moringa oliefera, Sesbania sesban* and *Leuceana leucocephala* but the lowest root collar diameter was recorded for *Gravilea robusta* at Dire Dawa and Harari environment condition. Growth in diameter at breast height also highly significant ($p<0.05$) for the five agroforestry tree species at both study areas. The difference in growth of diameter at breast height (1.3 m) above the ground of tree species *Azadarichta indica, Moringa oliefera, Sesbania sesban* and *Leuceana leucocephala* showed highest diameter at breast height (DBH) within three years data records at both Dire Dawa Administration, Adada2 and Harari Region, Erer Dodota environment condition. On the other hand *Gravilea robusta* showed the lowest diameter at breast height growth at both study areas.

Table 4. The mean of Plant height, survival rate, diameter at breast height and root collar diameter of agroforestry tree species for three years (2016/17 – 2018/19) at Dire Dawa Administration; Adada2.

Tree species	Survival rate (%)	Plant height(m)	Root collar diameter (cm)	Diameter at breast height (cm)
Sesbania sesban	83.00^{a}	3.383^{c}	7.750^{b}	4.867^{a}
Azadarichta indica	87.00^{a}	4.167^{a}	10.647^{a}	5.133^{a}
Leuceana leucocephala	82.33^{a}	3.467^{bc}	8.067^{b}	4.467^{a}
Moringa oliefera	90.33^{a}	3.900^{ab}	9.933^{a}	4.583^{a}
Gravilea robusta	48.00^{b}	1.503^{d}	4.913^{c}	3.247^{b}
LSD(0.05)	8.51	0.4806	1.182	0.769
CV (%)	5.8	7.8	7.6	9.2
Mean	78.1	3.284	8.26	4.46
P value	<.001	<.001	<.001	0.004

NB: Means with the same letters are not significantly different using LSD, CV=Coefficient of Variation; LSD= Least Significant Difference

Table 5. The mean of Plant height, survival rate, diameter at breast height and root collar diameter of agroforestry tree species for three years (2016/17 - 2018/19) at Harari Region; Erer Dodota.

Tree species	Survival rate (%)	Plant height (m)	Root collar diameter (cm)	Diameter at breast height (cm)
Sesbania sesban	80.00^{b}	3.167^{b}	7.450^{b}	4.533^{a}
Azadarichta indica	84.33^{ab}	3.917^{a}	10.150^{a}	4.883^{a}
Leuceana leucocephala	79.67^{b}	3.217^{b}	7.883^{b}	4.267^{a}
Moringa oliefera	87.67^{a}	3.500^{ab}	9.667^{a}	4.400^{a}
Gravilea robusta	46.33^{c}	1.490^{c}	4.617^{c}	3.083^{b}
LSD(0.05)	7.078	0.5283	1.052	0.885
CV (%)	5.0	9.2	7.0	11.1
Mean	75.60	3.058	7.95	4.23
P value	<.001	<.001	<.001	0.013

NB: Means with the same letters are not significantly different using LSD, CV=Coefficient of Variation; LSD= Least Significant Difference

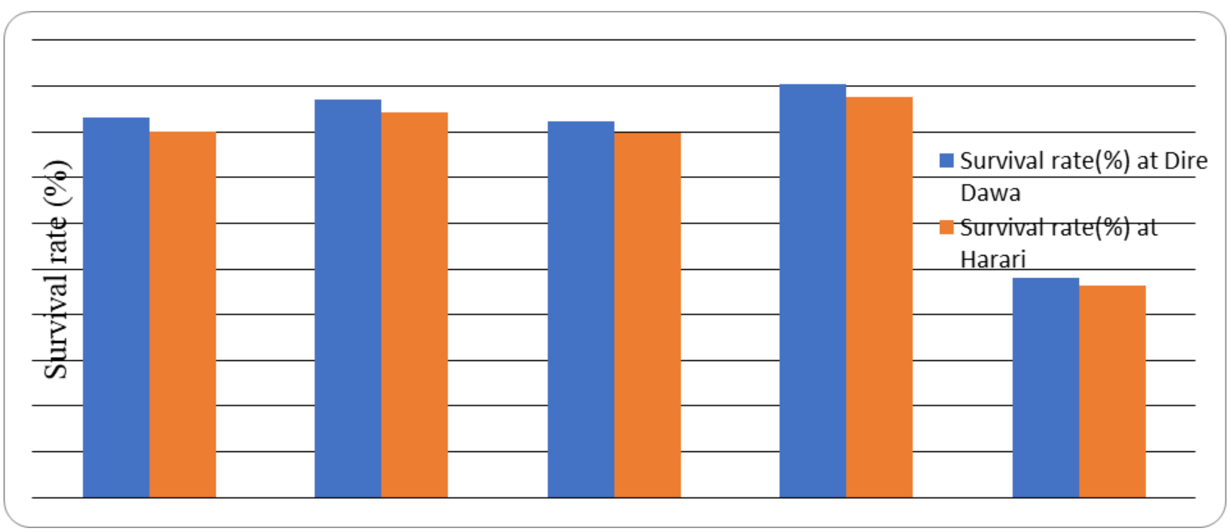

Figure 3**.** Means of survival rate (%) of *Gravilea robusta, Azadarichta indica, Leuceana leucocephala, Moringa oliefera* and *Sesbania sesban* through sequential periods from June 2016 to June 2019 at Dire Dawa Administration and Harari People Regional State.

Conclusion and Recommendation

The experiment was conducted for three consecutive years (2016-2019) to evaluate adaptation and growth performance of five agroforestry tree species at Dire Dawa Administration; Adada2 and Harari Region; Erer dodota. The results indicated that there were significant effect among treatments for plant height, survival rate, root collar diameter and diameter at breast height. The result revealed that the survival rate of *Moringa oliefera* was the highest at both experimental sites followed by *Azadarichta indica*, *Sesbania sesban and Leuceana leucocephala.* While *Gravilea robusta* showed poor survival rate at both study areas. Poor survival rate and growth performance might be attributed to the condition and termite problems of the study areas. *Moringa oliefera*, *Sesbania sesban*, *Leuceana leucocephala and Azadarichta indica* were the species attained the highest mean heights, while *Gravilea robusta* had the lowest values at both Harari Region and Dire Dawa Administration. The comparisons between the height and diameter growth average of the species showed that *Azadarichta indica* had the highest mean height followed by *Moringa oliefera, Le*uceana leucocephala and *Sesbania sesban* at both environment condition study areas.

Generally, results on growth performance showed that *Azadarichta indica*, *Sesbania sesban*, *Moringa oliefera and Leuceana leucocephala* had better performance than *Gravilea robusta at* both Harari Region and Dire Dawa Administration. Accordingly, those tree species which had better performance were recommended for further demonstration and evaluation in both study areas and similar agro ecologies. Therefore; planting of these better performing tree species and increase their promotion as agro forestry practices were recommended for soil conservation, shading, forage, fuel wood and in general multifunction purposes in the areas. Finally, on farm evaluation of *Sesbania sesban, Leuceana leucocephala* and *Moringa oliefera*, and their contribution to soil fertility improvement and crop yield either in inter-cropping or biomass transfer has to be further investigated to make use of their potential in agro forestry practices.

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Woody Species Management and Utilization in Agro-forestry Practices: Implication for the Conservation of Native Woody Species in Rift Valley Agricultural Landscape, Dugda District, East Shewa Zone, Oromia, Ethiopia

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Abstract

Low management and over-utilization exacerbated the benefits farmers obtain from native woody species. The study was conducted to assess and evaluate existing silvicultural management practices rendering for woody species and assess management of natural regeneration and identify farmers use preference of the woody species in the area and rank them based on their use. Qualitative data collection methods; field observation, key informants interview and household survey were used to obtain necessary data. Within the district, three kebeles were purposively selected based on their livelihood dependency on selected agro-forestry practices, i.e., Parkland Agro-forestry practice and public managed patches of tree woodland. A total of 100 households were interviewed for responding on important variables. Pruning and pollarding were the major silvicultural management practices being applied to trees in park land practices while thinning was sometimes applied to young regeneration. While farmers are pruning or pollarding trees for different objectives, they are preparing to reduce competition between trees and crops for the next cropping season. Total removal of live woody species is not allowed in both practices unless they are dead because of different biophysical factors. But, sometimes it is applied in parkland to reduce competition. Seven purposes of management were recorded for communal woodland practice in the district. Overall the woodland serves the community as buffer zone during times of difficulty in a year. A total of 18 preferred uses were identified from 31 woody species recorded at the area. Acacia albida 'Garbii', Acacia negrii 'Doddota' and Acacia tortilis 'Dhaddacha' were the three major tree species the respondents frequently raised during use preference and obtained the highest use value index, i.e., the first use rank. There is high dependency of local people on the uses that are obtained from native woody species in the area. Therefore, intensive improvements are important from individual species to the practice as whole to increase and sustain these native tree uses.

Key words: *Agro-forestry practice, Use value index, Silvicultural management, Woody species*

Introduction

Agro-forestry refers to land or farming system in which trees or shrubs are grown in association with agricultural crops, pastures or livestock and in which the positive interaction between trees and other components increase social, economic and environmental benefits for land users (*World Agro-forestry, 2017)*. It is a dynamic, ecologically based natural resource management system, diversifies and sustains production for increased social, economic and environmental benefits through the integration of trees on farm and in the landscape

(Mukadasi & Nabalegwa, 2008). Its practices range from open parkland assemblages, to dense imitations of tropical rainforests such as agro-forestry home-gardens, to planted mixtures of only a few species, to trees planted in hedges or on boundaries with differing levels of human management of the various components (Dawson et al., 2013).

As natural vegetation is cleared for agriculture and other types of development, the benefits that trees provide are best sustained by integrating trees into agriculturally productive landscapes, agro-forestry. Agro-forestry focuses on the wide range of working trees grown on farms and in rural landscapes (McCabe, 2013). The trees which are available on farmer's fields are either isolated or exist in scattered manner as remnants of natural forest and naturally regenerated plants. These trees are part of agro-forestry systems that the farmers manage to obtain a wide array of agro-ecosystem services (FAO 2000; Kleinn 2000). Farmers intentionally introduce trees with multipurpose values to obtain a range of benefits from scarcely available land (McCabe, 2013). Indigenous trees from a mosaic agricultural landscape provide the four major ecosystem services such as; provisioning, regulating, cultural and supporting services (Schreckenberg *et al*, 2016; Roothaert and Franzel, 2001; Sinclair 2001).

Trees are an integral part of land resources that need careful management for sustainable utilization (Tukur *et al*., 2013). Farmers commonly apply different management types to trees they commonly grow depending on the aim they brought them to agricultural lands. The variation in tree management is emanated from the level/intensity of tree interaction with crops, tree structure such as branching behavior. As the main aim of agricultural land is to grow crops and obtain yield, tree management is commonly designed to minimize competition but also prune the lower branches of trees to reduce shade, taking care not to affect tree development (Kowal 2000; Barrance*et al.*, 2003).

AGP-II (2016) report stated that there is lack of forest management or silvicultural practices of indigenous tree species, management on newly regenerated seedlings and positive attitude on tree growing. Lack of positive attitude on tree growing needs detail studies on what makes them against tree growing, in which practices and mostly on which trees are also important points to be considered. It is likely that the most important tree species will suffer the greatest harvesting pressure from local communities (Buyinza *et al.*, 2015) and also some slow growing species and those that are lowly valued by farmers are declining in abundance (Kyarikunda et al., 2017). Over utilization of these trees and management practices that are not supporting their maintenance results in low performance to elimination of these trees which leads to ecosystem unfriendly bare agricultural lands.

There was also limited information exist regarding indigenous trees management and sustainability in the study area and similar environments. Accordingly, generation of information and recommending important management mechanisms and practices for the reproductive and regenerative capacities of priority species that allow natural or artificial regeneration is important to ensure that populations have a long-term future (Young et al. 1996; Heywood and Stuart 1992; Saunders et al. 1991). These all helps improve the management of the trees in the areas and gives information if there are some negative attitudes to be worked on. Continuous and appropriate management practices make these native trees to be conserved and continue growth in their environment. Therefore, the objectives of the study were to assess and evaluate existing silvicultural managements rendering for the trees in the area, and assess management practices of natural regeneration and identify farmers use preference of the trees in the area and rank importance of these indigenous tree species based on their uses.

Materials and Methods

Description of the Study Area

Dugda District is located at distance of 132km from Addis Ababa along the main road that leads through Modjo to Hawassa. The population of the district is 163, 099 (CSA, 2012).

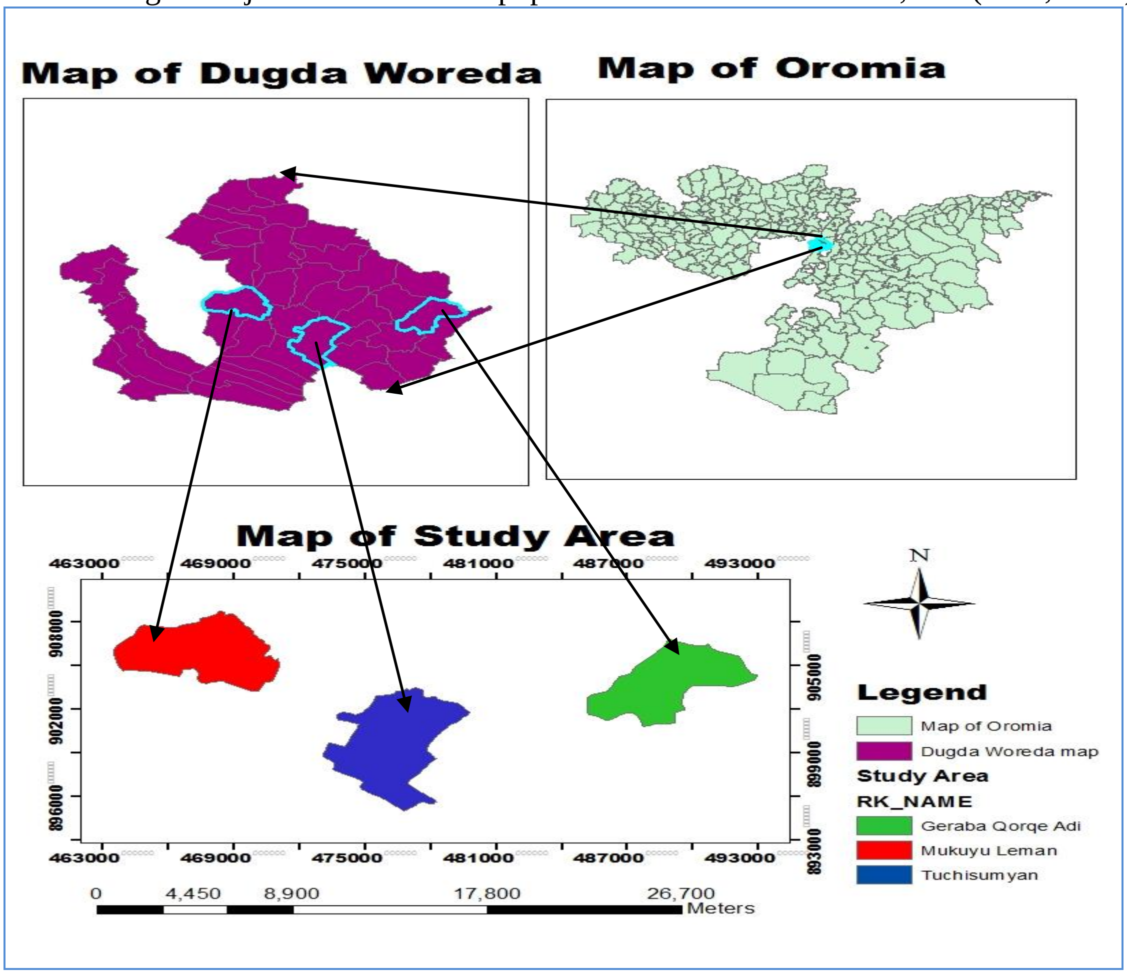

Figure 1: Location map of the study area

Altitude ranges from 1600 to 2020 meters above sea level (Spielman *et al.*, 2011). The mean annual temperature was about 22.8^{0}C, while mean annual rainfall was 750 mm (DWAO, 2015).

Land use: cultivated land (65.25%), forest (8.32%), pasture (3.55%), water bodies (12.54%), swampy and rocky mountain areas (0.31%) and 10.03% others and, the dominant types of crops are maize, wheat and teff (DWAO, 2015).

Vegetation and soil: *Acacia tortilis, Balanites aegyptiaca, Acacia seyal, Cordia africana, Faidherbia albida, Croton macrostachyus* are dominantly found. The soil textural class is clay loam (41%) and sandy loam (59%) (DWAO, 2015).

Practice Selection

Characterization of existing agro-forestry practices of the area is important before taking any action. Agro-forestry practices of the area were characterized based on *the type of components and management practices being given.* Methods used for characterization were *field observation and key informants' interview.* Based on the above criteria the agro-forestry practices of the area included:

1) Isolated trees on farm land: Mixed tree species at some places and Acacia tortilis was the dominant at most.

2) Parkland agro-forestry practice: Low to high dense of tree species and mixed tree species mostly. *Faidherbia* was the dominant at some places.

Patches of tree woodland

Characteristics

Silvo-pastoral **-** direct interference of livestock in-to the woodland during dry season times, ***cut and carry system*** and ***Entomoforestry*** - Production of honey also exists here. Trees are naturally established/regeneration and some are under enrichment at the border with mixed species of woodlot.

Management

Management practices were under cooperative, church (*Orthodox*) and communal. Huxley (1999) categorized managed tree plots as one of agro-forestry practices and put some specific types as fodder banks using woody species, fuel wood lots, mixed orchards (especially several products, e.g., fruits and honey).

3) Other practices: Livestock with trees on some open areas and buffer zone around lake with mix of different species (from grass to woody shrubs) mostly with animals.

Finally**,** practices important for the study objectives were purposively selected. These were *parkland agro-forestry practice, patches of tree woodland which were the* dominant practices contributing to the livelihoods of the community. Tree management was applied where trees were available.

Site Selection

Sites/kebeles which had two dominant practices were purposively selected. The kebeles were Giraba *Qorke Adi* (945 households), *Tuchi Sumayan* (524 households) and *Mukiye Laman* (467 households) (Dugda District Agriculture and NR Office, 2018).

Household Survey

Key informant interview was conducted before household interview to develop necessary variables. Households were randomly selected for interview from the selected kebeles. 5% of the population of selected kebeles (total of 100 HH) was interviewed to obtain trees utilization and management aspects information data. SPSS statistical package (Version 20) was used for variables analyses.

Species use ranking

Use value index technique was used to rank and prioritize the most important trees (Phillips and Gentry, 1993).

$$UV = \Sigma Ui/n$$

Where **Ui** is the number of uses mentioned by each respondent for a given species, **n** is the total number of respondents. The species was then ranked based on the overall use value.

Results and Discussion

Socio economic description of farm households

The respondents' sex category of the area was male 73% and female 27%. Their education status included illiterate (37%), read & write (13%), elementary education (44%) and high school education (6%). This shows that the education status of the households is not as such as obstacle for required extension message. Average size of household was 7 persons with minimum 1 person and maximum 16 persons. Average number of trees recorded on plots (40x40 m) taken from farmer field was 6, with maximum 9 and minimum 3. When converted to hectare basis on average 38 trees per hectare, while 56 and 19 maximum and minimum trees per hectare, respectively.

Table 1: Farm land holdings of the area

Categories of land owned	Percent
< 1 ha	39
1 up to < 2 ha	19
2 up to < 3 ha	27
3 up to < 4 ha	10
≥ 4 ha	3

Trees utilization

A total of 18 woody species uses were recorded during key informant's interview as below,

1. Shade
2. Fodder
3. Fence
4. Charcoal
5. Farm implements
6. House materials
7. Firewood
8. Cultural value
9. Medicinal
10. Rope (temporary)
11. Tooth brush
12. Smoke (for house and equipment's like milk and local beer)
13. Edible (fruits)
14. Cleaner (during crop threshing)
15. Construction purposes (lumber, split wood and direct uses)
16. House utensils
17. Moisture conservation
18. Fertility improvement

Fruits of trees mostly not edible by humans are used as fodder for animals. Most of the species met these services raised by the respondents included *Acacia albida*, *Cordia africana*, *Acacia tortilis*, *Balanites aegyptiaca*, *Erythrina brucei* and *Ziziphnus spina-christi*. Other species also could give this service.

Farmers' species use preference and ranking

Table 2: Farmers tree species use preference

Tree species	**Uses (from high to low)**
Acacia abyssinica (Laaftoo)	Fence; Charcoal; Shade; Firewood, Fodder and House tool; Farm implement and Lumber
Acacia albida (Garbii)	Fence; Firewood; Shade; Fodder; House tools; Lumber; Charcoal; Farm implements; Split wood (House construction); Moisture conservation and Local rope
Acacia nilotica (Burquqqee)	Shade; Firewood, Fence and Farm implement; Fodder and Charcoal
Acacia negrii (Doddota)	Firewood and Fence; Charcoal; House Construction (as Split wood); Fodder and Shade; Lumber; House tools; Medicinal; Farm implement
Acacia senegal/Acacia asak (Saphansa)	Fence; Firewood; Charcoal and Fodder; Shade; House construction (as Split wood)
Acacia seyal (Waaccuu)	Fence and Firewood; Charcoal; Fodder; Farm implement; Shade and Medicinal; House Construction (as Split wood)
Acacia tortilis (Dhaddacha)	Fence; Firewood; Shade; Charcoal; Fodder; House tools; Farm implement; Split wood; Lumber; Cultural value; Medicinal value; Local rope
Acokanthera schimperi (Qaraaruu)	Shade; Firewood and Fodder; Fence; Charcoal, Medicinal and Farm implement
Balanites aegyptiaca (Baddannoo)	Firewood and fence; Shade; Fodder; Charcoal; House tools; Farm implement
Capparis tomentosa (Arangama)	Fence; Firewood, Split wood and Fodder; Charcoal
Celtic africana (Ceekaa)	Firewood; Charcoal, Shade, Fodder, Medicinal, Farm implement, Lumber, House Construction (Direct use) and Fence (as Split wood)
Cordia africana (Waddeessa)	Lumber; House tools and Shade; Firewood; Fence; Farm implement; Fodder; Firewood
Croton macrostachyus (Bakkanniisa)	Lumber; Firewood; House tools; Fence and Shade; Farm implement; Medicinal; Charcoal; Local rope
Dichrostachys cineria (Jirimee/ Haxxee)	Fence; Firewood and Fodder; Charcoal; Shade
Dodonaea viscosa (Itacha)	Charcoal, Firewood, Farm implement and House tools
Ehretia cymosa (Ulaagaa)	Farm implement; Firewood; Shade and Fence; Charcoal
Erythrina abyssinica (Walensu)	Fence, Farm implement, Fodder and House tools
Ficus sycomorus (Odaa)	Shade, Farm implement, Cultural value (Boku tree) and Lumber
Ficus vasta (Qilxu)	Shade, Farm implement and House tool
Grewia bicolour (Harooressa)	Firewood, Fodder and Farm implement; Charcoal, Medicinal and Fence
Juniperus procera (Gaattiraa)	Lumber and House tools; Farm implement
Maytenus arbutifolia (Kombolcha)	Fence; Firewood; Charcoal; Fodder, Shade, Split wood, and House construction
Olea europaea (Ejersa)	Smoke (for materials); Farm implement; Firewood; House tools; Charcoal and Lumber; Fodder, Shade, Medicinal, Fence, Local rope, and Cultural value
Podocarpus falcatus (Birbirsa)	Lumber, House tools and Farm implement
Rhus vulgaris (Daboobessaa)	Farm implement; Charcoal, Firewood, Fodder and Shade
Ziziphus spina-christi (Qurqura)	Firewood; Fodder; Farm implement; Shade and House tool; Charcoal and Fence; Lumber; House Construction (as Split wood)

The uses recorded above are almost in line with what Mesele Negash (2007) reported on livelihood contribution of trees for farmers.

