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Preface

Realizing the key role that it plays in the national economy, the Ethiopian government has given due emphasis to the agricultural sector development. 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 amarket-oriented economy. Guided by this national policy and strategy, different consecutive national plans, programs and projects focusing on the development of the agriculture sector has been implemented and is being implemented throughout the country. Among such programs, the Agricultural Growth Program (AGP-II) is one and perhaps the biggest World Bank and other donors supported project launched to support agriculture research and development.

The AGP-II project which is currently under implementation is providing financial supports to the agricultural research and extension both at national and regional levels. The project has four components of which the research component is one. The aim of the research component is to adapt or generate agricultural technologies, undertake pre-extension demonstration of proven technologies, produce source technologies that would serve as a base for large scale technology multiplication and enhance capacity of the research systems to improve technology supply.

Being one of the implementing institutions, the Oromia Agricultural Research Institute (IQQO) is conducting various technology adaptation and generation, pre-extension demonstrations, source technology multiplication and capacity building activities. Of the total technology adaptation/generation and pre-extension demonstrations conducted in 2016/17 cropping seasons 23 technology adaptation/generation and 14 pre-extension demonstration activities have been completed and their results are by now ready for use.This workshop is organized with the purpose of reviewing research findings related to pre-extension demonstration of improved agricultural technologies. The workshop involves researchers from different disciplines, research directors and other relevant stakeholders.

Asefa Ta'a (PhD)
Deputy Director General
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CROP TECHNOLOGIES

Registration of "Bulala" a Newly Released Durum Wheat (*Triticum durum* L.) Variety for Mid and Highland Areas of Bale Zone

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Abstract

Bulala is a name given to a newly released durum wheat variety released by Sinana Agricultural Research Center in 2016/17 from a selection made among durum wheat germplasm introduced from ICARDA. Seventeen durum wheat genotypes were tested along with three standard checks for two years (2012 and 2013) at four locations (Sinana, Agarfa, Ginir and Gololcha) of high lands of Bale. The combined analysis of yield data across years and locations showed that, Bulala gave highest mean yield (5641.5 kg/ha) as compared to the remaining test entries. Moreover, Bulala showed more stable grain yield performance, disease resistance, uniformity, high protein and gluten content, , high biomass and and also early maturing than checks (Tate, Toltu and Ingilize). During variety verification trial, these variety was the most preferred varieties by the farmers as compared to the checks in the trial.It was evaluated both on farmer's field and on research station during variety verification trial along with checks (Dire and Ingilize) during 2016 cropping season and was officially released in 2017 for durum wheat growing areas of Bale.

Keywords: Durum Wheat, Grain Quality, Protein Content, Disease Reaction

Introduction

Durum wheat (*Triticum durum* L.) is the second most cultivated wheat in the world next to bread wheat (Peña and Pfeiffer, 2005). It is indigenous to Ethiopia and it has been under cultivation since ancient times. It is traditionally grown on heavy black clay soils (Vertisols) of the central and northern highlands of Ethiopia between 1800-2800 meters above sea level. Durum is the hardest of all wheat. Its density, combined with its high protein content and gluten strength makes it the preferred choice for producing pasta products. Pasta made from durum wheat is firm with consistent cooking quality. The dough is less elastic than bread dough's, but this makes it easier to roll into pasta shapes. Semolina of durum wheat is the preferred raw material for the production of high quality pasta due to its unique color, flavor and cooking quality. Pasta is a popular wheat-based food worldwide, due to its convenience, palatability and nutritional value (Aravind *et al.*, 2011).

In Ethiopia, durum wheat is consumed as leavened bread, common bread, macaroni, spaghetti, biscuits, pastries, and in various indigenous food preparation. The straw is mainly used for cattle feed and for fuel at times of scarcity (MANR, 2016)**.** However, the productivity of durum wheat in the country is very low compared to world average. This is due to lack of improved variety, low cultural practices, moisture stresses, and other biotic and abiotic factors. Rust is among the major problem limiting durum wheat productivity in Ethiopia. Thus, it is crucial for breeders to develop and recommend the right variety for commercial production in the target agro ecologies.

Variety origin and evaluation

Bulala was originally introduced from abroad through ICARDA. A number of durum wheat genotypes along with checks were tested at different breeding stages starting from observation nursery. Seventeen pipeline durum wheat varieties were evaluated against three standard checks (Tate, Toltu and Ingilize) for two years (2012 and 2013) at Sinana, Agarfa, Ginir and Gololcha of Bale high land.

Agronomic and morphological characteristics

Bulala has medium plant height (82cm) with good tillering capacity, lodging resistance, erected growth habit, large ear size, lodging resistance. Details of agronomic characters of Bulala is presented in Table 1.

Yield Performance

The combined yield data of the two years across four locations showed that, Bulala was the best high yielding variety with mean grain yield of 5641.5 kg ha^{-1}**.** Bulala has 16.9% and 25% yield advantage over two checks viz., Toltu and Englize, respectively (Table 2).

Table 1. Agronomic and Morphological Descriptors of Newly Released Durum Wheat Variety (Bulala)

1	Variety	Bulala
2	Agronomic & morphological characters	
	2.1.Adaption area	Mid and high lands of Bale
	Altitude(ma.s.l)	2000-2500
	Rain fall (mm)	750-1500
	2.2. Seed rate (kg/ha)	150
	2.3.Spacing (cm)	0.2 between rows
	2.4.Planting date	Mid-June to early September
	2.5. Fertilizer rate (kg/ha)	P_2O_5=69
		N=41
	2.6. Days to flowering	68
	2.7. Days to maturity	136
	2.8.Plant height (cm)	86
	2.9. 1000 seed weight (g)	45.1
	2.10. Seed color (g)	Amber
	2.11. Growth habit	Erect
	2.12. Crop pest reaction	Resistance to diseases & tolerance to major wheat pests
	2.14.Proten content (%)	13.3
	2.15.Gluten (%)	30.3
	2.16. Hectoliter weight (kg/L)	83.0
	2.14.Yield (Qt/ha)	
	Research field	48.2-55.3
	Farmer’s field	39.5-76.3
3	Year of release	2017
4	Breeder seed maintainer	Sinana Agricultural Research Center earch Institute

Table 2. Mean grain yield, agronomic performance and disease reactions of 20 durum wheat genotypes tested in durum wheat regional variety trial combined over four locations for years 2012 and 2013

SN	Code of genotypes	Agronomic and disease data								
		DH‡	DM‡	PH‡	TKW‡	TW	GY‡	SR	YR	LR
1	DW ICARDA -01	71	136	85.6	43.1	83.6	4704.9	15s	5ms	5ms
2	DW ICARDA -02	70	136	85.0	40.0	83.1	4631.8	10ms	0	15s
3	DW ICARDA -03	69	134	87.7	43.5	83.7	5269.2	15ms	trmr	10ms
4	DW ICARDA -04	70	136	87.2	44.2	83.7	5131.6	15s	5mr	5ms
5	DW ICARDA -05	74	137	82.2	44.8	81.8	5330.8	5ms	0	5ms
6	DW ICARDA -06	73	136	81.7	43.8	82.5	4887.8	10ms	0	10ms
7	**Durum ICARDA/EthiopiaPDYT-322**	**68**	**136**	**86.6**	**44.4**	**82.8**	**5641.5**	**10ms**	**5mr**	**5ms**
8	DW ICARDA -08	67	134	86.6	43.6	83.5	4613.0	5ms	0	5ms
9	DW ICARDA -09	68	135	78.8	46.2	81.5	4575.2	10ms	trmr	10ms
10	DW ICARDA -10	67	137	87.4	47.7	82.4	4624.1	5ms	5mr	5ms
11	Durum ICARDA/Ethiopia SR.R-6	68	133	81.4	40.8	83.1	5391.3	10mr	5mr	10ms
12	DW ICARDA -12	67	135	86.7	47.1	82.6	4651.3	5ms	trmr	5ms
13	DW ICARDA -13	66	134	86.8	50.9	81.9	4721.5	5ms	trmr	5ms
14	DW ICARDA -14	67	137	88.0	50.4	83.3	4660.5	10ms	0	10ms
15	DW ICARDA -15	68	135	82.8	47.9	83.0	4641.1	10ms	5mr	10ms
16	DW ICARDA -16	67	135	88.2	48.3	83.2	4384.5	5ms	5mr	10ms
17	DW ICARDA -17	67	134	86.6	44.1	82.9	4622.5	5ms	0	10ms
18	Tate	70	136	87.0	44.4	83.2	5278.7	15s	trmr	10ms
19	Toltu (standard check)	69	133	79.5	40.5	83.2	4995.6	10ms	5mr	5ms
20	Englize (Local check)	67	135	110.7	44.3	82.7	4609.7	10ms	trms	15s
Mean		**69**	**135**	**86.3**	**45.0**	**82.9**	**4868.3**			
CV (%)		**1.9**	**1.6**	**5.3**	**5.3**	**3.0**	**12.9**			
SE		**0.26**	**0.43**	**0.94**	**0.48**	**0.51**	**127.72**			
LSD (5%)		**0.73**	**1.21**	**2.62**	**1.34**	***ns***	**355.39**			

Note: DH= days to heading, DM= days to maturity, PH= plant height (cm), TKW= thousand kernel weight (gm), TW= test weight (kg/hl), GY= grain yield (kg/ha), SR= stem rust (%), YR= yellow rust (%), LR= leaf rust (%), S= Susceptible, ms= moderately susceptible, mr= Moderately resistant, TR: Trace, Trms: Trace with moderately susceptible, Trmr: Trace with moderately resistant, R: resistant, CV(%): Coefficient of variations, SE: standard error of the mean, LSD: Least significant differences

Quality Characteristics

Bulala has higher protein (13.3%) and gluten (30.3%) content than the standard check, indicating that it has good pasta making quality. Its seed color is also good and preferred by consumers. Detail data are given in Table 3.

Reaction to diseases

The major durum wheat disease according to their importance in the growing area is rusts (yellow, stem and leaf rusts). Disease data across locations and years were scored. Accordingly, Bulala showed 5mr % reaction to both stemand yellow ruststand tms % to leaf rust during verification trial in the season 2016 (Table 3). Over all, this variety is resistance to the major wheat rusts as compared to the checks and hence farmers in durum wheat growing areas of the highlands of Bale can use this variety to reduce the effect of rust epidemics.

Adaptation and agronomic recommendations

Bulala released for the mid and highland areas of Bale. It is adapted to areas having an altitude ranging from 1700 to 2500 m.a.s.l. with areas receiving annual rainfall amount ranging from 750 to 1500 mm.Besides, this variety is recommended for production in the areas with similar agro ecologies. Recommended seed is 150kg/ha while fertilizer rate is 41kg/ha and 110kg/ha P_2O_5 and N, respectively. UREA application should be applied in split application- 1/3 at planting and 2/3 at tillering stage to get maximum yield and quality. Planting date is in mid-June to early September.

Variety Maintenaner: Breeder and foundation seed of the variety will be maintained by Sinana Agricultural Research Center of Oromia Agricultural Research Institute.

Conclusion

Bulala is officially released in year 2017 for durum wheat growing areas of Bale high lands for its high grain yield, disease resistance, uniformity, good quality traits (protein and gluten), good test weight, earliness, higher thousand kernel weight and higher biomass than the checks. It is highly preferred by consumers.

Table 3. Mean agronomic performance, disease reactions and quality parameters of the Bulala along with checks evaluated in variety verification trial in year (2016)

Genotypes	Agronomic, disease and quality data											
	DH	DM	PH	GY	TKW	TW	SR	YR	LR	Gluten (%)	M %	Protei n %
Bulala(DurumICAR DA/Ethiopia PDYT-322)	68.5	136	86	56	45.1	83.9	5mr	5mr	trms	30.3	10 .4	13.3
Dire	66	134	76	49	33.3	83.8	10ms	10ms	trms	24.9	9. 7	11.7
Durum ICARDA/Ethiopia SR.R-	68	133	82	52	47.8	83.7	10s	10s	10s	28.1	9. 9	12.8
Ingilize	67.5	136	111	46	43.3	82.9	10s	5ms	15s	31.16	9. 5	13.1

Note: DH= days for heading, DM= days to maturity, PH: plant height (cm), TKW: thousand kernel weight (gm), TW: test weight (kg/hl), GY: grain yield (kg/ha), SR: stem rust (%), YR: yellow rust (%), LR: leaf rust (%), S: Susceptible, MS: moderately susceptible, MR: Moderately resistant, TR=, trace, Trms: Trace with moderately susceptible

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Registration of ‘Walin’ (BG-004-1) Sesame (S*esamum indicum* L.) Variety

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Abstract

The name Walin was given to sesame variety developed and released by Bako agricultural research center of Oromia agricultural research institute in the year 2017. It is selected from landraces collection made in Benishangul gumuz area after pure and homogenouse line is developed from population with accession number BG004-1.. This variety gave high grain yield with 22.2% advantage over the standard check, Chalasa and has high oil content (55.1%). Furthermore, Walin is tolerant to bacterial blight and has marketable high seed size and erect plant height. It was released for Uke, Chewaka and Angare Gute areas and similar agro ecologies.

Key Words: *Sesamum indicum,* Variety Verification, Variety Release

Introduction

Sesame (*Sesamum indicum L., 2n = 26),* which belongs to the Sesamum genus of the Pedaliaceae family, is one of the oldest oilseed crops and is cultivated in tropical and subtropical regions of Asia, Africa and South America (Zhang *et al.,* 2013*).* Sesame is the first ranking export oilseed crop in Ethiopia. It is cultivated by both small and large scale farmers. There is huge gap between the average national grain yield which is less than 1 t ha^{-1} and the genetic potential of sesame in Ethiopia. This was mainly due to shortage of improved sesame varieties (Negash, 2015). Western Ethiopia is characterized as high rainfall areas where bacterial blight is the bottle neck for sesame production. Due to high disease pressure, only three varieties were adapted to western part of Ethiopia among a number of sesame varieties released at national level. The demand of improved sesame variety is currently high in western part of Oromia. Given the fact that western Ethiopia is one of the potential areas for sesame production (FAO, 2015), the demand for adaptable improved varieties of this crop is very high. Therefore, developing of a new variety with high yield and desirable agronomic traits is the main objectives of sesame improvement program. Therefore, there is a need to identify high yielding and stable sesame variety with disease resistance for the western part of Oromia.

Varietal Origin and Evaluation

Walin (BG-004-1) was selected out of land races population collected from Benishangul Gumuz of western Ethiopia. Including Walin and the standard check, fifteen sesame genotypes were evaluated in sesame regional variety trial at Uke and Chewaka for two years (2014 and 2015) and at Gutin and Mender-10 for one year (2015).

Agronomic and morphological characteristics

The released sesame variety 'Walin' has acceptable marketable seed size and thousand seed weight (3g), erect growth habit which is very important trait, white seed color and it is tolerant to major sesame diseases prevailing in the areas. The detail description of the released variety is presented in Table 1.

Table 1. Agronomic and morphological characteristics of new sesame variety 'Walin'

1	Variety	Walin (BG-004-1)
2	Agronomic & morphological characters	
	2.1.Adaption area:	Chewaka, Uke, Gutin and similar agro ecologies
	Altitude(ma.s.l)	1250-1450
	Rain fall (mm)	<750
	2.2. Seed rate (kg/ha)	5-10
	2.3.Spacing (cm)	40x5 (Inter and Intra rows)
	2.4.Planting date	Late May to early June
	2.5. Fertilizer rate (kg/ha	100 kg/ha NPS and 50 kg/ha UREA
	2.6. Days to flowering	54-68
	2.7. Days to maturity	80-110
	2.8.Plant height (cm)	120-160
	2.9. 1000 seed weight (g)	3
	2.10. Seed color	Dull white
	2.11. Growth habit	Erect
	2.12. Crop pest reaction	Tolerant to major sesame diseases
	2.14.Yield (Qt/ha)	
	Research field	10-13.8

	Farmers field	9.5-11
3	Year of release	2017
4	Breeder seed maintainer	Bako agricultural research center

Yield Performance

Walin was evaluated in multi-location trial with thirteen pipe line varieties against one standard check, Chalasa for two years (2014 and 2015). It gave grain yield varying 10-13.8 qt/ha on station (Table 2). The on farmers' field grain yield performance of Walin was ranged from 9.5-11qt/ha.

Adaptation and agronomic recommendations

Newly released sesame variety, Walin is recommended for Uke, Chewaka and Gutin and areas with similar agro-ecologies of Ethiopia. It is well adapted in altitude ranging from 1250 to 1450 m.a.s.l. with annual rainfall of 750 mm. Recommended seed rate is 5kg/ha while fertilizer rate is 100kg/ha NPS at planting and 50kg/ha Urea 30 days after planting. The recommended planting time ranging from late May to early June depending on the onset of the rain fall.

Table 2. Mean seed yield (kg/ha) across locations and years in Sesame Regional Variety Trial (2014-2015).

Pipe line variety	Grain (kg/ha)						mean	Yield advantage (%)
	2014		2015					
	Chewaka	Uke	Gutin	Chewaka	Uke	Mender 10		
BG-005	892.4	987.2	510.9	1016.1	893.7	1038	889.7	-0.19
EW-009	1093.2	1059.5	551	1229.7	1058.3	1150	1023.6	14.8
EW-022	512.2	1060.2	420.3	911.5	981.7	965.6	808.5	-9.3
EW-023	1054.5	1112.8	575.5	1040.6	867.7	1210.4	976.9	9.6
BG-004-1	**1054.8**	**1294.3**	**843.2**	**1258.9**	**971.8**	**1114.6**	**1089.6**	**22.2**
EW-007	1098.5	955.8	611.9	1286.5	954.7	1096.4	1000.6	12.2
EW-021	1244.6	1023.4	665.6	1396.4	918.2	1331.8	1096.6	23
EW-005-1	1138.2	918.7	667.7	1283.3	871.3	1297.4	1029.4	15.4
EW-009-1	1012.2	850	771.3	1055.7	713	1250	942.0	5.6
EW-008	1063.2	933.7	703.1	1133.9	784.9	1107.8	954.4	7
WW-005-1	1206.6	1235.6	842.2	1377.1	951.5	1364.1	1162.8	30.4
IL-003	1366.6	1198.7	904.2	1583.9	841.1	1450	1224.0	37.3
BG-004(1)01BK	1324.3	892.7	683.8	1386.5	714	1046.9	1008.0	13
EW-011(2)-01BK	858.8	1160.4	774.5	1082.3	866.7	1401.6	1024.0	14.8
Chalasa(EW-023)	823.7	1255.8	536.9	976.6	878.1	877.6	891.4	0

Grand mean	1049.5	1062.5	670.8	1201.2	884.4	1180.1	1049.5	13
CV (%)	13.2	15.2	14.2	13.7	10.1	13.6		
LSD (5%)	231.3	271.1	159.2	274.5	149.4	269.2		
F – value	**	**	**	**	**	**		

Quality Attributes and reaction to disease

As compared to the candidates and the check Walin (BG-004-1) was the best variety with oil content of 55.1% (Table 3). Bacterial blight is the most limiting factor for sesame production in western part of Oromia. Walin is moderately resistant to this disease

Table 3. Oil content and disease reaction of tested sesame varieties

No	**Variety**	**Oil content (%)**	Reaction to bacterial blight (1-9 scale)
1	BG-004-1 (Walin)	55.1	3.75
2	WW-005-1	52.6	3.75
3	IL-003	54.2	5
4	Chalasa (check)	52.7	5

NB: disease score Where: 1 - 3 = resistance; 4 = moderately resistant; 5 - 6 = moderately susceptible; 7 - 8 = susceptible 9 = highly susceptible

Conclusion

Walin sesame variety was officially released in April 2017 for its high and stable grain yield performance, tolerance to major sesame diseases, high oil content, acceptable seed size, and early maturing withan erect growth habit. This variety is recommended for production in Uke, Chewaka, Angar Gute areas and similar agro ecologies.

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The development and registration of "Alloshe", faba bean variety for the highlands of Bale, Ethiopia

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Abstract

Fifteen faba bean (Vicia faba L.*) lines were selected and tested under regional variety trial for two years (2013/14 to 2014/15) at four locations (Sinana, Sinja, Adaba and Agarfa) districts in Bale highland. Among these,, EH 03043-1 (Alloshe) was found to be the highest yielding variety with a yield advantage of 20.4% over the standard check Shallo; stable performance, best adapted, having large number of pods per plant and tolerant to chocolate spot (Botrytis fabae* Sard.*), Rust (Uromyces Vicia-fabae) and aschochyta blight (Aschocyta fabae Speg*.). *Due to these and other merits "Alloshe" was released in 2017 cropping season for the highlands of Bale and similar agro-ecologies.*

Key words: Faba bean (*Vicia faba* L,) Variety Release, Stability

Introduction

Faba bean (*Vicia faba* L.*)* is a diploid species (2n=12). Botanically, it has been divided based on seed size into types as minor, equine and major, even though there is no discontinuity in seed size between them. This species originated in southwest Asia but its immediate ancestor is not known. On the basis of morphological and geographical considerations, ancestors have been proposed within the species complex *V.narbonensis* L. (2n=14). Faba bean is a partially auto-gamous species and naturally out crossing under field condition is normally in the range of 20-50% (Hawtin and Webb, 1982).

In Ethiopia, pulse crops production accounts 13.4% of the total land produced with an average yield of 10.6% over the whole crops produced (CSA, 2011). Faba bean is cultivated in the "*Wayina Dega*" Zone (with altitudes 1800-2200m a.s.l., average annual rainfall of 740mm and mean daily temperature of 18-22 ^{0}C) and *"Dega"* Zone (with altitudes >2200m.a.s.l, average annual rainfall of 900mm and mean daily temperature of 10-18 ^{0}C). It is planted from June to December in rotation with cereals. The national total area and production of faba bean in the year 2011 accounted for about 3.8% of the total areas allocated for pulse with an average yield of 3.3% of the total crops area cultivated (CSA, 2011).

Faba bean is an important source of protein supplement for the majority of the Ethiopian population and is used in various popular dishes and used as a source of foreign earning (Asfaw *et al.,* 1994). The green immature beans are boiled and eaten as vegetable. The mature seeds can be used for feeding livestock, swine, and equine and poultry animals. The stock or haulms is used as animal feeding staffs. Faba bean also serves as a rotational crop which play great role in controlling disease epidemics in areas were cereal mono-cropping is abundant (Yohannes, 2000).

In the process of developing new cultivars, plant breeders select to improve plant adaptation in a target population of environments. These environments comprise a complex mixture of types which challenge the genotypes and expose differences in adaptation (Cooper *et al.*, 1996). Improvement of quantitative characters in plant breeding programs proceeds by selecting among genotypes based on their phenotypic performance. The phenotype is a result of genetic and no-genetic influences (Comstock and Moll, 1963) and selection exploits only those components of phenotypic variability that have a genetic base.

It is known that variety is released whenever it has merits over the local cultivar and the previously released varieties both in terms of seed yield, other agronomic traits and their reaction to diseases. Variety releasing is an ongoing process since a given variety has performed well for specific period of time and reduces its production potential after sometime due to segregation, becoming susceptible to diseases, and to some degree due to out crossing. Therefore, the present study was undertaken, to evaluate and release faba bean genotypes that are stable, wider adaptation and resistant/tolerant to major faba bean diseases in the highlands of Bale, South eastern Ethiopia.

Materials and Methods

Faba bean variety verification trial was conducted at four locations; Sinana, Agarfa, Adaba and Sinja on vertisol under rain fed conditions in the meher season (August-January) in 2016 cropping season both on station and on farmers' field. None replicated 10mx 10m plot were used. Seeding rate was applied at the rate of 200 kg/ha and fertilizers were applied at the rate of 100kg DAP/ha. Weeds were controlled by hand. Data were collected on both plot and plant basis.

Result and Discussion

The combined analysis over locations revealed significant variation among the genotypes for mean seed yield and other agronomic traits. From the two year data, *EH03043—1* showed a consistence and stable performance over the six environments (year by location). Because of the desirable agronomic performance over the checks, genotype EH03044-1 was selected and verified in 2016 cropping season (Table 1). The verification trial after being evaluated by the National Variety Release Committee (NVRC), the genotype was released for the highlands of Bale, South eastern Ethiopia, and other similar agro-ecologies with an altitude of 1800-2600m.a.sl. The variety was released under the name “Alloshe”.

Varietal Characters

Alloshe is an erect variety with light green seed coat, yellow cotyledon and white with black spot flower. Alloshe has an average plant height of 141cm, and requires 61days for flowering, and 141 days to reach physiological maturity. It has average thousand seeds weight of 434.3gm, and on average 15 medium length pods per plant (Table 2).