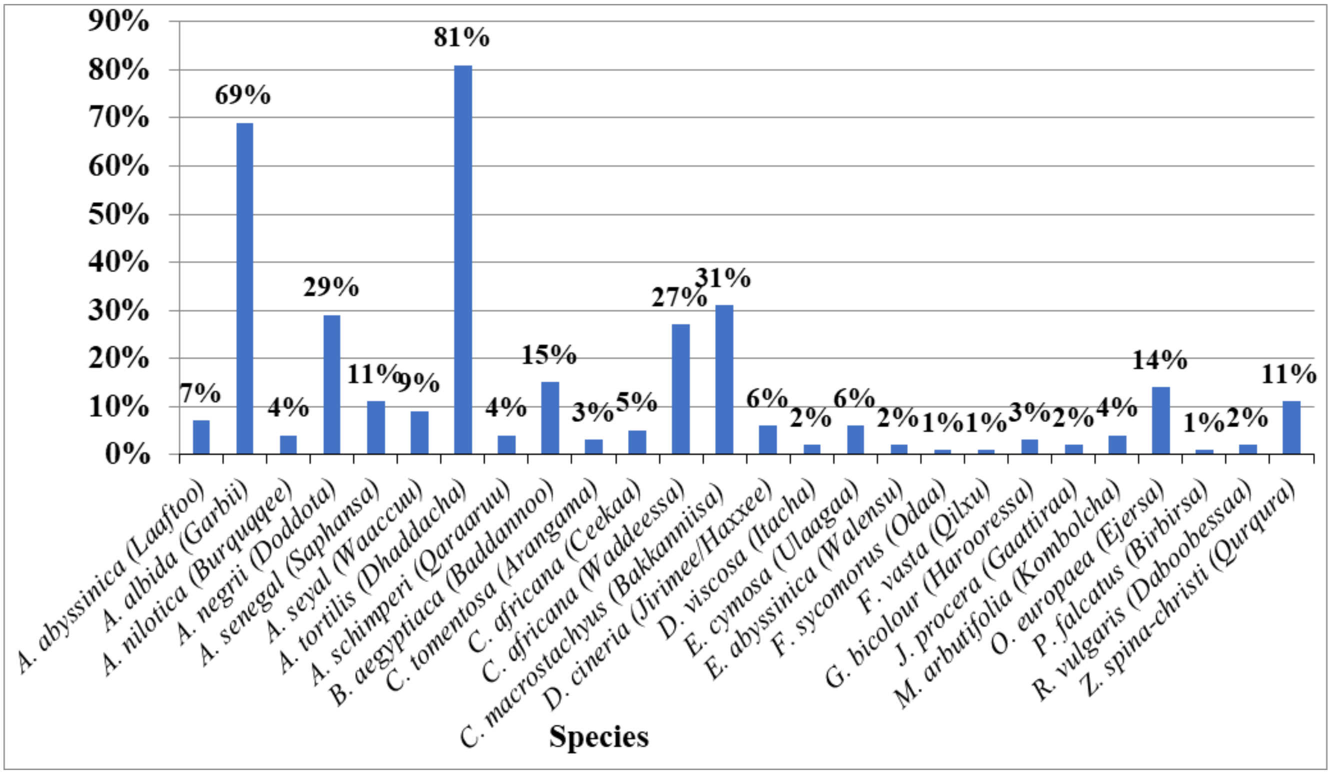

Figure 2: Frequency of respondents on tree species preferred uses

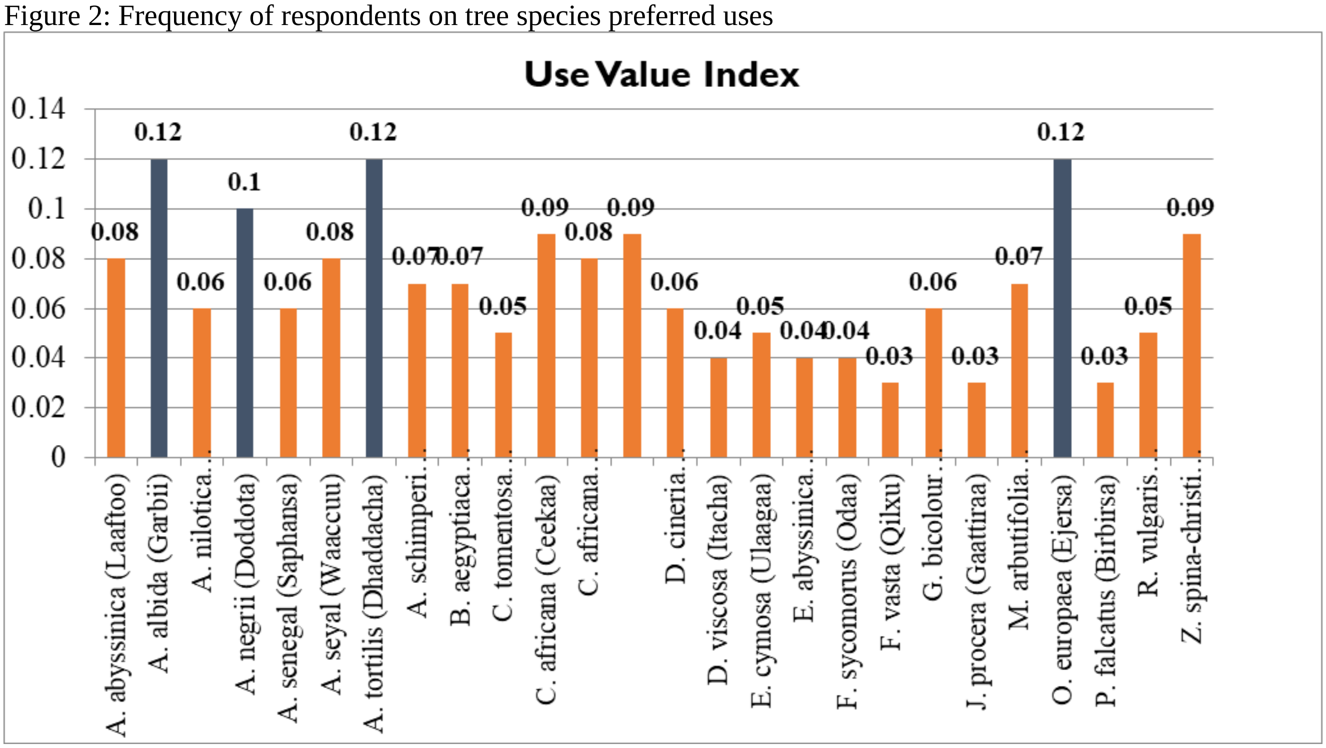

Figure 3: Species use value index

Based on species use value index above, the species use ranking are as follows,

Table 3: Species use ranking

Tree species	**Rank**	**Tree species**	**Rank**
A. abyssinica (Laaftoo)	5	*D. cineria (Jirimee/Haxxee)*	9
A. albida (Garbii)	1	*D. viscosa (Itacha)*	13
A. nilotica (Burquqqee)	9	*E. cymosa (Ulaagaa)*	11
A. negrii (Doddota)	1	*E. abyssinica (Walensu)*	13
A. senegal (Saphansa)	9	*F. sycomorus (Odaa)*	13
A. seyal (Waaccuu)	3	*F. vasta (Qilxu)*	15
A. tortilis (Dhaddacha)	1	*G. bicolour (Harooressa)*	9
A. schimperi (Qaraaruu)	5	*J. procera (Gaattiraa)*	15
B. aegyptiaca (Baddannoo)	7	*M. arbutifolia (Kombolcha)*	7
C. tomentosa (Arangama)	9	*O. europaea (Ejersa)*	1
C. africana (Ceekaa)	3	*P. falcatus (Birbirsa)*	15
C. africana (Waddeessa)	3	*R. vulgaris (Daboobessaa)*	11
C. macrostachyus (Bakkanniisa)	3	*Z. spina-christi (Qurqura)*	2

Ranking gave information for the priority trees to be conserved and worked on to make utilization ease of access. But this is not to mean that all valuable and important trees have completely included here. *The preferred species use* frequently rose by the respondents did not mean that the species got first use rank based on the species use value index. *Croton macrostachyus (Bakkanniisa)* didn't get first use rank *compared to Acacia negrii (Doddota);* however, its uses got high frequency of respondents (Figures 1 & 2).

Silvicultural Management

Parkland agro-forestry practice

Pruning

From the total respondents, 63% pruned lower tree branches, while only 10% pruned both lower and middle tree branches at the same time. The reason for pruning included; fencing (55%), fuelwood (13%), to support growth of upper branches (10%), to make cultivation easy for short trees (25%), firewood (37%), house construction (3%) and to reduce shade effect on crops (29%). Pruning frequency of tree species is described in Table 4.

Table 4: Frequency of pruning per tree species

Species	**Frequency of pruning**
Acacia albida (Garbii)	One year (17 %), Two year (23 %), Three year (1 %), Five year (2 %)
Acacia abyssinica (Laaftoo)	One year (4 %), Two year (2 %)
Acacia negrii (Doddota)	One year (8 %), Two year (8 %), Three year (5 %)
Balanites aegyptiaca (Baddannoo)	One year (4 %), Two year (4 %), Three year (2 %), Four year (1 %)
Croton macrostachyus (Bakkanniisa)	One year (8 %), Two year (6 %), At any time of importance (1 %)

Cordia africana (Waddeessa)	One year (4 %), Two year (4 %)
Acacia tortilis (Dhaddacha)	One year (18 %), Two year (21 %), Three year (4 %), Five year (1 %)
Acacia senegal (Saphansa)	Two year (4 %), Three year (2 %)
Dichrostachys cineria (Jirimee/Haxxee)	One year (1 %), Three year (1 %)
Zizphus spina-christi (Qurqura)	One year (1 %), Two year (3 %)
Acokanthera schimperi (Qaraaruu)	One year (1 %), Two year (1 %)
Acacia seyal (Waaccuu)	One year (2 %), Two year (1 %)

Table 5: Pruning season of tree species

Pruning season	**Percent**
During cropping phase	16
During crop harvest	16
After crop harvest	11
On set of cropping or rainy season	38
At any season of importance	6

Pollarding

About 87 % of the respondents pollarded trees on their farm land. The purpose of total branch removal (pollarding) included; for fencing (80 %), to reduce light competition (shade effect) on underlying crops (79 %), weakens the development of lower tree branches (32 %), disease incidence (3 %), firewood (61 %), fuelwood (19 %), charcoal (4 %), construction purpose (10 %) and to obtain new flash of branches(4 %).

As to farmers knowledge if the objective was new flash of branches or sprout of branches, total branch removal was important otherwise there were different biophysical impacts of upper branch on the remaining bottom branches.

Table 6: Pollarding season of tree species

Pollarding season	**Percent**
During cropping phase	6
During crop harvest	40
After crop harvest	9
On set of cropping or rainy season	62
At any season of importance	6

The way of applying pollarding was that few farmers pollarded all trees at the same time (13 %), while the majority of them (74 %) applied through shifting or not pollarding all trees at the same time. The reason behind pollard shifting was that no trend of applying pollard on trees with less and immature branch biomass (21 %), to get sustainable branch biomass production (16 %) for different wood services, or both (37 %).

Table 8: Frequency of pollarding tree species

Species	Frequency of pollarding
Acacia albida (Garbii)	One year (21 %), Two year (39 %), Three year (11 %), Four year (1 %), Five year (2 %), At any time of importance (1 %)
Acacia abyssinica (Laaftoo)	One year (4 %), Two year (2 %), Three year (3 %),
Acacia negrii (Doddota)	One year (2 %), Two year (8 %), Three year (9 %)
Balanites aegyptiaca (Baddannoo)	Two year (6 %), Three year (6 %), Four year (1 %)
Croton macrostachyus (Bakkanniisa)	One year (7 %), Two year (10 %)
Cordia africana (Waddeessa)	One year (21 %), Two year (39 %), Three year (1 %), Five year (1 %)
Acacia tortilis (Dhaddacha)	One year (12 %), Two year (38 %), Three year (18 %), Four year (1 %), Five year (1 %), At any time of importance (1 %)
Acacia senegal (Saphansa)	Two year (6 %), Three year (5 %)
Dichrostachys cineria (Jirimee/Haxxee)	Three year (1 %)
Z. spina-christi (Qurqura)	Two year (4 %), Three year (1 %)
Acokanthera schimperi (Qaraaruu)	Two year (1 %)
Acacia seyal (Waaccuu)	Two year (4 %), Five year (1 %)
Erythrina abyssinica (Walensu)	Five year (1 %)

Note: Pollarding is practiced at any time of importance, mostly when branches mature for the desired objective of utilization.

Table 7: Over all pollarding frequency of trees species in the areas

Pollarding frequency	Percent
One year	33
Two year	61
Three year	27
Four year	1
Five year	7

Total tree removal
About 26 % of the respondents applied total tree removal. Purpose of total tree removal included; to avoid shade effect on underlying crop (9 %), to avoid disease incidence (4 %), removal for different uses (12 %), removal only when dried (3 %), for charcoal (1 %) and removal when became barrier for ploughing (2 %).

Regenerations management
The ways farmers establish trees on their farm lands were almost fully (99 %) through natural regeneration. Mesele (2007) also reported farmers used natural regeneration for tree seedlings. This finding is also in line with FAO (2000) and Kleinn (2000) reporting. 81 % of the respondents observed regeneration of new seedlings on their farm, while 19 % not. Regeneration was grown as group of seedlings (39 %), single growth (28 %) and both (13 %). For groups of seedlings grown together or bunch of seedlings, 46 % of them operated thinning for continual growth of one stand, 1 % transplant inside other part of farm land, 3 % transplant on the boarder of farmland, and 8 % removed at all. For single grown regeneration, 29 % managed as it was for continual growth, 7 % transplanted inside other part of farmland, 2 % transplanted on the border of farmland and 10 % removed at all. The majority of the respondents, 60 % had no knowledge of transplanting, while 36 % had knowledge. Based on these results, only 26 % of the respondents transplanted new regeneration yet while 68 % did not. For those transplanted regenerated seedlings, 20 % responded successful seedlings.

Disease and pest management
From total farmers, 52 % saw disease and pest incidence, while 46 % did not see on trees in their farmlands. Symptoms that made farmers consider disease occurrence were leaf color change (26 %), leaf and branch death (12 %), total tree dying (23 %), fruit pod blackness (1%) and pest incidence (3%). They also argued pest incidence happened when trees cut off during rainy season. So they were careful in cutting trees during rainy time.

Table 9: Age of trees when susceptible to disease

Age category	Age of trees susceptible to disease (%)	Age of trees withstand disease (%)
Up to 5 year	16	11
Above 5 year	8	11
Up to 7 year	1	6
Above 7 year	16	9
Up to 1 year	2	2
Above 1 year	1	1
Up to 3 year	1	
Above 3 year		1
All age	2	2.
Not know	12	16

This is to show farmers knowledge and assumption on how they detect and manage diseases on trees on their farmland. However, they assured that in the occurrence of disease incidence, the situation is not as much serious among them. The ages they assumed trees were susceptible and withstand disease were varied among respondents.

Communal tree woodland practice

The purpose of managing the communal woodland as a general included income from dried trees/for fire wood (35 %) and grass through cut and carrying for house construction and livestock feed (100 %) as well as grazing during dry season by renting limited area with low cost (100 %). The income obtained from it supported the protection of woodland from illegal harvest and animal browsing. Total removal of dried trees was also a common practice almost in all woodlands. Over all there was no replacement planting (35 %) for tree removed from the practice, but, removing the live tree was prohibited. Environmental purpose/good climate especially attracting rainfall (32 %), branches for firewood and house construction during ceremonies/wedding and funerals (40 %), honey production (12 %) and Habitat for wild animals (39 %) were also some of the purposes of managing woodland. FAO (2010) confirmed the biological and socio-economic importance of woodlands in African dry lands. Bluffstone *et al*. (2007) also reported that in rural areas of low-income developing countries such kind of natural resources benefited households for fuels, animal feed, building materials, fruits and medicines.

From total respondents, 72 % confirmed as the protection have been applied to the practice. Biological soil and water conservation (70 %) with some exotic and few native trees (13 %) was also one of the management practices being given in some woodland, while in most cases with only exotic trees (59 %). Other kinds of management being given to the practice included, protection from animals (100 %), protection from harvest (87 %) and enrichment planting (5 %) mostly at the borders.

Pollarding (40 %) was one of the silvicultural management practices applied on some tree woodlands. It was applied mostly during different ceremonies (funeral, wedding, etc.) to get wood products. Permission from public leaders was a must for any activities undertaken in the woodlands.

Conclusions and Recommendations

Conclusions

The benefits communities are obtaining from native-woody species are not dermined. However, the area is known for its wood shortage mostly for energy purpose, Parkland agro-forestry is the most common practice accessing community with different wood uses.

In parkland practice farmers manage trees based on the benefit they obtain from them. Except few of them established trees through both natural and artificial planting, tree establishment at the area was at most through natural regeneration. Pollarding was the most tree management operation under use compared to pruning and total tree removal. The pollarding frequency of the trees was at most every two years. It rewarded farmers with enough amount of biomass for different uses or wood services. Mostly in the area any pollarding or pruning was after crop harvest or at the onset of cropping/rainy season. Some winter months closer to '*arfasa'* got rains. Conducting it at the onset of cropping season was for crops, field fencing and reducing competition between trees and crops while after crop harvest was mostly for fencing crop residue. The purposes of management of woodland were the same among kebeles unless some differences were found regarding the management practices. Woodland mostly served community for environmental purposes while also conserving biodiversity. Whether the management was under cooperatives, church or public there was at least one tree woodland practice in kebeles which had a prominent role for sustainable agro- ecosystem and related services. The management of woodlands was different between kebeles. There was a huge livestock intervention to the practice which communities were considering as managed and protected, i.e., woodland. The multiple uses obtained from it for the community was positive until it had not hurt the current and future vegetation habitat. Total removal of live tree was a prohibited act in both practices and no substitute for a single tree use.

Recommendations

Most of the trees preferred by farmers were not easily available around their locality which needed future intervention through *in-situ* conservation. The patch of tree woodlands was a good option for re-planting those trees in the area and increase community use from it. Tree planting on individual land holdings could be based on farmer's preference under different management and utilization regimes. It could be arranged as trees in cropland (mostly as parkland practice), as boundary planting and/or by planting as woodlot on parcel of land adjacent to crop fields. Technical solutions like agro-forestry component arrangement are important for increasing advantages obtain from those trees on crop lands. Farmer's tree compatibility selection with crops especially in practices like tree intercropping or integration should also take into account. Research and development intervention through extension advices and provision of materials increases the quantity and quality of honey production (api-forestry) in woodland. For current woodland practice, silvicultural management practices are important to increase trees ability of standing against changing climatic environment. Communal tree woodland practice should be scaled up to other areas at least one per kebele where there is open communal land. It has no easy role in overall biophysical resources enhancement in the area including biodiversity development and conservation. Working on individual household based woodlot mostly composed of native trees (mixed species woodlot) can alleviate the problem of wood energy in such area while saving the environment. Finally, to the area and other farmland practices, tree management and utilization policy should be encouraged at local level; because, at every locality there have been different management and utilization practices. Farmlands should not stay bare and for every cutting there should be a replacement planting.

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AGRICULTURAL ENGINEERING

Design, Construction & Evaluation of Engine Operated Rotary Tiller

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Abstract

*Currently, as Ethiopia is importing most of the agricultural mechanization technologies, including power tillers, there are significant shortages for using powered farm machineries in the country. Thus, this activity was initiated to design and construct an engine operated rotary power tiller locally and test performances. Accordingly, the design of this machine was based on the total specific energy requirements which carried out for an L-shape rotary tiller blade through using mathematical model***.** *This rotary tiller was operated by 10 hp motor engine out of this 2.25 hp of the power was used to dig the soil. The performance of the machine was evaluated in terms of theoretical field capacity, actual field capacity and field efficiency on clay soil. The results indicated that the theoretical field capacity, the actual field capacity and the field efficiency was 0.146 ha/hr., 0.134 ha/hr. and 91.78 % respectively at 1.11 g/cm*^{3} *soil bulk density and 30.3 % soil moisture content. The soil mean clod diameter after pass through by rotary was 0.127 mm. But, the designed rotary tiller requires some improvement on operation system as writing on recommendation parts before demonstration.*

Key words*: design, tillage, rotary tiller, performance, power*

Background and Justification

Tillage may be defined as the mechanical manipulation of soil for any purpose, but usually for nurturing crops. In the tillage operations, tillage tools direct energy into the soil to cause some desired effect such as cutting, breaking, inversion, or movement of soil. Soil is transferred from an initial condition to a different final condition by this process [Smith R J. etal. 1995].

Secondary tillage operations are intended to create refined soil conditions following primary tillage. The final tillage operation prior to planting a crop is usually secondary tillage, but farmers may use more than one secondary tillage operation. In some situations, a tillage operation may fit the definition of both secondary and primary tillage.

Rotary tillers are the tillage machine used for accomplishment both the primary and secondary tillage operations. Rotary tiller is a tillage machine used in arable field and fruit garden in agriculture. Rotary tiller has a mixing capacity seven times more than a plough. This tool decreases the soil traffic to a great extent by blending the soil. Using rotary tiller is increasing nowadays because of its various benefits [Topakci M. 2008]. Rotary tiller is advantageous over the conventional implement (i.e. moldboard plow and rake) due primarily to the main effect of the direct application of power to the soil-engaging tool rotating around a horizontaltransverse axis. Rotary tiller achieves both plowing and harrowing in a pass of machine on the field (Sirisak C., et al, 2008). The rotary tiller has the high capacity of mixing and pulverizing the tilled soil well; resulting in a good clod size distribution. The number of tillage passes required to achieve an acceptable tilth quality, using rotary tiller, is also significantly reduced in comparison to the series of operations that could result in the same tilth quality with the use of passive tools.

The major problem in Ethiopia is that using the same implement known locally as the" maresha," the ard (whose shape and structure have remained largely unchanged for thousands of years) still serves as a key farming implement. In Ethiopia's traditional farming system, farmers rely on the ard which is pulled across the field by a pair of oxen for both primary and secondary tillage types. So the objective of this activity was to design and develop an engine operated rotary tiller for tillage operation and evaluates its performance to solve the problems concerning secondary tillage.

Materials and Methods

Description of the machine

The designed rotary tiller was operated by 10hp motor engine by guidance of one person. Totally there was 12 blades out of them 3 are jointly act on the soil. There was depth controlling mechanisms which act as a wheel.

Figure 1. Description of designed and constructed rotary tiller

Power requirement

The design characteristics of any rotary tiller blades are the biggest determinants of power consumption. The measurement of the total power required has been expressed in terms of total specific energy required per unit volume of soil tilled. Optimizing the total specific energy requirement is one of the performance efficiency and the selection of criteria for land preparation implements. Dalin and Pavlov (1950) presented a general theoretical equation of rotary tiller to predict total power requirement as:

$$P_{total} = P_{push} + P_{cut} + P_{throw} + P_{loss} + P_{mf}$$

Where, P_{Total} = Total power requirement, kW, P_{Cut} = cutting power requirement, kW, P_{Throw} = throwing power the cut soil slice power requirement, kW, P_{Loss} = Power loss in the power train, kW, P_{mf} = overcoming soil-metal friction power requirement, kW, P_{Push} = pushing power requirement, kW.

The total specific energy requirement (power per unit volume of soil tilled) modification model is defined as a function of pushing (P_{Push}), cutting and loosening the soil slice (P_{cut}), overcoming soil- metal-friction (P_{mf}) and throwing the cut soil slice (P_{Throw}) power requirement and volume of soil tilled (V_{st}). The modified total specific energy requirement for the various rotary blades is exhibited as (Subrata Kr. et al., 2016)

$$E_{TSP} = \frac{P_{push} + P_{throw} + P_{mf} + P_{cut}}{V_{ST}}$$

Determination of power required to dig the soil

The power requirement would be calculated using the following equations:

$$Pd = \frac{Cr * d * w * v}{76} (hp)$$

Where, Pd is power required to dig soil, Cr is soil resistance, w is width, d is depth of tillage

Calculation of the optimal diameter of rotor

Torque is the most important factor that is affected by the dimensions. Bending moment and weight are neglected because of minuscule (very small) value of them [Bernacki et al.,1972]. Therefore, selecting the circular cross section for rotor axle and considering the torque, optimal diameter can be determined by the following relationship [Beer F, Johnston J. E. R, Dewolf J, et al, 2008]:

$$d = \sqrt[3]{\frac{16M_S}{\pi\tau}}$$

Where, *d* is the optimal diameter of rotor in cm; *Ms* is the maximum torque at the rotor axle in N.cm; τ is the allowable shear stress at the rotor axle in N/cm2.

Rotary tiller blades design

The design of the rotary tiller blades depends on the type and number of the blades and also the working condition of the rotary tiller. In this design, the L-type blades were considered for rotary tiller. In the rotary, one fourth of the blades action would be jointly on the soil. The number of rotary tiller flanges (fn) can be calculated by the following equation (Subrata Kr. et al., 2015)

$$fn = \frac{A}{A_i}$$

Where, A is the working width and A_i is the distance between the flanges on the rotor

Determination of the soil force acting on each blade

The soil force acting on each of the blade was determined using the following formula (Subrata Kr. et al., 2010)

$$K_e = \frac{K_s C_p}{f_n Z_e n_e}$$

The dimensions of the blades are defined as the form of figure presented below. The values of w, B, S1 and S are considered as 10, 0.5, 15 and 3.5 cm respectively.

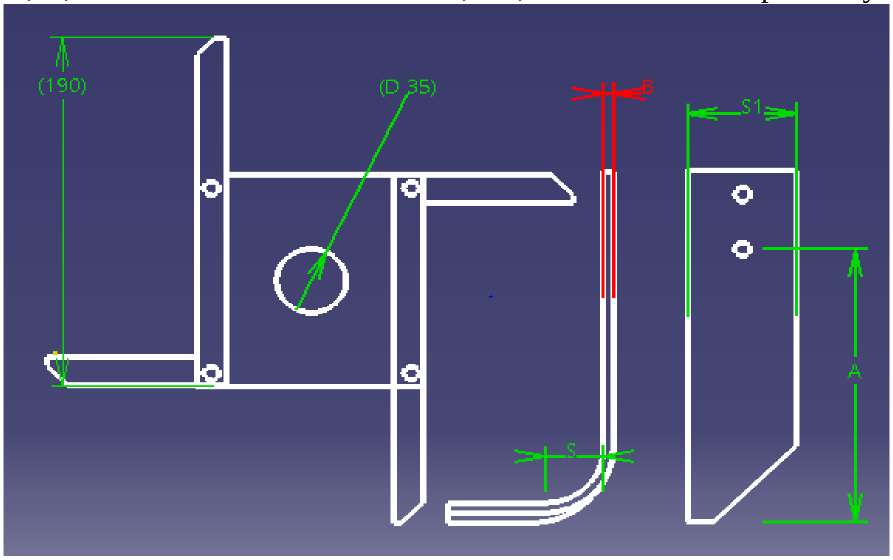

Figure 2. Dimensions of flange and blade

Pulley and belt design

According to Aaron (1975), the desired revolution per minute the diameter of driving and driven pulley will be determined as follow.

$$D_4 N_4 = D_3 N_2$$

$$N_4 = \frac{D_3 N_2}{D_4}$$

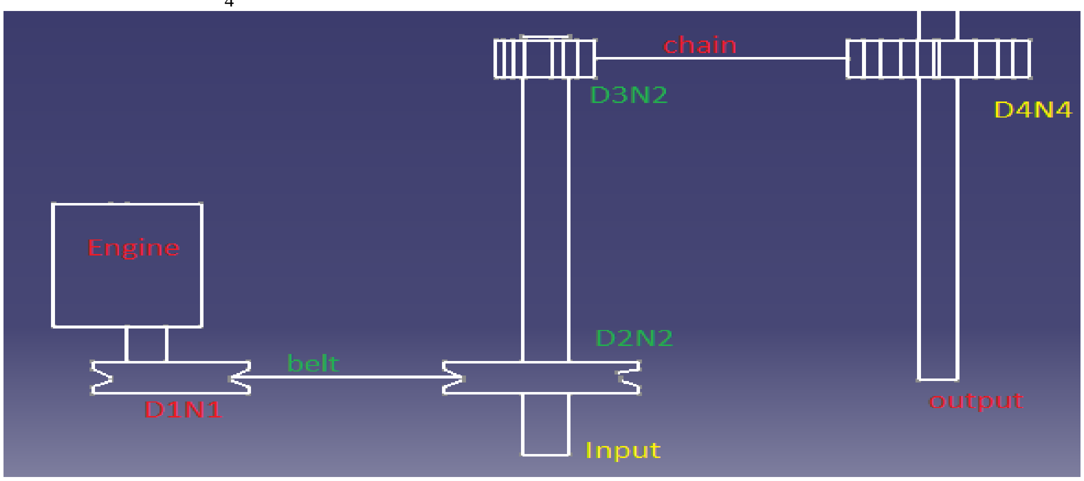

Figure 3. One pulley belt mechanism and one chain sprocket mechanism

Performance evaluation of rotary tiller

The performance indicator parameters of this machine would be measured both on station and in the field. These parameters are: Tilling capacity per hour, Depth of tilling, Width of tilling, Aggregate size distribution (clod mean diameter), Soil dry bulk density, Soil moisture content. The machine performance was evaluated using actual field capacity and design field capacity of the machine as shown in equation:

$$FCt = S * W (ha/hr)$$

$$FCe = \frac{land\,covered}{time\,taken}(ha/hr)$$

$$Field\ efficiency = \frac{FCe}{FCt} * 100$$

Where, FCt =theoretical field capacity, FCe = actual field capacity, S = forward speed (in m/s), W = width of the implement (in m)

Result and Discussion

Table 1. Measured and Standard Machine design parameter

No.	Parameters	Notations	Values
Measured parameters			
1	Blade span (mm)	W	80
2	Width of soil cut (m)	W_c	0.06
3	Depth of soil cut(m)	D	0.083
4	Rotor radius (m)	R	0.205
5	Blade angle (degree)	θ	120
6	Clearance angle(degree)	β	18
7	Blade thickness (mm)	t	5
8	Engine power (hp)	p_e	10
9	Machine forward velocity (m/s)	v_f	0.75
10	Rotational speed (rpm)	N	428.29
11	Shaft diameter (mm)	D	4
Standard parameters			
12	Prime mover's efficiency	η_c	0.9
13	Coefficient	η_z	0.75
14	Specific soil resistance(kg/cm^3)	K_{sp}	7000

Power consumption determination

In general, by derivation and simplifying the equations described in the methodology, the total specific energy requirement was obtained 81.03 KJm^3. This Specific energy/work is defined by Srivastava *et al.* (1993) as the ratio of the total energy expended during soil processing by a tillage tool to the volume of the soil disturbed.

Determination of power required to dig the soil

The power requirement to dig the soil was about 2.24 hp and the total power required to dig the soil using this rotary was obtained 2.25 hp. Using the draft and power requirements of tillage tools, the concept of specific energy or specific work was used extensively (Kepner *et al*., 1978; Srivastava *et al.*, 1993) to determine the performance of different tillage tools; including the performance of rota vators (Beeny & Greig, 1965; Beeny & Khoo, 1970).

Determined blade bending, shearing and equivalent stress

Considering the shape of the blade, the bending stress, the shearing stress and the equivalent stress was 121.5 kg/cm^2, 292.72 kg/cm^2 and 31.7 MPa respectively. This result indicated that the maximum bending stress, shearing stress and combined effect of the two are affect the blade shape when they are higher than these values.

Designed Pulley and belt

The belt and pulleys are the power transmission elements. So while designing power transmitted by pulley and belt, and diameter of pulley w considered. The power transmission was both pulley and belt, and chain and reciprocate mechanism in order to reduce the speed of the rotary. The rpm of the rotary was reduced to 428.26 rpm.

Determined soil force acting on each blade

The soil force acting on each of the blade was determined using the above formula was 67.5 kg. This force was the combination of tangential force acting at the tip of the blade and soil force acts perpendicular to the edge of the blade.

Soil physical properties

The performance evaluation of the machine was done on clay soil which had the following properties. These properties have significant influence on the energy requirements of tillage tools as studied by Ros, et al, (1995). This is because these properties affect the soil strength, which has to be overcome by a tillage tool during a soil tillage operation (Gill & Vanden Berg, 1967).

Table 2. Summary of soil physical properties

Soil physical properties	Values
Soil moisture content (%)	30.3
Soil bulk density(g/cm^3)	1.11
Mean clod dia. (mm)	0.127

As shown in the table above, the mean clod diameter of the soil after plowing was about 0.127 mm. As Fang H., et al (2016) studied that the mean clod diameter was smaller at higher rotational speed, while the rate of soil breakage increased with increasing rotational speed.

Performance of the machine

The machine performance was evaluated using actual field capacity and design field capacity of the machine. The width of operation, theoretical Field capacity, actual field capacity and the field efficiency of the machine was obtained 50cm, 0.146 ha/hr, 0.134 ha/hr and 91.78 % on clay soil respectively. Bayan A., et al (2018) study the performance of Sifang Power Tiller on secondary tillage and the result shows that, width of operation, theoretical field capacity, effective field capacity and efficiency on clay soil were, 60 cm, 0.15 ha/hr, 0.08 ha/hr and 53%, respectively.

Conclusion

The Machine is necessary for the agriculture to increase the production and productivity as well as overcome the burden on the farmer. The working capacity and efficiency of the machine was 0.134 ha/hr. and 91.78 % on clay soil at 30.3 % moisture content and 1.11 g/cm3 dry bulk density. This machine was loosened the soil up to 0.127 mm mean clod diameter which is suitable for crop growth.

Recommendation

- The machine is best for farmers having motor engine which used for thresher to use as dual purpose if some of the following problems are solved.
- The rotary tiller was selected soil condition to walk by its power and the wheel of the rotary will be modified because it was resist the forward motion of the rotary if the soil clod is big.
- The other problem of this machine is dust during operation which is very difficult to control. Therefore it required modification on controlling the dust.
- The rotary tiller needs to incorporate clutch mechanism to manage the operation

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Development of Livestock Feed Mixer

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Abstract

A livestock feed mixer was designed, constructed and evaluated for its performance using mass of shelled corn as tracer. The machine was tested using a feed composed of 12.63 kg wheat bran, 12.63 kg wheat powder, 12.63 kg faba bean bran, 10.1 kg cotton cake, 1.18 kg of salt, 0.84 kg molasses and 2 kg ungrounded corn replicated thrice at four mixing durations of 5, 10, 15 and 20 minutes and paddle shaft speed of 480, and 580 rpm. The effectiveness of mixing was assessed on the basis of mass of shelled corn, and percent of coefficient of variation (CV %) and degree of mixing of sample collected at the end of each test. The best values of coefficient of variation (13.09 %) and degree of mixing (86.91 %) were obtained at mixing paddler shaft speed of 580 rpm and mixing time of 10 minutes. Hence, it can be concluded that the machine, the prototype livestock feed mixer, should be operated at speed of 580 rpm with maximum holding/mixing time of 10 in order to make the owning and operating of the machine productive (in terms of kg/hr) and economical (in terms labour and energy cost birr/kg of mixed quality feed. The capacity of the machine is about four quintals per hour or 32 quintals per day of 8 hours of work.

Keywords: feed mixer, Livestock, livestock feeds

Background and Justification

Livestock is an integral part of the agriculture and the contribution of live animals and their products to the agricultural economy accounts for 40%, excluding the values of draught power, manure and transport of people and products (Winrock International, 1992). Ethiopia holds the largest livestock population in Africa estimated at about 43.1 million heads of cattle, 23.6 million sheep, 18.6 million goats, 4.5 million donkeys, 1.7 million horses, 0.33 million mules, 34.2 million chicken and 4.9 million beehives (CSA, 1996). Similarly, contributions of livestock to cash income of the smallholders account for up to 87% and, subsistence of some pastoral communities is entirely based on livestock and livestock products. Despite these roles, the productivity of livestock in general is low and compared to its huge resource its contribution to the national economy is below expected. Zegeye (2003) indicated that feed shortage, poor genetic potential for productive traits, poor health care and management practices are the major contributors to the low productivity.

Livestock feed is the general term for food given to farm animals. The regular supply of food to farm animals is very essential to a healthy and productive life. Feed production for livestock, poultry or aquatic life involves a range of activities, which include grinding, mixing, pelleting and drying operations. Different types of machinery needed for the production of various types of feeds include; grinders, mixers, elevators and conveyors, mixer, extruders, cookers, driers, fat sprayers and steam boilers (New, 1987). The mixing operation in particular, is of great importance, since it is the means through which two or more ingredients that form the feed are interspersed in space with one another for the purpose of achieving a homogenous mixture capable of meeting the nutritional requirements of the target livestock, poultry or aquatic life being raised (Balami, et al., 2013).

Feed mixing can be done either manually or mechanically. The manual method of mixing feed entails the use of shovel to intersperse the feed's constituents into one another on open concrete floors. This method is generally characterized by low output, less efficient, labor intensive and may prove unsafe, hence, hazardous to the health of the intended animals. A wide variety of mixers are available for use in mixing components, the selection of which depends mainly on the phase or phases the components exists such as solid, liquid or gaseous phases. But in Ethiopia, different organizations and research centers have imported and or developed various types of animal feed choppers and millers. But as their efforts missed mixer part of the process, the small scale farmers are forced to use the manual method of chopped/ milled feed. Therefore, this activity was initiated with objectives of developing and evaluating a mixer machine capable of mixing livestock feed constituents effectively and uniformly for small and medium scale farmers.

Materials and Methods

Materials

The raw materials used for production of livestock feed mixer was steel shaft having diameters of 35 and 20 mm, 2 mm and 1.5 mm sheet metal, 4 mm * 40 mm * 40 mm angle iron and 3 mm * 30 mm * 30 mm size square pipe, 5 mm x 50 mm x 50 mm angle iron, 10.5hp diesel engine, pulleys having diameters of 460 mm, 180 mm and 140 mm, UCP bearings of 204 and 6205, different sizes of bolt and nut and hinges.

Instruments

In order to measure different size and dimension of construction and testing materials measuring tape, digital balance, tachometer, caliper, small bags and others were used during construction and data collection on the field.

Methods

Description of Livestock Feed Mixer

A horizontal livestock feed mixer was developed and constructed in Asella Agricultural Engineering Research Center (AAERC). The mixer consists of the essential component parts like: feeding unit, mixing unit, power driving unit and feed discharging unit. The mixing section has half cylindrical shape in the lower side and rectangular shape on the upper side. The mixing chamber is provided with centrally based horizontal and vertical acting auger and paddles that operate inside a mixing chamber. Feeding unit is attached to the mixing unit on the upper left side while discharging part is attached in the lower right side. All these machine components were connected to each other with bolt and nut and welding on the main frame (Figure 1).

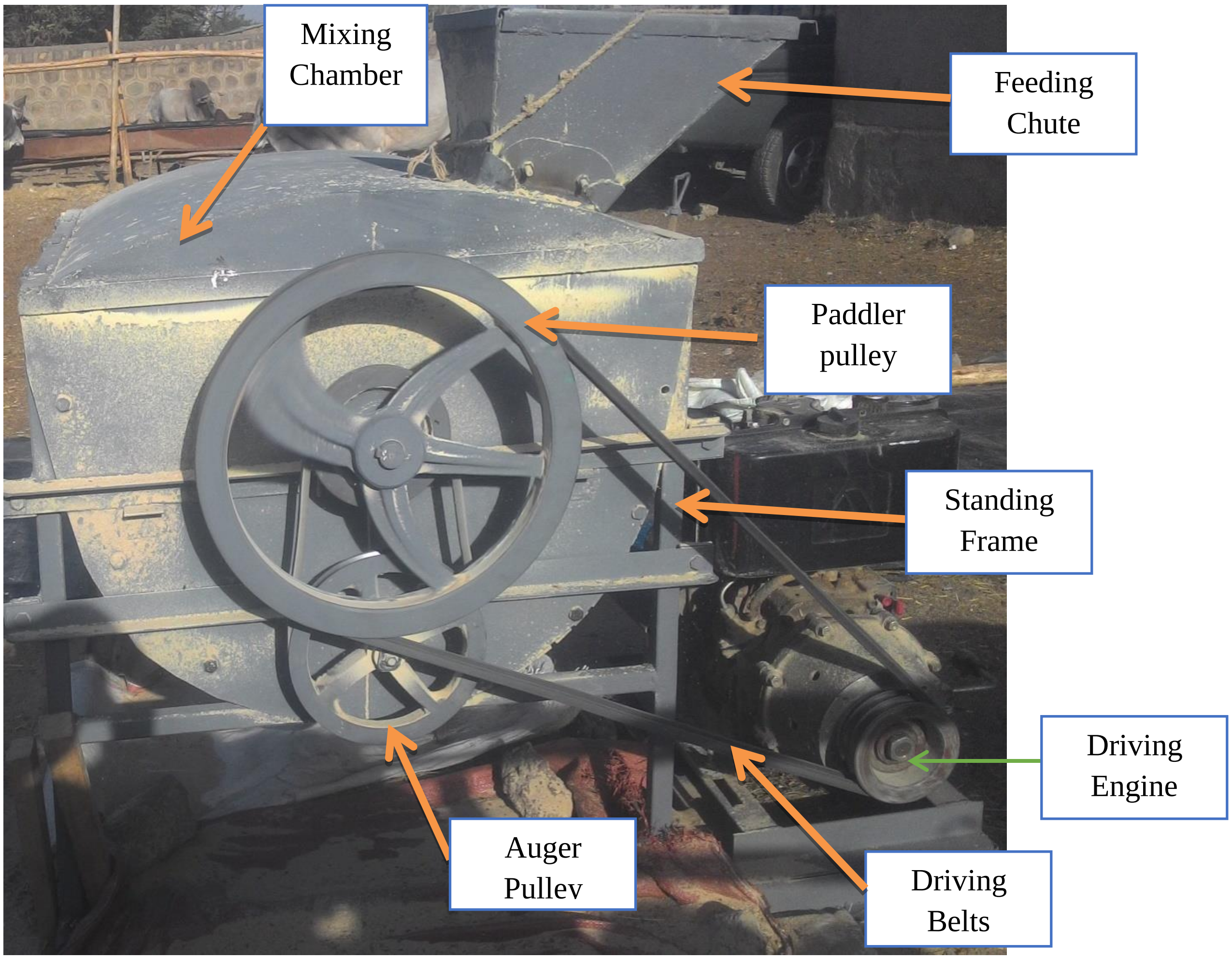

Figure 1: The developed feed mixer machine parts

Working Principle of the Machine

Feed ingredients are introduced into the mixer via a feeding unit located at the upper part of the mixing compartment. Material introduction into the mixer is in order of quantity, with the bulkier material among the feed components being introduced into the machine first. The diesel engine used to drive the mixer for mixing livestock feed ingredients is on. The rotating action of the paddles located on the centrally rotating shaft and auger moves the feed ingredients front, back, down, up and sideways. After a thorough mixing was achieved, the discharge chute was opened to allow the flow of mixed feed material out of the mixer.

Part Description

The developed livestock feed mixer consisted of the following major parts: a mixing chamber, a mixing unit, frame, feeding hopper, feed outlet, engine sit, drive and driven Pulleys, screw (auger) conveyor, bearing, steel shaft, and V-belt.

Feeding hopper construction

Feeding hopper has a trapezoidal shape located at upper end of the prototype mixer. The inclination of the feeding trough from the vertical or horizontal was decided by considering the largest angle of repose of the materials which was 60^0.

Mixing chamber

The mixing chamber has a half cylindrical shape in the lower and rectangular shape on the upper part by rolling and bending. This mixing chamber was made from 2 mm sheet metal which was cut, rolled and welded together with the standing frames.

Feed chute construction

An opening of 150 x 70 mm size, provided at the bottom end of the mixing chamber, is connected to the discharge chute. The chute has a shutter mechanism used for closing and opening the gate in order to facilitate discharge of the material after mixing or maintain the material within the chamber during mixing.

Frame construction

The frame was constructed from square pipe of 30 x 30 x 3 mm and 5 x 50 x50 mm angle iron considering the rated strength and stability during service. The frame has height of 900 mm, width of 840 mm and length of 1210 mm.

Mixing unit

A horizontal axis screw and paddler were operated inside a mixing chamber to effect the mixing process. As per the recommendation of Balamiet al. (2013), who designed, manufactured and evaluated an animal feed mixer, a screw with helix of uniform diameter of 145 mm and a pitch of 100 mm was selected and all the necessary design analyses were made on the basis of the dimensions stated above.

Selection of Drive and Transmission

Selection of pulley diameters

The diameters are selected based on the need to reduce the diesel engine speed to the required paddle type horizontal feed mixer shaft. It is given by the following equation

$$D_1 \times N_1 = D_2 \times N_2$$

Where: D1 = Diameter of driving pulley in (mm), D2 = Diameter of driven pulley in (mm), N1 = Speed of driving pulley in (rpm), N2 = Speed of driven pulley in (rpm)

Selection of the drive

V-belt and pulley arrangements were adopted in this work to transmit power from the Diesel engine to the shaft of the paddle type horizontal feed mixing shaft. The main reasons for adopting the v-belt drive is its flexibility, simplicity, and low maintenance costs. Additionally, the v- belt has the ability to absorb shocks there by mitigating the effect of vibratory forces (Khurmi and Gupta, 2005).

Determination of belt contact angle

The belt contact angle and angles of wrap for smaller and larger pulley is given by the following equation (Khurmi and Gupta, 2005).

$$\varphi = Sin^{-1}\left(\frac{R-r}{C}\right)$$

$$\alpha_1 = 180 - 2Sin^{-1}\left(\frac{R-r}{C}\right)$$

$$\alpha_2 = 180 + 2Sin^{-1}\left(\frac{R-r}{C}\right)$$

Where: R = radius of driven pulley, mm;r = radius of driving pulley, mm;φ = belt contact angle, deg; α_1 = angle of wrap for the driving pulley, deg;α_2 = angle of wrap for the driven pulley, deg;C = is the center distance between the two center pulleys.

Determination of belt length

The length of belt appropriate to drive the system is calculated using the equation given below by Shigley and Mischike (2001).

$$L = 2C + \frac{\pi}{2}(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C}$$

Where: L = belt length, m; C = center distance between pulleys, m; D_2 = pitch diameter of driven pulley, m; D_1 = Pitch diameter of driver pulley, m.

Speed of the belt was calculated by using the equation as given by Khurmi and Gupta (2005). $v = \frac{\pi D_1 N_1}{60}$

Bearing selection

Bearing selection was made in accordance to American Society of Mechanical Engineers (ASME) standard as given by Hall *et al.* (1988).

Determination of belt tensions

To determine tensions on the tight and slack sides of the belt the following equations is used (Khurmi and Gupta, 2005).

$$T_1 = T - T_c$$

$$T = \sigma_{\max} a$$

$T_c = mv^2$ Where: $T_c$and T= the centrifugal and maximum tension of a belts (N); T_1 and T_2 = tension in the tight and slack sides (N), $\sigma_{\max}$= maximum safe normal stress (N/mm^2); a = is cross sectional area of belt (mm^2), m = mass per unit length of belt (kg/m);v = is speed of belt (m/s), Values of $\sigma_{\max}$, a and m are taken from standard tables.