Table 1 Mean seed yield and other Agronomic traits of 15 faba bean genotype tested in Regional Variety Trial at four sites (Adaba, Agarfa, Sinja and Sinana) during 2013 and 2014 cropping season

Entry	Genotype code	Days to flower	Days to mature	Plant ht (cm)	Disease score (1-9 scale)			No. pod/plant	No. seed/pod	Thousand seed wt (g)	Seed yield (kg/ha)
					Rust	Chocolate spot	Aschochyta blight				
EHO3073-1	1	60	142	139	6	5	6	17	3.0	694.0	3239
EK 01019-7-5	2	59	142	143	8	5	6	16	3.1	784.4	3379
EK CSR 01009	3	62	141	146	7	5	5	18	2.7	799.5	3312
EHO3021-4	4	62	142	143	6	5	6	17	2.8	705.8	3368
EHO3055-2	5	60	141	138	7	6	6	19	2.9	632.0	3166
EK02006-2-1	6	62	143	143	6	5	6	17	2.9	747.4	3284
EKLS 01022-1	7	62	141	143	7	5	6	18	2.8	781.3	3239
EKLS 01013-1	8	60	142	146	4	4	3	17	2.9	781.6	3931
EH00005-6-1	9	61	141	139	7	5	5	19	2.8	650.8	3465
EHO3043-1 (Alloshe)	**10**	**61**	**141**	**141**	**3**	**4**	**3**	**18**	**2.7**	**698.3**	**4128**
EHO3052-3	11	60	141	142	7	6	7	19	2.8	755.4	3430
EHO3029-2	12	60	140	139	6	5	5	20	2.6	649.8	3249
Shallo	13	59	141	139	7	5	5	19	2.8	575.4	3429
Degaga	14	60	141	143	7	5	5	21	2.8	571.2	3290
Local check	15	59	141	144	7	7	6	19	2.8	579.9	3056
MEANS		60	141	142				18	2.8	694	3398
5% LSD		1.25	1.75	4.93				2.59	0.29	35.56	298.74
C.V.		4.2	2.5	7.1				24.0	20.0	10.0	17.9

Yield performance

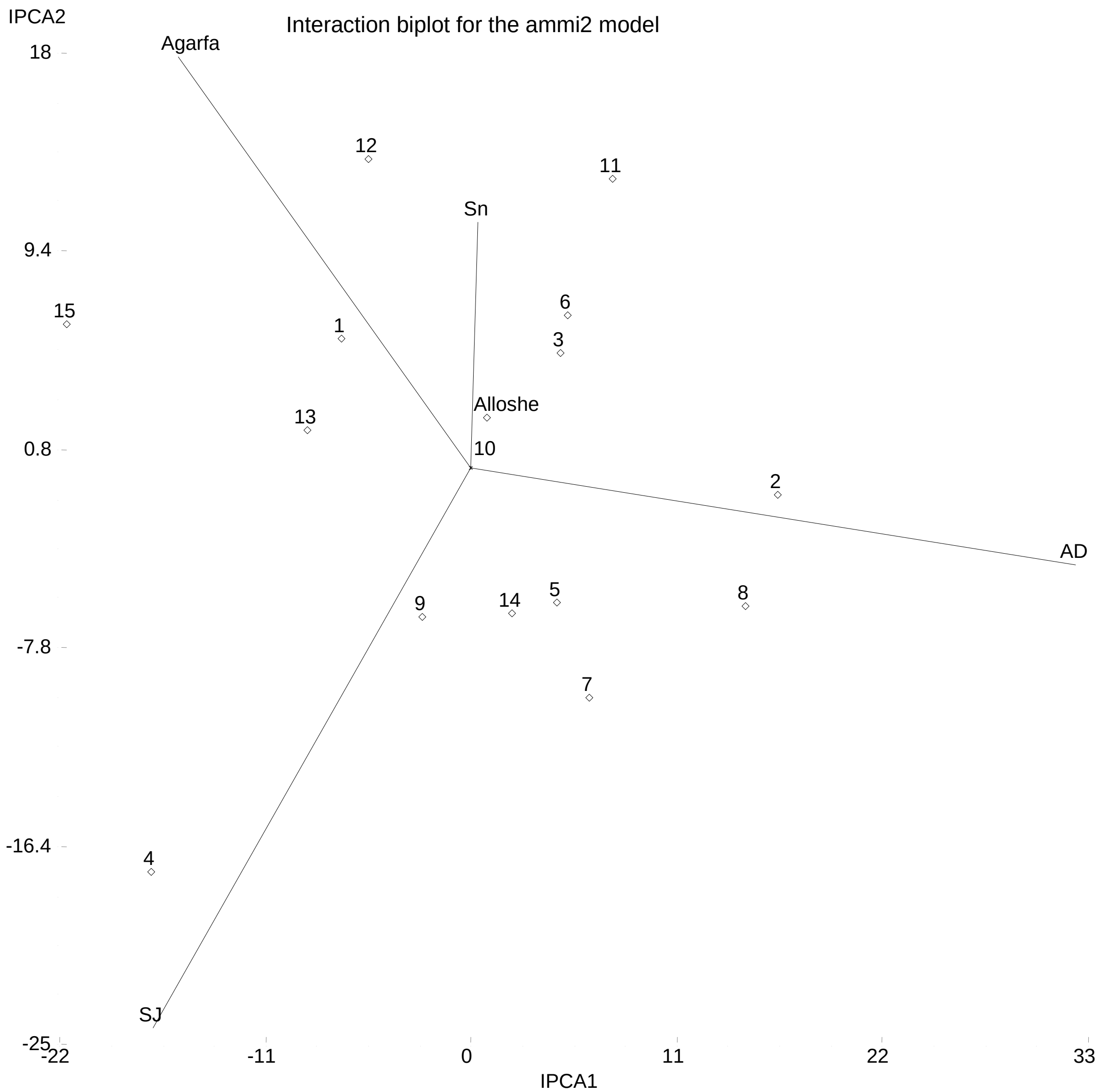
The average seed yield of Alloshe combined over locations and over years is (4.1t/ha) which is higher than Shallo (standard check) (3.4t/ha), and the local check (3.0t/ha). Under research field, Alloshe's seed yield ranges from 4.4 to 5.0t/ha while on farmers' field, it ranges from3.5-4.1t/ha..

Table 2: Agronomic and morphological characteristics of Alloshe (EH03043-1)

No	Agronomical and Morphological Characteristics		
1	Adaptation area		Sinana, Goba, Agarfa, Gassera, Goro (Meliyu), Adaba, Dodola (W. Arsi) and other similar agro-ecologies
2	Altitude (m.a.s.l.)		2300 – 2600
3	Rainfall (mm)		750 – 1000
4	Seed Rate (Kg/ha)		175-225
5	Planting date		End of July to Early August
6	Fertilizer Rate (DAP kg/ha)		100
7	Days to Flower		61
8	Days to Maturity		141
9	Plant Height (cm)		141
10	Growth habit		Indeterminate
11	1000 Seed Weight (gm)		698.3
12	Seed Color		Light green
13	Cotyledon Color		Yellow
14	Flower Color		White with black spot
15	Yield (Qt/ha)	Research Field	44-50
		On-farm	35-41
16	Disease reaction		Tolerant to chocolate spot, Rust and Aschochyta blight
17	Yield advantage over Shallo (%)		20.39
18	Year of Release		2017
19	Breeder and Maintainer		SARC (OARI)

Stability Performance

Yield stability in 15 faba bean genotypes were studied for two years across four locations, based on the model of Eberhert and Russel (1996). The result of the study showed that Alloshe was the best productive variety in yield performance and showed maximum stability. The biplot figure below also revealed that, genotype 10 (EH03043-1) or Alloshe which is found close to the origin is as a stable variety across the testing locations.



Variety: Gykg/ha data file: fbrvt011 model fit: 92.1% of gxe

Reaction to disease

The major faba bean diseases according to their importance in the growing areas are chocolate spot (*Botrytis fabae* Sard.), Rust (*Uromyces Vicia-fabae) and* Aschochyta blight (*Aschocyta fabae Speg*.) (Asfaw *et al*., 1993). In 1-9 rating scale, Alloshe, scored a mean of 3 for rust and aschochyta blight , 4 for chocolate spot, and being characterized as moderately resistant (Table 1).

Adaptation

Alloshe is released for the highlands of Bale, south eastern Ethiopia. It is well adapted in areas having an altitude of 1800 to 2600m.a.s.l and annual rain fall of 750 to 1000mm. Furthermore; production of Alloshe can be extended to areas having similar agro-ecologies. Alloshe performs best if it produced with recommended fertilizer rate of 100kg DAP/ha and seed rate of 200 kg/ha in clay-loam soil. Recommended planting date is from the end of July to early August in Meher season and to the end of March in Belg season.

Variety Maintainer

Breeder seed of the variety is maintained by Oromia Agricultural Research Institute (OARI), Sinana Agricultural Research Center.

Conclusion

Alloshe is a stable variety according to its grain yield performance. It has good agronomic traits that make it suitable for production both in the main and short rain season for areas having bimodal rainfall pattern like Bale zone, south-eastern Ethiopia. Alloshe is moderately resistant to major diseases faba bean.

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Participatory Variety Selection of Food Barley (*Hordeum vulgare* L.) Varieties at Dugda and Lume Districts of East Shoa zone

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Abstract

Participatory evaluation of released barley varieties was conducted in Dugda and Lume districts of East Shewa with the objective of identifying adaptable food barley variety for the areas and similar agro-ecologies. Three improved barely varieties viz., Bentu, Gobe and Dirbie released for moisture stress areas and one for high land areas (HB-1307) were tested on field of nine farmers at three Kebeles. There was significant difference between varieties released for stress area and that recommended for high land areas in yield performance. Higher grain yield was obtained from Gobe, Bentu and Dirbie than that of HB-1307. Based on the grain yield performance of the varieties and farmers selection criteria, two varieties namely, Bentu and Dirbie were recommended for Luma and Dugda districts of East Shewa zone.

Keywords: Food Barley; Moisture Stress; Participatory Variety Selection

Introduction

Ethiopia ranked twenty-first in the world in barley production with a share of 1.2 percent of the world's total production of barely (Abu and Teddy, 2014).There are two types of barley in Ethiopia: food barley for human consumption and malt barley which can be converted into malt, a key ingredient in beer making. In Ethiopia, barely is the fifth most important crop after teff, maize, sorghum and wheat. It is used in different forms such as bread, porridge, soup, and roasted grain and for preparing alcoholic and non-alcoholic drinks. Its straw is used for animal feed, thatching roofs and bedding.

In high land, large area of land was allotted for barley production but it has been replaced by the ever expanding production of bread wheat (CSA, 2013). Similar trend is also happening in the low moisture stress areas and there is serious shortage of improved barely varieties in the low moisture stress areas of Ethiopia including mid rift valley of East Shewa. Therefore, there is a pressing need to introduce improved barley varieties that are drought tolerant to this part of the country. Participatory variety selection has shown success in identifying more number of preferred varieties by farmers in shorter time than the conventional system; in accelerating their dissemination and increasing cultivar diversity (Witcome and Joshi, 1996). It is, therefore, imperative to test the adaptability of moisture stress tolerant released barely varities with the participation of farmers to creating an option and access to farmers is the priority of this research.

Materials and Methods

Four improved food barley varieties namely Gobe, Bentu, Dirbie, and HB-1307 were evaluated in this trial. The first three varieties were released for moisture stress areas while the fourth variety (HB-1307) was originally recommended for high land areas. Date of maturity, altitude range of recommendation, rainfall requirement and the yield potential of the barley varieties used in this study were shown in Table 1.

Table 1. Maturity, adaptation area and yield potential of barley varieties used in this experiment

Characteristics	Varieties			
	Gobe	Bentu	Dirbie	HB-1307
Days to maturity	80-110	71-99	na*	na
Altitude	1700-2300	1700-2300	1700-2300	1700-2300
Rainfall	>500	>500	>500	>500
Yield (qt ha^{-1})	42	12-24	19-31	na

*not available

The experiment was laid out in Randomized Complete Block Design (RCBD) and farmers field were considered as replication. The plot size used was 10m x10 m. The experimental fields were prepared using oxen plow. Seed was planted at a rate of 85 $kgha^{-1}$ in rows of 20 cm spacing and a fertilizer rate of 100kg/ha Urea. Half of it was applied at planting and the remaining half was top-dressed 15 days after planting. Plots were kept free of weeds by hand weeding.Dugda and Lume districts of East Showa zone were selected as the study areas. Two

FREG at Lume and one at Dugda districts were established. A group consisting of 15 to 20 farmers was organized to form one FREG. From each FREG three farmers were selected to host the field experiment. Farmers in each FREG were independently invited to determine their own selection criteria. Finally farmers selected yield, seed per spike, seed size and early maturity as the best selection criteria. Overall Preferential Rank (OPR) was calculated as the average of the trait scores. Agronomic traits like plant height, tillers per plant, grain yield, seed per spike, thousand seed weight, spike length, and effective tillers were recorded and analyzed.

Result and Discussion

Combined analysis of variances showed that there was highly significant difference among the genotypes and the locations for grain yield. The main effect of location were significantly affected number of tiller per plant, number of seed per spike, thousand seed weight and grain yield (Table 2). The mean grain yield of Gobe, Bentu and Dirbie were comparable and they were by far better than HB-1307 (Table 3).

Table 2. Mean square for agronomic characteristics of food barley varieties evalauted

Source of variation	DF	PH (cm)	TPP	ET	SL	SPS	TSW	GY(Qt ha^{-1})
Varieties	3	48.6ns	2.3ns	1.4ns	1.4ns	604.2**	10.7ns	64.5**
Location	2	135.6ns	28.1**	1.4ns	2.1ns	120.6**	78.2**	68.4*
Varieties by Location	6	63.8ns	0.5ns	0.7ns	0.7ns	14.6ns	22.1ns	3.7ns
CV (%)		12.5	12	4.3	14.7	8.4	8.6	17.4

Table 3. Mean performance of yield and some major agronomic traits of barley varieties

Varieties	**TPP**	**SPP**	**TSW (g)**	**GY(Qt ha^{-1})**
Gobe	4.0	25.42c	36.37	22.5a
Dirbie	4.2	42.27ab	37.19	22.4a
Bentu	3.3	42.89a	35.03	21.8a
HB-1307	4.4	39.44b	36.20	16.9b
SE (±)	0.33	1.051	1.03	1.21
$LSD_{0.05}$	NS	2.67	3.099	3.55

TPP= tiller per plant, SPP= spikes per plant, TSW= thousand seed weight, GY= grain yield

Participatory variety evaluation of food barley

At all locations yield was taken by the farmers as the best and first trait to rank barley varieties. The next important traits were seed size, seed per spike and early maturity. Based on these criteria, two varieties namely Bentu and Dirbie were ranked first followed by Gobe while HB-1307 was the last. In general, the result of participatory variety selection (PVS) showed that the most preferred varieties consisting the top two important selection criteria of farmers were Bentu and Dirbie (Table 4).

Table 4. Farmers' food barley variety ranking

Varieties	Ranking index	Overall rank
Bentu	24	1
Gobe	48	3
Dirbie	24	1
HB-1307	64	4

Conclusion and recommendation

Participatory varietal selection has shown success in identifying more number of preferred varieties by farmers in shorter time than the conventional system and as a better strategy in accelerating their dissemination. Accordingly, the experiment was conducted with the objective to test adaptability of improved food barley varieties. Highest biological yield was obtained from Gobe, Bentu and Dirbie. Based on both mean grain yield across locations and farmers section criteria, farmers preferred Bentu and Dirbie barley varieties among the varieties evaluated in this study. Hence, these two selected varieties were recommended for Lume and Dugda districts and areas with similar agro-ecologies.

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Grain yield stability and agronomic performance of tef genotypes in western Oromia

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Abstract

Tef, Eragrostis tef (Zucc.) Trotter is the major Ethiopian cereal grown on about 3 million hectares annually. Because of its gluten-free proteins and slow release carbohydrate constituents, tef is recently being advocated and promoted as health crop at the global level. Regardless of its importance, research on tef is still limited. This experiment was conducted across three locations for two years (2015/16 and 2016/17) to identify stable high yielding pipeline varieties for possible release. A total of nine genotypes were evaluated against the standard check, Kena. The design used was randomized complete block design with three replications. The combined analysis of variance across the three locations revealed highly significant (p<0.01) difference among genotypes for plant height, panicle length, shoot biomass, lodging % and grain yield. Genotype and genotype by environment interaction (GGE) analysis showed that two genotypes, viz.236952and 55253 were stable and high yielder. Besides, these two genotypes were lodging tolerant across locations with grain yield advantage of 26% and 19.29% over the standard check, respectively. Therefore, based on their high yield and stable performance, genotypes 236952 and 55253 were promoted to Variety Verification Trial for possible release.

Keywords: *Eragrostis tef,* stability, Genotype and genotype by environment interaction (GGE)

Introduction

Eragrostis tef (Zucc.) Trotter is a self-pollinated warm season annual grass with the advantage of C_4 photosynthetic pathway (Miller, 2010). Tef is among the major Ethiopian cereal crops grown on about 3 million hectares annually (CSA, 2015), and serving as staple food grain for over 70 million people. Tef grain is primarily used for human consumption after baking the grain flour into popular cottage bread called "*injera*". Tef has an attractive nutritional profile, being high in dietary fiber, iron, calcium and carbohydrate and also has high level of phosphorus copper, aluminum, barium, thiamine and excellent composition of amino acids essential for humans (Abebe *et al*., 2007; Hager *et al*., 2012). The straw is an important source of feed for animals. Generally, the area devoted to tef cultivation is increasing because of both the grain and straw fetch high domestic market prices. 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).

The continued cultivation of tef in Ethiopia is accentuated by the following relative merits: 1) as the predominant crop, tef is grown in a wide array of agro-ecologies, cropping systems, soil types and moisture regimes; 2) with harvests of 4.75 million tons of grain per year from about 3 million hectare, Tef constitutes about 30% of the total acreage and 20% of the gross yearly grain production of cereals in Ethiopia followed by maize which accounts for about 21% of the acreage and 31% of the overall cereal grain production (CSA, 2015); 3) the values of the grain and straw contribute about four billion Birr to the national GDP; 4) it has a good export market, although domestic grain price hikes led to food grain export ban; 5) tef grain has got relatively good nutritive value especially since it contains relatively high amounts of iron, calcium and copper compared to other cereals. Because of its gluten-free proteins and slow release carbohydrate constituents, tef is recently being advocated and promoted as health crop at the global level (Spaenij-Dekking *et al*., 2005).

Agricultural Development Led Industrialization (ADLI) policy requires an increase in productivity of tef such that, apart from satisfying the household consumption, it feeds into the emerging grain processing industries that are cropping up due to the change in life-style as well as the recently burgeoning global tef market. Besides, the export-led research policy requires increased tef productivity particularly in view of exploiting the recent globalization and consequently burgeoning global tef market.

The most important bottlenecks constraining the productivity and production of tef in Ethiopia are: i) low yield potential of farmers' varieties under widespread cultivation; ii) susceptibility to lodging particularly under growth and yield promoting conducive growing conditions; iii) biotic stresses such as diseases, weeds and insect pests; iv) abiotic stresses such as drought, soil acidity, and low and high temperatures; v) the culture and labor-intensive nature of the tef husbandry; vi) inadequate research investment to the improvement of the crop as it lacks global attention due to localized importance of the crop coupled with limited national attention; and vii) weak seed and extension system (Kebebew *et al.*, 2013). Therefore the objective of this activity was to select and release high yielding, lodging and diseases resistant/tolerant tef varieties for tef growing areas of western parts of the Oromia.

Material and Methods

Nine genotypes were evaluated in multi-location trial at tef growing areas such as Shambu, Gedo and Arjo research sub site during 2015/16 and 2016/17 cropping season. The experiment was conducted using Randomized Complete Block Design with three replications on a plot size (experimental unit) of 2m x2m (4m^2) each with 0.2m of row spacing. The distance between block was 1.5m and between plots was 1.0m. Fertilizer rate of 100/50 kg DAP/UREA and seed rate of 10 kg/ha was used. Other agronomic practices were applied uniformly as required. Data on days to emergence, days to heading, days to maturity, panicle length, plant height, shoot biomass, lodging %, effective tiller, Stand %, grain yield per plot and disease score (1-9 scale) were collected and subjected to statistical analysis using SAS (SAS, 2008) statistical software.

Results and Discussions

The combined analysis of variance across the three locations revealed highly significant ($p<0.01$) difference among genotypes for plant height, panicle length, shoot biomass, lodging % and grain yield Qt/ha (Table 1). Accession 236952 gave the highest grain yield

(22.98qt/ha) followed by accession 55253 (21.76 qt/ha) and DZ-01-102 (20.27qt/ha). The standard check Kena gave 18.24 qt/ha. The three candidate genotypes had yield advantage of 26%, 19.29%, and 11.13% over the standard check, respectively (Table 1). In agreement with this finding; previous studies of Genotype x environment on 22 tef genotypes at four locations in Southern regions of Ethiopia have indicated significant variations in grain yield for the tested genotypes (Ashamo and Belay, 2012). Phenotypic diversity in tef germplasm uder pot experiment using 124 single panicle sample collection showed substantial variability for traits such as plant height, panicle length, maturity, seed color, seed yield, lodging and panicle type (Malak-Hail *et al*., 1965).

The combined analysis of variance for biomass depicted significant (P<0.01) difference among the tested genotypes. Accession 236952 gave the highest shoot biomass (10.6t/ha) followed by accession DZ-01-102 (10.10 t/ha) and accession 55253 (10.6 t/ha). The standard check, kena, gave a shoot biomass of 7.1ton/ha. The analysis of variance for lodging percent revealed that low percent for genotype 55253 (7.11%) followed by genotype DZ-01-102 (11%) and genotype 236952 (15%) respectively.

The stability study indicated that genotypes 236952 and 55253 found to be stable and high yielders across the tasted locations with grain yield advantage of 26% and 19.29% over the check, respectively. The GGE biplot analysis revealed that three candidate genotypes showed stable adaptability across the three locations (Fig 1).They were also high yielders than the best check and fall relatively close to the concentric circle near to average environment axis, suggesting their potential for wider adaptability with better grain yield performance

Table 1. Mean grain yield (qt/ha) of tef genotypes per locations across years

Accession	Shambu		Gedo		Arjo		Mean	% yield advantage	Rank
	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17			
Acc.236952	25.07	21.2	22.56	23.3	21.34	23.63	22.85	26.00	1
Acc.55253	21.87	23.02	21.95	21.81	20.12	21.81	21.76	19.29	2
DZ-01-1001	19.16	20.61	17.03	18.58	16.75	18.87	18.50		9
DZ-01-1004B	19.31	20.42	16.53	16.77	16.72	16.52	17.71		10
DZ-01-102	21.80	20.30	19.00	20.10	20.74	19.69	20.27	11.13	3
DZ-01-385	20.44	18.82	18.71	21.02	14.77	20.81	19.10		5
DZ-01-739	19.22	19.97	19.43	18.48	17.55	18.41	18.84		7
DZ-01-778	20.65	19.02	20.02	18.00	18.53	18.83	19.18		4
DZ-01-821	20.18	18.94	19.38	18.51	18.31	19.14	19.08		6
Kena	20.09	20.43	18.30	16.37	17.83	16.44	18.24		8
Local	16.91	17.98	17.48	18.06	17.06	17.77	17.54		11
Mean	20.25	20.43	19.18	19.27	18.16	19.27			
CV	8.9	6.3	6.6	6.1	11.3	4.3			
F-Value	<0.005	<0.002	<0.001	<0.001	<0.028	<0.001			
LSD 0.05	2.46	4.22	2.38	4.30	2.03	4.12			

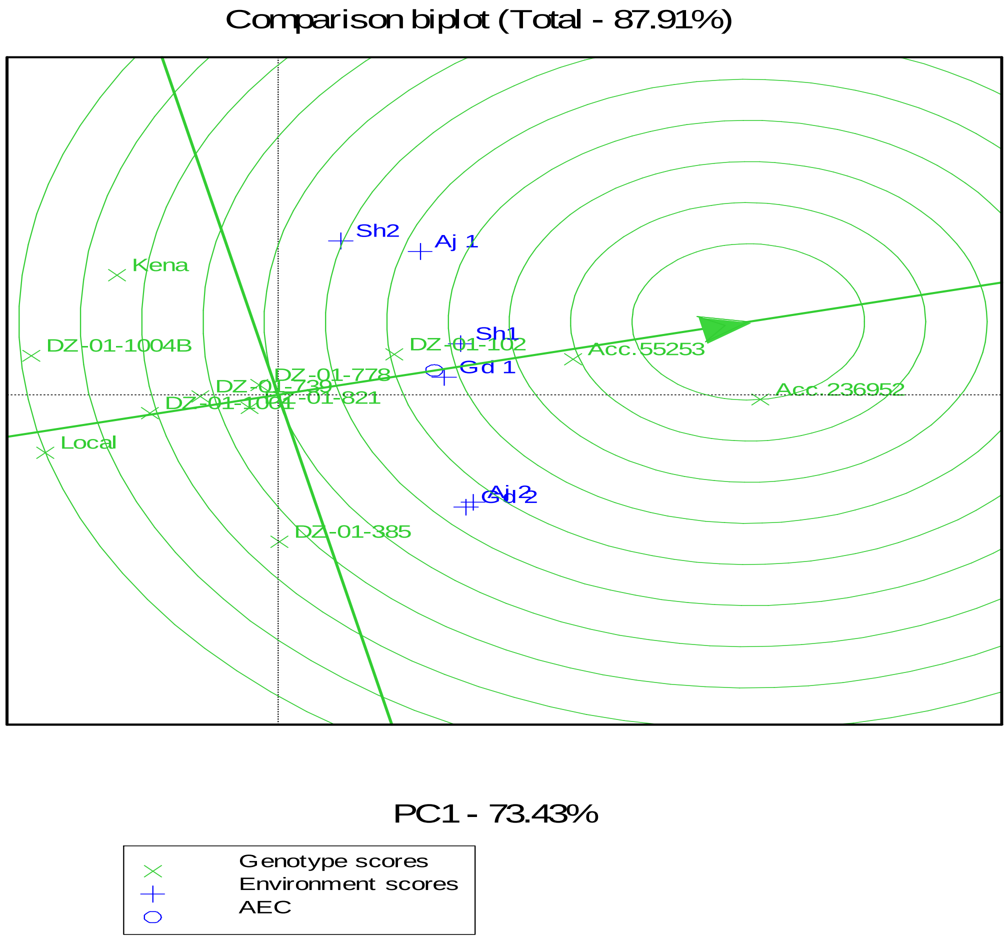

Fig-1. Genotype and Environment that fall in the central circle are considered ideal environments and stable genotypes, respectively

Conclusion and Recommendation

Combined analysis of variance for the genotypes portrayed highly significant differences for plant height, panicle length, shoot biomass, lodging % (data not presented) and grain yield qt/ha. Genotype 236952and 55253 were found stable, high yielders and lodging tolerant across the tasted locations with grain yield advantage of 26%, 19.29% and 11.13% over the standard check respectively. As a result of these all merits, these three genotypes *viz.* 236952and 55253 were identified as candidate genotypes to be verified at three sites in the coming cropping season for their possible release.

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Participatory Variety Selection of Bread Wheat (Triticum aestivum L.) Varieties at Dugda and Lume districts of East Shoa zone

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Abstract

Wheat is the major cereal crop grown in the highlands of Ethiopia. In east Shoa zone of Dugda and Lume districts improved variety of wheat is not well popularized and most farmers depend on local cultivars. The objective of this experiment was to identify adaptable and most preferred bread wheat variety for the areas. Four varieties vz. Kingbird, Ogolcho, Kekeba and Bika were tested against farmer's variety, Hawi. These varieties were tested at two kebele's of Lume and one kebele of Dugda district. Three varieties namely Kingbird (23.8qt/ha), Kekeba (23.8qt/ha) and Ogolcho (23.7 qt/ha)) gave comparable grain yield and they are better in yield as compared to Bika (21.0 qt/ha) and the check, Hawi (21.2 qt/ha). At Tephochorke kebele of Dugda district, yield, drought tolerance and early maturity were selected by farmers as the top three selection criterion. At Ejersa Joro and Bika kebele of Lume district farmer's selection criteria were yield, spike length and early maturity. Across the two districts, Ogolcho and king bird were selected as the best among these tested bread wheat varieties. These varieties were recommended for moisture stress areas of Lume and Dugda districts of east Showa zone and areas with similar agro ecologies.

Keywords: Bread Wheat; Grain Yield; Participatory Variety Selection; Ethiopia

Introduction

Wheat is the major cereal crop grown in the highlands of Ethiopia with in altitudes of 1500 to 3200m.a.s.l. In Ethiopia, the current national average wheat yield is 2.54 ton ha^{-1} (CSA, 2015), which is far below the yield (5 ton ha^{-1}) obtained from experimental plots even before two decades ago (Hailu, 1991). Wheat production is constrained by many yield-limiting factors under farmer's field of which low moisture is the most important in Lume and Dugda districts of east Shoa zone. In Ethiopia, conventional wheat breeding was started in 1960s and as a result, a large number of bread wheat cultivars were released (MNR, 2016). The most important advantage of participatory variety selection (PVS) is adoption of new cultivar is much faster than under the formal crop improvement and also the dissemination of varieties from farmer-to-farmer through the local seed system will be very fast and thus guaranteeing a further good adoption (Bellon *et al*., 2002). According to Sperling *et al*. (2001), PVS may have many advantages, such as increased and stable crop productivity, faster release and adoption of varieties, better understanding of farmers' criteria for variety selection, enhanced biodiversity, increased cost effectiveness, and facilitated farmers learning and empowerment.

The participation of farmers in the testing and selection process of the varieties was very limited. Besides, among the so far released bread wheat varieties, very limited were recommended for moisture stress wheat growing part of the country. Therefore, it is not possible to say that all these varieties had been properly utilized by the farmers. The conventional wheat breeding approach in Ethiopia is based on the development of varieties under high management level of experimental stations.

Dugda and Lume districts of east Shoa zone are drought prone area and the improved varieties of wheat were not well popularized. A possible option for addressing this constraint is increasing varietal adoption through participatory variety selection and mobilizing farmers to produce good quality seed of the improved varieties suited for their environment and seed marketing at local levels. This experiment was, therefore, designed to evaluate wheat varieties with farmers group in order to know farmers variety selection criteria, identify adaptable and most preferred variety for further production in the study area.

Materials and Methods

Four improved varieties of bread wheat viz Bika, Ogolcha, Kekeba, and King Bird and farmer's variety (Hawi) were include in this study. The characteristic of each variety is presented in Table 1. All varieties were released for the the moisture stress areas of the country. The study was conducted at Dudga and Lume districts of east Shoa zone. The altitude of the districts varies from 1600 m.a.s.l (Ziway Lake) to 2020 masl (Bora Mountain). At Lume district two kebele namely Bika and Ejersa-Joro and at Dugda district one Kebele (Tephochorke) were selected for this study. At each Kebele, one FREG was established and three host farmers were selected from each Kebele. Date of maturity, altitude range of recommendation, rainfall requirement and the yield potential under research managed condition of the bread wheat varieties used in this study were presented in Table 1.

Table 1. Maturity, adaptation area and yield potential of bread wheat varieties included in this study

Characteristics	Varieties				
	Bika	Ogolcho	Hawi	Kekeba	Kingbird
Days to maturity	95	102	105-125	90-120	90-120
Yield (qt ha^{-1})	32-54	33-50	40	33-52	33-52
Altitude	1600-1950	1600-2000	1800-2200	1500-2200	1500-2200
Rainfall	450-800	400-500	>500	500-800	500-800

The experiment was laid out in randomized complete block design and each host farmer was considered as replication. The experimental fields were prepared using oxen plow. Seed was sown at the rate of 85 $kgha^{-1}$ in rows (20cm between rows). As source of nitrogen UREA with the rate of 100kg/ha was applied half at planting and the remaining half was top-dressed at 15 days after planting. Plots were kept free of weeds.

Two FREG at Lume and one at Dugda districts were established. A group consisting of 15 to 20 farmers was organized to form one FREG. From each FREG three farmers were selected to host the field trials. Participatory evaluation of bread wheat varieties was done at early harvest of the crop. Farmers in each FREG were invited to determine their own selection criteria. Firstly, discussion was made among farmers on plant characters to be used for bread wheat variety selection. From the discussion made, traits such as seed color, early maturity, drought tolerance, biomass yield, tillering ability 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 plant height, tiller per plant, seed per spike, thousand seed weight, spike length, and effective tiller were recorded and analyzed.

Results and Discussion

Combined analysis of variance showed that there was significant variation among the studied varieties for plant height, effective tiller and spike length (Table 2). However, the difference among the varieties for gain yield were not statistically significant. This may be due the effect of moisture stress on the productivity of the varieties. Grain yield, spike length and seed per spike were significantly affected by location. Variety by location interaction for grain yield was not significant.

Table 2. Mean square for agronomic characteristics of bread wheat

Source of variation	Df	PH(cm)	TPP	ET	SL	SPS	GY($qtha^{-1}$)
Varieties	4	648.94*	4.15ns	5.14*	2.58**	240.36ns	31.43ns
Location	2	36.22ns	2.22ns	1.60ns	1.09**	38.14**	15.995**
varieties x location	6	30.78ns	0.86ns	0.49ns	0.24ns	19.08***	4.499ns
CV (%)		12.5	12	28	6.9	7	7.9

In terms of grain yield performance, Kingbird, Kekeba and Ogolcho gave comparable yield and showed better than Bika and Hawi. These varieties showed 12% yield advantage over the local check (Hawi) and Bika (Table 3).

Table 3. The main effect of varieties and environment on agronomic characters of bread wheat

Varieties	**PH**	**ET**	**SL**	**GY(qt ha^{-1})**
Kingbird	64.8ab	2.9ab	7.4ab	23.8
Kekeba	63.4ab	2.5b	7.8a	23.8
Ogolcho	65.1a	3.6a	7.0b	23.7
Bika	60.1b	3.3a	7.9a	21.0
Hawi (local check)	63.1ab	3.1ab	7.5ab	21.2
SE (±)	**1.673**	**0.29**	**0.135**	**0.61**
LSD$_{0.05}$	**4.882**	**0.84**	**0.39**	**1.79**

Grain yield, drought tolerance and early maturity were among the top three farmers selection criteria for selecting bread wheat varieties. Other traits such as seed color, disease resistance/tolerance, biomass and tillering ability of the varieties were considered for ranking the varieties. At Tepho Choroke kebele of Dugda district King Bird and Ogolcho were selected as a top two preferred bread wheat varieties (Table 4).

Table 4. Bread wheat variety ranking at Tepho Choroke kebele of Dugda district

Varieties	seed color	early maturity	drought tolerance	disease tolerance	Biomass	tillering ability	yield	Ranking index	Overall rank
Bika	3	5	5	1	2	5	4	125	5
Hawi	3	2	1	5	1	1	4	85	4
Kekeba	3	2	1	1	2	2	2	65	3
Kingbird	1	1	1	1	2	2	1	45	1
Ogolcho	2	1	1	1	2	2	3	60	2

At both Bika and Ejersa-Joro kebele of Lume district participatory evaluation of bread wheat varieties conducted at early harvesting stage of the crop by 15 farmers (6 women and 9 men) at each location. The farmers agreed that spike length, early maturity, seed size, seed color, and yield are important parameters for bread wheat variety selection at both Bika and Ejersa Joro Kebele. Among all these traits, grain yield, spike length and early maturity were selected as the top three important selection criterions. Accordingly, Ogolcho and King Bird were selected as the best two preferred bread wheat variety by the farmers at both Bika and EjersaJoro kebeles (Table 5)

Table 5. Bread wheat variety ranking at Bika and Ejersa Joro kebele of Lume district

Varieties	Spike length	Early Maturity	Seed size and color	Yield	Ranking index	Overall rank
Bika	3	5	3	4	75	4
Hawi	5	3	4	5	85	5
Kekeba	4	2	4	2	60	3
Kingbird	2	1	2	3	40	2
Ogolcho	1	3	1	1	30	1

Conclusion and recommendation

At Tephochorke PA of Dugda district the top three selection criterion were yield, drought tolerance and early maturity. Based on these selection criteria, King bird and Ogolcho were selected as the best two preferred bread wheat varieties. While at EjersaJoro and Bika PA farmers selection criteria were yield, spike length and early maturity. Similar to that of Tephochoroke PA, Ogolcho and King bird were selected as the top two preferred bread wheat varieties by the farmers at Bika and EjersaJoro PAs. The result of this study showed that Ogolcho and king bird were the best two varieties selected by farmers for both Dugda and Lume districts.

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Participatory variety selection of Chickpea (*Cicer arietinum* L.) Varieties at Dugda Districts, mid rift valley of East Shoa zone, Oromia.

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Abstract

Chickpea is one of the most important food legume commonly used for human nutrition, and it is second most important among pulses in the world and in Ethiopia. Production of this crop was mainly depends on traditional varieties where the yield is considerable low as compared to improved varieties. Therefore, there is a pressing need to introduce improved varieties to farmers of the study areas. Accordingly, six varieties of chickpea were evaluated at Dugda in participatory variety selection approach to identify high yielding variety of chickpea at Dugda districts. Among the varieties tested, Minjar from Dessi type (26 Qt ha^{-1}) gave higher mean grain yield followed by Habru from Kabuli type (23 Qt ha^{-1}). Participant farmers also selected Minjar variety from Dessi type for its high grain, biomass yield, earliness and uniform in maturity. In addition, Habru from Kabuli type showed better grain yield and well adapted to the area and thus highly preferred by the farmers.

Keywords: chickpea; participatory variety selection; Ethiopia

Background and Justification

Chickpea as a one of the most important food legume commonly used for human nutrition and it is second most important among pulses in the world and being cultivated on more than 11 million hectares with annual production of 9 million tons (Anonymous, 2007). It is a high-value pulse crop that is adapted to deep black soils in the cool semi-arid areas of the tropics, sub-tropics as well as the temperate areas (Joshi et al., 2001; Shiferawet al., 2004). Ethiopia has suitable agro-climatic conditions for production of both Desi and Kabuli type chickpeas.

The crop is highly integrated into the farming system and ecologically friendly for growing in many areas that suffer from soil nutrient depletion (Haile, 2010). The chickpea cultivated in the country, which occupies about 239,755 hectares of land annually with estimated production of 458682.2 tones (CSA, 2015).

Chickpea cultivation has many advantages such as improving crop production and productivity, maintain soil fertility, and provide supplementary nutritional value for consumer. Regardless of its importance, the production and productivity of the crop has been limited to some Kebele in Dugda district. Therefore participatory variety selection of check pea in districts is important to select based on farmers own criteria and suitable for farming system and uses in the target area. Therefore, current research was initiated with the objective to identify high yielding variety of chickpea in Dugda district and to demonstrate best adapted chickpea technologies in the districts.

Materials and Methods

The study was conducted in Dudga districts of east Shoa zone. One potential kebele was selected and three farmers were selected for the study based on the active involvement of the farmers in the production of chickpea in the district. Six improved chickpea varieties were selected for the trial. The varieties were Arerti, Habru, Tektay, Minjar, Natoli and Ejere. The characteristics of each varieties is presented in Table 1 below.

Table 1. General Characteristics of chickpea varieties during their release

Characteristics	Arerti	Habru	Tektay	Minjar	Ejere	Natoli
Type	Kabuli	Kabuli	Kabuli	Desi	Kabuli	Desi
Days to 50% maturity	105-155	91-150	85-150	86-143	118-129	86-143
Areas of adaptation						
Altitude (m)	1800-2600	1800-2600	1800-2600	1800-2600	1800-2600	1800-2600
Rainfall	700-1200	700-1200	700-1200	120-140	700-1200	120-140
Yield (tha^{-1})	18-47	14-50	20-23	20-40	12-15	20-40

Experimental Design

The experiment was laid down in randomized complete block design (RCBD) and number of farmer's field on which the trials were conducted were considered as replications. Packaged production technologies (seed rate, seed treatment, spacing, fertilizer and weed management) recommended for the chickpea crop production was used to establish the trial.

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 distance of 1m was used in the experiment. Field layout was prepared and each treatment was assigned to experimental plots within farmer field. Seeds were sown at the recommended rate of 110kgha^{-1} in rows at 40cm apart and 10cm between plants.

Participatory Variety Selection (PVS) was carried out by farmers' research group members representing the farming community of the area. Farmers ranked each cultivar for all traits based on their own selection criteria. Scoring was based on the number of genotypes tested and the relative performance of each genotype. Overall Preferential Rank (OPR) was calculated as the average of the trait scores.

Data collected and analysis

Major agronomic characteristics were considered in the current experiment which includes plant height, primary branch, secondary branch, thousand seed weight, number of pod per plant, number of seed per plant, and grain yield. All the data was subjected to ANOVA by using the GLM procedure of Genstat software ver.15. Mean separation was performed at $P<0.05$ using least significant difference (LSD) (VSN Int. ltd., 2012).

Results and Discussion

The analysis of variance revealed that varieties showed non-significant variation for plant height, number of primary branch, number of secondary branch and grain yield at ($P<0.05$). While genotypes showed significant difference at ($P<0.01$) for number of seed per pod, pod number per plant and grain yield (Table 2).

Table 2. Mean square of major agronomic characteristics of chickpea varieties at Tephochorke PA of Dugda district

Source of variation	PH	PB	SB	SPP	PNPP	GYHa
Variety	54.18NS	0.5889NS	4.456NS	2263.56**	2263.56**	41.63**
CV (%)	12.2	2.1	33.4	12.7	12.5	20.9

The highest number of pod per plant was obtained from Habru (101) followed by Tektay (66); while the lowest number of pod per plant was from Ejere variety (31). In the same way the highest number of seeds per plant was also obtained from Habru variety followed by Teketey. Top yielder in the current research were Minjar (26 Qt ha^{-1}) followed by Habru (23Qt ha^{-1}) while the lowest yielder were Ejere (Table 3).

Table 3. Effect of variety on selected characteristics of chickpea varieties

Varieties	PNPP	SPP	GYQt/ha
Habru (Kabuli)	101a	124a	23.33ab
Teketey (Kabuli)	66b	66bc	19.56ab
Natoli (Desi)	50c	54cd	19.48ab
Arerti (Kabuli	41cd	74b	16.25b
Minjar (Desi)	38d	63bc	25.65a
Ejere (Kabuli)	31d	47d	16.55b
SE (±)	6.27	9.05	4.21
$LSD_{0.05}$	11.4	16.5	7.7
CV (%)	11.5	12.7	20.9

Participatory variety selection Farmer’s evaluation based own their own selection criteria

Participatory evaluation of the varieties was conducted at harvest by 15 farmers (6 women and 9 men) at Tephochoroke PA. Initially, discussion was made with farmers on plant characters used by farmers for chickpea variety selection, and agreed that yield, early maturity, drought tolerance, uniformity at maturity and biomass are important parameters for chickpea variety selection at TephoChoroke kebele of Dugda district. Most farmers identified yield, drought tolerance and uniform maturity as top selection criteria.

The variety Minjar was chosen by farmers' focus group discussion (FGD) for its high grain and biomass yield, earliness and uniform maturity (Table 4). Moreover, it has special merit such as drought and disease tolerance were important as additional factors. In fact, the two improved desi types, minjar and Natoli, have shown remarkable resistance to the severe moisture stresses in the area. Under optimum environments especially with sufficient moisture, the Kabuli types can express their high yield potential while under drought stress, the improved desi types were found to be resistant and more productive. Based on the analysis and participatory evaluation results, the improved desi variety minjar was selected. Moreover, it may be necessary to include one kabuli type chickpea variety since both selected varieties were desi type which, have slightly less market value than the kabuli types. Based on the ranking, Habru is additionally recommended provided that it is planted early.

Table 4. Chick pea participatory evaluation varietal ranking

Variety	Yield	Early Maturity	drought tolerance	Uniform maturity	Biomass	Ranking index	Overall rank
Ererti	5	5	5	6	1	110	5
Minjar	1	1	2	1	3	40	1
Ejere	5	6	6	5	1	115	6
Tektay	3	3	3	1	3	65	3
Natoli	4	3	3	4	3	85	4
Habru	2	1	1	1	3	40	1

Conclusion and recommendation

One of the most proven means of enhancing productivity with minimized cost in shorter time period is through introduction of adapted high yielding crop varieties. Participatory varietal selection has shown success in identifying preferred varieties by farmers in shorter time than the conventional system and thus accelerating their dissemination. Accordingly, this experiment was conducted with the objective to test adaptability of improved chickpea varieties. The highest grain yield was recorded for Desi type Minjar (26 Qt ha^{-1}) followed by Kabuli type Habru (23 Qt ha^{-1}). Minjar was primarily chosen by farmers' FGD for its high grain and biomass yield, earliness and uniformity in maturing. Based on the analysis and participatory evaluation results, the improved desi variety minjar was selected as a top yielder variety followed by Habru for its grain yield and high marketability.

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Effect of Different Weed Management Practices on Growth, Yield and Yield Components of Faba Bean (Vicia faba L.) in Bale Highland Conditions, Southeastern Ethiopia

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Abstract

Weed is the major production constraints for faba bean production in Bale Highlands. Its management is quite important to increase the production and productivity of the crop. To this end, this experiment was conducted to address such pressing needs. The experiment was conducted at Sinana on-station and on farmers' field during 2015 and 2016 "Bona" main cropping seasons to evaluate the effect of hoeing plus hand weeding frequencies on growth, seed yield and yield components of faba bean. The treatments consisted of eleven weed management options. It was laid out in a randomized complete block design (RCBD) with three replications. Results indicate that faba bean plant flower and mature early when infested with weeds as compared to well weed controlled treatments at both sites. The growth and yield attributes of faba bean were significantly reduced when the crop left unweeded. The result also showed there was 41% and 35% yield reduction due to total weed infestation of faba bean as compared to the recommended two times hand weeding at on-station and on-farm, respectively. Hoeing at 7 DAE plus twice hand weeding gave a yield advantage of 51% and 17% as compared to weedy check and the recommended two times hand weeding at on-station. There was 51% and 41% yield penalty while farmers remove weed at 50% pod setting stage for the purpose of feeding their livestock as compared to hoeing at 7 DAE plus twice hand weeding and the recommended two times hand weeding at on-station. Similarly, there was a yield loss of 17% if weed removal at 50% pod setting stage as compared to the recommended two times hand weeding and hoeing at 28 DAE plus once hand weeding at 40-45 DAE at on-farm. The economic analysis indicated that the highest marginal rate of return was obtained from hoeing at 7 DAE plus hand weeding at 25-30 DAE at both locations. Therefore, it was economically profitable to manage weeds in faba bean field and increase production and productivity of the crop in Bale highlands and similar agro-ecologies.

Key words: *Faba bean, Weed, Days after emergency, hoeing*

Introduction

Faba bean ***(****Vicia faba* L.) is a valuable crop plant worldwide. It is the leading most important pulse crop grown in the highland areas of Ethiopia. In Bale zone of Oromia regional state, the crop is widely cultivated by the state farms and small scale farmers. It can be used as an effective break crop in cereal rotations since it substantially improves soil fertility through biological nitrogen fixation. At the same time, it produces seeds with high protein content frequently exceeding 20-41% (Crepona *et al*. 2010). It has been considered as a meat extender or substitute and as a skim-milk substitute (Talal and Ghalib, 2006). It also generates household income for the farming community. However, the yield of faba bean is generally low due to several biotic and abiotic yield limiting factors. Among them, poor weed mangements in addition to poor soil fertility, untimely sowing, and the lack of improved varieties are the major ones (Ghizaw and Molla, 1994).

Faba bean is a very sensitive crop to competition of both broad-leaf and grass weed species (Getachew and Rezene, 2006). They also observed that the extent to which the yield is reduced by weeds depends not only on the weed species and density, but also on the period for which the crop is exposed to weeds. Therefore, inadequate and untimely weed control operation is one of the crucial factors causing low yields of the crop. In the study area, weeds are a challenging problem to pulse crop producers. Since simple, inexpensive herbicide solutions, as used in cereal production, are not as available in pulse crops to control weeds. Due to mentioned fact, hand weeding is the common cultural practice to remove weed from pulse crop fields. However, most of the farmers in Bale highlands, where faba bean is widely grown, have been practicing differently at different growth stages of the crop in order to remove the weeds. Some of the farmers remove at the recommended time and the others react after severe competition occurred. In the meantime, in addition to hand weeding, most farmers started hoeing to reduce weed pressure. On the other hand, some farmers do not remove the weed until pod setting since they maintain the weeds for animal feeds in areas where shortage of animal feeds are the main challenges. These temporal variations of weed managements considerably varied the yield performances of the crop and as a result its production and productivity across locations and seasons is low in which the average yield under small holder farmers' is not more 1.8t/ha as compared to its potential productivity (3.8tha) the recently released variety (Variety registration year book, 2016). However, the right time of hoeing and hoeing in combination with hand weeding frequencies and their economic feasibility studies were lacking in the study area. Therefore, this study has been designed to evaluate the effect of hoeing and hand weeding frequencies on growth, seed yield and yield components of faba bean and to recommend economically profitable cultural weed management options.

Materials and Methods

Experimental Sites

The experiment was conducted on research field of Sinana Agricultural research center and Sinana on-farm in the highlands of Bale, South-eastern Ethiopia under rainfed conditions during the main cropping season of 2015 and 2016. Sinana is located at a distance of about 463 km from Addis Ababa at about $7^0$07'N longitude and $40^0$10'E latitude, at an altitude of about 2400 meters above sea level. The area is characterized by bimodal rainfall pattern which is locally called "*Bona*" and "*Ganna*" based on the time of crop harvest. The seasonal total rainfall of the area during the cropping seasons (2015 and 2016 main cropping season) were 475 mm and 594mm, with the average minimum temperature of 15.81°C and 14.95°C and maximum temperature of 21.37°C and 23.84°C respectively (Figure 1and 2). Soil of the area was characterized by Cambisol. The preceding crops planted in experimental sites were bread wheat which is the precursor of the current faba bean.