Tensions on the tight and slack sides of the belt will be estimated using the equation given by Khurmi and Gupta, (2005):

$$\frac{T_1 - T_c}{T_2 - T_c} = e^{\mu \alpha_1 \operatorname{cosec} \frac{\beta}{2}}$$ Where: μ = coefficient of friction between a belt and a pulley from design book 0.25, β = groove angle 40^0, α_1 = angle of wrap on driver pulley

According to Khurmi and Gupta (2005) torsional moment (T_r) due to belt tensions was determined using the following equation.

$$T_r = (T_1 - T_2)\frac{D_2}{2}$$

where: T_1 = tension on tight side of a belt (N), T_2 = tension on slack side of a belt (N), D_2 = is the diameter of driven pulley (mm).

Determination of Screw Shaft Diameter

According to American Society of Mechanical Engineers (ASME) code (ASME, 1995) for the design of solid transmission shafts, the maximum permissible working stresses in tension or compression may be taken as112 MPa for shafts without allowance for keyways and 84 MPa for shafts with allowance for keyways. The maximum permissible shear stress may be taken as 56 MPa for shafts without allowance for key ways and 42 MPa for shafts with allowance for keyways. According to maximum shear stress theory, equivalent twisting moment (T_e) and that of a mixer shaft diameter (*d*) is determined as follow:

$$T_e = \sqrt{(MK_b)^2 + (TK_t)^2}$$

According to maximum normal stress theory, equivalent bending moment is given as:

$$M_e = \frac{1}{2}\left(K_b M + \sqrt{(K_b M)^2 + (K_t T)^2}\right)$$

$$M_e = \frac{\pi \sigma_b d^3}{32 \times fs}$$

Where: where: T_e = equivalent twisting moment, Nm; M = maximum bending moment, Nm; M_e= equivalent bending moment, Nm; σ_b= maximum allowable normal stress, 84 MPa; T = twisting moment, Nm;= maximum allowable shear stress, 42 MPa; fs = factor of safety assume 2, d = diameter of mixer shaft, m.For rotating shafts, with load suddenly applied and minor shock, combined shock and fatigue factor were applied to bending and torsional moment as recommended; the values used were K_b = 1.20 to 2.00, and K_t= 1.00 to 1.50, (Khurmi and Gupta (2005). Therefore, the values of K_b = 1.20 and K_t = 1.00 were used in this work.

Performance Test

Performance testing of the mixer was targeted at evaluating its ability to mix feed components, duration of mixing and rate of discharge. At the onset of the test, 37.89 kg of wheat bran, 37.89 kg of wheat flour,37.89 kg of faba bean bran, 30.30 kg of cotton cake, 3.54 kg of salt, 2.52 kg of molasses and 6.00 kg of ungrounded maize as tracer were divided into three equal measures of 12.63 kg of wheat bran, 12.63 kg of wheat flour, 12.63 kg of faba bean bran, 10.10 kg of cotton cake, 1.18 kg of salt, 0.84 kg of molasses and 2.00 kg of ungrounded maize, and the mixer's performance test was conducted and replicated thrice according to the standard test procedure for farm batch feed mixers developed by ASAE, (R2006) and Ibrahim and Fasasi (2004). Four mixing durations of 5 min, 10 min, 15 min and

20 min and two mixing speed 480 rpm and 580 rpm where considered in the cause of conducting the tests. At the end of each test run, ten samples of 1 kg were drawn from the mixed components and the coefficient of variation among mixed samples and mixing levels, were computed using the expressions below as given by Ibrahim and Fasasi (2004):

$$CV = \frac{SD}{\bar{y}} \times 100$$

$$\bar{y} = \frac{\sum y_i}{n}$$

$$SD = \sqrt{\sum \frac{\left(y - \bar{y}\right)^2}{(n-1)}}$$

$$DM = 100 - \%CV$$

Where: CV = percent coefficient of variation, DM = percent degree of mixing, SD = standard deviation, $\bar{y}$ = mean, $\sum$ = sum, y_i= individual sample analysis results, n = total number of samples

Experimental design and Statistical Analysis

The experimental design is randomized complete block design with three replications. Treatments consisted of factorial combinations of two mixing speeds (480 and 580 rpm) and four mixing times (5, 10, 15 and 20 min). Data was subjected to analysis of variance following a procedure appropriate to the design. Analysis was done using GenStat 15th edition software. The treatment means that were different at 5% level of significance was separated by using LSD.

Results and Discussion

The necessary design parameters needed for the development of a horizontal livestock feed mixer were considered in depth. Proper shaft, paddler and auger design analysis was carried out on the machine to avoid failure on both paddler shaft and auger shaft. A prototype of the livestock feed mixer was manufactured using materials available on market, with the AAERC's workshop technicians. Its performance tests were carried out at four mixing times and two mixing speeds (paddler shaft speeds, rpm) to evaluate the mixing performance of the prototype feed mixer.

Table 1: Technical Characteristics of the Mixing Machine

No.	Technical characteristics	Determined and selected values
1	D_2= Diameter of pulley for the mixing paddler	460 mm
2	C_1= center distance between larger pulley	869 mm
3	L_1= length of larger belt	2710 mm
4	v= Speed of the belt m/s	13.96 m/s
5	T_1= tension of belts on the tight side of larger pulley	298.10 N
6	T_2= tension of belts on the slag side of larger pulley	165.18 N
7	T_{12}= tension of belts on the tight side of smaller pulley	166.88 N
8	T_{22}= tension of belts on the tight side of smaller pulley	88.80 N
9	$T_c$and T= the centrifugal and maximum tension of a belts on larger pulley	42.10 N and 340.20 N
10	$T_c$and T= the centrifugal and maximum tension of a belts on smaller pulley	3.22 N and 170.10 N
11	W_{lp} = weight of larger paddler shaft pulley	103.01 N
12	W_{sp} = weight of smaller paddler shaft pulley	23.54 N
13	ρ = density of feed	621.38 kg/m^3
14	W_p = weight of paddles found on shaft	62.59 N
15	R_{VAy} = Vertical reaction force at bearing close to pulleys	1467.67 N
16	R_{VBy} = Vertical reaction force at bearing far from pulleys	117.07 N
17	R_{HAx} = Horizontal reaction force at bearing close to pulleys	84.10 N
18	R_{HBx} = Horizontal reaction force at bearing far from pulleys	7.47 N
19	BM_{VCmax} = Vertical maximum bending at the center of mixing hopper say C	117.71 Nm
20	BM_{HCmax} = Horizontal maximum bending at the center of mixing hopper say C	9.32 Nm
21	T_r = torsional moment due to belt tensions	59.91 Nm
22	M = total bending moment	118.08 Nm
23	T_e = equivalent twisting moment	153.43 Nm
24	M_e= equivalent bending moment	147.56 Nm
25	d = Paddler shaft diameter	35 mm

Table 2 gives the average weight of ungrounded corn recovered from each of the 10 samples drawn from the mass of mixed components after a mixing period of 5, 10, 15, and 20 min in respect of the three replicated tests at paddler shaft speed of 480 rpm.

Table 2. Prototype livestock feed mixer performance at paddler shaft speed of 480 rpm and mixing time of 5, 10, 15 and 20 minutes

Mixing time (Minute)	Mean weight of ungrounded Corn/ Tracer (Kg)	Mean Coefficient of Variation (CV %)	Degree of Mixing (DM %)
5	0.0214	36.85	63.15
10	0.0207	20.75	79.25
15	0.0226	19.20	80.80
20	0.021	15.91	84.09

The average weights of ungrounded corn recovered from the three replicates are 0.0214 kg, 0.0207 kg, 0.0226 kg and 0.0210 kg with corresponding coefficient of variability (CV) of 36.85 %, 20.75 %, 19.20 % and 15.91 %, during mixing times of 5, 10, 15 and 20 minutes respectively. From Table 2, it can be noted that at the mixing time of 20 minutes, the percentage coefficient variation and degree of mixing values were 15.91 and 84.09 % respectively. The values indicate that as the time of holding increases the percentage of coefficient variation decreases while percentage degree of mixing increases.

Table 3 gives values of performance indicators such as percentage mean mass of ungrounded corn, coefficient of variation, and degree of mixing at the mixing paddler shaft speed of 580 rpm and different mixing time in minutes.

Table 3. Prototype livestock feed mixer performance at paddler shaft speed of 580 rpm and mixing time of 5, 10, 15 and 20 minutes.

Mixing time (Minute)	**Mean weight of ungrounded Corn/ Tracer (Kg)**	**Coefficient of Variation (CV %)**	**Degree of Mixing (DM %)**
5	0.0144	42.42	57.58
10	0.0184	13.09	86.91
15	0.0177	26.12	73.88
20	0.0194	26.76	73.24

The mean weight of ungrounded corn, and percentage coefficient of variation and degree of mixing of the prototype machine at mixing paddler speed 580 rpm and mixing time of 5, 10, 15, and 20 minutes were found to be 0.0144, 42.42 and 57.58, 0.0184, 13.09, and 86.91, 0.0177, 26.12 and 73.88 and 0.0194, 26.76 and 89.73.24, respectively. From Table 3, it can be seen that, at the mixing paddler shaft speed of 580 rpm, mixing time of 10 minute resulted in percentage coefficient variation of 13.09 %. The value of coefficient variations obtained at mixing times 10 minute is within upper boundary of rating as indicated by Herrman and Behnke (1994) (values of percentage coefficient of variations < 10, 10 – 15, 15 -20 and > 20 are rated excellent, good, fair and poor, respectively, in terms of uniformity/thoroughness of mixing). Hence, the mixing uniformity was superior at the combination of 580 rpm and 10 minutes of mixing time.

From figure 3 we observe that as the time of mixing and speed of the paddler increasing mean percent of mixing increases up to the optimum value attained. When the speed of paddler shaft is 480 rpm and duration of mixing time increases degree of mixing increases to some optimum level but it is not economical in terms of cost.

Results of the analysis of variance (ANOVA) presented in Table 4 revealed that the mixing paddler shaft speed and the interaction with mixing time had no significant effect while mixing time had significant effect (p = 0.05) on coefficient of variation. Table 4 shows the effect of mixing paddler shaft speed, mixing time and the combined effect of screw shaft speed with mixing/holding time on mean percent of coefficient of variation (CV %).

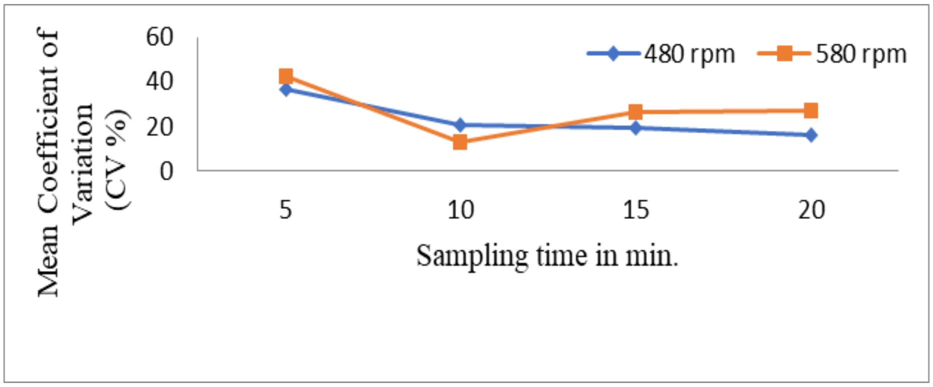

Figure 2. Effect of n sampling time and rpm on the coefficient of variation for the mixer using weight of ungrounded corn as the tracer (based on Tables 1 and 2)

From the above figure we observe that as the time of mixing and speed of the paddler increases percent coefficient of variation decreases and percent degree of mixing increases up to some extent and then vice versa.

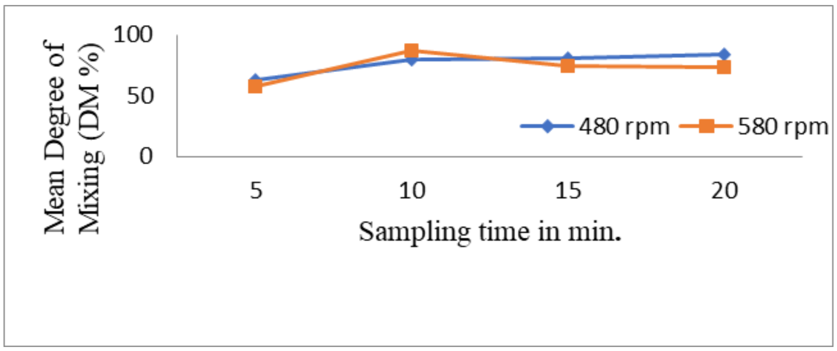

Figure 3. Effect of n sampling time and rpm on the degree of mixing for the mixer using weight of ungrounded corn as the tracer (based on Tables 2 and 3)

Table 3. Paddler shaft speed, mixing time and their interaction on means of % CV

Parameter	Paddler shaft speed (R), rpm			CV %		LSD 5%	SE(M)
	480			22.8^{a}			
	580			27.2^{a}		12.16	4.01
	Mixing time, min						
	5			39.7a			
	10			16.9^{b}		17.19	5.67
	15			22.8^{ab}			
	20			20.7^{b}			
	Interaction R * T						
		5 min	10 min	15 min	20 min		
	480 rpm	36.7^{ab}	20.7^{ab}	19.3^{ab}	14.7^{b}	24.31	8.02
	580 rpm	42.7^{a}	13.1^{b}	26.3^{ab}	26.7^{ab}		

Means with similar letters indicated that there is no significant difference between them at 5% of significance level.

Conclusion and Recommendation

Conclusion

The livestock feed mixing machine was successfully designed, developed and tested. A mixing performance of up to 86.91% was attained in 10 minutes of operation and emptying of mixed materials from the mixer was accomplished in 5 minutes with the mixer at full capacity with small amount of feed left. The average value of coefficient of variation for the three replicates was 13.09 %. The salient implication of the result of this study is that the mixing machine developed from available materials on the market is effective, simple and easy to maintain. The mixer can mix about four quintals per hour.

Recommendation

In order to use this machine, the user must consider the following recommendations. First, all the ingredients used for livestock feed preparation must be chopped and milled based on the size of their recommendation. The ingredients that have larger volume and density must be filled first and then the next continued in the same manner. The machine is used for all stock raisers. The machine can mix uniformly when the ingredients is not filled below half and at its full level.

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Effects of Alternate Furrow Irrigation and Its Interval on Yield and Water Use Efficiency of Tomato Production at Erer Woldiya District of Harari Reginal State

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Abstract

Increasing population has resulted in demand for more food and fiber, which is met through increasing irrigated agriculture. It is critical therefore that proper management and efficient utilization of available water resources is necessary; especially in arid and semi-arid area where irrigated agriculture is pinned. The experiment was conducted at Erer Woldiya district of Harari Regional State on farmers' field for two consecutive years. The purpose of the study was to evaluate the effects of Alternate Furrow Irrigation (AFI) and Every Furrow Irrigation (EFI) with different irrigation intervals on growth components, yield and water use efficiency of tomato. The experiment was designed as a two factor factorial experiment in RCBD, replicated three times. The two factors were 2 irrigation methods (IMs): AFI and EFI) and 3 Irrigation Intervals (IIs); 4, 6 and 8 days. The study revealed that plant height (PH) at harvest, number of fruits per plant (NFPP) and total yield were significantly (P<0.05) influenced by IMs. Similarly, IIs had highly significantly (P<0.01) effect on PH, NFPP and total yield during both cropping seasons. Water saved from treatment combination of AFI with 4, 6 and 8 days IIs were 16, 44 and 58% of gross irrigation water applied. Whereas, EFI with 6 and 8 days IIs saved 33.3 and 50% irrigation water, respectively. AFI with 4 days II shows little yield reduction (4.97%) as compared with no stressed (EFI with 4 days II). But AFI with 4 days II saved 16% from gross water applied for EFI with 4 days II. Treatments with 6 days II of AFI and EFI indicated significant yield reduction of 15.74 and 14.61%, respectively. But, gross volume of irrigation water saved was 44 and 33.3% for same treatments. Hence, water saved from AFI and EFI with 6 days II could irrigate additional irrigation land in water limited or shortage environments. Crop water productivity indices (CWUE, IWUE and EWP) were highly significantly (P<0.01) influenced by both IMs and IIs. It was clearly confirmed that, AFI had beneficial advantage over EFI on water saving and the same happened for IIs (i.e., increasing irrigation interval from 4 day followed by 6 to 8 days increases water use efficiency of the tomato crop). Hence, the result indicates that interaction effect of factors (IMs and IIs) save significant amount of water.

Key words: Alternate furrow irrigation, every furrow irrigation, irrigation interval, tomato, growth and yield parameters, water productivity

Introduction

Agriculture is the largest freshwater user on the planet, consuming more than 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.*, 2014a), and freshwater shortage is becoming critical in the arid and semi-arid areas of the world (Forouzani and Karami, 2011). About 93%

of the available fresh water resources are currently utilized in the agricultural sector (Bhangar and Saima, 2008). The increasing population has resulted in demand for more food and fiber, which is met through increasing irrigated agriculture. It is critical therefore that management and utilization of available water resources is improved at all scales; from catchment, to irrigated district, to farm and field scale.

Traditional surface irrigation methods (basin, border and furrow) are widely used to irrigate crops. These are however inefficient methods of irrigation and are considered one of the main causes of waterlogging and salinization (Burt *et al*., 1997). It is because of these sorts of problems that the use of modern, high-tech and efficient micro irrigation methods (drip, bubbler, sprinkler etc.) are advocated worldwide. However, farmers are often reluctant to adopt these high-tech methods, especially in Ethiopia and other developing countries, due to their high cost of installation, operation and maintenance. As a result these methods have not yet been widely adopted by farming communities in developing countries. There is a need therefore for more efficient irrigation methods that are economical, easy to install and operate, and which are readily acceptable to the farming community.

However, there are also potential in some cases for a reduction in crop yield (CraMashori, 2013). It has been observed that farmers prefer to stick with traditional flood irrigation methods due to their simplicity, ease of operation and maintenance and low installation/construction cost. If the conventional/every furrow irrigation method (EFI) is transformed into alternate furrow irrigation (AFI), then it might be readily accepted by farmers. However, before introducing and advocating this method to local farmers for adoption, the method needs to be evaluated under soil and climatic conditions of a given areas being targeted.

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 (Nasri *et al*., 2010; Kashiani *et al.*, 2011). Sepaskhah and Khajehabdollahi (2005) found that corn grain yield in fine-textured soil with a deep water table and AFI at 7-day intervals was statistically lower EFI at 10-days 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). In Egypt, Abdel-Maksoud *et al*. (2002) found that AFI at 14-days interval seemed to not significantly decrease maize (*Zea mays* L.) yield, whereas yield increased under AFI at 7-days intervals as compared with the EFI method. They also found that WUE values improved under AFI as compared with the EFI method. The economic and environmental benefits of using the AFI method are higher than all other irrigation methods because less water is applied and the economic return is higher (Nelson and Al-Kaisi, 2011).

They adopt traditional flooding without any strategic water use as observed, even though they paid high cost of fuel for pump to exploit water. The discharged volumes of water is not much pump fuel consumption, for the reason that, of pumping head rapidly fall and ground water table also fall yearly. On other hand, this small amount was totally supplied to irrigable area by means of traditional flooding (which is basin irrigation without selecting) appropriate, slope, soil and crop, thus these practices has contributed to a low water use efficiency and consequent farmers waste irrigation water in the form of surface runoff, especially high deep-percolation.

Inorder to resolve this ineffective irrigation practice and, to enhance best water saving, as compared to this situation they have to adopt optimum water productivity methods through practicing and promoting water-use efficiency and productivity techniques to optimize yield and cost incurred. FI at appropriate irrigation interval achieve good on-farm water management and thus enabled to get better yield with this scarce resource and minimize other variable cost. Therefore, this experiment was aimed to evaluate the effect of AFI with different irrigation intervals on yield and water use efficiency of tomato.

Materials and Methods

Description of the study area

The study was conducted in Harari Regional State of Erere Waldiya district in Erer Dodota kebele. Preliminary survey and site selection was conducted with collaboration of district agriculture and natural resource office. Thus, representative sites were selected purposively based on availability of resources required and willingness of the farmer to provide the experimental plot, as well as access for field monitoring and follow up. Accordingly, the selected site was situated at $42^0$11' 00" to $42^0$15' 30" East latitude and 9^0 15' 22" to 9^0 19' 35" North longitude respectively. The site receives a mean annual rainfall of 400 mm. It has erratic and uneven distribution, with mean minimum and maximum temperatures of 25 ^{0}C and 35 ^{0}C, respectively. The major soil types which occur in lowlands of the Erer Waldiya districts are Luvisols (Sandy soil) 90% and Nit sols (clay) 10% (AGP-II, 2016). The soil type in the experimental site of Erer dodota is sandy loam.

Major crops grown in the study area include sorghum, maize, pulse or oil crop, chat, sugar cane, and mango are practiced almost under rain-fed agriculture. Whereas commonly grown irrigated vegetable crops, in the vicinity of the site, by using basin and border strip irrigation are tomatoes, onion, pepper and khat accordingly.

Treatments and experimental design

The experiment has two factors, factorial design arranged in randomized complete block design (RCBD) with three replications. The treatments considered for the experiment were namely two furrow irrigation methods; Alternative furrow irrigation (AFI) and every furrow irrigation (EFI) and three irrigation intervals or days (4, 6, and 8, interval for successive /next irrigation), hence there are six treatment combinations (Table 1).

The experiment was conducted on individual plot size of 3.5 m x 5 m (15 m^2) with 18 number of such plot. The spacing between the blocks and plots were kept as 2 m and 1 m respectively. Each plot had 5 furrows and 4 planting ridges (rows) with 0.8 m and 0.3 m furrow and between plants spacing, respectively.

A test crop tomato (*Melka shola variety*) seeds (cultivar: *OPV variety*) was used which was adapted in study area with a purity test of 98%, and having germination percentage of 85 collected from Fedis Agricultural Research Center (FARC) horticulture team. Five weeks after germination seedlings were transplanted on experimental plots.

Table 1: Treatment description

Treatment	Treatment Combination
AFI_1	Alternative Furrow Irrigation (AFI) with 8 II
AFI_2	Alternative Furrow Irrigation (AFI) with 6 II
AFI_3	Alternative Furrow Irrigation (AFI) with 4 II
EFI_1	Every Furrow Irrigation (EFI) with 8 II
EFI_2	Every Furrow Irrigation (EFI) with 6 II
EFI_3	Every Furrow Irrigation (EFI) with 4 II

II: Days of irrigation interval

Commonly recommended fertilizer rate was applied manually in the experimental plots. All plots received the same amounts of fertilizer consisted of 150 kg ha^{-1} of urea and 100 kg ha^{-1} of P_2O_5 (DAP). The irrigation water used in the study was obtained from a well. Crop water requirements was estimated using the CROPWAT computer software program using climatic, soil and crop data as inputs.

Soil texture and water holding analysis

Soil samples from the experimental plots were taken to analyze bulk density, texture, moisture content at filed capacity and permanent wilting point from the field at three points along the diagonal of the experimental plot at two depths; 0-20 cm and 20-40 cm.

Soil texture, organic matter and pH measurement

The particle size distribution in the soil profile was done using hydrometric method following the procedure outlined in Staney and Yerima (1992. Organic carbon (%) was determined by potassium dichromate wet combustion producer (Walker and Black, 1934). Organic matter was obtained by multiplying organic carbon by conversion factor of 1.724. The pH of the soil in experimental site was determined by calibrated AD-8000 model (EC, TDS, PH meter) measuring instrument by preparing soil water solution of 1:2.5 ratio (soil to water) following procedures or guide line given by manufacturer.