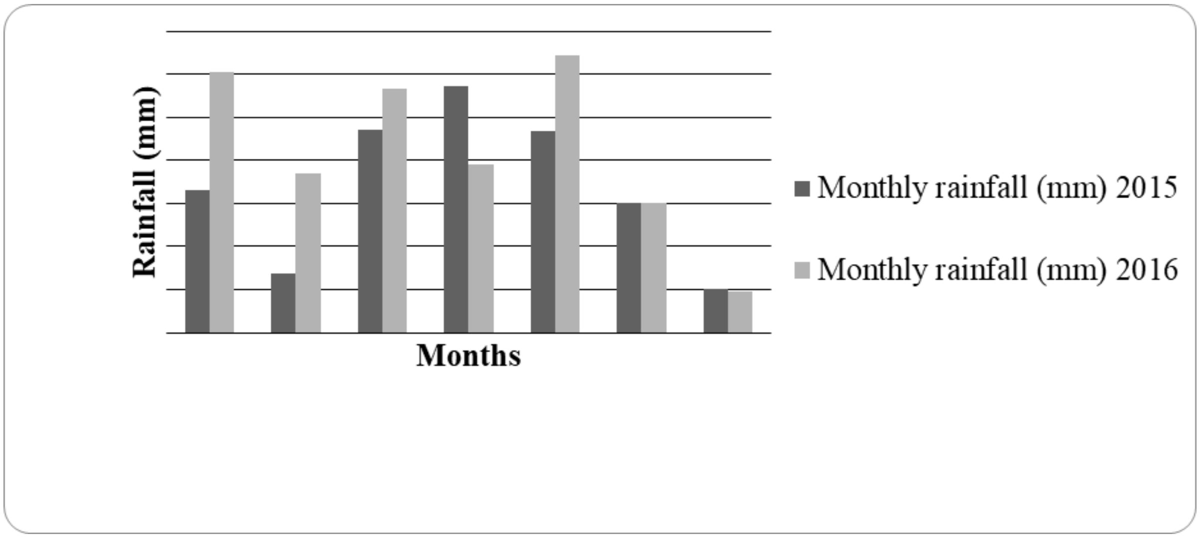

Figure.1.Monthly rainfall during the experimental years (2015 and 2016 main cropping seasons) at Sinana, Source: Sinana Agricultural Research Center Meteorological Station

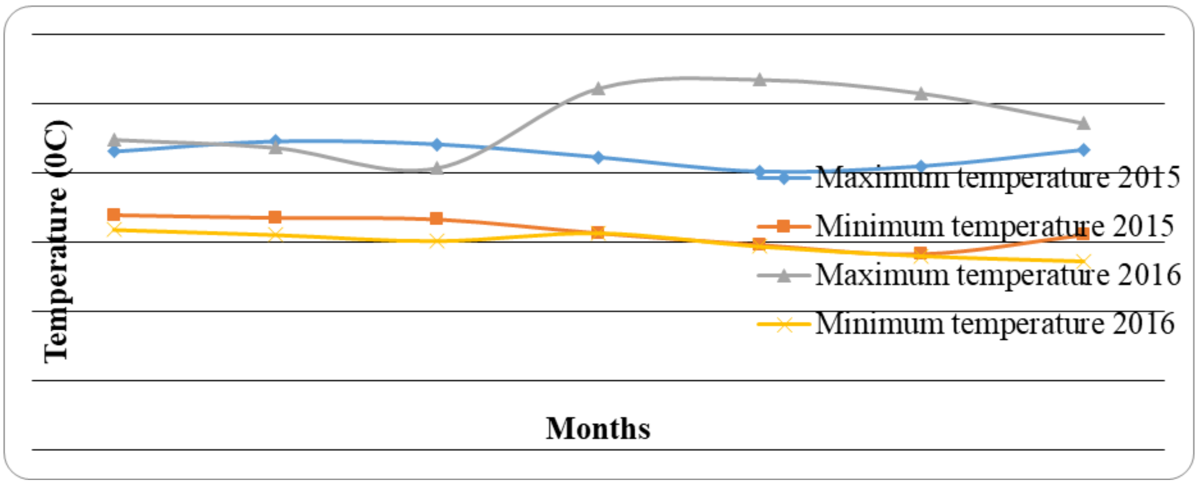

Figure.2. Mean monthly maximum and minimum temperatures (^{0}C) during the experimental years (2015 and 2016 main cropping season) at Sinana, Source: Sinana Agricultural Research Center Meteorological Station

Experimental Treatments and Design

For this experiment, faba bean variety called 'Mosisa', was used as a test crop. It is a released variety of Sinana agricultural research center in 1999/2000. The treatments consisted of eleven weed management options: (1) Weedy check, (2) Hand weeding at 25-30 days after emergence (DAE) and 40-45 DAE, (3) Hoeing at 7 DAE, hand weeding at 25-30 DAE and

40-45 DAE, (4) Hoeing at 7 DAE and hand weeding at 25-30 DAE, (5) Hoeing at 7 DAE and hand weeding at 40-45 DAE, (6) Hoeing at 14 DAE, hand weeding at 25-30 DAE and 40-45 DAE, (7) Hoeing at 14 DAE and hand weeding at 25-30 DAE, (8) Hoeing at 14 DAE and hand weeding at 40-45 DAE, (9) Hoeing at 21 DAE and hand weeding at 40-45 DAE, (10) Hoeing at 28 DAE and hand weeding at 40-45 DAE, (11) Hand weeding or weed harvesting at 50% pod setting stage. The experiment was laid out in a randomized complete block design (RCBD) replicated three times. Each plot consisted of 3 meter long 4 rows spaced 40 cm a part. The size of each plot was 3m x 1.6m ($4.8m^2$) and the adjacent blocks and plots were separated by 1m and 0.6m distances, respectively. The net central unit area of each plot consisted of 2 rows for sample measurements, leaving aside plants in the two outer rows and those at both ends of each of the rows to avoid border effects. The distance between plants was 10cm. The recommended seed rate of 125 kg ha^{-1} and 100 kg ha^{-1} NPS fertilizer was uniformly supplied for each treatment at planting.

Partial Budget Analysis

The partial budget analysis was done using CIMMYT (1998) to identify the rewarding treatments. Actual yields from experimental plots were adjusted down ward by 10% to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment. This is due to optimum plant population density, timely labor availability and better management in weed control and better security under experimental conditions (CIMMYT.1998). To find out the gross return the price of faba bean (sale price of 12.50 Birr kg^{-1}) prevailing in the local market at the time of harvest which is the average of one month was taken into account. Similarly, the variable costs that vary included the cost of labor for hoeing and hand weeding frequencies were; hoeing at 7, 14, 21 and 28 DAE was valued as 1800, 2100, 2400 and 2700 Birr ha^{-1} respectively. On the other hand, once hand weeding at 25-30 DAE and 40-45 DAE which followed hoeing was 1800 and 2100 Birr ha^{-1} respectively. The two times hand weeding followed hoeing and once hand weeding was 1500 Birr $ha^{-1}$and weed removal at 50% pod setting stage was 2700 Birr ha^{-1}. Two times hand weeding (at 25-30 and 40-45 DAE) without hoeing was 2400 and 2100 Birr ha^{-1} respectively.

Data Collection

Data were collected on: Days to flower, days to maturity, plant height, number of pods per plant, number of seeds per pod, aboveground biomass yield (kg ha^{-1}), seed yield (kg ha^{-1}) and 1000 seed weight in gram were recorded from each net plot. Thus, Days to flower was determined by counting the number of days from the date of emergency to the period when 50% of the plants had flower based on visual observations. Days to maturity was determined by counting the number of days from the date of emergency to the period when 90% of the plants had reached the physiological maturity based on visual observations. Plant height (cm) was measured in meter from five randomly selected plants in each net plot area from the base to the tip (apical bud) of the main stem at physiological maturity. Number of pods per plant was determined by counting the number of pods from each randomly selected non-border five plants and the average count was taken as number of pods per plant. Number of seeds per pod was determined by dividing the total number of seeds from five randomly selected non-border plants by the total number of pods from each selected five plants. Aboveground dry biomass yield (kg ha^{-1}) were determined as; at physiological maturity, plants from the central four rows of a net plot size 1.6m x3m (4.8m^2) were manually harvested close to ground surface using sickle. Then the harvested plants were sun dried in open air and then weighed to determine the aboveground biomass yield per hectare. Seed yield (kg ha^{-1}) was measured after threshing the sun dried plants harvested from each net plot size 4.8m^2 and the cleaned seed yield was weighted using an electronic balance and adjusted at 10.5% seed moister content. Finally, yield per plot was converted to per hectare basis. 1000 seed weight (g): was determined by counting 1000 seeds randomly sampled from seed lots of each treatment and weighted using an electronic balance.

Data Analysis

All the collected data were analyzed using SAS statistical software version 9.1.3 (2009). The treatments were compared for their significance using calculated least significance difference (LSD) values at 5% level of probability.

Result and Discussion

In 2015/16 cropping season, the experiment was conducted at Sinana experimental station and on-farm and all the required field data were collected. Even though the experiment was repeated at the same locations in the second year (2016/17), the on-farm trial was totally failed due to frost damage occurred before the time of maturity stage. Therefore, the current report was summarized from the two years data of Sinana research station and one year data from farmer's field.

Table 1 and 2 showed that weed management practices had significant effect on all considered parameters at both locations except number of seeds per pod at on-station and plant height, number of pods per plant and 1000 seed weight at on farmer's field. The result indicated that hoeing either at 7 DAE and then hand weeding at 25-30 and 40-45 DAE or hoeing at 7 DAE and then hand weeding at 25-30 DAE at on-station flowered late compared to other treatments. On the other hand, hoeing at 7 DAE and followed by hand weeding at 40-45 DAE and hoeing at 14 DAE and then hand weeding at 25-30 and then 40-45 DAE at on-farm flowered lately compared to the other treatments. While weedy check plots were flowered early at both locations. This may be due to resource competition caused narrow leaf which fix low amount of nitrogen and less translocation of photosynthates from source to sink which resulted in late flower formation. Regarding maturity period at both locations,, hoeing at 28 DAE with hand weeding at 40-45 DAE matured lately as compared to weedy check and weed harvesting at 50% pod setting stage. This implies that the presences of weeds in the faba bean field might cause severe resource competition with the crop that may leads to forced maturity.

The highest in plant height (114.3 cm) and number of pods per plant (13.9) at on-station were recorded when hoeing at 7 DAE and hand weeding at 40-45 DAE and followed by hoeing at 7 DAE and hand weeding at 25-30 and then at 40-45 DAE, respectively. This may be early weed removal facilitates plants to have more resources for growth. These results agreed with Ahmed *et al*. (2011) and Bedry (2007), they found that twice hand weeding increased these parameters while unweeded treatment had poor yield. Similarly, number of seeds per pod was significantly influenced by weed management at on-farm while no significant variation was observed at on-station. The highest number of seeds (2.9) was recorded by hoeing at 21 DAE and hand weeding at 40-45 DAE. This result was in line with Amaregouda *et al*. (2016) reported the highest number of seeds per pod under weed free treatment while; the lowest was obtained under weed infested treatment.

At Sinana on-station, different weed management practices significantly affected the biomass yield, seed yield and 1000 seed weight. The highest biomass yield (9653 kg/ha) and grain yield (4068.8 kg/ha) were obtained by hoeing at 7 DAE plus hand weeding at 25-30 and then at 40-45 DAE. The next highest biomass (8125 kg/ha) and grain yield (3768.8 kg/ha) were obtained when hoeing at 7 DAE plus hand weeding at 25-30 DAE were practiced. Hoeing at early growth stage (7 DAE) in combination with hand weeding at 25-30 DAE and then at 40-45 DAE had showed significant biomass and grain yield increase by 20% and 17%, respectively, compared to hand weeding practices at 25-30 DAE and then 40-45 DAE (Table 1). This result implies that in addition to early established weed control, hoeing at early growth stage may improve soil aeration that could help for effective microbial activities, particularly for biological nitrogen fixation and hence N availability to the crop might be improved. However, hoeing at or after 14 DAE and even with two times hand weeding at 25-30 DAE and 40-45 DAE considerably reduced grain yield by not less than 31% as compared to hoeing at 7 DAE plus two times hand weeding (25-30 and 40-45 DAE). The yield reduction could be varied from 13-31% when hoeing at or after 14 DAE in combination with different hand weeding frequencies at different crop growth stage. This result clearly revealed that hoeing at early stage is a determinant effect on the yield performance of the crop in Sinana and similar agro-ecological areas. However, the lowest biomass (3993 kg/ha) and seed yield (1990 kg/ha) were obtained under weedy check and followed by weed harvesting at pod setting stage.

Weed harvesting at pod setting stage significantly affected yield and about 47% and 51% grain yield reduction were observed compared to hoeing at 7 DAE plus hand weeding at 25-30 DAE and hoeing at 7 DAE plus hand weeding at 25-30 DAE and then 40-45 DAE, respectively. This indicate that faba bean production without weeding until pod setting stage significantly affected yield performance although farmers use the weed as animal feeds when the feed shortage is critical. Similar to this finding, Saad.(2003) and Sharara *et al*. (2005); reported that faba bean hand hoeing resulted in a good control of weed.

At Sinana on-farm, various cultural weed management practices had significantly ($P \leq 0.05$) influenced biomass yield. The maximum biomass yield (11667 kg ha^{-1}) was obtained under hoeing at 14 DAE plus one hand weeding at 25-30 and then at 40-45 DAE but, statistically in par with most treatments. Whereas, the lowest value was recorded under weedy check (7431 kg ha^{-1}) followed by weed removal at pod setting stage (8472 kg ha^{-1}). The higher biomass yield under intensive weed management practices might be due to the effect of weed control from the early establishment of the crop by hoeing and then hand weeding that significantly reduced the completion effect.

Moreover, plants under weed free environment might be obtained efficient resource utilization, better translocation of water and nutrients, and more number of nodules per plant which fix more amount of atmospheric nitrogen and supplied to the vegetative parts or sink resulting in higher production of above ground biomass yield. In agreement with this result, Getachew *et al*.(2017), reported the highest biomass yield were obtained at one hand weeding plus hoeing at 4 weeks after crop emergency which was non-significantly different from one hand weeding plus hoeing at 3 weeks after emergency, and complete weed free treatments. They further reason out that it might be due to better condition in soil rhizosphere which improved the competitive ability of the crop and favored more vegetative growth. Moreover, Mizan *et al.* (2009); reported the increased biomass yield of the crop was highly governed by the length of weed free period.

Concerning the seed yield (kg ha^{-1}), all treatment means, except weedy check, were statistically similar yield responses under various cultural weed management practices. Hoeing plus different weeding frequencies statistically showed similar yield responses compared to only two times hand weeding (25-30 DAE and 40-45 DAE) and even weed harvesting at pod setting stage. Even though yield performance was not significantly different, a 17% numerical yield reduction could be occurred when weed harvesting at pod setting stage was practiced as compared with hoeing at 28 DAE and then one hand weeding at 40-45 DAE and two times hand weeding (25-30 DAE and 40-45 DAE). This result, indicated that weed pressure at early crop establishment were low as compared to Sinana on-station. Since, at Sinana on-station early weed management practices resulted in positive yield response as compared to on-farm which respond to late weed management like hoeing at 28 DAE and then at 40-45 DAE and two times hand weeding at 25-30 DAE and then 40-45 DAE. From these two contrasting result it was observed that the variation was might be variation in moisture availability or rainfall distribution happened during the experimental season. Thus, during the experimental season at planting time, high amount of rainfall distribution was observed at Sinana on-station not for less than two weeks as compared to on-farm. However, enough moisture was observed at on-farm at crop maturity stage than on-station though, separate meteorological data was not available. Therefore, from Sinana on-farm data, it was observed that the highest seed yield was recorded when hoeing at 14 DAE plus one hand weeding at 40-45 DAE and two times hand weeding at 25-30 DAE and then 40-45 DAE followed by hoeing at 7 DAE plus one hand weeding 40-45 DAE. The result also showed yield reduction of about 35% was observed when faba bean was unweeded completely as compared to hoeing at 28 DAE and then one hand weeding at 40-45 DAE and two times hand weeding at 25-30 DAE and then at 40-45 DAE.

Table.1. Effect of weed management practices on faba bean growth, yield and yield components at Sinana research station during 2015 and 2016 main cropping season

Treatments	DF	DM	PH (cm)	PPP	SPP	BY (kg/ha)	SY (kg/ha)	TSW (g)
1	55^{c}	127^{ab}	98.7^{c}	7.4^{c}	2.4	3993^{d}	1990.2^{d}	483^{bcd}
2	55^{c}	128^{a}	98.7^{c}	12.7^{ab}	2.3	7708^{abc}	3387.8^{abc}	488^{bcd}
3	57^{a}	128^{a}	103.1^{abc}	13.9^{a}	2.1	9653^{a}	4068.8^{a}	476^{bcd}
4	57^{a}	128^{a}	104.2^{abc}	11.7^{abc}	2.2	8125^{ab}	3768.8^{ab}	463^{d}
5	56^{abc}	113^{b}	114.3^{a}	12.1^{ab}	2.6	7465^{abc}	3557.9^{abc}	505^{ab}
6	56^{abc}	129^{a}	98.9^{c}	11.6^{abc}	2.4	6528c	2803.7^{bcd}	485^{bcd}
7	56^{abc}	128^{a}	105.2^{abc}	12.9^{ab}	2.5	8021^{abc}	3517.1^{abc}	467^{cd}
8	56^{abc}	128^{a}	111.7^{ab}	12^{ab}	2.3	5868^{cd}	2635.8^{cd}	500^{abc}
9	55^{c}	128^{a}	100.9^{bc}	12.3^{ab}	2.5	6493^{bc}	2988.5^{a-d}	493^{a-d}
10	55^{c}	130^{a}	101.2^{bc}	11.8^{abc}	2.4	7292^{bc}	3229.0^{abc}	527^{a}
11	55^{c}	127^{ab}	100.3^{bc}	9.2^{bc}	2.3	4167^{d}	1992.3^{d}	493^{a-d}
Mean	55.7	127	103.4	11.6	2.4	6846.6	3085.44	489.09
LSD (5%)	1.51	15.04	12.238	4.54	Ns	2252.4	1125.7	35.52

CV (%)	2.33	10.26	10.22	33.76	17.1	28.39	31.49	6.27

Key: Means with the same letters are non-significant, DF= Days to flowering, DM= Days to maturity, PH= Plant height, PPP= Pods per plants, BY= Biomass yield, SY =seed Yield, TSW= Thousand seed weight, CV= Coefficient of variation, LSD= Least significant difference.

Table.2. Effect of weed management practices on faba bean growth, yield and yield components at Sinana on-farm during 2015 main cropping season

Treatments	DF	DM	PH (cm)	PPP	SPP	BY (kg/ha)	SY (kg/ha)	TSW (g)
1	63^{d}	132^{b}	132	13	2.3^{ab}	7431^{d}	2349^{b}	496
2	64^{cd}	134^{ab}	137	19	2.6^{ab}	10417^{abc}	3616^{a}	496
3	64^{cd}	135^{ab}	131	14	2.6^{ab}	10764^{ab}	3577^{a}	484
4	65^{ab}	134^{ab}	132	15	2.5^{ab}	10764^{ab}	3392^{a}	489
5	66^{a}	135^{ab}	135	15	2.7^{ab}	9375^{bcd}	3262^{a}	493
6	66^{a}	135^{ab}	134	17	2.7^{ab}	11667^{a}	3338^{a}	459
7	64^{cd}	134^{ab}	135	18	2.2^{b}	10139^{abc}	3231^{a}	451
8	65^{ab}	135^{ab}	135	17	2.4^{ab}	10972^{ab}	3422^{a}	493
9	64^{cd}	134^{ab}	132	14	2.9^{a}	10347^{abc}	3212^{a}	465
10	65^{ab}	136^{a}	133	20	2.4^{ab}	10139^{abc}	3621^{a}	498
11	65^{ab}	132^{b}	129	16	2.5^{ab}	8472^{cd}	2987^{ab}	474
Mean	64.6	134.2	133	16.2	2.5	10044.3	3273.4	482
LSD (5%)	1.66	3.70	ns	ns	0.65	2047.9	706.51	ns
CV (%)	1.51	1.62	4.91	24.1	15.1	11.97	12.67	6.95

Key: Means with the same letters are non-significant, DF= Days to flowering, DM= Days to maturity, PH= Plant height, PPP= Pods per plants, BY= Biomass yield, SY =seed Yield, TSW= Thousand seed weight, CV= Coefficient of variation, LSD= Least significant difference

Economic analysis of different weed management options revealed that weed control in faba bean by the use of hoeing plus hand weeding frequencies gave different economic return as compared to weedy check, weed removal at 50% pod setting stage and hand weeding frequency (Table 3 and 4). Thus, hoeing at 7 DAE plus two times hand weeding at 25-30 and then at 40-45 DAE and two times hand weeding at 25-30 and then 40-45 DAE gave the highest net benefit (40674.00 and 36180.00 birr) followed by hoeing at 7 DAE plus hand weeding at 25-30 DAE and hoeing at 28 DAE plus hand weeding at 40-45 DAE with net benefits of (38799.00 and 35936.25 birr) from on-station and on-farm respectively. However, the maximum marginal rate of return (455.8 and 406.2%) was recorded for hoeing at 7 DAE plus hand weeding at 25-30 DAE at both locations and showed that it was an economical for weed management option in faba bean production. Thus, it was concluded that the use of weed management options as of hoeing at 7 DAE plus hand weeding at 25-30 DAE was more economical than other weed management options designed in this study.

Conclusion and Recommendation

Weed pressure is the main driver factors that influence the production and productivity of faba bean. Even though integrated weed management approaches is the best option for effective and sustainable weed control, cultural practice is one of the best strategy for the control of weed, particularly in areas where access to post or pre-emergence herbicide is very limited. Among different cultural practices, hoeing and hand weeding are some of them. The result of this experiment, which focused on different cultural practices, revealed that hoeing at 7 DAE plus two times hand weeding (25-30 DAE and then at 40-45 DAE) at on-station and hoeing at 28 DAE plus once hand weeding at 40-45 DAE and twice hand weeding at 25-30 DAE and the at 40-45 DAE performed the best yield advantage compared to other treatments (Table 1 and 2). However, hoeing at 7 DAE plus once hand weeding at 25-30 DAE at both locations showed economically an optimum and more than minimum acceptable MRR (456% and 406%) and hence advisable for weed control in areas where the weed pressure under different crop stage is very high. In the other hand, even though some farmers in the study areas practiced weed harvesting at pod setting stage for the purpose of animal feeds when the feed shortage is critical, significant yield losses were observed and hence not advisable for faba bean production.

Table 3.Economic and Marginal Analysis of Weed Control Practices at Sinana Research Station, Highlands of Bale, during 2015 and 2016 Main Cropping Seasons

Treatments	Yield (kg/ha)	AdY (kg/ha)	GI (Birr)	VC (Birr)	NB (Birr)	*MRR* (%)
Weedy check	1990.2	1791.2	22389.75	0	22389.75	---
HW at 25-30 & 40-45 DAE	3387.8	3049.0	38112.75	4500	33612.75	D
Hoeing at 7 DAE+HW at 25-30 & 40-45 DAE	4068.8	3661.9	45774.00	5100	40674.00	125
Hoeing at 7 DAE + HW at 25-30 DAE	3768.8	3391.9	42399.00	3600	38799.00	456
Hoeing at 7 DAE + HW at 40-45 DAE	3557.9	3202.1	40026.38	3900	36126.38	D
Hoeing at 14 DAE+HW at 25-30 & 40-45 DAE	2803.7	2523.3	31541.63	5400	26141.63	D
Hoeing at 14 DAE + HW at 25-30 DAE	3517.1	3165.4	39567.38	3900	35667.38	D
Hoeing at 14 DAE + HW at 40-45 DAE	2635.8	2372.2	29652.75	4200	25452.75	D
Hoeing at 21 DAE + HW at 40-45 DAE	2988.5	2689.6	33620.63	4500	29120.63	D
Hoeing at 28 DAE + HW at 40-45 DAE	3229.0	2906.1	36326.25	4800	31526.25	D
Weed Removal at 50% Pod setting stage	1992.3	1793.1	22413.38	2700	20613.38	D

Table 4.Economic and Marginal Analysis of Weed Control Practices at Sinana On-farm, Highlands of Bale during, 2015 Main Cropping Season

Treatments	GY(kg/ha)		GI(ETB)	VC (ETB)	NB (ETB)	MRR (%)
Weedy check	2349	2114.1	26426.3	0	26426	-
Weed Removal at 50% Pod setting stage	2987	2688.3	33603.8	2700	30904	166
Hoeing at 7 DAE + HW at 25-30 DAE	3392	3052.8	38160	3600	34560	406
Hoeing at 7 DAE + HW at 40-45 DAE	3262	2935.8	36697.5	3900	32798	D
Hoeing at 14 DAE + HW at 25-30 DAE	3231	2907.9	36348.8	3900	32449	D
Hoeing at 14 DAE + HW at 40-45 DAE	3422	3079.8	38497.5	4200	34298	D
HW at 25-30 & 40-45 DAE	3616	3254.4	40680	4500	36180	180
Hoeing at 21 DAE + HW at 40-45 DAE	3212	2890.8	36135	4500	31635	D
Hoeing at 28 DAE + HW at 40-45 DAE	3621	3258.9	40736.3	4800	35936	D
Hoeing at 7 DAE + HW at 25-30 & 40-45	3577	3219.3	40241.3	5100	35141	D
Hoeing at 14 DAE + HW at 25-30 & 40-45	3338	3004.2	37552.5	5400	32153	D

HW = Hand weeding, DAE = Days after emergency, AdY = Adjusted yield, GI = Gross income, VC = Variable cost, NB = Net benefit, MRR = Marginal rate of return, D = Dominated

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The Effect of Pre-emergence Herbicide (dual gold) and Hand Weeding Frequencies on Growth, Yield and Yield components of faba bean in Bale highlands

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Abstract

This experiment was conducted at Sinana on-station and Agarfa sub-site during 2015 and 2016 "*Bona"* cropping seasons to evaluate the effect of pre-emergence herbicide (dual gold 960 EC) and hand weeding frequencies on yield and major yield components of faba bean. The treatments consisted of five weed control methods: Weedy check, Two times hand weeding at 25-30 and 40-45 days after emergence (DAE), Sole dual gold, Dual gold + once hand weeding at 25-30 DAE, and Dual gold + two times hand weeding at 25-30 and 40-45 DAE. It was laid out in a randomized complete block design (RCBD) with three replications. Results indicated that number of pods plant^{-1}, total biomass and seed yield kg ha^{-1} and 1000 seeds weight were significantly influenced by different weed management options. The highest values for those parameters were obtained when dual gold at the rate of 1.5Lha^{-1} plus once and twice hand weeding and two times hand weeding while the lowest was recorded by weedy check and sole dual gold application. The result showed that more than 38%, 27% and 33% yield advantages were obtained when dual gold application in combination with one and two times hand weeding and only two times hand weeding was used respectively. Moreover, more than 7% yield advantage was obtained when dual gold plus two times hand weeding were practiced as compared to only two times hand weeding. The result of marginal rate of return analysis indicated that the highest net return was obtained from dual gold application at the rate of 1.5 Lha^{-1} plus two times hand weeding. Therefore, it was concluded that dual gold was used as a supplemental herbicide to control weeds from faba bean field in combination with hand weeding and also economically profitable to use. However, it was needed to find out another pre or post-emergency herbicide which control weeds without supplementing of hand weeding.

Key words: Faba bean, Dual gold, Days after emergency, Hand weeding

Introduction

Faba bean (*vicia faba* L.) is one of the most important legume crops world wide since it is nitrogen fixing leguminous plant, offering highquality protein, capable of returning atmospheric nitrogen to the soil (Amin, 1988). Faba bean is one of the greatest production areas among major pulse crops grown in Ethiopia (CSA, 2012).. However, its productivity is very low compared to its potential productivity (1.3 ton ha^{-1} compared to 1.8 ton ha^{-1} of world average) (FAOSTAT, 2010). One of the main factors that attribute to low productivity is abiotic factors, of which poor weed control option is the most important one that influence its production and productivity.

Weeds are a challenging problem to pulse crop in general and to faba bean production in particular. Faba bean is a very sensitive crop to the competition of both broadleaf and grass weed species (Getachew and Rezene, 2006). In line with this, Fessehaie (1994) reported that faba bean suffered a significant yield loss of about 24% due to weed competition. Since the crop is highly sensitive to weed competition from the early establishment to the early flowering stage, it requires weed control during these critical period. Research finding reported by Getachew and Rezene (2006).at Holeta area showed that, different weed control options significantly affected plant height, number of pods per plant and seeds per pod.

Bale highland is a wheat belt area where many alternative choices of herbicides to control weeds and mechanization for postharvest handling of the cereal crops were available However, hand weeding is the only option to control weeds from faba bean fields due to unavailability of pre and/or post emergence herbicides to control weeds in the area. But, dual-gold 960 E C is one of the pre-emergency herbicide which is available to kill both grassy and broadleaf weeds at the early and later growth stage of the crop to reduce yield loss. On the other hand, integrated weed management approaches, like pre-emergence application combined with hand weeding practices can be the best options for sustainable weed management practices. However, in the study area, no work has been done, particulary on the effect of the application of dual gold for the control of weed problem in faba bean. Therefore, the present study was designed to evaluate the effect of pre-emergence herbicide (dual gold) application and hand weeding frequencies on yield and yield components of faba bean and to see the economic feasibility of this herbicide.

Materials and Methods

Description of the study areas

The experiment was conducted under rain-fed conditions at Sinana on-station and Agarfa sub-site during 2015 and 2016 main cropping seasons. Sinana is located at a distance of about 463 km from Addis Ababa in the South-Eastern direction in the highlands of Bale Zone, South-eastern Oromia, and33 km East of Robe town, the capital of the Bale Zone. It is located at $7^0$7'N longitude and $40^0$10'E latitude, at an elevation of 2400 meters above sea level. On the other hand, Agarfa is located at a distance of about 460 km from Addis Ababa in the South-eastern direction situated in the highlands of Bale zone, South-eastern Oromia. It is situated at 38^0 40'to $46^0$3' East longitude and 4^0 to 8^0 11' N latitude at 2350 meters above sea level. The soils of the areas are characterized by Cambisol at Sinana and *Vertisol* at Agarfa. The preceding crop planted in experimental sites was bread wheat which is the precursor of the current faba bean.

Experimental Treatments and Design

For this experiment, faba bean variety called 'Mosisa', which was released from Sinana agricultural research center, was used as a test crop. The treatments consisted of five weed management options: Weedy check, two times hand weeding at 25-30 days after emergence (DAE) and 40-45 DAE, sole pre-emergence herbicide (dual gold 960 EC) application, dual gold + one times hand weeding at 25-30 DAE, dual gold + two times hand weeding at 25-30 DAE and 40-45 DAE. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The size of each plot was 3 m x 2.4 m (7.2 m^2) and distances between the plots and blocks were 0.6 m and 1.5 m, respectively. The distance between rows and plants were 40 and 10 cm respectively. Pre-emergence herbicide Dual gold 960 EC at the rate of 1.5 lit ha^{-1} with 200 lit ha^{-1} of water was applied at the third date of planting. The crop was planted at the recommended seed rate of 125 kg ha^{-1} and 100 kg ha^{-1} NPS fertilizer (19% N, 38% P and 7% S) was uniformly supplied for each treatment at planting.

Partial Budget Analysis

To evaluate the economic benefits of shift in practice, partial budget analysis was done to identify the rewarding treatments according to CIMMYT (1998). Actual yields from experimental plots were adjusted down ward by 10% to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment. This is due to optimum plant population density, timely labor availability and better management (e.g. weed control, better security) under experimental conditions (CIMMYT.1998). To find out the gross return, the price of faba bean (sale price of 12.50 Birr kg^{-1}) prevailing in the local market at the time of harvest which is the average of one month was taken into account. Similarly, the variable cost that vary included were the cost of input, the field price of Dual gold herbicide during planting time which is 450 Birr lit^{-1} (the herbicide cost plus the cost of transportation from the point of sale to the farm) and labor cost for its application 1-3 days after planting was 50 Birr ha^{-1}. On the other hand, labor cost for integrated use of herbicide and hand weeding frequencies were; one and two times hand weeding which followed dual gold application and one times hand weeding were valued as 2100 and 1500 Birr ha^{-1} respectively. In similar manner, the only two times hand weeding treatment of the first hand weeding (25-30 DAE) was 2700 Birr ha^{-1} due to weed pressure was high in the absence of herbicide in the early growth stage of the crop. All costs and benefits were calculated on hectar basis in Ethiopian Birr.

Data Collection

Data were collected on days to flowering, days to maturity, plant height, number of pods per plant, number of seeds per pod, biomass and seed yield (kg/ha) and 1000 seed weight(g) from each net plot. Days to flower were determined by counting the number of days from the date of planting to the period when 50% of the plants had flower based on visual observations. Days to maturity were determined by counting the number of days from the date of planting to the period when 90% of the plants had reached the physiological maturity based on visual observations. Plant height (cm) was recorded by measuring from the base of the plant to the tip of the plant panicle by taking five plants from each plot at mature stage. Number of pods per plant were determined by counting the pods from each selected five plant and the average count was taken and reported as number of pods per plant. Number of seeds per pod were determined by dividing the total number of seeds from five randomly selected non-border plant by the total number of pods from each selected five plants. Above ground biomass yield (kg ha^{-1}) were determined as; at physiological maturity, plants from the central four rows of a net plot size of 1.6 m x3m (4.8m^2) were manually harvested close to the ground surface using a sickle. The harvested plants were sun-dried in the open air and weighed to determine the above ground biomass yield. Seed yield was measured from the harvested central unit area of 4.8 m^2 and then seeds were cleaned following harvesting and threshing, weighted using an electronic balance and adjusted to 10.5% moisture content. Finally, yield per plot was converted to per hectare basis.1000 Seed Weight (g) was determined based on the weight of 1000 seeds randomly sampled from the seed lots of each treatment by counting using an electric seed counter and weighing by an electronic balance.

Data Analysis

All the agronomic data collected were analyzed using SAS statistical software version 9.1.3 (2009). The treatments were compared for their significance using calculated least significance difference (LSD) values at 5% level of probability.

Result and Discussion

Flowering and maturity date

Analysis of variance showed flowering and maturity date of faba bean was not significantly influenced by the different weed management options (Table 1). The result indicated that though the variation was non-significant, weedy check treatment flower and mature early as compared to the other intensive weed management treatments. This might be due to weed competition effect for resources which caused forced phonological growth of the crop.

Plant height

Plant height was not significantly influenced by the different weed management methods. Though it was statistically non-significant; the highest values were obtained under intensive weed management methods (dual gold application plus one and two times hand weeding). While the shortest plant height was recorded for only dual gold applied treatments. In agreement with this result, Sadegh *et al.* (2013) reported that the highest plant height was recorded at Bentazon + once hand weeding and the lowest at control treatment in red bean (*phaseolus calcaratus* L). Similarly, Kavurmaci *et al*. (2010) also reported that, the tallest plant was obtained in weed free treatment while the shortest plant was observed from control treatment. In contrary, Getachew *et al.* (2017) reported that the highest plant height was obtained in weedy check plot than intensive weed controlled plots. They pointed out that, weed infested plot compete for resources especially for light throughout the season which resulted in enhanced plant height in weedy check.

Number of pods per plant

Analysis of variance revealed that the highest number of pods per plant (12.3) were recorded by applying dual gold plus one times hand weeding at 25-30 DAE though it was statistically at par with other treatments except under use of only dual gold application. The highest number of pods per plant under integrated use of herbicide plus hand weeding might be due to integrated role of herbicide and hand weeding in weed control. Thus, application of a suitable herbicide at the early growth stages controls weeds efficiently and hand weeding removed late comer weeds which makes crop the winner of competition which resulted in formation of more number of pods per plant. Similar result was reported by Sadegh *et al* (2013), who explains the integrated role of both herbicide and hand weeding in weed control.

Number of seeds per pod

The different weed control options had showed non-significant effect on number of seeds per pod of faba bean. These results are in line with Getachew and Mekdes (2016) who observed the different weed management practices (different herbicides, herbicide plus hand weeding at different week interval after emergency) did not show significant influence on number of seeds per pod of cowpea. However, contrary to the current result, Amaregouda *et al*. (2016)

reported the highest number of seeds per pod under weed free treatment. While the lowest was obtained under weed infested treatment. This might be attributed to effective control of weeds during the early stages of crop growth and helped in better development of infrastructure of the plant. Due to less competition for nutrients, radiation and water from weeds facilitated for the better growth and development of the crop.

Above ground biomass yield (kg/ha)

The results for the above ground biomass yield indicated significant difference among the treatments (Table 1). The highest biomass yield per hectare was obtained when dual gold application plus two times hand weeding and use of only two times hand weeding followed by dual gold plus one times hand weeding. Whereas, the lowest biomass yield was recorded under sole use of dual gold application and weedy check. The maximum biomass yield under intensive weed management might be due to the effect of weed control from the early establishment of the crop through use of herbicide and hand weeding that significantly reduced the completion effect. Moreover, under weed free conditions, there was efficient resource utilization and translocation, and more number of nodules per plant which fix atmospheric nitrogen and supplied to the vegetative part which resulted in more production above ground biomass yield.

Seed yield (kg/ha)

On the other hand, the highest biomass and seed yield per hectare were recorded when dual gold application plus two times hand weeding and use of only two times hand weeding followed by dual gold plus one times hand weeding, but all are statistically at par. The lowest biomass and seed yield were, however, recorded under sole use of dual gold application and weedy check. The current result clearly revealed that more than 38% and 33% yield advantages could be obtained when dual gold application in combination with two times hand weeding and only two times hand weeding were applied followed by (27%) dual gold application in combination with one times hand weeding. Even though statistically not significant, more than 7% yield advantage could be obtained when both pre-emergence herbicide and two times hand weeding were practiced as compared to only two times hand weeding. This yield increment might be due to the effect of pre-emergence herbicide that considerably control the weed infestation, particularly at the early establishment of the crop that significantly reduce the competition. Hence, application of dual gold 1-3 days after planting of the crop is very crucial to control early weed emergence. However, at least one time hand weeding at a later stage is the most important practices as it was significantly increased the yield performance of the crop compared to weedy check. In agreement with this result, Diwash *et al*, (2014) reported that combined use of herbicide plus hand weeding resulted in significantly higher seed yield of green gram.

1000 seed weight (g)

Contrary to the yield response, the highest 1000 seed weight (500.1g) was recorded when sole application of dual gold and followed by only two times hand weeding and weedy check, but all means showed statistical parity. However, the lowest values (461 and 471.3 g) were scored by application of dual gold plus hand weeding at 25-30 DAE and two times hand weeding at 25-30 and 40-45 DAE, respectively. This result indicated that 1000 seed weight was inversely correlated with a number of pods plant^{-1}. This implies that as number of pods per plant increase, there was more number of seeds per plant observed in which there is severe resource competition between seeds. As a result, low 1000 seeds weight was recorded.

Table 1.Effect of Pre-emergency Herbicide (Dual-gold) on Faba Bean Growth, Yield and Components of Yield at Sinana and Agarfa, in 2015 and 2016 Cropping Seasons

Treatments*	DF	DM	PH (cm)	PPP	SPP	BY (kg/ha)	SY (kg/ha)	TSW (g)
Weedy check	61	121	101.9	9.8^{ab}	2.4	6305.0^{b}	2058.6^{b}	481.9^{ab}
Dual gold application	62	122	99.6	9.2^{b}	2.3	7225.1^{b}	2201.5^{b}	500.1^{a}
Dual gold + Hand weeded (1x)	63	125	107.0	12.3^{a}	2.1	9030.7^{a}	2808.2^{ab}	461.0^{b}
Dual gold + Hand weeded (2x)	63	124	104.6	10.6^{ab}	2.4	9539.9^{a}	3309.2^{a}	471.3^{b}
Hand weeded (2x)	62	123	101.7	10.0^{ab}	2.5	9308.4^{a}	3084.2^{a}	479.1^{ab}
Mean	62	123	103	10.4	2.3	8281.8	2692.3	478.7

LSD (5%)	Ns	Ns	Ns	2.50	Ns	1461.4	757.83	24.25
CV (%)	4.92	4.42	13.69	29.42	19.75	14.74	34.34	6.18

Key: Means followed by same letter(s) are not significantly different at 5% probability levels following LSD, LSD = Least Significant Difference, CV = Coefficient of variation, ns = Non-significant, DF = Days to flowering, DM = Days to Maturity, PH = Plant Height, PPP = Number of pod per plant, SPP = Number of Seed per pod, BY = Biomass Yield, SY = Seed Yield, TSW = Thousand Seed Weight.

Economic analysis

The Partial budget analysis for different weed control options in faba bean production revealed that the use of pre-emergency herbicide (Dual gold 960 EC) combined with different hand weeding frequencies gave a different economic return as compared to weedy check, and either use of only pre-emergency herbicide or hand weeding alone (Table 2). Thus, application of Dual gold at the rate of 1.5 lit ha^{-1} plus two times hand weeding at 25-30 and 40-45 DAE gave the highest net benefit (32603.5 Birr) and marginal rate of return (575%). Alternatively, application of dual gold combined with one time hand weeding is economically better than two times hand weeding alone, particularly at critical labor competition for other farming activities, since its MRR is greater implying that more return could be obtained as per unit cost investment required to control the weed using dual gold application plus one time hand weeding. This implies that uses of pre-emergence herbicide as supplemental weed control options are very optimal in addition to hand weeding at the later stage.

In agreement with this result, Sadegh *et al.* (2013) reported that the maximum grain yield of red bean was achieved in application of herbicide plus once hand weeding treatment. This might be herbicide alone or hand weeding control methods were less effective in reducing the number of weeds per unit area than using both chemical and hand weeding control methods. Therefore, it can be concluded that the use of Dual gold (960 EC) application at 1-3 days after planting in combination with two times hand weeding at 25-30 and 40-45 DAE could be used as the best weed management options for faba bean production. Alternatively, combined use of dual gold plus one time hand weeding at a later stage could also be advisable for the control of weed in areas where labor competition is very high at critical period of time that need more labor for other farming activities. In line with this result, Diwash *et al* (2014) indicated that maximum net return and cost-benefit ratio were obtained from use of herbicide though the hand-weeding significantly reduce weed biomass and improved the grain yield but gave less benefit: cost ratio owing to higher cost of farm labor.

Table 2.Economic and Marginal Analysis of Weed Control Practices at Sinana and Agarfa, Highlands of Bale, 2015 and 2016 cropping seasons

Treatments	Yield (kg/ha)	AdY (kg/ha)	GI (Birr)	VC (Birr)	NB (Birr)	MRR (%)	Residual
Weedy check	2058.6	1852.74	23159.25	-----	23159.25	----	23159.25
Dual gold application	2201.5	1981.35	24766.88	725	24041.88	122.0	23316.88
Dual gold + Hand weeded (1x)	2808.2	2527.38	31592.25	2,825	28767.25	225.0	25942.25
Hand weeded (2x)	3084.2	2775.78	34697.25	4250	30447.25	118.0	26197.25
Dual gold + Hand weeded (2x)	3309.2	2978.28	37228.50	4,625	32603.5	575.0	27978.5

AdY = Adjusted yield, GI = Gross income, VC = Variable cost, NB = Net benefit, MRR = Marginal rate of return,

Conclusion and Recommendation

Weed is the major production constraints, particularly for faba bean production in Bale Highlands, and hence its management is quite paramount important to increase the production and productivity. The result of this experiment revealed that dual gold 960 EC application at the rate of 1.5 L ha^{-1} in combination with two times hand weeding at 25-30 and 40-45 DAE was given the highest yield and economically shown the maximum net benefit. Moreover, the highest marginal rate of return was also obtained from combined uses of dual gold plus two times hand weeding. In addition, application of Dualgold plus one times hand weeding at the later stage could also be used as an alternative weed management in areas where labor competition is very high during critical period.Therefore, integrated uses of pre-emergence herbicide with one or/and two times hand weeding practices can be recommended and advisable to be used by the end users in Bale highland areas. However, further research is required to find out another pre and/or post-emergency herbicide which can control weed problems without supplemental hand weeding practices.

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Adaptation Study of Released Potato (*Solanum tuberosum* L.) Varieties for Mid-altitudes of West and Kelem Wollega Zones

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Abstract

Adaptation trial of improved potato varieties were conducted at mata and Inango sites of Haro Sabu Agricultural Research Centre (HSARC) during the 2015/2016 main planting season with the objective of identifying adaptable, high yielding, insect pest and diseaseresistant/tolerant varieties of potato. Seven improved potato varieties introduced from Sinana and Holeta Agricultural Research Centers and one local check were evaluated using Randomized Complete Block Design (RCBD) with three replications on gross plot size of 4.5 m × 3 m at spacing of 75 cmx30 cm between rows and plant, respectively. Inorganic fertilizer- DAP-195 Kg/ha at planting while UREA-165 Kg/ha in split application (50% at planting and the remaining 50% at pick vegetative stage) were applied. Data were collected on thirteen traits and analysis of variance was done accordingly. The mean square for specific loction indicated significant ($p \leq 0.01$ or 0.05) varietal differences for all observed traits except for number of tuber per hill (NTPH), number of marketable yield per hill (NMYH), weight of marketable yield per hill (WMYH) and number of unmarketable yield per hill (NUMYH) at Mata site; tuber size (TS) and number of unmarketable yield per hill (NUMYH) at Inango site. The highest and significant mean performance of total tuber yield (TTYQt^{-ha}) were obtained from variety Belete followed by Gudane across locations. Gudane and Jalane were the two earlier maturing varieties but Belete, Hunde and Ararsa were late maturing. The disease data indicated that Jalane was significantly affected by bacterial blight but Dagim, Belete, Gudane and Gera showed better resistance/tolerance. Therefore, Belete and Gudane were identified as the best for different merits to be demonstrated and popularized in the study areas and other similar agro-ecologies.

Key words: *Solanum tubersom L., Adaptability, Yield Components*

Background and Justification

Potato *(Solanum tubersom L.)* is one of the most important food crops in developed as well as developing countries. It is an important crop for smallholders in Kenya, Uganda and Ethiopia, serving as both cash and food security crop. Potato is regarded as high-potential food security crop because of its ability to provide a high yield of high-quality product per unit input with a shorter crop cycle. It is considered to be one of the cheapest sources of energy and the production of protein per unit land and it is the highest yielder among the four major food crops (rice, maize, wheat and potato) (CIP and FAO, 1995). In Ethiopia it is the fastest growing staple food crop and source of cash income for smallholders having high potential for food security due to its high yield potential and nutritional quality, short growing period (mostly< 120 days),and wider adaptability (Tewodros et al., 2014).

Irish potato is one of the major root crops produced in Ethiopia next to Taro/Godere and sweet potato. The estimated producers of potatoes in both Belg and Meher season were accounted 3,705,879 smallholders in the country (CSA, 2016). Most highlands with altitudes ranging from 1,500 - 3,000 meters above sea level (m.a.s.l) and annual precipitation of 600 - 1,200 millimeters (mm) are suitable for potato cultivation (FAO, 2010). In west and kellem wollega, farmers produced potato under rain fed, irrigation and residual moisture (bone) to ensure food self-sufficiency and income generation. However, due to lack of improved and adaptable potato varieties, farmers in these areas still use local potato variety which is susceptible to disease and low yield potential. Moreover, farmers are following poor agronomic and postharvest practices. Therefore, adaptation trial was carried out at Seyo and Lalo Asabi sub-sites by collecting different released improved potato varieties from Sinana and Holeta Agricultural Research Centers to identify adaptable and high yielding variety/ies.

Materials and methods

The study was conducted at Mata sub site of Sayo district in Kelem Wollega and Inango sub site of Lalo Asabi district in West Wollega during 2015/16 main cropping season from June to November. These sites are located in western Ethiopia, Oromia Regional state. Seven improved potato varieties introduced from Sinana and Holeta Agricultural Research Centers (Dagim, Belete, Gudane, Hunde, Ararsa, Jalane and Gera) and one Local Check were evaluated using Randomized Complete Block Design (RCBD) with three replications. The gross plot size was 13.5 m^2 (4.5 m × 3 m) arranged in six rows of 75 cm spacing between rows and 30 cm between plants. The net plot size was 3 m × 3 m (9 m^2). A spacing of 1.5 m and 1 m between blocks and plots was maintained, respectively. Inorganic fertilizer DAP-195 Kg/ha at planting while UREA-165 Kg/ha were applied in split (50% at planting and the remaining 50% was applied during earthling-up or hoeing). Field data were collected for thirteen traits and analyzed using SAS statistical package (SAS, 2006 version 9.1.3).

Results and discussions

Analysis of Variance

Analysis of variance at Inango site revealed significant ($p \leq 0.01$ or $p<0.05$) difference for all traits with the exception of TS, NUMY and WUMY which were non-significant. On the other hand, DE, NTPH, NMY, WMY, NUMY, and WUMY showed non-significant difference while the remaining showed significant difference among varieties at Mata (Table 1).