Determining of FC, PWP moisture content and bulk density

Field capacity (FC), permanent wilting point (PWP) and bulk density (ρ_b) of the soil in the study area was determined from soil samples to be taken from soil textural class by using SPAW-version 6.2.0.75 software. After getting soil moisture values, water availability to crops from the soil was calculated. The total available water (TAW) in root zone is then be computed as the difference in moisture contents between field capacity (FC) and permanent wilting (PWP) as follows (Allen *et al.*, 1998).

Agronomic parameters of tomato

In this experiment the agronomic parameters of tomato were collected to evaluate the effect of alternate and every furrow irrigation methods under different water irrigation interval on physiological and yield response of tomato was measured and collected. The parameters include: plant height at harvest, number fruit per plant, total yield were used for evaluation.

Crop and irrigation water requirements

Crop coefficient (Kc) for initial, development, mid and late stages, root depth, allowable depletion level was determined from CROPWAT data base and FAO tables (Allen *et al.*, 1998). Meteorological data was collected from nearest station; Erer automatic meteorological station which was situated in Babile district. The station was established in 2015. Therefore, there are no long-term data records, of the station, so available data of 4 year was used for determination of crop evapotranspiration.

Table 2: Average monthly climatic data of reference evapotranspiration of FARC substation Erer meteorological station of 4 years (2015–2018)

Month	Min Temp (^{0}C)	Max Temp (^{0}C)	Humidity (%)	Wind in (km day^{-1})	Sunshine (hrs)	Radiation (MJ m^{-2}day^{-1})	ETo in (mm day^{-1})
January	7.0	32.1	51	111	8.5	20	3.75
February	14.5	32.5	68	104	8.2	20.8	4.12
March	15.4	33.6	63	112	7.0	20.1	4.37
April	16.1	33.5	76	104	14.5	31.9	6.14
May	18.7	29.9	85	92	15.4	32.5	6.04
June	18.2	29.7	89	95	16.1	32.8	5.98
July	16.8	29.8	97	92	18.7	36.8	6.55
August	13.7	30.9	87	78	18.2	37.0	6.56
September	11.0	32.0	78	86	16.8	35.1	6.17
October	7.5	30.6	63	104	13.7	29.2	4.99
November	13.0	23.9	49	95	11.0	23.7	4.07
December	12.8	23.5	52	138	7.5	18.2	3.58
Average	**13.7**	**30.2**	**72**	**101**	**13**	**28.2**	**5.19**

Water application and discharge measurement

Water source obtained from manual hand dug well pumped by using diesel fuel pump for irrigated vegetable production. The discharge was measured at pump delivery tube before reaching the field and it was directly measured at the outlet. Smaller supply channels that were feed the furrows for furrow irrigation system and through careful opening and closure of channel banks, the water was supplied into furrows and the flow was measured by parshall flume in the field.

Data analysis

All measured variables were subjected to analysis of variance appropriate for RCBD. Significant mean separation will be compared using least significant difference (LSD) and Duncan's Multiple Range Test (DMRT) by *Genstat* 15th version software was used for analysis of variance.

Results and Discussion

Physical properties of experimental soil

Laboratory analysis of particle size distribution indicated that the soil texture was sand clay loam throughout the depths of 0-20 cm and 20-40 cm. The average soil bulk density of 0-40 cm soil depth was 1.55 g cm^{-3}. Average available soil moisture content for the top (0-40 cm) soil depths was observed as 15.8% by volume and representative value of total available water (TAW) was 142.6 mm m^{-1} by considering the average of the upper 0-40 cm soil depth. The average OM of the soil was found as 1.2%. Representative value of the soil pH (1:2.5 soil to water) was 6.5. Field level infiltration test indicated that basic infiltration rate of the experimental area soil was 24 mm hr^{-1}(Table 3).

Table 3: Physical properties of experimental soil

Averaged values of 0-20 and 20-40 cm depth of soil						
			Particle size distribution (%)			
			Sand	Silt	Clay	Textural class
			65	25	10	Sandy loam
BD (g cm^{-3})	FC (Vol. %)	PWP (Vol. %)	TAW (mm m^{-1})	OC (%)	OM (%)	pH
1.55	24.49	14.26	142.6		1.2	6.5

Note: FC stands for field capacity volume base, PWP for permanent wilting point volume base, BD for bulk density, TAW for total available water, OC for organic carbon, OM for organic matter, pH for power of Hydrogen (soil reaction at 1: 2.5; soil: water)

Gross irrigation water applied for each growth stages

Gross water applied for each growth stages and comparison of irrigation methods under three different irrigation intervals were made as indicated in Table 4.

Table 4: Water applied per growth stages and water saved

Treatments	Irrigation water in (mm) per each growth stage				I_{gross} (mm)	Water saved in (%)
	Initial	Development	Mid	Late		
AFI with 8 days	33.14	45.28	64.64	49.90	321.58	58
AFI with 6 days	44.18	60.37	86.18	66.53	428.77	44
AFI with 4 days	66.28	90.55	129.28	99.79	643.16	16
EFI with 8 days	39.45	53.90	76.95	59.40	382.83	50
EFI with 6 days	52.60	71.87	102.60	79.20	510.44	33
EFI with 4 days	78.90	107.80	153.90	118.80	765.67	0
Total	**314.55**	**429.76**	**613.55**	**473.62**	**3052.46**	

In AFI, irrigation water was applied only to two or three furrows at each successive irrigation event, so water saved from this irrigation method was greater than EFI for each irrigation event throughout growth season, even though, the yield obtained was less than full or all furrow irrigated once per predetermined irrigation interval.

Hence, the result indicated that water saved from treatment combination of AFI with 4, 6 and 8 days irrigation intervals were 16, 44 and 58% of total gross volume of irrigation water applied. Whereas, EFI with 6 and 8 days irrigation interval saved 33 and 50% water, respectively (Table 4). According to Shahnazari *et al.* (2007) comparative report of full irrigation (FI) with partial root drying (PRD) for field grown potato, PRD treatments saves 30% of water which increases water use efficiency of the crop.

Effect of Irrigation methods (IMs) and irrigation interval (IIs) on growth components

Effect of IMs and IIs on plant height at maturity

The ANOVA result shows that plant height at harvest was significantly (P<0.05) influenced by irrigation methods, and it was highly significantly (P<0.01) affected by irrigation interval during both planting seasons. The highest mean plant height (72.85 cm) was recorded under EFI. The highest mean plant height (77.04 cm) was also recorded at 4 days irrigation interval, whereas the lowest value 64.21 cm was observed at 8 days water application interval (Table 5). Hence, from this finding, it was confirmed that plant height increased as frequency of application increase from 8 to 4 days interval. This result agreed with Wakrim *et al.* (2005), shoot and pod biomass was significantly decreased in both PRD and deficit irrigation as compared with FI of beans. Similarly (Li *et al*. 2005) reported that leaf area increment, averaged to single leaf, showed that CFI produced significantly larger leaves than the AFI and FFI in the early growth stage of cotton.

Table 5: Main effect of irrigation methods (IMs) and irrigation interval (IIs) on growth and yield components

Treatment		Two year data of crop growth and yield component					
		2017/18			2018/19		
		PH	NFPP	TY	PH	NFPP	TY
Irrigation method (IMs)	EFI	72.85	86.25	33.27	70.67	83.4	37.19
	AFI	70.01	80.79	31.48	67.45	73.6	34.92
	CV	-	-	-	-	-	-
	LSD	**2.22***	**4.91***	**1.42***	**3.032***	**5.95****	**2.028***
Irrigation interval (IIs)	4 days	77.04[a]	96.99[a]	39.57[a]	76.53[a]	91.79[a]	39.22[a]
	6 days	70.58[b]	82.64[b]	33.08[b]	66.44[b]	80.31[b]	35.29[ab]
	8 days	66.67[c]	70.93[c]	24.48[c]	64.21[b]	63.37[c]	33.65[b]
	CV (%)	**3.00**	**5.60**	**4.20**	**4.20**	**7.2**	**5.4**
	LSD	**2.72****	**6.01****	**1.74****	**3.713****	**7.28****	**2.484****

PH-Plant height (cm), NFPP- Number of fruit per plant in (No.) TY-Total yield in (ton ha^{-1}) and, Note: mean followed by the same letter in the columns are not significantly different: ***Note:*** CV of two treatments AFI and EFI is statistically not computed

Effect of IMs and IIs on number of fruits per plant (NFPP):

Statistical analysis indicates that number of fruits per plant (NFPP) was highly significantly (p<0.01) affected by Irrigation Intervals. But NFPP was significantly affected by (p<0.05) irrigation methods at both planting seasons. The highest mean NFPP (86.25) was observed under EFI during both planting seasons. Whereas, the highest mean NFPP (96.99) was produced at 4 days irrigation interval during 2017/18 cropping season. The lowest mean NFPP produced was 63.37 at 8 days irrigation interval (Table 5). Similarly, Kamel *et al.*, (2013) reported that FI treatments gave the highest yield, plant diameter and number of leaves of tomato crop. In contrast of this study result. In contrast of this study results, Acar *et al*. (2008) reported that different irrigation levels did not significantly affect mean leaf number and plant diameter.

Effect of Irrigation Methods and Irrigation Intervals on Yield:

ANOVA indicated that total yield was significantly influenced ($P<0.05$) by furrow irrigation methods in both planting season, and the effect of water application days on yield was highly significant ($p<0.01$). The maximum total yield recorded by EFI were 33.22 and 37.19 t ha^{-1} in respective planting seasons, while the minimum yield of 31.48 t ha^{-1} was found at AFI, during first year. Similarly, the yield obtained under different days' or (8 and 4) intervals of irrigation lied in between 24.76 to 39.75 t ha^{-1} respectively. This shows that water application interval has remarkable effect on tomato yield (Table 5) this may due to is less amount of water application in long day irrigation interval. Similar results were reported by El-Halim (2015) that the yield of maize under fixed furrow irrigated in 7 days interval and EFI treatments were higher than that obtained from FFI at 14 days interval, respectively. According to Ibrahim and Kandil (2007) frequent irrigation interval (7 days) in fixed-furrow resulted in higher grain yield than less frequent irrigation interval (14 days). Stickic *et al, (*2003) explored that tomato plants grown under PRD had 26% reduction in height, 10% reduction in number of leaves and 30% reduction in the number of fruits.

Effect of irrigation methods (IMs) and irrigation interval (IIs) on water productivity and yield reduction

EFI with 4 days water application treatment was received maximum amount of water of all treatment and produced maximum yield. Therefore, it could be used as control for comparison purpose. Whereas AFI with 4 days irrigation interval showed little yield reduction which was indicated as 4.97%, as compared with no stressed (EFI with the same irrigation interval). But AFI with 4 days irrigation interval saved 16% irrigation water (Table 6).

Table 6: Average water saved and relative yield reduction of two seasons

Treatments	I_{gross} (m^3)	Water saved (m^3)	Water saved (%)	Yield (kg ha^{-1})	Yield reduced (kg ha^{-1})	Yield reduced (%)
AFI with 8 day	3215.8	4440.9	58.0	27341.5	13056.9	32.3
AFI with 6 day	4287.7	3369.0	44.0	34040.0	6358.4	15.7
AFI with 4 day	6431.6	1225.1	16.0	38391.9	2006.5	4.9
EFI with 4 day	7656.7	0.0	0.0	40398.4	0.0	0.0
EFI with 6 day	5104.4	2552.3	33.3	34498.1	5900.3	14.6
EFI with 8 day	3828.3	3828.4	50.0	30625.8	9772.6	24.2

Similarly, treatments with 6 days irrigation interval of AFI and, EFI gave significant yield reduction of 15.7 and 14.6%, respectively. But, total amount of gross volume of irrigation water saved was 44 and 33.3% for the same treatments (Table 6). Hence water saved from AFI and EFI with 6 days irrigation interval could irrigate additional land in water limited or shortage environments. Pfeiffer and Lin (2014), reported that water saved through improved irrigation systems could allow for an expansion of cultivation land and increase crop production in water limited areas.

The result revealed that tomato performance under different irrigation methods with increasing irrigation interval from 4 to 8 days, the yield reduction also increased accordingly. Considering different factors, were the same for all treatment in the yield reduction not more than 15% is usually tolerable. Thus, AFI with 4 and 6 days, and EFI with 6 days irrigation intervals fall in tolerable range. This result agreed with that of Shock *et al.* (2013) that improper irrigation depth and frequency can substantially reduce yields by increasing the proportion of rough, misshapen tubers.

Effect of IMs and IIs water productivity

Crop water use efficiency (CWUE): The outcome of statistical analysis indicates that CWUE varied highly significantly (P<0.01) influenced by both IMs and IIs. The highest value produced as main effect by AFI was 11.55 kg m^{-3}, and the lowest was recorded by EFI as 7.98 kg m^{-3} during two planting seasons. Whereas, the result showed that CWUE was significantly increases as irrigation interval or application day decreased. Hence, the highest value of CWUE of 11.86 kg m^{-3} was obtained by 6 days irrigation interval followed by 8 days (11.60 kg m^{-3}), but statistically not significant, and the lowest 9.41 kg m^{-3} was recorded at 4 days irrigation interval in 2017/18 cropping season. Similarly, the highest and lowest mean value 10.65 and 6.22 kg m^{-3} of CWUE was recorded in second year (2018/19), respectively (Table 7). It is also evident that, at each irrigation methods, the CWUE increased with increasing water application intervals (i.e. 4 to 8 days).

Table 7: Effect of furrow irrigation methods and irrigation intervals on physical water productivity

Treatment		Two year data of crop water productivity					
		2017/18			2018/19		
		CWUE	IWUE	EWP	CWUE	IWUE	EWP
Irrigation method	EFI	10.34	6.21	49.65	7.98	4.79	38.29
	AFI	11.55	6.93	55.46	8.87	5.32	42.57
	CV (%)	**-**	**-**	**-**	**-**	**-**	
	LSD	**0.597****	**0.358****	**2.868****	**0.416****	**0.250****	**1.999**
Irrigation interval (days)	At 4	9.41[b]	5.65[b]	45.17[b]	6.22[c]	3.73[c]	29.86[c]
	At 6	11.84[a]	7.10[a]	56.81[a]	8.39[b]	5.04[b]	40.30[b]
	At 8	11.60[a]	6.96[a]	55.67[a]	10.65[a]	6.39[a]	51.13[a]
	CV (%)	**5.20**	**5.20**	**5.20**	**4.7**	**4.7**	**4.7**
	LSD at (5%)	**0.732****	**0.439****	**3.512****	**0.510****	**0.306****	**2.448****

CWUE=Crop water use efficiency in kg m^{-3}: IWUE=Irrigation water use efficiency in kg m^{-3}: EWP =Economic water productivity in ETB m^{-3}

Irrigation water use efficiency (IWUE): The analysis of variance, showed that IWUE was highly significantly (P<0.01) influenced by both IMs and IIs. The result (Table 7) revealed that irrigation water use efficiency was increased significantly from 4.76 to 6.93 kg m^{-3}, for EFI and AFI respectively that computed for both cropping seasons. Accordingly, IWUE had significantly affected by irrigation intervals. The highest mean value was recorded as 7.10 kg m^{-3} for 6 day's irrigation intervals, whereas the lowest (3.73 kg m^{-3}) was recorded at 4 days water application interval (Table 7).

Economic water productivity (EWP): The analysis of variance revealed that economic water productivity was highly significantly (P<0.01) influenced by both irrigation methods (IMs) and water application interval or days (II). The result indicated that mean maximum EWP value for AFI obtained was 55.46 Ethiopian Birr (ETB) m^{-3}, which was significantly different from that of EFI. The mean minimum EWP (38.39 ETB m^{-3}) was recorded by EFI for both planting season (Table 7). EWP was also found significantly influenced by different irrigation intervals. The maximum value (56.81 ETB m^{-3}) was obtained by 6 days irrigation interval which was not significantly different from that of 8 days. The lowest EWP at 4 days irrigation interval was recorded during first year cropping season. Whereas, the second year data indicates that maximum EWP (51.13 ETB m^{-3}) was obtained from 8 day irrigation interval and the lowest was 29.86 ETB m^{-3} (Table 7). This result reveals that, economic water productivity depends on the ratio of yield obtained in cash to the amount and frequency of water applied in volume (m^{-3}) basis. Hence each 8 days irrigation interval had least water application depth and similarly the yield was relatively lower when compared with 6 and 4 days water application intervals, thus resulted in higher economic water productivity.

Generally, from crop water productivity indices (CWUE, IWUE and EWP) studied, it was clearly confirmed that alternate furrow irrigation had beneficial advantage over every furrow irrigation on water saving and the same was happened for irrigation interval (i.e., increasing irrigation interval from 4 days followed by 6 to 8 days increases water use efficiency of crop). Hence, the result indicates that interaction effect of factors (IMs and IIs) save significant amount of water. Amount of saved water as described in Table 7 from each treatment have advantage of increasing addition land, time or labor productivity. Some study confirmed the same increased water productivity by using alternative partial root drying for different crops (Ahmadi *et al.*, 2010b). Guang *et al.* (2008) also reported that partial root zone drying significantly reduced yield by 24%, while water productivity increased by 52% compared with the FI (full irrigation).

Conclusion and Recommendation

Experiment was conducted at Eastern Ethiopia Harari Regional State of Erer Woldiya district, on-farm field for two years. The purpose of this study was to evaluate the effect of AFI and EFI with different irrigation intervals on growth component, yield and water use efficiency of tomato. Accordingly, the parameters for experimentation include growth component: such as plant height and number fruit per plant and yield parameter total head, yield and, water productivities.

Plant height at harvest maturity was significantly ($P<0.05$) influenced by irrigation methods (IMs), but (IIs) highly significantly ($P<0.01$) effected on plant height on both planting season. Statistical analysis indicates that number of fruits per plant was highly significantly ($p<0.01$) affected by IIs. But NFPP was significantly affected by ($p<0.05$) irrigation methods at both planting seasons. Total yield was significantly influenced ($P<0.05$) by furrow irrigation methods in both planting season, but the effect of water application days was highly significant ($p<0.01$)

Generally, from crop water productivity (CWUE, IWUE and EWP) it clearly confirmed that, alternate furrow irrigation had beneficial advantage over every furrow irrigation on water saving and the same consequent happened for irrigation interval i.e. increasing irrigation from 4 day followed by 6 to 8 days increases water use efficiency of crop. Hence the result indicates that interaction effect of factors (IMs and IIs) save significant amount of water. Hence water saved from treatment combination of AFI with 4, 6 and 8 day II were 16%, 44%

and 58% of total gross volume of irrigation water applied respectively. Whereas CFI with 6 and 8 application day obtained 33% and 50%. Therefore, amount of saved water from each treatment have advantage of increasing addition land, time or labor productivity. AFI with 4 day II shows little yield reduction which was indicated as 4.97%, as compared with no stressed (EFI with the same II). Accordingly, AFI and, EFI were shows significant yield reduction as 15.7% and 14.6% respectively. But total amount of gross volume of irrigation water saved as 44 and 33.3% for AFI and EFI of the same II treatment. Based on this finding for more popularization for irrigated farmers' at optimum yield reduction with equivalent water saving AFI with 4 day II is the best and first option and EFI and AFI with 6 day II the second if they pursue efforts to save water, do they often use it to expand their irrigated areas or shift to higher value crops.

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Effect of Deficit and Furrow Irrigation Methods on Yield and Water Productivity of Tomato (*Solanum Lycopersicum L.*) at Bako Tibe District of Western Oromia, Ethiopia

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Abstract

Improving water use efficiency in general and enhancing agricultural water productivity in particular is among important strategies for addressing prevailing water scarcity. A field experiment was conducted at Bako Tibe district of Western Oromia during the off-rain season of 2017/18 and 2018/19 cropping calendars. The study was to investigate the effect of deficit and furrow irrigation methods on yield and water productivity (WP) of tomato (Galelia variety) for better agricultural production and environmental sustainability. The experiment was carried out as a two factor factorial combinations of three irrigation systems (i.e., AFI-Alternative Furrow Irrigation, CFI-Conventional Furrow Irrigation and FFI-Fixed Furrow Irrigation) and three water application levels (i.e., 100% ETc, 75% ETc and 50% ETc application depths) arranged in randomized complete block design with three replications. Irrigation depth was monitored using a Parshall flume of an opening diameter 3 inch with discharge rate of 4.239 l/s at a head of 9cm. Results were compared in terms of yield and WP at ($P<0.05$). There were highly significant differences between the mean results of both irrigation systems and water application levels on yield and WP. The interaction effects between irrigation systems and water application depths were highly significant on WP, while irrigation systems with year, water application depth with year and irrigation systems with water application depth with year were none significant for both yield and WP. The maximum yield and WP of 27.85 ton/ha and 13 kg/m^3 were obtained under AFI at 100% ETc, while the minimum of 22.01ton/ha and 9.8 kg/m^3 where obtained from FFI systems at 100% ETc, respectively. Thus, AFI with 100% ETc application depth is found the best irrigation system for tomato production and recommended to be used for the communities of the study area and similar agro ecologies.

Key words: *Deficit Irrigation, Irrigation systems, Tomato yield, Water productivity*

Introduction

Water is one of the largest renewable natural resources but fresh water is expected to emerge as a key constraint to future agricultural growth. The changing situation comes partly from increasing demands such as population, industry and domestic requirements and partly from consequence of climate change (Ashebir et al., 2018). The major concern for future planetary fresh water resources availability are the effects of climate change on sea temperature and levels, drought and flood events, as well as change in water quality, and general ecosystem vulnerabilities (Xu et al.,2015). The unpredictability of climatic events is of key concern to farmers in all countries, particularly in Africa.

According to Awulachew et al., (2010), estimate the irrigation potential of Ethiopia was 5.3 million hectares. In terms of utilization, only about 12% (857,933 ha) has been irrigated by 2015 (FDRE, 2016). So, it is prudent to make efficient use of water by minimizing over application of irrigation water and bring more area under irrigation through available resources. This can be achieved by introducing advanced methods of irrigation and improved water management practices (Ashebir et al., 2018).

Deficit irrigation is one way of maximizing water use efficiency for higher yields per unit of irrigation water used in agriculture (Geerts and Raes, 2009; Nagaz et al., 2012). In deficit irrigation application, the crop is exposed to a certain level of water stress either during a particular growth period or throughout the whole growing season, without significant reductions in yields (FAO, 2011). The expectation is that the yield reduction by introducing controlled water stress will be insignificant compared with the benefits gained through diverting the saved water to irrigated additional cropped area (Gijon et al., 2007; Ali et al.,2007).

Tomato (*Solanum lycopersicon* L.) is one of the most important irrigated vegetable crops and is one of the most demanding in terms of water use (Peet, 2005). The application of various deficit irrigation strategies to this crop may significantly led to save irrigation water (Costa et al., 2007). In the study area, over application of irrigation water without considering the crop water requirement is identified as the major problem of a crop failure. Under such existing condition, practicing of deficit irrigation and water saving methods of furrow irrigation systems could help to increase agricultural production by expanding irrigable land with the given limited amount of water. Therefore, the objective of the study was to evaluate the effects of deficit irrigation under different furrow irrigation methods on yield and water productivity of tomato for better agricultural production and environmental sustainability.

Materials and Methods

Study Area Description

The experiment was conducted at Bako Tibe district of Western Oromia. It is located at distance of about 236 km away from Addis Ababa on the way to Nekemt and at Eastern of Bako town with altitude of 1676 m.a.s.l (Figure 1). The experimental site was characterized by clay loam soil type, dry and wet season. The majority of the rainfall occurs from May to September. The area receives an annual rainfall ranging from 1000 -2100 mm and an average annual temperature of 19 ^{o}C.