Table 1: Analysis of Variance (ANOVA) of potato adaptation trial

SV	DF	Mean square											
		DE		DM		SCAH		NMS		TS		NTPH	
		Inango	Mata	Inango	Mata	Inango	Mata	Inango	Mata	Inango	Mata	Inango	Mata
Replication	2	1.04	0.17	7.29	9.04*	36.17	21.38	11.38*	11.38*	0.53	0.51	0.67	4.88
Variety	7	7.90*	3.23	134.23**	163.12**	114.19*	83.04*	26.99**	26.99**	0.56	0.69*	16.19*	9.71
Error	14	0.8	2.07	1.91	2.14	18.26	8.47	2.42	2.42	0.34	0.22	3.38	7.59

Table 1: (Continued)

SV	DF	Mean square									
		NMY		WMY		NUMY		TTY(Qt$^{-ha)}$		DR	
		Inango	Mata	Inango	Mata	Inango	Mata	Inango	Mata	Inango	Mata
Replication	2	18.5	33.04	0.3*	0.08	6.13	33.04	4495.49*	607.62	0.12	0.05
Variety	7	78.80*	26.14	0.33*	0.13	5.24	26.14	6455.75**	6485.06**	0.91*	0.90**
Error	14	14.21	19.14	0.03	0.07	7.08	19.14	325.18	386.1	0.16	0.08

Key: DE = Days to 50% emerging, DM = Days to 90% maturity, DR=disease reaction, SCH = stand count at harvest, NMS = Number of main stem, TS= tuber size in centimeter, NTPH = Number of tuber per hill, NMYH=Number of marketable yield per hill, WMYH=weight of marketable yield per hill, NUMYH= Number of unmarketable yield per hill, SV=source of variation, WUMYH= Weight of marketable yield per hill, TTY Qt^{-ha} =total tuber yield in quintal per hectare.

Mean Performance of Yield and Yield Components

Mean separation was carried out for traits showing significant difference among the genotypesin each location and combined over locations using least significant difference (LSD) as suggested by Gomez and Gomez (1984). Different mean performance was observed among varieties for most of the traits in present study and the results were presented in tables 2, 3 and 4). Statistically significant mean squares were observed among the tested varieties for most of the traits at each location and combined over locations.

Yield components

Gudane, Belete, Jalane and Gera showed significantly higher mean value of total tuber yield (TTY Qt ha^{-1}) than the local check, however, Gudane (287.8 and 307) and Belete (262.6 and 303.9) were significantly higher yielder than the rest of the varieties at Inango and in the combined over locations analysis, respectively. However, varieties such as Hunde, Ararsa and Jalane showed lower mean tuber yield as compared to the local check at Mata (Table 2). Hunde exhibited significantly lower mean value of Marketable yield (WMY Qt ha^{-1}) than Dagim, Gudane and Belete at both locations. Nevertheless, Hunde showed significantly lower mean value of WMY as compared to Belete and Dagim only in the combined analysis (Table 2).

The highest mean value of number of marketable yield (NMY) was obtained for Gudane and Jalane over local check at Inango. In contrary, no significant difference observed among varieties for NMY at Mata site. None of the varieties recorded significantly higher mean value of tuber size (TS) over the local check at Inango and in the combined analysis. However, Dagim, Ararsa and Gera have higher mean value of TS at Mata (Table 2). Present study identified Gudane as the exceptional variety with significant and higher mean value of number of tuber per hill (NTPH). However, all the remaining varieties showed similar performance as compared to the local check at both locations and in combined analysis (Table 2).

Table 2: Marketable and total tuber yield of potato over locations and their combination

	Marketable yield (kg ha^{-1})			Tuber size			Total tuber yield (Qt^{-ha})		
Variety	Inango	mata	Comb.	Inango	mata	Comb.	Inango	mata	Comb.
Dagim	1.49a	1.51a	1.50a-c	4.07b	4.67a	4.37a-d	169.30d	314.80a	242.00bc
Belete	1.42a	1.44a	1.43 a	4.53ab	4ab	4.27a-d	262.60ab	345.20a	303.90a
Gudane	1.51a	1.49a	1.50ab	3.93b	3.83b	3.88cd	287.80a	326.30a	307.00a
Hunde	0.91b	0.95b	0.93bc	3.9b	3.73b	7.83a-c	188.10d	207.80c	198.00c
Ararsa	1.35ab	1.39ab	1.37ab	4.43ab	4.8a	4.67c	182.60d	249.30b	215.90bc
Jalane	1.00ab	1.20ab	1.1abc	4.83ab	4.23ab	7a-c	251.10bc	269.30b	260.20ab
Gera	1.11ab	1.15ab	1.13abc	5.1 a	4.77a	6.17bc	221.90c	260.70b	241.30bc
Local	1.28ab	1.32ab	1.30abc	4.57ab	3.63b	7.5a-c	167.00d	314.10a	240.60bc
Mean	0.85	1.28	1.067	4.42	4.21	7.23	216.3	285.93	251.11
SE(M)	0.19	0.27	0.38	0.58	0.47	0.57	18.03	19.65	51.72
Cv(%)	21.8	21.1	35.3	13.2	11.1	13.3	8.3	6.9	20.6
Lsd(5%)	0.33	0.47	0.44	1.02	0.82	0.67	31.58	34.41	60.44

Key: Comb=combination, SEM =standard error of mean, CV=coefficient of variation, lsd=least significant difference

Phenology and growth parameters of potato

Among the eight tested varieties studied, Dagim, Gudane, Jalane and Gera showed significantly earlier days to maturity (DM) than local check (103.7 days) at Inango. On the other hands, the combined mean value indicated that Gudane and Jalane were the two earlier maturing than the local check. On the contrary, Belete, Hunde and Ararsa were late maturing over the two locations and in their combination (Table-3).

Combined mean value showed that Gudane, Jalane and Dagim were the three varieties with significant and higher mean value of number of main stem (NMS) over the local check. In other ways, the first two varieties showed significantly higher mean performance of NMS at Inango and Mata as compared to the local check (Table 3). Almost all of the varieties studied exhibited better reaction to foliar disease (late bacterial blight) with the exception of Jalane which attained similar reaction with the local check statistically at Inango. In other words, Hunde and Jalane showed lower bacterial blight reaction compared to the other varieties and the local check while the remaining five varieties showed similar trend with the local at Mata. The combined mean value exhibited that Jalane was significantly affected by bacterial blight than the local check, however, Dagim, Belete, Gudane and Gera revealed had significantly better degree of reaction to late bacterial blight than the local (Table 4).

Table 3: Phenology and growth parameters of potato

	Days to emergency			Days to maturity			Number of main stem		
Variety	Inango	mata	Comb.	Inango	Mata	Comb.	Inango	mata	Comb.
Dagim	12a	12.67a	12.33 a	100.3d	99c	99.7c	169.30d	314.80 a	242.00bc
Belete	10.67ab	11.67ab	11.17ab	111.3a	112a	111.7a	262.60ab	345.20a	303.90a
Gudane	10b	10b	10bc	96.7e	96d	96.3d	287.80a	326.30a	307.00a
Hunde	10b	10b	10bc	110ab	110ab	110.0ab	188.10d	207.80c	198.00c
Ararsa	11.67a	10b	10.83ab	108b	108.7b	108.3b	182.60d	249.30b	215.90bc
Jalane	8c	10b	9 c	92.7f	93.3e	93.0e	251.10bc	269.30b	260.20ab
Gera	12a	10b	11ab	99de	97cd	98.0cd	221.90c	260.70b	241.30bc
Local	8c	10b	9 c	103.7c	96.7cd	100.2c	167.00d	314.10a	240.60bc
Mean	10.29	10.54	10.42	102.71	101.58	102.15	216.3	285.93	251.11
SE(M)	0.89	1.44	1.32	1.38	1.46	1.933	18.03	19.65	51.72
Cv(%)	8.7	13.7	12.7	1.3	1.4	1.9	8.3	6.9	20.6
Lsd(5%)	1.57	2.52	1.543	2.42	2.56	2.26	31.58	34.41	60.44

Key: Comb=combination, SEM=standard error of mean, CV=coefficient of variation, lsd=least significant difference.

Table-4: Mean performance of some observed traits in Potato Varieties adaptation trial

Variety	SCH			NTH			DR		
	Inango	mata	Combined	Inango	Mata	Comb	Inango	mata	Comb
Dagim	35 a	38.33a	36.67 a	3.33 c	8.3a	5.83bc	1.00c	1.17bc	1.08 c
Belete	31.33ab	39a	35.17a	5.67bc	11a	8.33ab	1.0 c	1.00 c	1.00 c
Gudane	33ab	39.33a	36.17a	10.33a	10.67a	10.50a	1.07 c	1.17bc	1.12 c
Hunde	26bc	27c	26.50bc	5.67bc	10a	5.67bc	1.27 c	1.50 b	1.38bc
Ararsa	16.33 d	27.33c	21.83c	3 c	6.33a	3 c	1.53bc	1.00 c	1.27bc
Jalane	32ab	36ab	34a	6.67b	7.33a	6.67b	2.00ab	2.63 a	2.32 a
Gera	28.67abc	32.67b	30.67ab	4.67bc	7.67a	4.67bc	1.00 c	1.33bc	1.17c
Local	23cd	39.33a	31.17ab	4.33bc	10.67a	4.33bc	2.47a	1.00 c	1.73b
Mean	28.17	34.88	31.52	5.46	9	5.46	1.42	1.35	1.38
SE(M)	4.27	2.91	5.74	1.84	2.76	3.06	0.39	0.28	0.46
Cv(%)	15.2	8.3	18.2	33.7	30.6	42.3	27.9	20.4	33.2
Lsd (5%)	7.48	5.09	6.71	3.22	4.82	3.58	0.69	0.48	0.54

Conclusion and recommendation

The present study identified adaptable potato varieties for West and Kelem Wollega Zones. Gudane (307 Qt ha^{-1}) and Belete (303.90 Qt ha^{-1}) showed better and consistence performance over the two locations followed by Jalane (260.20 Qt ha^{-1}) and Dagim (242 Qt ha^{-1}). In other words, Belete (the late maturing), Gudane and Dagim (the medium maturing) had better tolerance to late blight bacterial while Jalane (early maturing) was more susceptible to this disease. Therefore, Gudane and Belete were identified and selected as the best for different merits to be demonstrated and popularized in the studied areas. Furthermore, production packages of these varieties should be studied so as to increase the production and productivity of potato in mid-altitude of west and Kelem wollega zones thereby to justify food security of farming community.

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Milling and Bread-making Traits Associated with Grain Hardness in Ethiopian Bread Wheat Varieties Grown under Bale Condition

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Abstracts

Many food processing industries utilizing bread wheat as a raw material are being established in the country. As a result, information on physico-chemical characteristics to match end use quality is very essential. In line with this, the current study was initiated with objectives to characterize physico-chemical properties in relation to bread making quality and to classify bread wheat cultivars as soft and hard wheat based on data generated on quality analysis. The grain of 44 Ethiopian improved bread wheat cultivars were collected from different agricultural research centers in the country and grown on under rain fall condition at two locations (Ginnir and Sinana on station) during Bona (July-Jan., 2015/16 and 2016/17) growing season and analyzed for grain physical and flour chemical quality characteristics. The experiment was laid out in RCBD with three replications. Result of analysis of variance indicated that, there is significant variations in all quality parameters considered among cultivars. Grain physical characteristics, such as thousand kernel weight (TKW), percent vitreous kernel (%Vk), were showed highly significant difference (P<0.01) due to cultivars. Grain chemical quality as expressed by protein quantity (%P) and quality, percent gluten index (% Gl), Zeleny index (Zl), have also shown highly significant difference (P<0.01) due to effect of genotypes. In addition strong environmental variation was observed on measured quality characters. The present results indicated that there is huge genetic variation among Ethiopian wheat varieties for quality traits considered in this study.

Introduction

Bread wheat (*Triticum aestivum* L.) is an autogamous allo-hexaploid species (2n = 6x = 42) and three genomes, designated as A, B and D (AABBDD), were involved in its evolution (Morris and Sears, 1967). It combines the genomes of three diploid ancestrals, *Triticum* *urartu* (2n = 14, AA), *Aegilops squarrosa* (2n = 14, DD) and *Aegilops* species (2n = 14, BB). In Ethiopia, wheat ranked second in total cultivated land area coverage after tef & second both in total grain production & productivity after maize (CSA, 2011). Ethiopia is the largest wheat producer in the sub-Saharan Africa with a totall area covered by wheat is the country is 1.47 million hectares with a total production of 2.22 million tons (FAOSTAT, 2010). Of the current total wheat production area, 75.5% is located in Bale, Arsi and Shewa highlands (Hailu *et al*., 1991). Amount of wheat storage proteins as well as its quality is one of the most important quality characteristics of bread wheat that influence bread-making property which this quality trait is highly correlated with grain hardness.

Wheat is classified into hard & soft classes on the bases of texture of the grain which coincide with differences in milling energy, milling time and end-use properties. The distinction between soft and hard classes wheat is governed by the Hardness (*Ha*) locus on chromosome 5DS (Law et al., 1978) Hard wheat requires longer milling times and more milling energy, and produce a larger amount of damaged starch.

Currently in Ethiopia, with the emerging agro-industries using wheat as a raw material, bread wheat with good quality grain for processing has become increasingly important. There is a high demand by both commercial and small-scale peasant farmers for wheat cultivars with higher grain yield and better end-use quality (Efrem *et al*., 2002). As a result, marketing of bread wheat is carried out as hard and soft bread wheat through physical observation of the grain to decide whether it is Vitreous or not even though wheat class breeding is not started yet. In terms of market value, hard bread wheat fetch a 50-100EB/qt more price than soft bread wheat class. On the other hand, quality reports are available for only few of the bread wheat cultivars released so far. Hence, it is important to characterize Ethiopian bread wheat cultivars and promising genotyoes which are on pipe line for possible release for their quality triats. Therefore, this study was initiated with objective to identify Ethiopian bread wheat varieties with superior quality traits contributing to the bread making based on physico-chemical quality characteristics and classify those varieties as hard and soft wheat class based on quality traits.

Materials and Methods

Description of the study area and Experimental Design

This experiment was conducted at two districts in Bale (Sinana representing highlands areas Ginnir representing mid land areas. In this study, fifty bread wheat varieties of which 44 wheat were released cutivars and the remaining are promising genotypes selected for release. Seeds of these test entries were collected from different research center who are working on wheat research in Ethiopia and planted on the same plot of land at Sinana agricultural research center experimental site and at Ginnir on farm field during Bona (July-December) 2015/16 and 2016/17 cropping seasons under rainfall condition on plot area of $6m^2$ (6 rows with 0.2m spacing between rows and 2.5m length). Spacing between blocks and plots were 1.5m and 1m respectively. The experiment was laid out in in RCBD with three replicatins. All agronomic and disease management practices were carried according to the recommendation of bread wheat at each location.

Data collected

Agronomic data such as grain yield (GY) (kg ha^{-1}), and quality parameters including thousand kernel weight (TKW), Hectoliter weight (HLW), grain moisture content, grain protein content, percent gluten contents, Zylenel sedimentation volume and percent virtuousness kernel were determined at 12.5 % moisture content based on standard protocols (AACC, 2000) using dockage free samples from each wheat genotype.

Data Analysis

Statistical Analysis System (SAS) was used for the analysis of variance (ANOVA) using General Linear Model (GLM) procedure (SAS Institute, 2001) SAS version 9.1. Mean separation was carried out using Least Significant Difference test (LSD) at P<0.05 and P<0.01 probability levels.

Results and discussions

Statistically significant variation in all measured quality parameters ($P \leq 0.01$) was observed among Ethiopian bread wheat varieties grown under Bale condition (representative of both mid and highlands of Bale (Table 1 and 2). Higher mean yield was recorded at Ginnir district as compared to that of Sinana this perhaps due to the prevalence of conducieceve weather condition for wheat growth at Ginnir than at Sinana. The effect of growing environment on most of quality traits under study was also observed particularly on grain vitrousness which accounts for about 97% at Ginnir and for about 60% at Sinana on station. Thousand kernel weights has also shown significant variation at ($P \leq 0.01$) due to genotypic effect at both test locations. Its value ranges from 48 gm for variety Ogolcho to the smallest value of 32.57 for the variety ET-13 at Ginnir whereas the observed value for this trait at Sinana ranges from 46.79g for the variety Dinkinesh to 30.0g for the variety Lakech at Sinana on station. Similar variation in Thousan kernel weight in bread wheat genotypes were reported by different authors in different bread wheat cultivars grown in different countries (Randhawa *et al*., 2002; Brehanu, 2004 and Khodarahmi *et al*., 2010 in Pakistan, Ethiopia and Iran respectively.. In general, the present study revealed existence of wide variation for TKW among different wheat varieties considered in this study and this shows that there is huge possibility to exploit in improvement of this particular quality trait in breeding program. Similarly, Ermias, 2007 and Solomon *et al.,* 2000 also reported huge variability in bread wheat cultivars tested at Harameya and Kulumsa respectively with the values ranging from 33.2g to 44.8 g. for the wheat genotypes tested at Haramaya and 32.0g to 45.9 g for wheat genotypes tested at kulumsa and hence these all reports are in agreement with the present study.

This significant difference (P <0.01) in TKW among wheat cultivars is mainly due to genetic effects. Thousand kernel weight is an important indicator for flour yield (Zahoor, 2003) and wheat cultivars can be classified according to their thousand grain weight as 15-25 g (very small), 26-35 g (small), 36-45 g (medium), 46-55 g (large) and over 55 g (very large) (William *et al*., 1986). Accordingly, wheat cultivars in the current study fall in the range of small to large grain weight category.

Hectoliter weights is also another quality parameter which showed significant variation (P <0.01) due to test genotypes (Table1 and 2). Hectoliter weight (HLW) varied from 81.4 kg/hL for variety Galil to 86.40 kg/hL for variety Dinkinesh at Ginnir and 82.09 kg/hL for variety Dinkinesh to 89.27 kg/hL for variet Dinkinesh at Sinana on station.. The hectoliter weight, which is dependents on both grain size and shape, is considered to be one of the most important physical criteria in all wheat grading systems. Flour yield and other quality parameters positively correlated with HLW. The results obtained in this experiment were in close agreement with the reports of Cornish *et al*. (2001) and Walle (2006) who reported that HLW of 130 hard red spring bread wheat grown at different locations of USA varied from 66.2 to 80.20 kg/hL, and 77.91 to 82.15 kg/hL- in 20 bread wheat cultivars of Ethiopia, respectively. It is also in consistent with the earlier findings of other researchers such as Zahoor (2003), Muhammad *et al*. (2009) and Randhawa *et al.* (2002) who reported variations ranging from 68.30 to 81.00 kg/hl in different wheat varieties from different countries.

Protein is one of the primary quality components that influence most of wheat grain milling and baking quality characteristics. Protein quantity and quality determines wheat grain hardness, which intern determines its end use quality. Significant variation among the test cultivars was observed for grain protein content with the values ranging from 18.1% for variety K6295-4a to 13.37% for the variety Mekelle 04 at Sinana on station. Similarly, significant variation for grain protein content was with the of 15.03% for variey Millinium to 11.23% for variety Kubsa at Ginnir district. The high protein percent at Sinana on station is most probably due to terminal water stress encountered which reduced starch accumulation. Gluten percent on the other hand varied from 35.30% to 24.47% at Ginnir and from 44.27% to 27.63% at Sinana on station. In the same way Zenly sedmentation volume which is an indicator of wheat flour gluten strength varies from 75 for variety Mararo to 52.10 for variety Dodota at Ginnir and 82 for variety Mararo to 55.27 for variety Kubsa at Sinana on station. In general, the mean values of measured quality parameters are higher at Sinana on station as compared to Ginnir which indicate strong environmental influence in addition to genetic variation.

Table 1. Results of wheat grain quality characters for the experiment at Ginnir in 2015/16

SN	Variet	GY kg/ha	TKW	HLW	% Vit	Gluten	%MC	%PC	%Z I
1	**Hidase**	3160.73^{d-l}	44.47^{bc}	84.13^{b-j}	98.73^{a}	29.03^{c-l}	10.50	12.60^{e-q}	63.10^{b-m}
2	**Shorima**	3283.00^{c-j}	41.50^{c-g}	84.40^{b-i}	98.67^{a}	31.00^{a-h}	10.30	13.00^{c-k}	65.73^{b-i}
3	**UTIQUE**	3372.40^{c-j}	39.17^{f-l}	84.80^{b-g}	98.61^{a}	31.70^{a-e}	10.60	13.37^{b-j}	65.20^{b-j}
4	**Bika**	2946.53^{f-l}	40.10^{e-j}	84.13^{b-j}	97.80^{ab}	31.60^{a-f}	10.33	13.40^{b-i}	70.27^{abc}
5	**Alidoro**	3301.20^{c-j}	44.10^{bc}	83.67^{e-k}	96.85^{abc}	31.27^{a-g}	10.73	12.97^{c-m}	55.43^{k-p}
6	**Enkoy**	2805.80^{g-l}	34.63^{n-q}	83.87^{c-k}	95.07^{abc}	32.33^{a-d}	10.63	13.43^{b-h}	60.00^{f-p}
7	**Dereselign**	2913.53^{f-l}	39.90^{e-k}	82.67^{j-m}	96.33^{abc}	29.83^{c-j}	10.43	12.80^{d-0}	63.90^{b-k}
8	**Tay**	3904.47^{a-e}	36.60^{l-o}	82.53^{klm}	99.73^{a}	27.03^{f-m}	10.63	12.60^{e-q}	58.40^{h-p}
9	**Milennium**	2710.53^{h-l}	34.17^{opq}	82.13^{lm}	100.00^{a}	35.30^{a}	10.50	15.03^{a}	68.80^{a-e}
10	**Sofumer**	3588.40^{a-h}	42.87^{bcd}	85.47^{ab}	100.00^{a}	29.83^{c-j}	10.50	12.77^{d-p}	62.00^{c-n}
11	**K6290-Bulk**	2610.53^{i-l}	38.23^{h-m}	82.13^{lm}	99.67^{a}	34.53^{ab}	10.40	14.47^{abc}	71.63^{ab}
12	**M. walabu**	3458.33^{b-i}	44.33^{bc}	85.00^{a-e}	97.57^{abc}	27.23^{e-m}	10.93	12.57^{e-q}	58.00^{h-p}
13	**Dashen**	3155.00^{d-l}	39.93^{e-k}	83.47^{f-l}	98.18^{ab}	26.20^{i-m}	11.50	11.93^{h-q}	58.07^{h-p}
14	**Mekelle-03**	3847.13^{a-f}	40.43^{d-i}	83.20^{h-l}	98.20^{ab}	27.60^{e-m}	10.57	12.53^{e-q}	53.23^{op}
15	**K6295-4a**	2943.40^{f-l}	33.63^{pq}	84.27^{b-i}	99.00^{a}	33.10^{abc}	10.70	13.97^{a-e}	63.00^{c-m}
16	**Ogolcho**	4469.80^{a}	48.00^{a}	84.00^{b-k}	100.00^{a}	27.17^{e-m}	10.40	11.87^{j-q}	60.27^{e-p}
17	**Hoggana**	2514.20^{jkl}	38.67^{h-l}	83.60^{e-l}	99.20^{a}	29.63^{c-j}	10.50	12.70^{e-q}	60.40^{e-p}
18	**Gambo**	4333.40^{ab}	47.67^{a}	84.93^{a-f}	99.87^{a}	26.60^{h-m}	10.73	11.70^{l-q}	59.73^{f-p}
19	**Digelu**	2698.73^{h-l}	38.07^{h-m}	84.80^{b-g}	95.67^{abc}	25.80^{i-m}	10.90	11.83^{k-q}	54.43^{m-p}
20	**Danda**	3688.67^{a-g}	46.10^{ab}	83.33^{g-l}	97.33^{abc}	27.00^{g-m}	10.53	11.90^{i-q}	60.53^{e-p}
21	**Gasay**	3478.67^{b-i}	42.03^{c-f}	85.20^{a-d}	95.33^{abc}	26.27^{i-m}	10.40	11.43^{n-q}	57.03^{j-p}
22	**Jaferson**	3731.13^{a-g}	38.63^{h-l}	84.13^{b-j}	92.57^{c}	28.73^{c-l}	10.60	12.40^{f-q}	57.10^{j-p}
23	**Kingbird**	3591.20^{a-h}	39.00^{h-l}	84.27^{b-i}	98.40^{a}	27.07^{f-m}	10.67	12.27^{g-q}	59.30^{g-p}
24	**PAVON-76**	3577.80^{a-h}	37.53^{i-n}	84.40^{b-i}	99.33^{a}	29.30^{c-k}	10.57	11.73^{l-q}	62.10^{c-n}
25	**Simba**	3227.33^{c-k}	44.43^{bc}	84.13^{b-j}	100.00^{a}	30.97^{a-h}	10.63	13.30^{b-k}	68.27^{a-f}
26	Sirbo	2308.20^{kl}	35.00^{n-q}	84.67^{b-h}	100.00^{a}	32.40^{a-d}	11.43	13.83^{a-e}	69.57^{a-d}
27	Qulqulluu	2739.80^{h-l}	35.43^{m-q}	82.93^{i-m}	99.63^{a}	31.47^{a-g}	11.07	13.47^{b-g}	63.77^{b-k}
28	Hulluka	3293.87^{c-j}	37.40^{j-n}	83.87^{c-k}	77.33^{e}	25.33^{j-m}	10.80	11.50^{m-q}	53.77^{nop}
29	**Dinkinesh**	2955.33^{f-l}	42.80^{bcd}	81.47^{m}	100.00^{a}	32.30^{a-d}	10.63	14.23^{a-d}	67.23^{a-g}
30	**Mandoyu**	3619.80^{a-h}	37.50^{i-n}	84.67^{b-h}	95.33^{abc}	28.67^{c-f}	10.37	11.93^{h-q}	61.27^{d-o}
31	**Sula**	3213.53^{c-l}	39.90^{e-k}	85.20^{a-d}	99.00^{a}	30.20^{b-i}	10.40	12.87^{d-n}	66.33^{b-h}
32	**ET-13**	2330.47^{kl}	32.57^{q}	84.80^{b-g}	96.00^{abc}	24.53^{lm}	11.00	11.67^{l-q}	54.70^{l-p}
33	**Meraro**	2284.27^{l}	33.80^{pq}	84.80^{b-g}	100.00^{a}	34.70^{ab}	10.63	14.60^{ab}	75.00^{a}
34	**Mekelle -01**	4019.20^{a-e}	43.33^{bcd}	85.33^{abc}	100.00^{a}	31.13^{a-h}	10.50	13.10^{b-k}	67.93^{a-f}
35	**Bobicho**	3292.73^{c-j}	38.13^{h-m}	83.47^{f-l}	95.67^{abc}	27.97^{d-m}	10.50	12.47^{e-q}	58.80^{g-p}
36	**Tossa**	3240.67^{c-k}	37.37^{j-n}	85.20^{a-d}	100.00^{a}	29.70^{c-j}	10.70	12.63^{e-q}	62.83^{c-m}
37	Galil	3095.53^{e-l}	39.97^{e-k}	86.40^{a}	98.67^{a}	29.80^{c-j}	10.50	12.40^{f-q}	62.77^{c-m}
38	**Kubsa**	3331.40^{c-j}	37.07^{k-o}	83.73^{d-k}	86.00^{d}	23.73^{m}	10.57	11.23^{q}	52.43^{p}
39	**Abola**	3167.73^{d-l}	34.27^{opq}	84.80^{b-g}	95.33^{abc}	28.37^{d-l}	10.50	12.43^{f-q}	61.83^{c-o}
40	**Lakech**	2820.87^{g-l}	36.27^{l-o}	85.07^{a-e}	98.00^{ab}	29.73^{c-j}	10.53	12.63^{e-q}	62.87^{c-m}
41	**Mekelle 04**	3983.40^{a-e}	44.33^{bc}	84.13^{b-j}	96.33^{abc}	25.03^{klm}	10.53	11.33^{npq}	57.33^{i-p}
42	**Honkolo**	4142.47^{abc}	40.90^{d-h}	85.20^{a-d}	100.00^{a}	28.83^{c-l}	10.77	12.27^{g-q}	62.33^{c-n}
43	**Kakaba**	4034.60^{a-d}	40.80^{d-h}	84.93^{a-f}	82.00^{de}	23.47^{m}	10.33	11.27^{pq}	53.33^{op}
44	**Dodota**	3144.13^{d-l}	38.13^{h-m}	84.27^{b-i}	93.33^{c}	27.70^{e-m}	10.77	12.37^{f-q}	52.10^{p}
	Mean	**3280.23**	**39.53**	**84.17**	**96.93**	**29.12**	**10.63**	**12.65**	**61.41**
	CV	**17.55**	**4.67**	**1.09**	**3.19**	**9.73**	**2.72**	**7.33**	**8.63**
	F test	**	**	**	**	**	**	**	**
	LSD	**934.25**	**3.00**	**1.49**	**5.01**	**4.60**	**0.47**	**1.51**	**8.60**