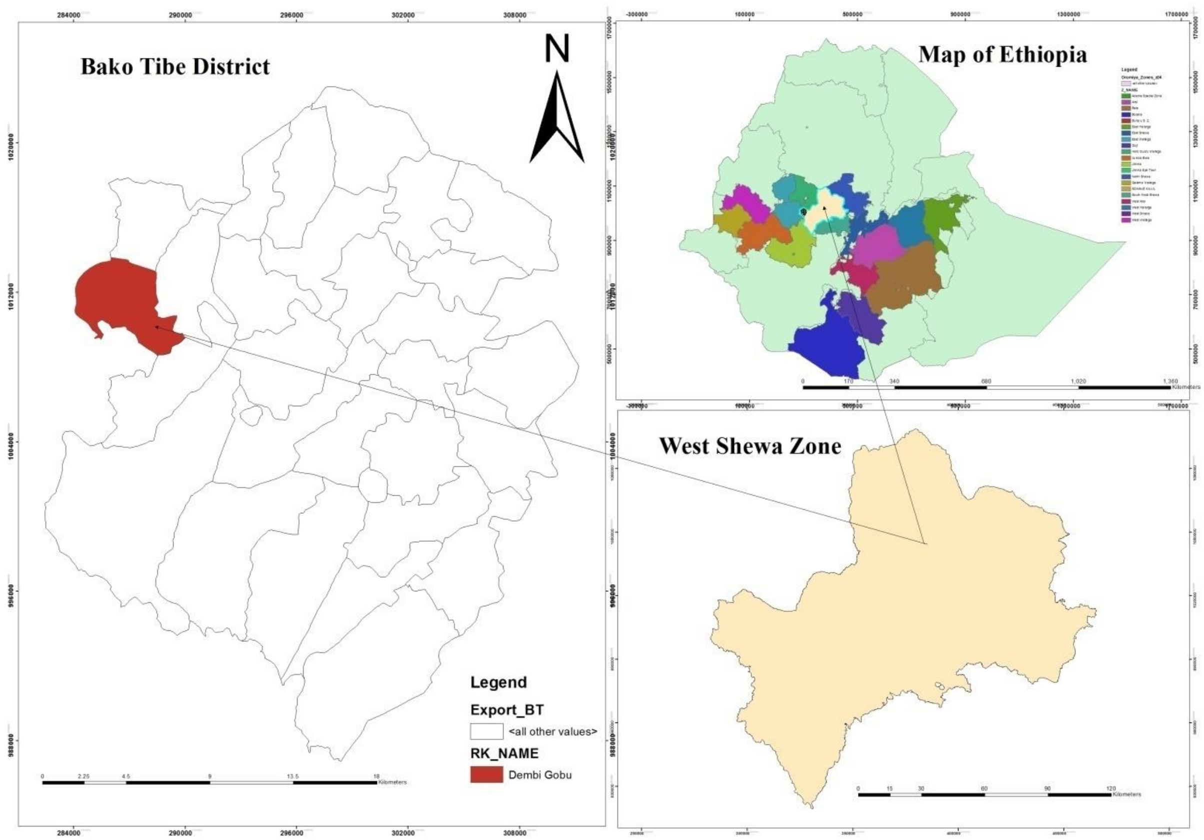

Figure 1: Map of study area

Experimental Design and Procedure

The experiment was implemented in two factorial combinations namely, three irrigation systems and three irrigation water application levels (Table1). The treatments combinations were arranged as completely randomized blocks design with three replications. The depth of water applied to the field was measured by Parshall Flume of 3 inch throat diameter. The effective head of 9 cm was calibrated and hence the resulting discharge rate was 4.239 l/s. The plot size was 4 m × 10 m with 1 m and 2 m space between plots and blocks respectively. Each plot contained four ridges and four furrows. Each bed had 1m width and 10 m length. The trapezoidal shape furrow was prepared with an average depth of 40 cm and width of 30 cm and 20 cm at the top and bottom, respectively.

Table.1. Treatments used for the experiment

Irrigation systems	Water application levels		
	100% ETc	75% ETc	50% ETc
AFI	AFI100% ETc	AFI 75% ETc	AFI 50% ETc
FFI	FFI100% ETc	FFI 75% ETc	FFI 50% ETc
CFI	CFI100% ETc	CFI 75% ETc	CFI 50% ETc

Key: AFI100% ETc, FFI100% ETc and CFI100% ETc were alternative, fixed and conventional furrow irrigation with full irrigation respectively, AFI 85% ETc, FFI 85% ETc and CFI 85% ETc were 85% of the full irrigation (15% deficit), AFI 70% ETc, FFI 70% ETc and CFI 70% ETc were 70% of full irrigation (30% deficit) and AFI 50% ETc, FFI 50% ETc and CFI 50% ETc were 50% of full irrigation (50% deficit).

Soil Sample Collection and Analysis Methods

Depending on the greatest root depth concentration which is 30 cm for transplanted tomatoes, the disturbed and undisturbed composite soil sample before planting were collected at a depth of 0-20 and 20-40 cm. Different soil physical properties such as bulk density, texture, infiltration, field capacity and permanent wilting point were done by core sampler method, pipette method, double ring infiltrometer and pressure plate apparatus, respectively.

Determination of Crop Water and Irrigation Requirement

Crop water requirement of tomato for the growing season was determined from the reference evapotranspiration and crop coefficient using Equation (1). Soil (Table 2) and Meteorological data (Table 3) were used to determine reference crop evapotranspiration (ETo). Farmers' experiences were used to determine the numbers of days of each growing stages to estimate reliable crop coefficient factor (Kc) for the respective growing stages. Higher application efficiency (60%) was adopted, since water was applied more accurately and no runoff. Irrigation scheduling of the crop was computed using FAO CROPWAT program (Allen et al., 1998).

$$ETc = Kc \times ETo \quad (1)$$

where: ETc = crop evapotranspiration (mm/day),
Kc = crop coefficient (dimensionless), and
ETo = reference crop evapotranspiration (mm/day).

Table 2. Input soil data for CROPWAT model

Depth of sampling (cm)	FC (%) by vol.	PWP (%) by vol.	Bd (g/cm^3)	Sand %	Silt %	Clay %	Textural class	Infiltration rate (mm/hr)
0-20	32.98	24.33	1.31	37	23	40	Clay	
20-40	36.33	27.3	1.35	37	27	36	Clay loam	7.2
Average	34.66	25.82	1.33	37	25	38	Clay loam	

Note: FC, PWP and Bd were field capacity, permanent wilting point and bulk density respectively.

Table.3. Climate data and ETo value of the study area

Months	Temp. max. (^{0}C)	Temp. min. (^{0}C)	Humidity (%)	Wind speed (km/hr)	Sun shine (hr)	Solar radiation (MJ/M^2/day)	Rain fall (m)	ETo (mm/day)
January	30.0	11.4	53.0	2.9	8.3	523.7	11.4	3.19
February	31.0	12.6	49.7	3.3	8.3	537.5	16.2	3.54
March	31.4	14.2	50.5	3.6	7.5	529.7	47.2	3.76
April	31.0	14.6	53.0	3.6	7.4	516.9	63.7	3.88
May	28.9	14.8	61.3	3.6	6.8	506.6	144.7	3.69
June	26.1	14.6	69.0	3.0	5.5	469.3	223.8	3.26
July	24.1	14.9	74.1	2.4	3.5	402.1	251.7	2.76
August	24.2	14.7	74.7	2.1	3.4	419.6	233.0	2.77
September	25.3	14.4	72.6	2.0	4.8	464.0	145.6	3.07
October	27.6	13.1	64.4	2.0	7.7	517.8	70.2	3.53
November	28.6	11.7	59.8	2.2	8.5	530.1	26.9	3.34
December	29.3	10.9	55.9	2.4	8.7	533.4	12.6	3.15

Source: Bako Agricultural Research Center station, 1961-2017 G.C.

Crop Agronomy and Management

Improved tomato *Galilea* variety having a total growing period of 90 days after transplanting was grown on nursery for 21 days and transplanted on experimental plots on 15th January, 2018. The crop variety was selected for its good adaptability, disease resistant and widely grown in the study area. The seedlings were transplanted on four ridges of each experimental plots based on recommended spacing of 60 cm between plants and 100 cm between rows. Recommended fertilizer rate of 200 kg ha^{-1} DAP at the time of transplanting and 150 kg ha^{-1} Urea twice, half at the time of transplanting while, half at 21 days after transplanting were equally and uniformly applied to each treatment. The crop was cultivated and weeded four times during the growing season. For further analysis; the yield harvested from the two central ridges to avoid boarder effect.

Depth and discharge measurement

The total amount of water required for the crop was diverted to the furrow with calibrated parshall flume which has appropriate opening diameter of three inch (3") with a length of 2 m and its appropriate head ranges from 3-33cm. The discharge was calculated as suggested by Michael (2008):

$$Q = 0.1771h^{1.5} \qquad (2)$$

where: Q = discharge from parshall flume, (l/s)
h = effective head of Parshall flume causing flow, (cm)

The time required to deliver the desired depth of water into each furrow was calculated using the equation recommended by Israelsen (1980).

$$t = \frac{d \times w \times l}{360 \times q} \qquad (3)$$

where: t= application time, (hr)
d= gross depth of water applied, (cm)
l= furrow length in, (m)
w= furrow spacing in, (m)
q= flow rate (discharge), (l/s)

Yield assessments (y)

$$\text{Yield obtained in ton per ha} = y \times 10^4 \qquad (4)$$

where: y = yield obtained per square meter

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):

$$WP = GY/Wa \qquad (5)$$

where: GY = grain yield (kg/ha)
Wa = total irrigation water applied (m^3/ha)

Partial Budget Analysis

It is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. It will be described finally interms of marginal rate of return (MRR). MRR is revealed how the net benefits from an investment increases as the amount invested increases and it will be calculated as:

$$MRR = \frac{\Delta TR * 100\%}{\Delta MC} \quad (6)$$

Where: MRR= marginal rate of return (%)

ΔTR= change in total revenue (birr/ha)

ΔMC= change in marginal cost

Statistical Analysis

The collected data were analyzed using GenStat 18th edition, ANOVA and the mean difference was estimated using the least significance difference (LSD) comparisons.

Results and Discussions

Crop water requirements and irrigation scheduling of Tomato

The seasonal irrigation water requirement of tomato was found to be 5984 m^3. This amount of water was needed for 100% ETc with CFI (full irrigation) level treatment, while 75% and 50% of ETc with CFI were 4488 and 2992 m3, respectively. The total irrigation water applied to AFI and FFI systems with 100%, 75% and 50% were 2992, 2244 and 1496 m^3 accordingly. The depth of irrigation water required at each irrigation interval and number of irrigation events were described on Table 4. The result indicates that, the maximum depth of water was applied during mid of March which is the mid development stage of tomato. Sahasrabudhe (1996) suggested that, this is the time when the crop needs high amount of water. Maximization of crop yield and quality can be achieved through meeting crop water requirement during this critical period, given all other factors are met. Probably the high tomato water requirement during this stage of development can be accounted for development of flowers and fruit which is high energy demanding and peak physiological phase for the crop growth (Sahasrabudhe, 1996). By sufficiently supplying water to the plant, during such critical time and ensuring its uptake, it is possible to improve crop water productivity.

Table 4. Irrigation interval and depth of applied water to each treatment

Irrigation systems	Water application levels	Irrigation period and depth of applied water (m^3/ha)									
		15th January	21th January	28th January	04th February	12th February	20th February	01st March	10th March	21th March	31th March
	100% ETc	572	656	668	880	1192	1396	1604	1652	1716	1632
	75% ETc	429	492	501	660	894	1047	1203	1239	1287	1224
CFI	50% ETc	286	328	334	440	596	698	802	826	858	816
	100% ETc	286	328	334	440	596	698	802	826	858	816
AFI	75% ETc	214.5	246	250.5	330	440	523.5	601.5	619.5	643.5	612
	50% ETc	143	164	167	220	298	349	401	413	429	408
	100% ETc	286	328	334	440	596	698	802	826	858	816
	75% ETc	214.5	246	250.5	330	440	523.5	601.5	619.5	643.5	612
FFI	50% ETc	143	164	167	220	298	349	401	413	429	408

Where: CFI, AFI and FFI are conventional furrow irrigation, alternative furrow irrigation and fixed furrow rrigation, respectively.

Effect of Irrigation Systems and Water Application Levels on Tomato Yield

The analysis on marketable tomato yield showed that, both irrigation systems and water application levels were highly significant at P<0.05 (Table 5). But, the interaction effect between irrigation systems and water application levels, were not significant.

Table 5. Analysis of variance of mean yield (ton/ha) and water productivity (kg/m^3)

Source of variation	df	MS (yield)	MS (WP)
Irrigation systems (IS)	2	1621.14**	47.1992**
Water application levels (WAL)	2	3658.04**	67.0226**
Irrigation systems * Water application levels (WAL)	4	82.13^{ns}	6.0413**

where: df- degree of freedom, MS- mean square, WP- water productivity

According to table 6, the yield obtained from the three irrigation systems and water application levels were significantly different from each other. The maximum marketable yield of 27.85 ton/ha and 29.98 ton/ha were obtained from alternative furrow irrigation (AFI) systems and 100% ETc, while the minimum marketable yield of 22.01 ton/ha and 20.98 ton/ha were observed from fixed furrow irrigation (FFI) systems and 50% ETc water application levels, respectively. The yield obtained in AFI system was better than CFI system under 50% reductions in applied irrigation water. This is probably because of the better application efficiency and physiological response associated with AFI (Zhang et al., 2000) and less evapotranspiration associated with AFI (Stone et al., 1979). The significant yield difference among the water application levels were consistent with the report of continuous water stress during the period of fruit set and fruit development can results significantly reduced fresh fruit yield and blossom-end rot (Sahasrabudhe, 1996).

Table 6. Effect of irrigation systems and water application levels on yield

Irrigation systems	Yield (ton/ha)
Alternative furrow irrigation (AFI)	27.85^{a}
Conventional furrow irrigation (CFI)	26.12^{b}
Fixed furrow irrigation (FFI)	22.01^{c}
Water Application Levels	
100% ETc	29.98^{a}
75%ETc	25.02^{b}
50% ETc	20.98^{c}
$LSD_{0.5}$	12.08
SE	4.2
CV (%)	7

Effect of Irrigation Systems and Water Application Levels on Water Productivity

As depicted from the analysis of variance (Table 5), irrigation systems and water application levels and their interaction were highly significant at (P<0.05) on water productivity. The water productivity of the three irrigation systems and water application levels were significantly different from each other (Table 7). The maximum and minimum of 13 kg/m3 and 9.8 kg/m3 water productivity were obtained from AFI and FFI, respectively. This is because of the higher rate of lateral flow towards the dry soil part in AFI system under low water application levels rather than down ward flows. This is consistent with the significant improvements in water productivity that have been associated with AFI (Feyen and Zerihun 1999; Kassa, 2001; Woldesanbet, 2005). The maximum and minimum water productivity of 13.7 kg/m3 and 9.9 kg/m3 were observed under low and high water application levels of 50% ETc and 100% ETc, respectively. Both irrigation systems and water application levels were better in water productivity under low irrigation water application depth. This is because of the difference in percentage of water actually converted to evapotranspiration out of the total amount applied.

Table 7. Effect of irrigation systems and water application levels on water productivity

Irrigation systems	Water productivity (kg/m^3)
Alternative furrow irrigation (AFI)	13^{a}
Conventional furrow irrigation (CFI)	12^{b}
Fixed furrow irrigation (FFI)	9.8^{c}
Water Application Levels	
100% ETc	9.9^{c}
75%ETc	11.2^{b}
50% ETc	13.7^{a}
$LSD_{0.5}$	0.66
SE	0.23
CV (%)	8.4

According to table 8, water productivity was highly influenced under FFI systems at 100% water application levels. This may be due to, the application of irrigation water to the fixed furrow of the plot throughout the growing season of the crop.

Table 8. Interaction effects of irrigation systems and water application levels on water productivity (kg/m^3)

Irrigation systems	Water application levels			Mean
	50% ETc	75% ETc	100% ETc	
AFI	16.2^{a}	12.5^{c}	10.2^{de}	12.96
CFI	14^{b}	11.3^{d}	10.7^{de}	12.00
FFI	11^{d}	9.6^{ef}	8.8^{f}	9.80
Mean	13.73	11.13	9.9	11.59
$LSD_{0.05}$		1.15		
CV (%)		8.4		

Partial Budget Analysis

From the economic analysis results (Table 9), AFI with 100% ETc is better in marginal rate of return and more advantageous to irrigators. Because, for 1birr/ha on average invested cost, the farmers may get 1birr/ha plus an extra of 90.87 birr/ha net benefits. In addition to this, the net benefits of 22,940 birr/ha is obtained while changing from CFI system with 100% ETc to AFI system with 100% ETc which is 50% reduction in volume of irrigation water applied. This means 2,992 m^3 volume of water is needed to irrigate 1 hectare area in CFI system which is enough to irrigate 2 hectare area of land in AFI system. So, when the area to be irrigated becomes double in AFI system using the saved volume of water, the yield and income obtained also becomes double.

Table 9. Irrigation water & time of irrigation saved and cost-benefit analysis of the interaction effects of irrigation systems and water application levels

Treatments	Time saved (hr/ha)	Water saved (m^3/ha)	Sum of cost that varies (MC) (birr/ha)	Total yield (ton/ha)	Adjusted yield (10%) (ton/ha)	Total revenue (TR) (birr/ha)	Net benefits (birr/ha)	DA	MRR= $\frac{\Delta TR*100\%}{\Delta MC}$
AFI with 50% ETc	183.11'35"	748.5	31538	144.65	130.19	139150	107612	D	-
FFI with 50% ETc	183.11'35"	748.5	31540	107.35	96.62	130750	99210	D	-
AFI with 75% ETc	165.19'43"	149.7	44333.2	169.76	152.78	181725	137391.8		298.39
FFI with 75%ETc	165.19'43"	149.7	44563.1	117.35	105.62	158300	113736.9	D	-
AFI with 100% ETc	57.38'51"	1497	45896.1	188.97	170.07	280769	234872.9		9087.47
FFI with 100% ETc	57.38'51"	1497	46646	160.26	144.23	206550	159904	D	-
CFI with 50% ETc	126.37'50"	1497	48569.1	135.73	122.16	141500	92930.9	D	-
CFI with 75% ETc	95.18'22"	299.2	67366.48	151.98	136.78	177075	109708.52		89.26
CFI with 100% ETc	0	0	71492.1	192.5	173.25	283425	211932.9		2477.79

Note: D, DA, MRR, ΔMR and ΔMC were dominance, dominance analysis, marginal rate of return, change in marginal revenue and change in marginal cost, respectively.

Summary and Conclusions

Tomato needs high amount of irrigation water during the flowering and fruit setting stage and continuous stress significantly reduces fresh fruit yield, especially in FFI system as half of the root stay dry throughout the growth period.

The irrigation water used in AFI system is 50% of CFI system and because in CFI system four furrows irrigated at the same time while in AFI and FFI only two furrows out of four furrows. This may improves working conditions as technology allows irrigator moving on the dry furrows. It is possible to double the irrigated command area by using the saved irrigation water.

Alternative furrow irrigation system at 100% ETc is the best technology among the tested technologies to be recommended for the communities of the study area, because of its high net benefits, water productivity and yield performance, in addition to time and irrigation water saving.

Over application and high frequency irrigation was a known constraint in the study area and giving training and advisory service for communities on how to use crop water requirement-based irrigation system will be a better solution.

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Modification and Performance Evaluation of Animal Drawn Potato Harvester

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Abstract

The post-harvest loss of potato in Ethiopia is more than 25% which includes harvesting loss. To minimize the harvesting loss, providing of appropriate harvesting equipment is essential. As a result, a study was carried out to modify the existing animal drawn potato harvester for small potato producers. The existing potato harvester was modified by adding a frame for beam and handle. Performance of modified potato harvester was tested and compared with existing potato harvester. The performance data were analyzed using descriptive statistics and non-parametric statistical tests. The mean field performance results of the modified potato harvester were 0.106 ha/h, 73.8%, 87.21%, 89.44% 10.9% and 1.71% for field capacity, field efficiency, harvesting efficiency, exposing efficiency, harvesting loss and tuber damage respectively. The modified potato harvester field performance result showed better performance than existing potato harvester. Thus, it was recommended to promote the technology for reduction of post-harvest loss of the potato production.

Key words: *Potato Harvester, Harvesting Efficiency, Exposing Efficiency, Harvesting Loss,*

Introduction

Potato (*Solanum tuberosum* L.) is one of the tuber crops grown in Ethiopia. It is a high potential food security crop due to its high yield potential per hectare and nutritious tubers. Potato is regarded a high-potential food security crop because of its ability to provide a high yield with a shorter crop cycle (mostly < 120 days) than major cereal crops like maize.

Potato production in Ethiopia is possible on about 70% of the arable lands; however, the post-harvest loss of potato in Ethiopia is more than 25% which includes harvesting loss (FAO, 2008). Harvesting the potato crop is a critical part of the entire potato production and marketing operation. Crop yield and quality cannot be increased during harvest, but they can be decreased, sometimes drastically. So that, harvesting operation is highly important practice which farmer should pay attention to conduct it in timely manner with minimum damage and cost.

In Ethiopia, harvesting of potato is mainly done manually by using hoe and oxen ploughs, the methods, which are not tiresome working condition in nature, but also known to cause more damages and losses to the harvest. One of the possible methods of availing better potato harvesting technology in developing country, like Ethiopia, is still depends on using animal drawn implements/ machineries, such as animal drawn potato digger. The animal drawn Potato digger is an improved potato harvesting implement that has been proved in improving harvesting by reducing losses and drudgery of the manual working conditions for small and marginal farmers.

However, the domestically developed potato diggers by many institutions, including the Asella Agricultural Engineering Research Center (AAERC), were made to be attached to traditional plough's (marasha's) beam called 'mofer' to be pulled by oxen during its operation. In this method of using the digger, it has got difficulty of fitting to different 'mofers', which also gives it different working alignments to the ground surface to be lifted. This implement therefore needs some modifications to improve its performance. Hence a study is planned to modify the animal drawn potato harvester to solve the problem. In this view, study is planned to modify the existing implement with the objective of development of new frame for potato harvester and evaluate the performance of the modified animal drawn potato harvester at farmer's field conditions.

Materials and Methods

Materials

Construction materials
Sheet metal, angle iron, flat iron and round bar were used for the construction of the digger.

Instruments and equipment used in the experiment
Stopwatch, measuring tape, digital and spring balance, polythene bags, core sampler and electric oven were used for measuring purposes during the experiment.

Methods
Description of modified potato harvester
The modified animal drawn potato harvester consists of share, lifter rod, frame, handle and beam as shown in figure 1.