In hard wheat, variation in loaf volume of bread can be attributed directly to differences in protein concentration (Fowler, 2002). The differences in protein content among different wheat cultivars could be related to wheat genetic difference (Kent and Evers, 1994). The results the present study is in agreement with the results reported by Solomon *et al.* (2002) who reported significant difference in grain protein contents among ten Ethiopian bread wheat cultivars grown under Arsi condition and with arrange of 7.7% to 13.2%. Besides, the results of the present studies also in agreement with the report of Mahmood, (2004) who found variation for this trait ranging from 9.71% to 15.42% among different bread wheat varieties.

The result of gluten content is also in close agreement with the findings of Miralbes (2003) who found variation ranging from 15.6 to 39.3 % in wet gluten content in different wheat varieties. Similar report was also obtained by Paliwal and Singh (1985) who reported wet gluten in the range 12.77 to 44.06% in Uttar Paradesh wheat varieties. This variation in wet gluten among the wheat cultivars considered in the present study may be attributed to the differences in genotypes and the environmental conditions such as temperature and rainfall.

Table 2. Results of wheat grain quality characters for the experiment at Sinana in 2015/16

SN	*Variety*	*BM t/ha*	*Gy (kg/ha)*	*TKW*	*HLW*	*Gluten*	*%MC*	*%P*	*ZI*
1	Hidase	3.73 $^{b-f}$	1593.17 $^{b-f}$	44.13^{abc}	86.25 $^{a-i}$	35.03 $^{i-q}$	11.50 $^{a-f}$	15.40^{e-m}	67.47 $^{e-n}$
2	Shorima	3.47 $^{c-f}$	1589.55 $^{b-f}$	40.98 $^{b-h}$	87.68 $^{a-f}$	37.80 $^{b-k}$	11.33 $^{c-f}$	15.93 $^{b-k}$	72.03 $^{c-i}$
3	UTIQUE	5.50^{a-e}	2115.05^{a-e}	42.92 $^{a-d}$	88.62^{abc}	37.83^{b-k}	11.27^{ef}	16.07 $^{b-i}$	73.50^{b-g}
4	Bika	4.10 $^{b-f}$	1488.01 $^{c-f}$	39.78^{c-l}	87.96^{a-e}	40.43^{bc}	11.20 ^{ef}	16.93 ^{abc}	79.07^{abc}
5	Alidoro	5.33 $^{a-f}$	1849.45 $^{b-f}$	41.80 $^{a-f}$	84.59^{c-j}	36.33^{e-o}	11.77 $^{a-d}$	13.87^{no}	55.57st
6	Enkoy	5.60 $^{a-d}$	2279.96^{a-d}	34.33 $^{m-q}$	85.00 $^{c-j}$	39.80^{b-f}	11.40 $^{b-f}$	15.97 $^{b-j}$	63.53^{l-s}
7	Dereselign	6.17^{ab}	2212.34^{a-d}	40.80 $^{b-i}$	86.50 $^{a-i}$	35.77^{g-q}	11.23 ^{ef}	15.47^{d-l}	65.43 $^{g-q}$
8	Tay	5.93^{abc}	2785.19^{a}	40.96 $^{b-h}$	85.09 $^{c-j}$	34.83 $^{j-r}$	11.37 $^{b-f}$	15.43^{d-m}	65.33 $^{h-q}$
9	Milennium	4.33 $^{b-f}$	1953.09^{a-f}	35.49 $^{j-p}$	83.15^{hij}	38.97^{b-i}	11.77 $^{a-d}$	16.73 $^{b-e}$	66.37 $^{f-q}$
10	Sofumer	5.07 $^{a-f}$	1699.92 $^{b-f}$	42.10 $^{a-e}$	84.30 $^{e-j}$	34.23 $^{k-r}$	11.90^{a}	14.93 $^{h-n}$	63.93 $^{j-r}$
11	K6290-Bulk	5.13 $^{a-f}$	2038.79 $^{a-e}$	38.69 $^{d-n}$	83.82 $^{f-j}$	39.60^{b-f}	11.50 $^{a-f}$	16.77 $^{a-d}$	71.67 $^{c-k}$
12	M. walabu	5.07 $^{a-f}$	1964.13 $^{a-f}$	43.06^{a-d}	84.98 $^{c-j}$	34.43^{k-r}	11.40 $^{b-f}$	15.33^{f-m}	63.90^{j-r}
13	Dashen	7.06^{a}	2314.52 ^{abc}	38.68 $^{d-o}$	86.53 $^{a-i}$	32.60^{n-s}	11.40 $^{b-f}$	14.73 $^{i-n}$	65.83 $^{g-q}$
14	Mekelle-03	4.60 $^{a-f}$	2151.29 $^{a-d}$	41.13^{b-g}	82.78^{ij}	33.77 $^{l-s}$	11.80 ^{abc}	15.13^{h-n}	56.63^{rst}
15	K6295-4a	5.60 $^{a-d}$	2061.06 $^{a-e}$	33.42^{opq}	83.26 $^{g-j}$	44.77^{a}	11.43 $^{a-f}$	18.10^{a}	76.03^{a-d}
16	Ogolcho	4.83 $^{a-f}$	2351.66^{abc}	42.62 $^{a-d}$	85.98 $^{a-j}$	34.70 $^{j-r}$	11.50 $^{a-f}$	15.30^{g-m}	69.03 $^{d-l}$
17	Hoggana	4.47 $^{b-f}$	1912.30 $^{b-f}$	37.16 $^{e-o}$	85.14 $^{b-j}$	37.03 $^{b-l}$	11.43 $^{a-f}$	15.80 $^{b-k}$	67.40 $^{e-n}$
18	Gambo	5.73^{a-d}	1528.27 $^{c-f}$	42.56 $^{a-d}$	88.43^{a-d}	33.53 $^{l-s}$	11.23 ^{ef}	14.90 $^{h-n}$	67.13 $^{e-o}$
19	Digelu	4.47 $^{b-f}$	1102.97^{f}	34.51 $^{m-q}$	86.71 $^{a-i}$	32.40^{o-s}	11.67 $^{a-e}$	14.63 $^{j-o}$	58.77^{q-t}
20	Danda	5.50 $^{a-e}$	1860.56 $^{b-f}$	45.11^{ab}	86.06 $^{a-j}$	32.70^{m-s}	11.43 $^{a-f}$	14.80 $^{i-n}$	63.67^{k-r}
21	Gasay	5.47 $^{a-e}$	1703.56 $^{b-f}$	38.08 $^{d-o}$	87.88^{a-f}	33.80 $^{l-s}$	11.40 $^{b-f}$	14.60 $^{k-o}$	65.47 $^{g-q}$
22	Jaferson	4.77 $^{a-f}$	1893.59 $^{b-f}$	34.70 $^{l-q}$	88.24^{a-e}	38.63^{b-j}	11.47 $^{a-f}$	16.20 $^{b-h}$	68.30 $^{d-m}$
23	Kingbird	4.93 $^{a-f}$	1820.69 $^{b-f}$	35.88 $^{g-p}$	84.85 $^{c-j}$	36.60^{c-m}	11.53 $^{a-f}$	15.87 $^{b-k}$	67.90^{e-n}
24	PAVON-76	5.40 $^{a-e}$	2451.27^{ab}	39.21^{c-m}	85.22 $^{a-j}$	31.07^{rst}	11.83 ^{ab}	14.10^{mno}	60.03^{n-t}
25	Simba	4.47 $^{b-f}$	1890.10 $^{b-f}$	40.02 $^{b-k}$	86.46 $^{a-i}$	36.47 $^{d-n}$	11.53 $^{a-f}$	15.93 $^{b-k}$	74.37^{a-f}
26	Sirbo	3.93 $^{b-f}$	1267.46^{ef}	35.62 $^{i-p}$	89.27^{a}	40.63^{b}	11.33 $^{c-f}$	16.97 ^{ab}	81.13^{ab}
27	Qulqulluu	4.60 $^{a-f}$	1755.64 $^{b-f}$	33.47 $^{n-q}$	84.40 $^{d-j}$	40.00^{b-f}	11.30 ^{def}	16.77 $^{a-d}$	71.80 $^{c-j}$
28	Hulluka	4.33 $^{b-f}$	1537.60 $^{c-f}$	36.62 $^{f-o}$	85.59 $^{a-j}$	35.63^{h-q}	11.33 $^{c-f}$	15.47^{d-l}	64.77 $^{i-q}$
29	Dinkinesh	3.50 $^{c-f}$	1600.65 $^{b-f}$	46.79^{a}	82.09^{j}	36.17^{f-p}	11.63 $^{a-f}$	16.20 $^{b-h}$	65.07 $^{i-q}$
30	Mandoyu	4.70 $^{a-f}$	2336.91 ^{abc}	36.01 $^{g-p}$	87.53 $^{a-f}$	35.10^{i-q}	11.33 $^{c-f}$	15.17^{g-n}	65.87^{g-q}
31	Sula	3.00 ^{ef}	1640.04 $^{b-f}$	39.03 $^{c-m}$	83.37 $^{g-j}$	39.17^{b-h}	11.83 ^{ab}	16.50 $^{b-g}$	72.80^{c-i}
32	ET-13	2.87^{f}	1419.53^{def}	35.83 $^{h-p}$	88.08^{a-e}	33.90 $^{k-s}$	11.17^{f}	14.87 $^{h-n}$	66.93 $^{e-o}$
33	Meraro	2.87^{f}	1156.21^{f}	31.20^{pq}	85.78 $^{a-j}$	40.40^{bcd}	11.83^{ab}	17.00 ^{ab}	82.07^{a}
34	Mekelle -01	5.40^{a-e}	1930.25 $^{a-f}$	42.21 $^{a-e}$	88.49^{a-d}	36.83 $^{b-l}$	11.43 $^{a-f}$	15.60^{c-l}	73.33 $^{b-h}$
35	Bobicho	3.40 $^{d-f}$	1775.00 $^{b-f}$	38.81^{d-m}	87.20 $^{a-h}$	33.3^{l-s}	11.30 ^{def}	14.90 $^{h-n}$	62.63^{l-t}
36	Tossa	5.10 $^{a-f}$	2098.92 $^{a-e}$	34.81 $^{k-q}$	89.24^{ab}	34.93^{j-r}	11.30^{def}	15.17^{g-n}	67.47^{e-n}
37	Galil	3.27 $^{d-f}$	1731.75 $^{b-f}$	36.31 $^{g-p}$	83.18^{hij}	40.23^{b-e}	11.77 $^{a-d}$	16.67^{b-f}	74.53^{a-e}
38	Kubsa	4.20 $^{b-f}$	1488.41 $^{c-f}$	36.26 $^{g-p}$	84.69 $^{c-j}$	32.07 $^{q-s}$	11.50 $^{a-f}$	14.37 $^{l-o}$	59.07^{o-t}
39	Abola	5.33 $^{a-f}$	1961.59 $^{a-f}$	35.00^{k-q}	87.30^{a-g}	33.33^{l-s}	11.57 $^{a-f}$	14.77 $^{i-n}$	68.00^{d-n}
40	Lakech	4.17 $^{b-f}$	1491.94 $^{c-f}$	30.00^{q}	85.32 $^{a-j}$	32.83 $^{m-s}$	11.23 ^{ef}	14.73 $^{i-n}$	60.53^{m-t}
41	Mekelle 04	4.20 $^{b-f}$	2168.97 $^{a-d}$	42.24 $^{a-e}$	85.98 $^{a-j}$	27.63^{t}	11.63 $^{a-f}$	13.37^{o}	56.50^{rst}
42	Honkolo	3.87 $^{b-f}$	2210.30 $^{a-d}$	38.92 $^{c-m}$	87.83 $^{a-f}$	32.37^{p-s}	11.23 ^{ef}	14.33 $^{l-o}$	64.83 $^{i-q}$
43	Kakaba	3.87 $^{b-f}$	1660.21 $^{b-f}$	40.59^{b-j}	87.73 $^{a-f}$	30.23st	11.27 ^{ef}	14.30 $^{l-o}$	55.27^{t}
44	Dodota	3.60 $^{c-f}$	1710.23 $^{b-f}$	37.87 $^{d-o}$	85.45 $^{a-j}$	35.43 $^{h-q}$	11.53 $^{a-f}$	15.37^{f-m}	58.87^{p-s}
	Mean	***5.35***	***1853.46***	***38.54***	***86.00***	***35.76***	***11.47***	***15.49***	***66.81***
	%CV	***33.56***	***28.79***	***8.42***	***2.95***	***6.80***	***2.67***	***5.32***	***7.44***
	F test	**	**	**	**	**	**	**	**

	LSD	***2.51***	***865.74***	***5.26***	***4.12***	***3.95***	***0.50***	***1.34***	***8.07***

Combined analysis of variance over year and location has shown statistically significant (P≤0.05) variation for the measured quality characters due to bread wheat varieties. The vitreousness kernel values (Table 3) ranged from 99.25 to 92.17% which is very high for all test verities. Higher vitreousness indicates higher protein content, a harder kernel, coarser granulation, during milling, higher flour yield, superior product quality and opportunity for premium price (Dowell, 2000). The gluten, protein and zanely sedimentation volume content of the test varieties also varied from 40.47 to 26.99, 16.46 to 13.17 and 81.60 to 54.99 respectively which revealed that the wheat genotypes were highly influenced by growing year and locations to express high quality character and fall under best to good bread-making quality class. In general bread wheat variety Mararo scored the highest quality characters while Makalle 04 with the lowest quality even though all the varieties fall under best to good bread making quality. Higher and significant quality values are also obtained at Ginnir in both years which most probably due to higher temperature and shorter maturity period which positively affects protein quality.

Table 3. Effect of variety on some grain milling and bread making quality characters combined over location and year

Varieties	**Vit. (%)**	**Gluten (%)**	**Moisture (%)**	**Proteins (%)**	**Z Index (ml)**
Hidase	98.35±1.38^{abc}	33.22±4.38^{e-i}	11.13±0.44 $^{a-d}$	14.57±1.60 $^{a-h}$	68.84±8.24 $^{c-k}$
Shorima	98.00±2.12 $^{a-e}$	35.51±6.05^{a-h}	11.04±0.51 $^{a-d}$	15.09±2.13 $^{a-h}$	70.21±11.92 $^{b-k}$
UTIQUE	98.24±1.56^{a-d}	34.65±6.01^{b-i}	10.36±2.60^{bcd}	14.93±1.84 $^{a-h}$	69.61±12.00 $^{b-k}$
Bika	97.28±1.85 $^{a-g}$	33.98±7.10^{c-i}	10.93±0.45 $^{a-d}$	14.76±2.16 $^{a-h}$	71.46±13.03 $^{b-g}$
Alidoro	97.30±2.24^{a-g}	34.76±4.94^{b-i}	11.22±043 ^{ab}	14.18±1.69 $^{c-h}$	61.33±7.70^{i-m}
Enkoy	97.68±2.36^{a-f}	36.68±6.34^{a-f}	11.03±0.58 $^{a-d}$	15.01±1.87 $^{a-h}$	66.76±9.18^{c-l}
Dereselign	97.50±1.88 $^{a-f}$	33.03±4.26 $^{e-i}$	10.95±0.39 $^{a-d}$	14.37±1.39 $^{c-h}$	66.07±8.17 $^{c-l}$
Tay	98.84±1.12^{ab}	33.73±5.94 $^{c-i}$	11.12±0.36 $^{a-d}$	14.83±1.87 $^{a-h}$	67.58±11.18 $^{c-k}$
Milennium	98.58±1.08^{abc}	35.84±6.56^{a-g}	11.17±0.53^{abc}	15.48±1.93 $^{a-f}$	66.63±11.19 $^{c-l}$
Sofumer	99.08±1.51^{a}	33.62±4.02 $^{c-i}$	11.24±0.68^{ba}	14.49±1.45 $^{b-h}$	67.33±7.30 $^{c-k}$
K6290-Bulk	98.17±2.37^{a-e}	37.55±8.43^{a-e}	11.17±0.57^{abc}	16.08±2.98^{abc}	72.97±14.77^{a-e}
M. walabu	98.14±1.72 $^{a-e}$	33.07±4.94 $^{e-i}$	11.21±0.30 ^{ba}	14.66±1.68 $^{a-h}$	66.01±8.89 $^{c-l}$
Dashen	96.80±2.62 $^{a-g}$	33.41±7.87 $^{c-i}$	11.32±0.40^{a}	14.74±2.71 $^{a-h}$	68.63±16.52 $^{c-k}$
Mekelle-03	96.88±1.68 $^{a-g}$	31.16±4.27 $^{g-j}$	11.18±0.60 ^{abc}	13.99±1.42 $^{d-h}$	57.66±9.33^{lm}
K6295-4a	98.33±1.83^{abc}	40.47±10.04^{a}	11.14±0.42 ^{abc}	15.88±5.03^{a-d}	74.04±15.88^{abc}
Ogolcho	98.00±4.51 $^{a-e}$	30.73±8.28^{hij}	11.16±0.56 ^{abc}	14.08±1.75 $^{d-h}$	66.09±8.06 $^{c-l}$
Hoggana	98.47±1.41^{abc}	34.62±6.69^{b-i}	11.18±0.50 ^{abc}	14.91±2.27 $^{a-h}$	65.96±10.93 $^{c-l}$
Gambo	96.22±6.72 $^{a-g}$	33.90±7.15^{c-i}	11.13±0.38 $^{a-d}$	14.62±2.50 $^{a-h}$	68.94±12.63 $^{c-k}$
Digelu	98.17±2.29 $^{b-e}$	32.09±7.32 $^{f-i}$	11.33±0.57^{a}	14.15±2.29 $^{c-h}$	63.81±13.78 $^{f-m}$
Danda	96.00±4.47 $^{c-g}$	33.29±5.42 $^{d-i}$	11.21±0.53 ^{ba}	13.28±4.28 ^{gh}	65.13±14.07^{c-l}
Gasay	96.00±3.28 $^{c-g}$	33.73±5.65^{c-i}	11.03±0.53 $^{a-d}$	14.33±2.00 $^{c-h}$	67.41±9.80 $^{c-k}$
Jaferson	95.06±5.91^{fg}	33.60±5.11^{c-i}	11.19±0.47 ^{ba}	13.43±3.91^{gh}	61.38±9.39^{h-m}
Kingbird	98.60±1.14^{abc}	34.12±6.20^{c-i}	11.19±0.21 ^{ba}	14.13±3.68 $^{c-h}$	68.84±11.45 $^{c-k}$
PAVON-76	97.92±1.68 $^{a-e}$	32.04±5.43 $^{f-i}$	11.18±0.53 ^{abc}	13.83±2.02 $^{e-h}$	65.21±10.78 $^{c-l}$
Simba	97.92±1.73 $^{a-e}$	34.97±6.54^{b-i}	11.18±0.46 ^{abc}	15.22±2.36 $^{a-f}$	72.73±12.34^{a-f}
Sirbo	96.75±4.45 $^{a-g}$	38.34±6.02^{abc}	11.34±0.28^{a}	16.34±2.13^{ab}	78.64±13.25^{ab}
Qulqulluu	98.07±3.42 $^{a-e}$	38.23±6.58^{a-d}	11.21±0.44 ^{ba}	16.04±2.32^{abc}	73.51±10.88^{a-d}
Hulluka	92.17±9.63^{h}	31.66±6.41 $^{g-j}$	11.13±0.09 $^{a-d}$	13.85±2.18 $^{e-h}$	63.68±10.88^{f-m}
Dinkinesh	98.50±1.09^{abc}	35.74±5.59^{a-f}	10.38±8.96^{bcd}	15.73±2.22^{a-e}	69.60±9.07 $^{b-k}$
Mandoyu	96.67±2.19 $^{a-g}$	33.28±5.80 $^{d-i}$	11.00±0.62 $^{a-d}$	13.34±3.89 ^{gh}	66.88±10.78 $^{c-k}$
Sula	98.75±1.54^{abc}	34.18±4.55^{c-i}	11.21±0.70 ^{ba}	14.65±1.66 $^{a-h}$	69.67±6.93 $^{b-k}$
ET-13	98.25±1.76^{a-d}	34.49±9.54^{c-i}	10.43±2.89^{-d}	15.01±3.15 $^{a-h}$	70.44±17.39 $^{b-i}$
Meraro	99.25±1.22^{a}	39.29±6.05^{ab}	11.23±0.51 ^{ba}	16.46±2.12^{a}	81.60±11.02^{a}
Mekelle -01	97.75±2.67 $^{a-f}$	32.94±4.78 $^{e-i}$	11.08±0.57 $^{a-d}$	14.23±1.37 $^{c-h}$	68.08±11.18 $^{c-k}$
Bobicho	96.67±3.55 $^{a-g}$	32.60±4.71 $^{f-i}$	11.03±0.59 $^{a-d}$	14.33±1.59 $^{c-h}$	64.83±10.36^{d-l}
Tossa	99.00±0.74^{a}	33.21±3.84 $^{e-i}$	11.13±0.35 $^{a-d}$	14.36±1.43 $^{c-h}$	67.04±6.96 $^{c-k}$
Galil	99.00±0.74^{a}	35.58±6.14 $^{a-h}$	11.16±0.63^{abc}	14.93±2.13 $^{a-h}$	70.52±9.32 $^{b-j}$
Kubsa	95.50±7.56 $^{d-g}$	30.43±5.80^{ij}	11.14±0.55^{abc}	13.75±1.94 ^{fgh}	63.07±11.68^{g-m}
Abola	95.42±4.80 $^{e-g}$	32.33±4.75 $^{f-i}$	10.27±2.78 ^{cd}	14.54±2.01 $^{a-h}$	68.80±10.15 $^{c-k}$
Lakech	98.42±1.56abc	30.61±3.29^{ij}	11.13±0.44^{a-d}	13.42±1.21^{gh}	60.63±6.09 ^{klm}
Mekelle 04	97.25±2.22 $^{a-g}$	26.99±8.82^{j}	11.13±0.59 $^{a-d}$	13.17±1.51 ^{h}	54.99±17.24^{m}
Honkolo	98.92±0.79^{ab}	32.85±6.66 $^{e-i}$	10.34±2.80 ^{bcd}	13.35±4.39 ^{gh}	67.40±12.88 $^{c-k}$
Kakaba	94.67±8.24^{gh}	31.56±6.42^{g-j}	10.23±2.76^{d}	14.22±2.22 $^{c-h}$	64.12±13.45^{e-l}
Dodota	97.00±3.19 $^{a-g}$	33.26±5.42 $^{d-i}$	11.16±0.50^{abc}	14.46±1.72 $^{b-h}$	61.25±9.21^{j-m}
Mean	**97.48±3.59**	**33.90±6.45**	**11.04±1.13**	**14.57±2.47**	**67.39±11.94**
CV	**3.54**	**18.37**	**2.29**	**16.72**	**16.91**
F test	**	**	**	**	**

LSD	2.76	4.99	0.91	1.95	9.14

Combined over location, non-significant but higher grain protein quantity and significantly (P≤ 0.05) higher protein qualities (gluten and zanely index) were observed at Ginnir (table 4), which most probably due to lower altitude, higher temperature and shorter crop maturity period which hinders starch accumulation and accelerate protein storage.