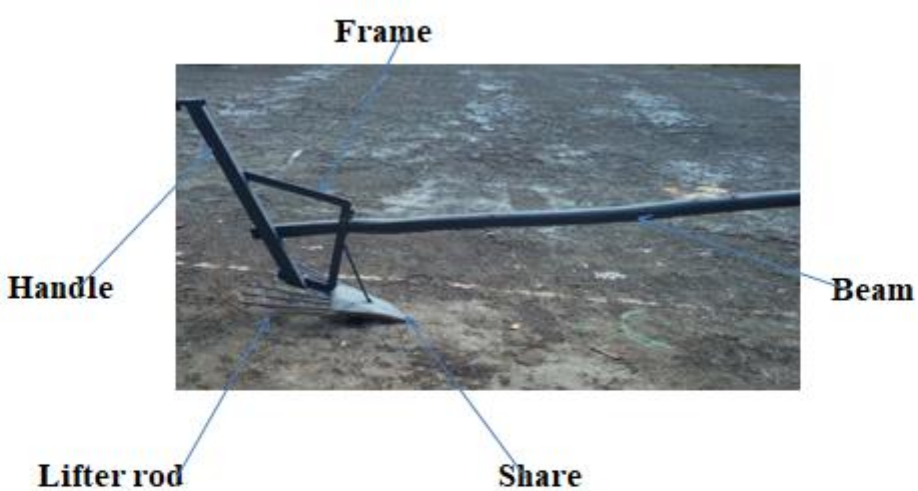

Figure 1. Description of modified animal drawn potato harvester

Test field conditions

Moisture content of the soil

Five soil samples were collected randomly from the field at 0 to 15 cm depth from the surface of the soil and place it loosely into the container. The collected soil samples from each location were weighed initially and then kept in an oven for 24 hours at 105° C for obtaining dry weight of soil. Dry weight of soil was also recorded by the following standard procedure moisture content (%) on dry basis was calculated by following formula.

$$M_C(\%) = \frac{W_W - W_d}{W_d} \times 100 \qquad (1)$$

Where, MC = Moisture content (%);
Ww= Weight of wet soil, g; and
Wd = Weight of dry soil, g.

Bulk density

Bulk density is the oven dry mass per unit volume of soil. It was measured by core cutter method before conducting experiment. Soil samples were taken randomly in field with the help of core cutter. Bulk density of soil samples were measured by core cutter having its inner diameter as 7 cm and height as 12 cm. The soil samples were collected at depth level of 0 to 15 cm before operation of digging. The bulk density was determined by dividing the weight of oven dried soil (at 105C^0 for 24 h) samples by volume it occupied and calculated by using the following formula:

$$\rho = \frac{M}{V} = \frac{4M}{\pi D^2 L} \qquad (2)$$

Where, ρ = Bulk density of soil, g/cm^3
M = Mass of soil contained in core sample, g
V = Volume of core sampler, cm^3
D = Diameter of core cutter, cm
L = Height of core cutter, cm

Field performance test and evaluation

Speed of operation

To calculate the speed of operation two poles 20 m apart were placed approximately in the middle of the test run. The speed was calculated from the time required for the implement to travel the distance of 20 m.

$$S = \frac{D}{t} * 3.6 \qquad (3)$$

Where: - S = harvesting speed, km / h.

D = travelling distance, m.
t = time, s.

Working width and depth

Actual working width of the harvester was measured at various places in each test plot. Finally average working width was computed for each test plot. Depth was measured at three places in a single test plot. It was measured by placing steel tap on two furrow crests and steel scale was used to measure depth of furrow by holding it form tape to furrow bottom. Finally average depth was calculated for each test plots.

Theoretical field capacity

Theoretical field capacity varies with speed of working animals and actual width of implement. The Theoretical field capacity was determined by using following formula.

$$TFC = \frac{S * W}{10} \qquad (4)$$

Where: - TFC = theoretical field capacity, ha/h.
S = working speed, km / h.
W = working width, m.

Effective field capacity

The effective field capacity was calculated by formula. (Jagdishwar Sahay, 2014)

$$EFC = \frac{A}{T_p + T_n} \qquad (5)$$

Where: - EFC = effective field capacity, ha/h.
A = Area of covered, ha
T_p = Productive time, hr
T_n = Nonproductive time, hr

Field efficiency

It is the ratio of effective field capacity to the theoretical field capacity.

$$FE = \frac{EFC}{TFC} \times 100 \qquad (6)$$

Where: - TFC = theoretical field capacity, ha/h.
EFC = effective field capacity, ha/h.
FE = field efficiency, %

Harvesting efficiency

Harvesting efficiency was determined by throwing a quadrant of 1m ×1m frame. The tubers dug out after harvesting by modified potato harvester in the quadrant was collected and weighted. The potato tuber, which was left in the soil, again dug out with the help of hand hoe without damage to tubers. These tubers were collected and weighed. Addition of both reading was gave us total weight of tubers present in the quadrant. It is the ratio of the weight of tubers dugout by potato implement to the weight of total tubers present in the soil as per unit area before harvesting. It was the measure of ability of the implement for harvesting tubers from the soil.

$$He\ (\%) = \frac{Wt.of\ tuber\ dugout\ by\ potato\ digger\ per\ square\ meter\ (Kg)}{Total\ wt.of\ tuber\ undug\ \&\ dugout\ per\ square\ meter\ (Kg)} \times 100 \tag{7}$$

Where: - He = harvesting efficiency

Exposing efficiency

Exposing efficiency was calculated using amount of exposed tubers at first and by hand digging at last. The quantity of undug potatoes left under the surface and total quantity of potatoes collected from the sample area expressed in percentage as follows:-

$$Exposing\ efficiency = \frac{Mass\ of\ undug\ potatos}{Mass\ of\ total\ potatos} \times 100 \tag{8}$$

Damaged potato tubers

A metal quadrant 1m×1m size from any test plot where harvesting operation was carried out the tubers dug should be collected and the entire damaged tuber should be separated manually and analyzed for the damaged tuber.

$$Percent\ of\ damage = \frac{Weight\ of\ damaged\ potatos}{Total\ weight\ of\ potatos} \times 100 \tag{9}$$

Cost estimation

Estimation of annual and hourly operational costs of the harvester were based on capital cost of the potato harvester, interest on capital, cost of repairs and maintenance, labor cost, and depreciation. Cost of harvesting operation performed for potato harvester was worked out on the basis of the prevailing input and fabrication price of the implements, machinery and rental wages of operator and labors required. The cost of operation of the potato harvester is divided into two heads known as fixed cost and variable cost. Fixed cost is independent of operational use while variable cost varies proportionally with the amount of use. (Kamboj*et al*, 2012).

The fixed cost of the potato harvester includes mainly depreciation and interest on the capital costs. Variable cost of the potato harvester mainly includes, repair and maintenances cost and wages. Cost of potato harvesting operation for the potato harvester was calculated as Birr/ha.

Fixed cost

Depreciation

It was a measure of the amount by which value of the implement decreased with the passage of the time. According to the Kepner*et al.* (2005), the annual depreciation was calculated as follows:-

$$D = \frac{C - S}{L\, x\, H} \qquad (10)$$

Where: - D = Depreciation per hour
C = Capital investments (Birr)
S = Salvage value, 10% of capital investment (Birr)
L = Life of implement in hours or years
H = Annual operational hours of the potato harvester

Interest

Interest is calculated on the average investment of the machine taking into consideration the value of the implement in the first and last year. These are usually calculated on yearly basis. The annual interest on the investment can be calculated as follows (Kepner*et al.* (2005) :-

$$I = \left(\frac{C + S}{2}\right) \times \left(\frac{i}{H}\right) \qquad (11)$$

Where: - I = Interest per hour
i = interest on the investment (%) per year

Variable cost

Repair and maintenance cost

The repair and maintenance cost of the potato harvester was taken as 2.5% of the cost of the potato harvester (Kepner*et al*., 2005 and Kamboj*et al.,* 2012).

$$RM = \frac{C \times 2.5\%}{H} \qquad (12)$$

Where: - RM = Repair and maintenance cost per hour
H = Annual working hours of the potato harvester

Wages of operator

Wages are calculated based on actual wages of workers per day or hour paid.

Total cost of potato harvesting per hour

The total cost of potato harvesting per hour of the potato harvester was calculated from the summation of total fixed cost per hour and total variable cost per hour as follows.
Total Cost/h = Fixed Cost per hour + variable Cost per hour

Results and Discussion

Moisture Content of the Soil

Five soils samples were taken randomly at 0-15 cm depth from the surface of soil to measure the moisture content. The average moisture content was determined as 14.27 %. The results are shown in Table 1.

Bulk Density of the Soil

Bulk density is the oven dry mass per unit volume of soil. It was measured by core cutter method before conducting experiment. Soil samples were taken randomly in field with the help of core cutter. Bulk density of soil samples were measured by core cutter having its inner diameter as 7 cm and height as 12 cm. The soil samples were collected at the depth level of 0 to 15 cm before operation of digging.

Table 1:- Moisture content and bulk density of soil sample

S. No.	Moisture Content, %	Bulk density, g / cm3
1	14.83	1.54
2	13.59	1.33
3	15.23	1.38
4	13.46	1.45
5	14.26	1.42
Ava.	14.27	1.42

The soil sample initially weighed before placing into an oven for 24 hours at 105º C. After drying the weight of sample was again measured. The average bulk density was found to be 1.42 g/cm^3 as shown in Table 1.

Performances Evaluation of Modified Animal Drawn Potato Harvester

The modified potato harvester was tested for its field performance at Munessa district of Arsi Zones. The crop and field parameter were recorded and computed as given in table 2.

Table 2. Performance evaluation of modified potato harvester in potato field

S/no	Parameter	Mean values of the plot trial			Overall mean value
		Plot 1	Plot 2	Plot 3	
1	Working depth, (cm)	*16*	*13*	*15*	14.68
2	Working width, (cm)	*56*	*58*	*62*	58.7
3	Working speed, (m/s)	0.673	0.680	0.683	0.678
4	Effective field capacity (ha/hr)	0.106	0.103	0.108	0.106
5	Theoretical field capacity, (ha/hr)	0.136	0.142	0.152	0.143
6	Field efficacy, (%)	77.90	72.50	71.10	73.80
7	Weight of tubers dugout, (kg/m^2)	4.457	5.104	6.308	5.290
8	Weight of damage tubers, (kg/m^2)	0.057	0.180	0.132	0.123
9	Weight of tubers left in soil,(kg/m^2)	0.646	0.508	0.698	0.617
10	Harvesting efficiency, (%)	87.45	87.05	87.14	87.21
11	Exposing efficiency, (%)	90.00	89.06	89.25	89.44
12	Harvesting loss (%)	10.00	11.94	10.75	10.90
13	Damage tubers, (%)	1.67	1.74	1.72	1.71
14	Man-hr, (hr/ha)	9.43	9.71	9.26	9.47
15	Cost of operation, (Birr/hr)	19.22	19.22	19.22	19.22
16	Cost of operation, (Birr/ha)	181.24	186.63	177.98	181.95

Working Speed

The working speed was noted with animal drawn potato harvester at the same distance a fixed time interval during the operation. The speeds of operation of animal drawn potato harvester at different plots are shown in Table 2. The working speed of animal drawn implement can be affected by moisture content of the soil and the amount of weeds in the field. Clean field gave best result as compared to weeded field.

Field Capacity and Efficiency

Field capacity and efficiency of the modified potato harvester are shown in Table 2. The field capacity depends upon the working width of the implements and speed of operation. Field conditions like topography of field and intensity of weed infestation also affects the speed of operation and consequently the field capacity of the implement. The unclogging time and number of unclogging of the implement also affects the time required to complete the operation and consequently field capacity of the implement. Table 2 shows the overall mean of effective field capacity and field efficiency of modified potato harvester 0.106 ha/h and 73.80% respectively. CIAE, Bhopal has developed animal drawn harvester for harvesting of potatoes and groundnut. It is operated by pair of bullocks and used for harvesting of groundnut and potato. The implement was evaluated for harvesting potato at a forward speed of operation of 2-2.5 km/hr. The field capacity and field efficiency were reported to be 0.05-0.12 ha/hr and 60% respectively.

Harvesting Efficiency

Harvesting efficiency of the modified potato harvester depicted in table 2. It reveals that the harvesting efficiency of 87.21%. Harvesting efficiency was found to be the highest, as compared to the existing potato harvester. The field performance evaluation result shows that harvesting efficiency of the implement depends on the moisture content of the soil and the amount of weeds in the harvested potato fields.

Exposing Efficiency and Tuber Damage

The results of inspecting samples for tuber damage after harvesting and exposing efficiencyof modified potato harvester are presented in Table 2. Modified animal drawn potato harvester has better exposing efficiency than the existing potato harvester. This is due to its shape and big size of the shear. It also has better working depth and width. The damage was lowest due to the shape and smoothness of the cutting edge. Our hypothesis were realized, by having appropriate angle of the harvester shear that the depth of lifter was increased by 2 cm and the damage was decreased by 2-4% compared to the existing potato harvester. Further, the exposing efficiency was increased by 2-3%.

The working speed influences the exposing efficiency. In most cases, when the speed decreases the exposing efficiency increases. Thus, speed and exposing efficiency are inversely related. However, the working capacity decreases as the speed decreases. The modified digger has better exposing efficiency. This is due to its better working depth and width.

Cost Estimation

Harvesting cost of potatoes by modified animal drawn potato harvester was determined considering fixed and variable costs. The production cost of modified potato harvester was determined by calculating the cost of different components and their fabrication cost was 448.85 birr. The annual fixed cost (64 birr) and variable cost (3011.2 birr) were found from the calculation. Annual operation of the harvester was considered as 160 hours based on 20days actual annual use in potato field and daily 8 hours useful operation. Annually coverage area was determined by multiplication of the effective field capacity and annual hours of operation.

Conclusion and Recommendation

The construction of the implement was made durable and light weight to match the draught capacity of local animals. The performance evaluation of the modified potato harvester was carried out and the result shows that the modified potato harvesterhas a great potential in mechanizing the harvesting process of potato. The findings confirmed that the performance of the modified potato harvester in terms field capacity, field efficiency, harvesting efficiency, exposing efficiency harvesting loss and tuber damage are 0.106ha/h, 73.8%, 87.21%, 89.44%, 10.90% and 1.71% respectively. Farmers also appreciated that the harvester easy to operate and shortening the time of harvesting even though these were not assessed thoroughly in this study. Given the issue of the food security in the country, a small increase in total output contributes a lot to the overall food availability in the country. Thus, generally, the results are promising and demonstration at large scales are recommended to all potato producing areas of the region.

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Performance Evaluation of CAAMS Teff Combine Harvester

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Abstract

Considering fragmented lands, time consumption of manual harvesting and postharvest losses of teff during harvesting and threshing, the performance of CAAMS teff combine harvester was evaluated at farmer's field. Average field capacity of the combine was found 1.44 ha/day with a field efficiency of 71%. The field performance evaluation results of the combine harvester of theoretical field capacity, effective field capacity, field efficiency, threshing efficiency, cleaning efficiency and fuel consumption were 0.152 ha/hr, 0.0796 ha/hr, 61.95%, 86.29%, 92.53% and 11 L/ha respectively. The harvesting losses recorded during performance evaluation of the combine harvester results for header loss, cylinder loss and blower loss were 1.165%, 6.383% and 2.331% respectively. Hence with CAAMS teff combine harvesting was better for all performance measures made except grain loss reduction. More grain loss in CAAMS combine harvesting was due to cylinder and leakages in some of CAAMS functional elements. Grain loss can be reduced by avoiding leakages of the combine functional elements. It was recommended in future that modifications should be done on cylinder loss so as to alleviate shortcomings in combine functional elements.

Key words: mechanized harvesting, teff, combine harvester, field capacity, field efficiency.

Introduction

Teff [*Eragrostis tef (*Zucc.) Trotter] is the most important indigenous cereal of Ethiopia. Its production area is increasing at unprecedented scale due to increased market demand (both local and foreign) and many other desirable characteristics, including higher nutritional value, low incidence of damage by insects, better adaptation to drought, adaptive to poor drainage and high straw value (Seyfu, 1997). Teff accounts for about two-third of the daily protein intake in the diet of the population (Ethiopian Nutrition Survey, 1959). Despite the versatile importance of teff in Ethiopia, but its production yields are remarkably low. Among several factors, it has been argued that low teff productivity is partly caused by lack of mechanization machineries for teff production.

Mechanized agriculture is the process of using agricultural machinery to mechanize the work of agriculture, greatly increasing farm productivity. Mechanization involves the use of an intermediate device between the power source and the work. This intermediate device usually transforms motion, such as rotary to linear, or provides some sort of mechanical advantage, such as speed increase or decrease or leverage. Current mechanized agriculture includes the use of tractors, trucks, combine harvesters, airplanes (crop dusters), helicopters, and other vehicles.

In Ethiopia, teff harvesting is dominated by traditional manual harvesting by using sickles. Due to the non-availability of mechanization, and labours, teff harvesting is often delayed which leads to a considerable loss of grains eating by animals and over drying, thus affecting the teff production. Timeliness of harvesting and threshing operations is the main criterion; so the use of combine harvester for harvesting of teff crop is the most important.

By understand the above bottleneck of the teff production, and improving the production of the teff, Ministry of Agriculture (MoA) has imported mini combine harvester called CAAMS, for verification in local conditions. Therefore, this study was carried out for the performance evaluation of CAAMS teff combine harvester with objective of evaluating the performance of CAAMS teff combine harvester and generate performance data under local field conditions.

Materials and Methods

Materials

The materials used for conducting this study was CAAMS teff combine harvester, stopwatch, digital and spring balance, metering tape and fuel measuring gauge cylinder. The stop watch was used for time and motion study of machine operations to determine threshing capacity and activity times of threshing operations. The weighing balance was used to weigh grain loss samples from all outlets. Metering tap was used for measuring the size of plot. Gauge cylinder was also used for measuring fuel consumption during the test.

Description of functional components of combine

Five major operations were performed by the combine harvester during the harvesting. These were; picking up or cutting the standing crop, feeding the cut crop to threshing unit, threshing the crops, cleaning the grain from straw and collecting the grain in a container. These operations are performed automatically as the material moved through different systems of combine harvester.

Methods

Performance testing of the machine was done to obtain data on overall machine performance, operating efficiency, work capacity and adaptability to harvesting conditions. The parameters tested included harvesting time, capacity and grain loss. During these tests, the FAO standards of testing and evaluation procedures for agricultural machineries published in 1994 have been used.

In performance testing, the data were categorized as data for test conditions and data for performance measures. The data for test conditions included, condition of the crop, condition of the field, and condition of the machine and operator. Performance measures were harvesting capacity, field efficiency, harvesting losses and fuel consumptions. Proper harvesting speed was selected based on grain loss, efficiency of functional parts and comfort in operating the machine. Based on these factors, speed of gear level 1 of the machine was selected and used in the tests.

The field trials were conducted as per test code for combine harvester-thresher, performance test and test code for combine harvester. Field observations viz., operational speed of the combine harvester, output (ha/h), number of man-hours required for machine harvesting, fuel consumption and grain losses due to the combine harvester were recorded.

Crop parameters

Condition of the crop include crop kind, crop variety, moisture content of the stem and the grain at the time of harvesting as well as yields per hectare. Hence, the crop conditions have influence on the performance of harvesting machine.

Plant length

The length of the plant from its base at ground level to its top when the plant is straightened was expressed in centimeters.

Stubble length

The length of the plant stalk attached to the ground immediately after harvesting was measured and expressed in millimeters.

Moisture content

The moisture content of the tef stem was measured by oven method; about 500 gm sample of stem was kept in an oven for 24 hours at 105^0C. The loss in weight of the sample was recorded and the moisture content in percent was determined as in equation.

$$M_C(\%) = \frac{W_W - W_d}{W_w} \times 100 \qquad (1)$$

Where: MC = Moisture content wet basis (%),
Ww = Weight of wet teff stem (g),
Wd = Weight of dry teff stem (g)

Grain-Straw Ratio

A square meter, made of bar was thrown in the field randomly. Crop was harvested from that area with the sickle, threshed manually and grain straw ratio was computed from it as follow:

$$Grain - Strw\ ratio = \frac{Weightof\ grain(g)}{Weightof\ straw(g)} \qquad (2)$$

Machine performance parameters

Data collected in performance evaluation of the machine included cutting width, cutting height, applicable inclined angle of the crop plant, percentage of miss harvesting and grain losses. Data collected for work rate and labour requirement included operational Travelling speed, actual operating hours, time spent for turning and harvesting, time spent for adjustment of the machine, time spent for machine trouble, field capacity (ha/h) and fuel consumption per hour (L/h).

Theoretical Field capacity

Theoretical field capacity was determined as per following formula.

$$Theoretical\ field\ capacity(ha/h) = \frac{W*S}{10} \quad (3)$$

Where: - W = Effective width of cutter bar, m

S = Speed of operation, km/h.

Field efficiency

$$Field\ efficiency(E_f)(\%) = \frac{T}{T_e + T_h + T_a} * 100 \quad (4)$$

Where: - T_0 = theoretical time per hectare

T_e = effective operating time = T_0 x 100/K

K = percentage of implement width actually utilized

T_h = time lost per hectare due to interruptions that are not proportional to area

T_a= time lost per hectare due to interruptions that are proportional to area

Effective field capacity

From the actual field capacity and field efficiency the effective field capacity was calculated as follows (Renoll, 1972):

$$Effective\ field\ capacity(ha/h) = \frac{W*S}{10} * \frac{E_f}{100} \quad (5)$$

Total harvesting losses

The total loss of the machine is the grain loss caused by different parts of machines are weighed and expressed as percentages of the total grain losses.

Header loss

Header losses are caused by the cutting mechanisms of the combine harvester. These losses were measured by placing a frame of known area in a number of locations at random over the field and picking up the uncut crops left within the frame and threshed manually. The header loss was determined at three places and average of the observation was reported.

Cylinder loss

The cylinder loss is the sum of grain losses of un-threshed grains passing out of threshing cylinder and the threshed grains passing out with straw. Materials discharged from straw outlet parts of the combine was collected and threshed so as to get the grains that would be lost. The grains lost are collected when the machine operates at a constant speed over a measured distance.

Blower loss

Blower loss is the loss of threshed grains blown out with the chaff. To determining this loss, the chaff was collected at measured distance separately and the grain thoroughly separated and computed as blower loss.

Fuel Consumption

The fuel tank was filled to full capacity before and after the test. Amount of refueling after the test was the fuel consumption for the test. While filling up the tank, a careful attention was paid to keep the tank horizontal and not to leave empty space in the tank. The fuel consumption was computed as litter per hour as follows:

$$F_C = \frac{F_r}{t} \qquad (6)$$

Where: - Fc = fuel consumption (l /hr)
Fr = re-filled quantity of fuel (1)
t = seeding time (hr)

Result and Discussions

Crop Parameters and Test Conditions

Some of the factors that affect the machine performance are crop conditions related to the crop varieties, steam length and moisture content of the crop. Table 1 present's height of stem, height of stubble, moisture content of stem and grain straw ratio of the harvested crop for performance evaluation of the machine. Harvesting before the plant gets too dry helps prevent losses owing to shattering (Seyfu, 1997).

Table 1. Crop parameters

	Mean values of the plots			
Parameters	P1	P2	P3	Average
Height of plant, cm	65	70	68	67.67
Height of stubble, cm	17	20	16	17.67
Moisture content of stem, % (w.b)	10.03	9.48	9.14	9.55
Grain Straw ratio	1:3.43	1:3.59	1:3.52	1:3.51

Performance Measures of the Machine

The performance of combine harvester such as quality of work, rate of work, durability and so on can be evaluated by their adaptability to the field and crop conditions which differ depending on the localities. Field performance tests were conducted on the quality of work and the rate of work to find the basic performance of combine harvester. Table 2 present operating speeds, effective field capacity, width of cut, threshing efficiency and cleaning efficiency of combine harvester.

Table 2. Field performance of CAAMS teff Combine Harvester

Parameters	Replications of plots P1	P2	P3	Average
Speed of operation, km/h	1.72	1.79	1.35	1.686
Width of cut, m	0.9	0.9	0.9	0.9
Theoretical field capacity, ha/h	0.155	0.161	0.122	0.152
Effective field capacity, ha/h	0.095	0.091	0.083	0.0796
Field efficiency, %	61.29	56.52	68.03	61.95
Grain Straw ratio	1:3.43	1:3.59	1:3.52	1:3.51
Threshing efficiency, %	88.12	85.98	84.78	86.29
Cleaning efficiency, %	91.00	95.16	91.43	92.53

Harvesting Losses of the Machine

The major performance parameter of combine harvester is the percentage of grain losses, as the teff is often lost in the harvesting and threshing process because of its size. Table 3 presents the average values of grain loss in combine harvesting include header loss (1.165%), blower loss (2.331%) and cylinder loss (6.383%). The three losses make a total loss of 9.879%. This seems reasonably lower loses as compared to post harvest losses occurred by traditional way harvesting and threshing reported by other authors. FAO, 2018 report shows that manual harvesting and threshing with the aid of animals results grain loss at harvesting, transporting near to threshing ground, piling and threshing are 5.6%, 2.2%, 6.3% and 7.7% respectively and also labour-intensive. According to the African post-harvest losses information system, a postharvest loss for teff was estimated as 12.3% (OABTTA, 2013). In the study of the teff value chain, Bekabil, et al., (2011) reported that teff yields are relatively low (around 1.2 t/ha) and high loss rates (25-30% both before and after harvest) reduce the quantity of grain by up to 50%.

Table 3. Harvesting losses of the combine

Parameters	Replications of plots P1	P2	P3	Average
Header (gathering) loss, %	1.2524	0.9542	1.28824	1.165
Cylinder loss, %	3.907	8.857	6.382	6.383
Separating (blower) loss, %	2.9474	1.988	2.0567	2.331
Total harvesting loss, %	4.16	2.94	3.35	9.879

Collecting (by reel and cutter) losses included uneven crop height, cutter bar loss and lodging. Lodged crop not cut by the cutter bar is considered as lodging loss. For optimum combine operation the crop should be cut just below the grain heads but the crop height was uneven and the crop was lodged in some places which were not cut due to lodging problem. Cutter bar loss is the cut grain heads that fall to land on the platform. Lodging, which is a problem associated with teff due to its susceptibility and this could account for up to 30% of the potential loss of teff yields (Bekabil, et al., 2011). There was two main factors that caused header loss, i.e. the crop themselves and the condition of the machines including the cutter bar speed and stem length.

Cylinder loss consists of threshed, un-threshed and seed discharged from the rear of the machine and straw outlet. Table 3 showed cylinder loss contributed more percentage

(6.383%) in total harvesting losses owing to flatness of the straw out let which is allowed the grain to dropout with straw. Cylinder loss depends on cylinder speed and the clearance between the cylinder and the concave. The crop varieties, grain and straw moisture and biometrical indices that changed during harvesting also influence the cylinder loss.

Effective field capacity and field efficiency were computed to be 0.0796 ha/h and 61.95% respectively, with the corresponding operating speed of 1.686 km/h. Therefore, it can be interpreted that by increasing forward speed of combine effective field capacity can be increased. The mean values of header (collecting) loss, cylinder loss and blower loss were 1.165%, 6.38% and 2.33% respectively.

Conclusion and Recommendations

Generally, the total grain loss of 9.879% is recorded during field performance evaluation of the combine harvester. Thus, based on the advantages of mechanization, there is the need to improve the CAAMS teff combine harvester and explore its full potential. From the study it was found that the use of combine was more beneficial than manual harvesting for harvesting of teff. In addition to the need for improving its performances, it was observed that some parts of the combine harvester were easily broken. Thus, the following recommendations were also given as improvement for the durability of the machine's parts.

1. Treated materials should be used in construction so as to reduce machine brutality.
2. Grain loss should be minimized by improving some of its functional elements (straw out let and etc).
3. Belt drives for the blower should be replaced with a chain drive to avoid the problem of slippage and hence wearing of belts.
4. The straw out let should be modified to allow separation of grain from straw so as to avoid grain outflow (cylinder loss).

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Performance Evaluation of CAAMS Teff Thresher

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Abstract

Teff is the most important indigenous cereal crops of Ethiopia, where it is thought to have originated, despite its versatile merits, teff production processes are dominated by traditional methods. To solve one of its postharvest production problems, the traditional threshing and the resulted losses of quantity and quality, engine powered threshers have been developed by different institutions, including AAERC. Nevertheless, as most of the existing machineries are constrained with low output and cleaning problems. An imported CAAMS teff thresher was evaluated and tested with the objective of evaluating its performances. The machine was tested at drum speeds of 800, 1000 and 1200 rpm and feed rates of 6, 8 and 10 kg/min respectively. From the test results, the grand mean of threshing efficiency, cleaning efficiency, threshing capacity, separation loss and fuel consumption of 100%, 97.34%, 2.511%, 111.32 kg/hr, 2.7% and 0.2 lit/hr were obtained respectively. In addition, the result of statistical analysis showed that, the drum speed have significant effects on cleaning efficiency and separation loss, whereas the feed rate have a significant effects on threshing capacity.

Key words: Teff, Cleaning Efficiency, Threshing Capacity, Threshing Efficiency, grain loss

Introduction

One of the economical cereal crops in Ethiopia is teff. It is indigenous to the country, and is a fundamental part of the culture, tradition, and food security of the people. This crop is gaining international recognition and acceptance, and is a means of foreign currency earning in addition to its value as food crop at home. Currently, teff is grown on approximately 2.80 million hectares of land which is 27% of the land area under cereal production. 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).

Teff accounts for about two-third of the daily protein intake in the diet of the population (Ethiopian Nutrition Survey, 1959). Teff has a high economic value as its grain can be kept for years without being seriously damaged by insects and pests in common storage (Tadesse, 1969).

Despite its versatile advantages and merits, teff production processes are dominated by traditional methods and tools, mainly due to lack of mechanization technologies for teff, as it is indigenous to Ethiopia.

The traditional methods of harvesting, threshing and postharvest handling of teff usually lead into contamination of the product with stones, sticks, chaff, dirt and dust. Traditionally teff is threshed on prepared ground called *Ogdi which is* made on gently slope ground smeared with cows' dung. Traditional threshing of teff crop is one of the times consuming, laborious and significant grain loss occurs. Agricultural mechanization, which includes threshers in the form of combined machine and single act machine, is the process of using agricultural machineries to mechanize the work of agriculture, greatly increasing farm productivity. With regard to developing threshers for teff production, the single acting engine powered threshers have been developed and numbers of farmers are also using for the threshing and cleaning of teff in some parts of Ethiopia, including Oromia. Nonetheless, the existing machineries in the country are, all constrained with low output per hour and cleaning problems, which are mainly associated with the difficult nature of the teff to detach from its panicle and its high straw than grain to separate.

Hence, to solve the problems associated with the domestic threshers, the Ethiopian Ministry of Agriculture (MoA) imported a Chinese firm (Chinese Academy of Agricultural Mechanization Sciences) made teff thresher called CAAMS thresher, which is specifically designed for teff threshing and cleaning purpose. To verify its performances for the threshing and cleaning purposes, MoA was submitted the machine to Asela agricultural Engineering Research Center (AAERC) to conduct farm level test and generate its performances data before the machine is passed to agricultural extension sections for promotion and distributions to Farmers.

Therefore, this project was initiated with the objective of farm level performance testing of the CAAMS teff thresher and to generate data on the effectiveness of the machine's threshing capacity, threshing efficiency, separating and cleaning in terms of separation efficiency, separation loss, cleaning efficiency, cleaning loss and fuel consumption based on drum speed and feed rate.

Material and Methods

Instrumentation 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 (white teff) commonly called "manya" in Ethiopia was used for the evaluation.

Methods

The performance study was under taken at different threshing drum speed and feed rate of the machine. Thus, different parameters like threshing capacity, threshing efficiency, cleaning efficiency and grain loss and fuel consumption were measured to assess the suitability of threshing machine.

Determination of drum speed

The thresher was evaluated at three levels of cylinder speed of 800, 1000 and 1200 revolutions per minute by using the tachometer. The ranges were selected based on the speed required to cause threshing of the crop without unnecessary overrunning of the thresher. It was also assumed that, running the thresher at a speed below 800 rpm would not achieve effective threshing of the crop and running it at speed above 1000 rpm may only cause wastage of energy without corresponding increase in threshing efficiency.

Determination of feed rate

The feed rate of the developed thresher was determined by measuring out 6, 8 and 10 kilograms of un-threshed teff. These masses of the un-threshed crop were measured using spring balance. The times to feed in the various masses of the teff were measured and each was converted into kilograms per minute. The feed rates of 6, 8 and 10 kg/min were therefore used for the evaluation of the thresher. These feed rates were selected based on the mass of un-threshed crop that an operator can manually feed into the thresher through the chute per unit time.

Performance evaluation parameters of the thresher

The threshing efficiency was used to determine how effectively the thresher was in carrying out its primary function of threshing the teff. The cleaning efficiency was used for the evaluation of the ability of the thresher to clean the crop effectively. In addition, the throughput capacity was used to evaluate how fast the thresher can perform its given task of threshing and cleaning. Lastly, the amounts of grain loss by the thresher were considered asses the machine's overall performances, in extensively and intensively methods. For measurements of the main performance parameters, the testing principles of FAO (2007) were used as follows.

Threshing efficiency (TE)

Threshing efficiency (*TE*) is defined as the percentage ratio of the threshed grain to the total quantity of sample grain after a threshing process.

$$TE = 100 - \frac{Q_U}{Q_T} \times 100 \qquad (1)$$

Where:- TE = threshing efficiency in percentage,

Q_U = un threshed quantity of grains in a sample in kg, and

Q_T = the total quantity of grains (kg) threshed and un-threshed in the sample

Cleaning efficiency (CE)

Cleaning efficiency (*CE*) is the ratio by weight of the grains collect at grain outlet to the total weight of the chaff and grains collect at the same outlet expresses as a percentage.

$$C_E = \frac{W_t - W_c}{W_t} \times 100 \qquad (2)$$

Where: - C_E = Cleaning efficiency in percent

W_t = total weight at the outlet in kilogram and

W_c= chaff weight at the outlet in kilogram.

Throughput capacity (TC)

The machine throughput capacity is the amount of the actual cleaned grain that a machine is able to thresh per a given time.

$$T_C = \frac{Q_S}{T} \times 60 \qquad (3)$$

Where: - T_C = Throughput capacity expressed in kilogram per hour (kg hr^{-1})
Q_S = quantity of grains collect at the grain outlet in kilogram and
T = time taken to thresh in minutes.

Non collectable grain losses

The non-collectable grain loss of the machine is the sum of drum loss and separation loss.

$$\text{DL}(\%) = \frac{Weight of\ unthreshed grain\ (Kg)}{Total\ grain\ weight\ (Kg)} * 100 \qquad (4)$$

$$\text{SL}(\%) = \frac{Weight of\ grain goes with\ dust (Kg)}{Total\ grain\ weight\ (Kg)} * 100 \qquad (5)$$

Where:- DL = drum loss
SL = separation loss

Fuel consumption

The fuel tank was filled to full capacity before and after the test. Amount of refueling after the test was the fuel consumption for the test. While filling up the tank, careful attention was taken to keep the tank horizontal and not to leave empty space in the tank.

$$F_C = \frac{F_r}{t} \qquad (6)$$

Where, Fc = fuel consumption (l /hr)
Fr = re-filled quantity of fuel (1)
t = seeding time (hr)

Experimental design and data analysis

The performance tests of teff threshing were conducted at three levels of drum speed, three levels of crop feed rate and three replications by using completely randomized design (CRD) of a 3x3x3 factorial experiment with three replications in each treatment and comparison between treatment means by least significance difference (LSD) at 5 per cent level. The drum speeds of 800, 1000 and 1200 rpm were considered for experiment and were attained with the help of fuel controlling throttle valve. Three levels of feed rates 6, 8 and 10 kg/min were considered for experiment and were attained by varying the time of feeding the crop in the threshing drum. The Three levels of drum speeds and three levels of feed rates were taken as independent variables. The effect of both independent parameters on non-collectable grain losses, cleaning efficiency, threshing efficiency and threshing capacity was studied.

Results and Discussions

Effect of Drum Speed and Feed Rate on Cleaning Efficiency

Table 1 show the effect of threshing drum speed, crop feed rate and the combined effect of drum speed and feed rate on mean percent of cleaning efficiency similarly, figure 1 shows the relation between drum speed and feed rate on mean cleaning efficiency. The analysis of variance (ANOVA) revealed that the threshing drum speed had significant effect ($p < 0.05$) on cleaning efficiency, whereas crop feed rate and interaction of drum speed and feed rate had no significant effect ($p > 0.05$) on cleaning efficiency. The combined effect of drum speed and crop feed rate had significant effect on percentage of cleaning efficiency. Nonetheless, as can be seen from Table 1, the effect was dominantly due to variation in drum speeds than crop feed rate.

Table 1. Effects of threshing drum speed, feed rate and their interaction on cleaning efficiency

Parameter	Source of variation				Measure of differences
	Drum speed (rpm)	Ds_1	Ds_2	Ds_3	LSD (5%)
Cleaning efficiency (%)		95.868[c]	97.569[b]	98.576[a]	0.348
	Feed rate (kg/min)	Fr_1	Fr_2	Fr_3	
		97.496[a]	97.309[a]	97.208[a]	0.348
	Interaction (Ds*Fr)				0.6027
	Drum speed level	Fr_1	Fr_2	Fr_3	
	Ds_1	96.020[c]	95.817[c]	95.767[c]	
	Ds_2	97.703[b]	97.580[b]	97.423[b]	
	Ds_3	98.763[a]	98.530[a]	98.433[a]	

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

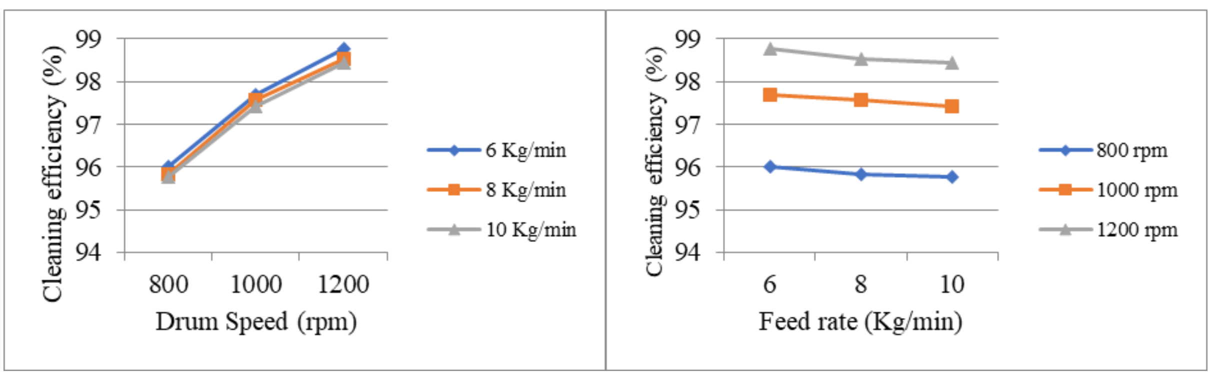

Figure 1. Effect of drum speed and feed rate on cleaning efficiency

Fig 1 shows that cleaning efficiency has direct relationship with drum speed, i.e. with the increase in the drum speed the cleaning efficiency increased, and it decreased with the increase in feed rate. The cleaning efficiency increased with increase in drum speed as the threshing cylinder and cleaning system were mounted on the same shaft. Hence, increase in the speed of threshing drum increased the material other than grain separation. On the other hand, cleaning efficiency decreased with the increase in feed rate, as at higher feed rates, frequent choking occurred. 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.

Effect of Drum Speed and Feed Rate on Threshing Efficiency

The effect of drum speed and feed rate and the interaction of drum speed and feed rate were non-significant and at all cases 100 per cent. This happen due to straw out let auger which have rubbing action. In general, average threshing efficiency of the machine was 100 percent.

Effect of Drum Speed and Feed Rate on Threshing Capacity (TC)

The ANOVA revealed that the crop feed rate had significant effect ($p < 0.05$) on threshing capacity. Whereas threshing drum speed and interaction of drum speed and feed rate had no significant effect ($p > 0.05$) on threshing capacity. From Table 2 it can be seen that the combined effect of drum speed and crop feed rate had significant effect on mean values of threshing capacity. However, the effect was dominantly due to variation in crop feeding rate than drum speeds. Threshing capacity varied with crop feed rate but had insignificant variation with drum speed. The grain straw ratio of the crop affects the threshing capacity of the machine, which was at the ratio of 1:3.2 in this experiment.

Table 2. Effects of threshing drum speed, feed rate and their interaction on threshing capacity

Parameter	Source of variation				Measure of differences
	Drum speed (rpm)	Ds_1	Ds_2	Ds_3	LSD (5%)
Threshing capacity (Kg/hr)		110.92^{a}	111.74^{a}	111.30^{a}	1.371
	Feed rate (kg/min)	Fr_1	Fr_2	Fr_3	1.371
		92.79^{c}	112.69^{b}	128.48^{a}	
	Interaction (Ds*Fr)				2.375
	Drum speed level	Fr_1	Fr_2	Fr_3	
	Ds_1	92.38^{c}	111.77^{b}	128.60^{a}	
	Ds_2	93.48^{c}	113.73^{b}	128.00^{a}	
	Ds_3	92.50^{c}	112.57^{b}	128.83^{a}	

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

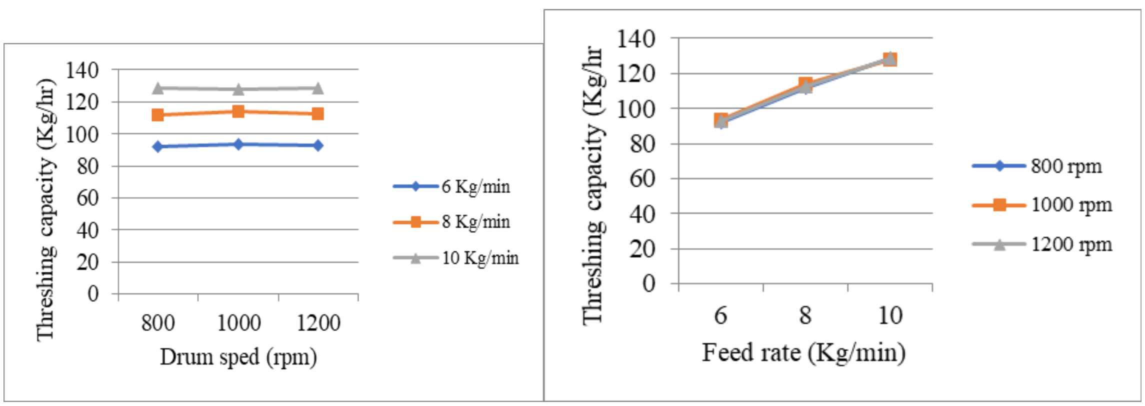

Figure 2 Effect of drum speed and feed rate on threshing capacity

Effect of Drum Speed and Feed Rate on Total Grain Losses

Grain separation losses are those losses that cannot be collected from chaff outlet and aspirators. ANOVA revealed that the threshing drum speed had significant effect ($p < 0.05$) on grain separation loss, whereas crop feed rate and interaction of drum speed and feed rate had no significant effect ($p > 0.05$) on separation loss. From Table 3 it can be seen that the crop feeding rate haven't any significant effect on grain separation loss. The combined effect of drum speed and crop feed rate had significant effect on percentage of grain separation loss. However, the effect was dominantly due to variation in drum speeds than crop feed rate.

Thus, the factor means clearly indicate that grain separation losses were directly related to the drum speed, i.e. with the increase in drum speed, the grain separation losses also increased, while these were inversely proportional to crop feed rate i.e. with increase in crop feed rate, the grain separation losses decreased (figure 3). The minimum grain separation losses (1.807 per cent) was obtained at drum speed of 800 rpm and feed rate of 8 Kg/min., whereas the maximum separation loss was recorded (3.203 percent) at drum speed of 1200 rpm and feed rate of 6 Kg/min. The reason for grain separation losses increasing with increase in drum speed is due to mounting of both the drum and aspirator on same shaft, and thus, leading to higher non-collectable losses. Studies conducted by FAO (2018) on food loss analysis of causes and solutions of teff supply chain in Ethiopia, showed that, threshing with the aid of animals trampling on the grains lead to losses of 7.7 %, which is higher than the losses obtained in this study.

Table 3. Effects of threshing drum speed, feed rate & their interaction on grain separation loss

Parameter	Source of variation				Measure of differences
	Drum speed (rpm)	Ds_1	Ds_2	Ds_3	LSD (5%)
Separation loss (%)		1.841^c	2.514^b	3.178^a	0.0967
	Feed rate (kg/min)	Fr_1	Fr_2	Fr_3	
		2.523^a	2.502^a	2.508^a	0.0967
	Interaction(Ds*Fr)				
	Drum speed level	Fr_1	Fr_2	Fr_3	
	Ds_1	1.847^c	1.807^c	1.870c	0.1674
	Ds_2	2.520^b	2.517^b	2.507^b	
	Ds_3	3.203^a	3.183^a	3.147^a	

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

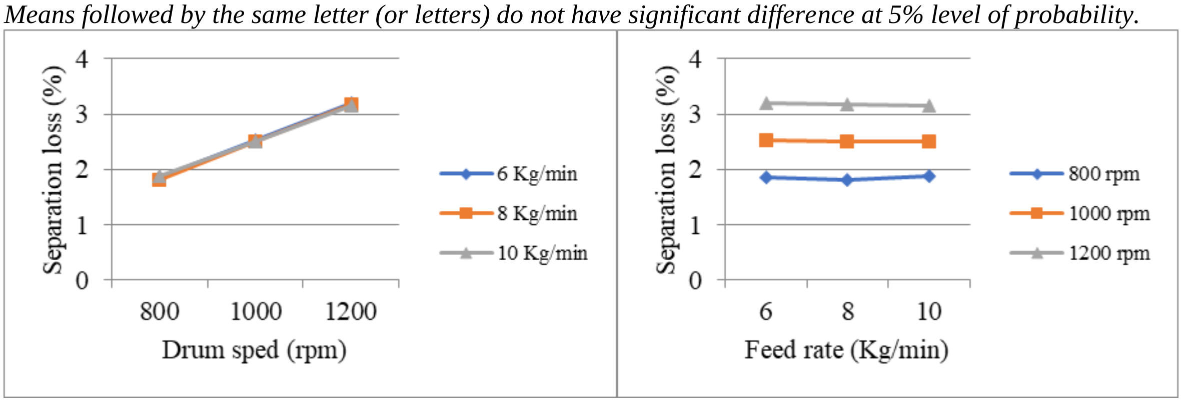

Figure 3 Effect of drum speed and feed rate on grain separation losses

Optimum Values of Independent Parameters

The effects of drum speed and feed rate on dependent variables were grain separation losses, cleaning efficiency and threshing efficiency. To obtain optimum combination of parameters the criteria adopted was that the threshing efficiency should be the maximum, percent 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 drum speed 800rpm 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 drum speed of 800rpm and crop feed rate of 8 Kg/min (1.807%).

Conclusion and Recommendations

The performance evaluation of the imported CAAMS 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. Data from this study led to the following conclusions: The optimum threshing efficiency of 100 % was obtained for all combinations while threshing capacity and cleaning efficiency were obtained at 1200 rpm drum speed and 10 kg/min feed rates and at 1200 rpm drum speed and 6 kg/min feed rates respectively. Whereas, the minimum total seed losses of 1.807 % were obtained at feed rate of 8 kg/min, and drum speed of 8 rpm. Thus from the analysis of the performance result of the test on the teff thresher, the following improvement recommendations were forwarded.

1. It was noticed from the operation of the machine that grains are being lost through the hopper inlet opening; hence the hopper inlet opening should be minimized and crop bundle resting table should be incorporated.
2. Frequent chocking/blocking was occur; hence the straw auger should be modified based on crop stem properties.
3. The thresher has low threshing capacity; to improve on threshing capacity up to 3 quintals per hour modification should be done on the threshing drum size. This is to give room for the feeding of the thresher at greater rates than those used in the evaluation of the thresher.

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