Table 4. Some wheat quality parameters as affected by growing Environment

Environment	Vitriousness (%)	Gluten (%)	Moisture (%)	Protein (%)	Zaleny Index
Ginnir	97.65±4.13	34.78±7.26[a]	10.74±10.74[b]	14.66±2.73	71.01±13.56[a]
Sinana	97.32±2.94	33.02±5.39[b]	11.34±11.34[a]	14.48±2.19	63.78±8.71[b]
G. Mean	**97.48±3.59**	**33.90±6.45**	**11.04±11.04**	**14.57±2.47**	**67.39±11.94**
CV	**3.68**	**18.88**	**9.86**	**16.98**	**16.91**
F test	**ns**	**	**	**ns**	**
LSD	**0.61**	**1.09**	**0.19**	**0.42**	**1.95**

Conclusion

It has been known that the grain properties predetermine both the milling and final end-use of quality of bread wheat. The result of the present study confirmed the existence of considerable variation among the test varieties with respect to some physical and other grain quality characters due to genetic and environmental variations. In addition to genetic variation strong, environmental influence was also observed on all measured quality characters. Higher grain protein quantity and qualities were observed at Sinana on station which is due to the terminal moisture stress encountered during growing season. On the other hand better vitreous grain quality was obtained at Ginnir site as the environment is mid lowland having short maturity period with higher mean daily temperature. Generally, most bread wheat varieties tested under this study fall under good to best bread making quality properties based on qualities traits analyzed in this study, however, the experiment should be repeated over seasons and locations to have a clear quality classification of Ethiopian bread wheat varieties.

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LIVESTOCK

The development of "*Degagsa* and *Belebas*" Pigeon pea (*Cajanus cajan*) varieties for western Oromia

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Abstract:
*Ten pigeon pea genotypes including the standard check were tested across three environments (Bako, Chewaka and Gute) in western Oromia, Ethiopia during 2014 and 2015 main cropping season to evaluate the performance of pigeon pea genotypes for both herbage and grain yield, and their stability across environments. The genotypes were arranged in randomized complete block design (RCBD) with three replications. Two genotypes ILRI Acc. # 11575 and ILRI Acc.# 16527 were shown to have superior yielding ability both in herbage and grain yield and other desirable traits over the standard check '*Tsigab*' cultivar. The two genotypes had significantly higher herbage yields of 7.22 and 6.40 ton ha^{-1} per harvest with 77% and 57% yield advantage over the standard check, Tsigab (4.07 ton ha^{-1}), respectively. Those two varieties were verified on station and on farmers' field across location during 2016/17 cropping season, evaluated by the national variety releasing committee and finally officially released on April 2017. Those variety now named as Degagsa (11575) and Belabas (Acc. 16527). Degagsa and Belebas varieties gave high grain yield (22.59 qt ha^{-1} and 26.99 qt ha^{-1}) with the yield advantage of 41% and 68% over the best standard check Tsigab (16.02 qt ha^{-1}). GGE biplot analysis also confirmed Degagsa and Belebas varieties showed better stability and thus ideal varieties recommended for production in the test environments and other similar agro ecologies.*

Keywords: *Genotypes, herbage yield, ILRI, Pedigree; pigeon pea (Cajanus cajan), Stability*

Introduction

In Ethiopian livestock industry the crop-livestock mixed farming systems is one the most common production systems practiced in mid and high altitude of the country. Most lands previously meant for livestock production are under continuous stress due to increased crop cultivation; as a result animals are kept on limited land that further leads to land degradation, and declined size and productivity of grazing lands (Funte *et al*., 2010). This causes declined quantity and quality of feeds that further exacerbated by the increase in human and livestock population in most part of the country (Gemeda, 2010). The decreased feed production resulted in low production and productivity of animals that further affected the benefits they provide at household or national level. Adapted multipurpose trees which can be used as cheap source of protein supplements to improve the nutrient supply and utilization of poor quality feeds.

Pigeon pea is well adapted to the climate and uniquely combines such optimal nutritional profiles, high tolerance to environmental stresses, high biomass productivity and most nutrient and moisture contributions to the soil. Its foliage is an excellent fodder with high nutritional value. It contains 20-22% crude protein, 1.2% fat, 65% carbohydrate and 3.8% ash. In addition, they are found to possess different minerals and vitamins and are good source of carbohydrates for all mono-gastric animals (Khandelwal *et al*., 2010). In addition, By-product of split and shriveled seeds of Pigeon pea are used as livestock feed and as an inexpensive alternative to high cost animal feed sources such as bone meal and fish meal. As a result, production and feeding of such fodder tree legumes through integration with food crops were suggested as some of the potential options to improve the nutrient supply to livestock (Solomon, 2001).

Nevertheless, the adoption rate and wider use of multipurpose trees by livestock keepers in Ethiopia is not significant probably because of scantiness in information regarding the feeding value and less dissemination of these fodders, high genetic variability that exists within the cultivated and wild relatives remains to be explored for further uses. Hence, different accessions of Pigeon pea were evaluated against standard check across different locations to tackle the existing production problem. Therefore, the objective of the experiment was to evaluate the performance of pigeon pea genotypes for both herbage and grain yield and their stability across environments.

Materials and Methods

Ten pigeon pea genotypes including standard check 'Tsigab' were evaluated across locations (Bako, Chewaka and Gute) in altitude ranging from 1300 to 1900 meters above sea level for two years (2014-2015). The objective was to evaluate the performance of pigeon pea genotypes for both herbage and grain yield and identify stable high yielder across environment for further verification trial. Genotypes were arranged in a randomized complete block design (RCBD) with three replications in which each plot comprises of four rows having 4m length. The spacing between rows and plants were 50cm and 1m, respectively. A 100kg ha^{-1} DAP fertilizer was applied at planting. Agronomic management practices were uniformly applied as per the recommendations for the particular plant. Data from herbage yield, seed yield and other important agronomic traits and forage quality parameters were measured as dependent variables. For sampling 200gm fresh biomass were taken and dried in an oven at 65^oC for 72 hours to a constant weight. Partially dried feed samples were crushed and sieved by 1mm sieve screen using Wiley mill and stored in airtight plastic bags for chemical analysis to Holeta Agricultural Research Center animal nutrition laboratory. Based on yield and nutritional analysis data, two pipeline genotypes were selected for further verification trial. During 2016/17 cropping season, verification trial was conducted at Bako, Chewaka and Gute on station and on farmers' field. The two best performing genotypes ILRI-Acc#11575 (now named Degagsa) & ILRI-Acc#16527 (now named as Belebas) were grown along with the standard check across location and evaluated by the national variety releasing committee.

Results and discussions

Varietal Origin/Pedigree and Evaluation

Degagsa and Belebas are the name given by the breeder to released pigeon pea (*Cajanus cajan*) varieties with the pedigree of ILRI-Acc#11575 and ILRI-Acc #16527), respectively. These and the other pigeon pea genotypes were originated from ILRI (International Livestock Research Institute) and evaluated against the standard check 'tsigab', across three environments (Bako, Chewaka and Gute in 2014 and 2015 main cropping seasons.

Herbage yield performances

Significant differences ($P<0.01$) were observed among genotypes in the mean herbage yields and grain yields (Table 1). Degagsa and Belebas varieties gave higher herbage yields of 7.22 and 6.40 ton ha^{-1} per harvest with 77% and 57% yield advantage, respectively over standard check (4.07 ton ha^{-1}). Besides, the Degagsa and Belebas pigeon pea varieties had higher ($P<0.01$) grain yields of 22.59 qt ha^{-1} and 26.99 qt ha^{-1} with 41% and 68% in that order than the best standard check (16.02 qt ha^{-1}).

Table 1: Mean herbage yield (DM tha^{-1}) and Grain yield ($Qtha^{-1}$) of different accessions of Pigeon pea genotypes across locations from the year 2014 - 2015 G.C.

Genotypes	**2014**						**2015**						Mean HY	Mean GY
	Bako		Chewaka		Gute		Bako		Chewaka		Gute			
	HY	GY	HY	GY	HY	GY	HY	GY	HY	GY	HY	GY		
ILRI-Acc#16274	2.69	10.76	4.99	12.89	3.57	13.89	2.66	16.11	3.37	12.61	2.85	15.56	3.36	13.64
ILRI-Acc#16277	2.80	9.98	4.48	21.60	4.62	15.33	3.22	15.38	3.58	12.28	2.93	19.66	3.61	15.71
ILRI-Acc#16520	2.57	10.35	5.27	20.54	3.80	14.03	2.77	13.99	3.27	9.72	2.78	22.35	3.41	15.16
ILRI-Acc#16524	2.56	8.31	3.84	26.08	2.91	18.50	3.71	17.33	3.53	9.13	2.70	21.48	3.21	16.81
ILRI-Acc#16526	2.33	13.37	4.53	23.41	3.53	15.94	3.60	19.43	3.31	13.39	2.97	21.61	3.38	17.86
Belabas(16527)	**5.53**	**23.25**	**8.16**	**27.44**	**6.46**	**29.39**	**5.80**	**25.66**	**6.95**	**27.11**	**5.51**	**29.06**	**6.40**	**26.99**
ILRI-Acc#16528	3.01	7.81	4.89	22.37	2.91	20.50	2.57	24.04	2.96	8.56	2.64	21.75	3.16	17.51
Tsigab (11566)	3.86	11.67	5.42	20.67	3.71	14.22	3.91	19.15	3.90	10.84	3.59	19.56	4.07	16.02
ILRI-Acc#16555	4.30	13.16	6.47	23.14	5.96	13.16	5.01	15.00	6.21	13.78	4.73	18.16	5.45	16.07
Degagsa (11575)	**6.39**	**19.13**	**9.00**	**20.28**	**7.25**	**25.45**	**6.27**	**25.81**	**7.86**	**21.11**	**6.52**	**23.78**	**7.22**	**22.59**

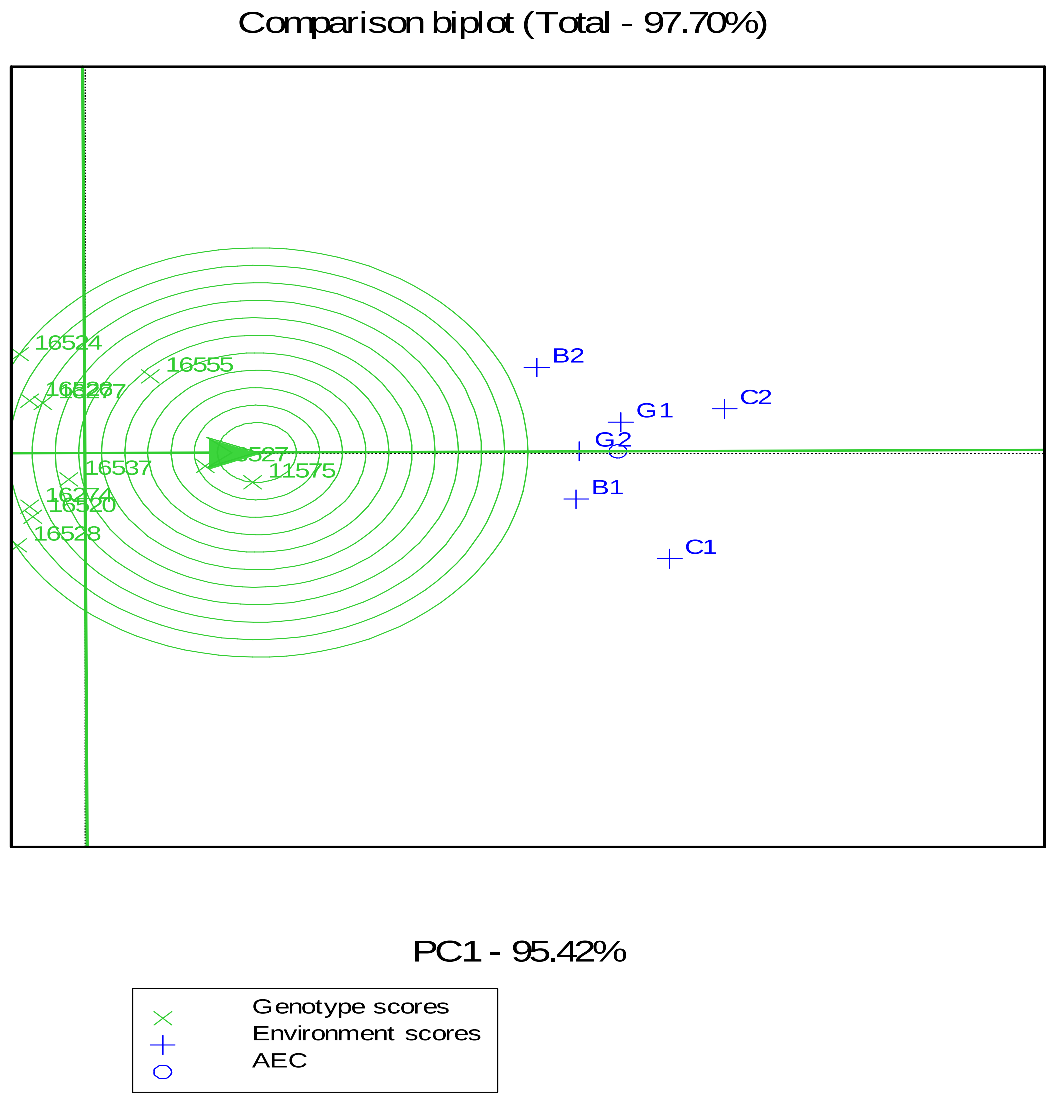
Mean	3.61	12.78	5.71	21.85	4.47	18.04	3.95	19.19	4.49	13.85	3.72	21.30
CV (%)	12.4	25.1	11.6	15.4	14.4	16.8	23.1	28.8	13.4	21.4	9.6	15.4
LSD (0.05)	0.76	5.51	1.14	5.77	1.10	5.20	1.52	9.47	1.04	5.09	0.61	5.63
SL	**	**	**	*	**	**	**	*	**	**	**	*

Key: **= highly significant, SL=significance level, HY = herbage yield, GY. = grain yield.

Stability of Performance/Adaptation

Analysis using the GGE biplot confirmed that Degagsa and Belebas varieties showed better stability compared to the remaining tested genotypes and standard check and thus ideal varieties recommended for production in the test environments and similar agro-ecologies (Fig 1). Besides, Degagsa and Belebas varieties showed herbage yield advantage of about 77% and 57%, respectively, over the standard check, Tsigab.

Φιγ 1. Σηοωεδ τηατ σταβιλιτψ ανδ αδαπταβιλιτψ οφ πιγεον πεα γενοτψπεσ αχροσσ ψ εαρσ ανδ λοχατιονσ



Key: B1=Bako 1st year, B2=Bako 2nd year, G1=Gute 1st year, G2= Gute 2nd year, C1= Chewaka 1st year, C2= chewaka 2nd year

Nutritional Quality Analysis

Evaluation of nutritional quality of pigeon pea genotypes were conducted at Holota Agricultural Research Center Nutrition laboratory. The analysis result showed that significant variations were observed ($p \leq 0.001$) in Crude protein (CP) content among the pigeon pea genotypes. The CP ranged from 18.98 to 22.08 %. Degagsa pigeon pea variety has higher CP value (22.08 %) than the standard check 'tsigab' and other tested genotypes. On the other hand, no different value was observed in dry matter and DOMD concentrations among the genotypes. But Degagsa variety has recorded the higher numerical value in in vtro (DOMD) than the other genotypes (Table 3). But no significant variations were observed among the genotypes in other quality parameters.

Table 2: Pooled mean DM, CP and DOMD values of different genotypes of Pigeon pea across locations (Chewaka, Gute and Bako)

			DM %	
No	**Genotypes**	DM%	CP	DOMD
1	ILRI-Acc#16274	89.30	19.14^{cd}	51.94^{bc}
2	ILRI-Acc#16277	90.29	18.98^{d}	51.93^{bc}
3	ILRI-Acc#16520	89.58	20.04^{b}	51.67^{c}
4	ILRI-Acc#16524	88.73	19.90^{bc}	51.60^{c}
5	ILRI-Acc#16526	89.90	20.02^{b}	51.88^{bc}
6	**Belabas (16527)**	**89.70**	$\mathbf{20.15^{b}}$	$\mathbf{51.90^{bc}}$
7	ILRI-Acc#16528	88.69	19.80^{bc}	51.65^{c}
8	Stand. check (Tsigab)	89.20	20.32^{b}	52.02^{ab}
9	ILRI-Acc#16555	89.49	20.53^{b}	52.29^{ab}
10	**Degagsa (11575)**	**89.64**	$\mathbf{22.08^{a}}$	$\mathbf{52.57^{a}}$
Grand mean		89.45	20.10	51.94
LSD(0.05)		1.671	0.772	0.598
CV%		1.1	2.2	0.7
LS		NS	**	NS
p-value		0.637	<.001	0.073

Key: NS =none significant, **= highly significant, CV=coefficient of variation, SL=significance level, LSD= least significant difference, DM=dry matter, CP=crude protein, DOMD=digestible organic matter in dry matter (in vitro).

Reaction to Major Diseases

Phytophthora blight, Cercospora leaf spot and Fusarium leaf blight are economically importance disease for pigeon pea production. Fortunately, the released varieties and other tested genotypes including the standard check revealed resistance to these diseases throughout the study periods (Table 3).

Agronomic and Morphological Characteristics

The released varieties, Degagsa (ILRIAcc. #11575) and Degebas (ILRIAcc.#16527) have light yellow and yellow flower color, respectively. They are small perennial tree legumes. Degagsa and Degebas pigeon pea varieties had 1000 seed weights of 22.59 and 26.98 g, respectively and had 1.05 and 1.22 of leaf to steam ratio in that order. The detailed agronomic characters of the newly released variety are indicated in (Table 3).

Table 3. Agronomic/morphological characteristics of Degagsa, Degebas varieties and standard check.

Characteristics	Degagsa	Degebas	Tsigab (S.Check)
Adaptation area:	Bako, Biloboshe, Gute, Chewaka and similar agro ecologies		
Altitude (masl)	1300 – 1900		
Rainfall (mm)	800 – 1200		
Seeding rate (kg/ha):	4-4.5 kg		
Spacing (m)	Between row 1.00 and between plant 0.50		
Planting time:	At late June-early July		
Fertilizer rate: (kg/ha):	P_2O_5: 46; N: 18		
Days to 50% flowering:	115		
Days to seed maturity:	165		
Height at biomass harvest (cm):	134.83	146.78	139.57
Growth habit:	Small tree	Small tree	Small tree
Life span	Perennial	Perennial	Perennial
Flowering color	Light yellow	Yellow	yellow
Seed color:	Dark brown	Red brown	Saddle brown
Seed size:	bold	bold	bold
Thousand seed weight (g):	97	93	89
Yield			
Grain yield(qt ha^{-1})	22.59	26.98	16.02
Biomass yield (DM/t ha^{-1}/cut):	7.22	6.4	4.07
Leaf-to-stem ratio	1.05	1.22	1.01
Crop pest reaction (1-9 scale)			
Fusarium leaf blight	1	2	2
Cercospora Leaf Spot	2	2	2
Fodder quality:			
DM (%):	89.64	89.70	89.20
CP (%):	22.08	20.15	20.30
OM (%):	92.74	93.31	
IVDMD (%):	52.57	51.90	52.02
Ash (%):	7.26	6.69	
NDF (%):	68.89	70.04	
ADF (%):	46.47	46.49	
ADL (%)	14.34	15.61	
Special merits:	High biomass yield	High gran yield	
Year of release:	2017	2017	
Breeder/maintainer:	BARC		

Conclusion and recommendation

Degagsa and Belebas pigeon pea varieties outperform in both herbage and grain production and other desirable traits over the standard check 'Tsigab' cultivar. The two varieties had better nutritional quality, especially Crude Protein and invtro digestibility, good general adaptability and moderately resistant to disease such as Cercospora leaf spot and Fusarium leaf blight than the standard check. Therefore, the varieties were officially released and an ideal varieties recommended for production in the test environments and other areas with similar agro-ecologies.

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Effect of planting season and stage of harvesting on forage yield and quality of oats varieties in the highland of Bale

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Abstract

The experiment was conducted to determine the appropriate planting season and optimum stage of harvesting for forage yield and quality of fodder oat varieties at Sinana on-station and Agarfa (sub-site) of Bale highlands. Two newly released varieties of fodder oat (Bonsa and Bonabas) were used for the study. The material were sown in two cropping seasons in a year with varieties as main plot and stage of harvest as sub plot (boot, heading, milk, and soft dough stage) for two years. The analysis of variance showed that interaction of varieties and harvesting stages significantly affected (P<0.05) leaf to stem ratio (LSR) and total dry matter yield (DM). The chemical analysis of the data indicated that varieties and harvesting stages significantly affected (P<0.05) Dry matter (DM %), Ash (Ash %), Organic matter (OM %), Crude Protein (CP %), Neutral detergent fiber (NDF %), Acid detergent fiber (ADF %). As the age of the crop advances; biomass yield, Organic matter (OM %), Neutral detergent fiber (NDF %) and Acid detergent fiber (ADF %) showed an increment and Quality parameters such as Crude Protein (CP %), and invitro organic matter digestibility (TIVOMD %) indicated decreasing. The highest DM (13.2 t/ha) and lowest CP% (7.0 ton/ha) was obtained for Bonabas harvested at soft dough stage. Seasonal variation was also observed on yield and quality of fodder oat.

Key words: *Crude protein, Biomass, fodder oat*

Introduction

Livestock production has been an integral part of the Bale landscape for many centuries. Until recent few decades the livestock system was extensive with small numbers of people and livestock moving in a free and mobile manner. However since the time of Haile Selassie-I regime there have been numerous influencing factors that have changed the trend of livestock production in Bale. This began with the introduction of land measurement and taxes which encouraged settled agricultural expansion, aggravated by the declaration of grazing lands as 'no-man's lands'. At the same time, large scale mechanized farms were established in the areas, forcing livestock producers into the higher altitude regions and limit their livestock number and types. Currently most of the areas in the highlands of Bale are under cultivation of food crops. This was forced local farmers to keep large number of livestock on limited grazing area leading to overgrazing and poor productivity of livestock. Though, expansion in the cultivation of cereal crops was increased the utilization of crop residues for animal feeding. Crop residues nutritive value is bellow requirement of the animal not only for production even for animal body maintenance. According to NRC (1978) sole Barley and wheat straw which is the commonly used basal diet in the area have CP of 4.1% and 4.2%, respectively which is extremely bellow the animal requirement. Hence, shortage of nutrients for livestock is increasingly becoming serious in the area.

Since last three decades, to harmonize the livestock production with extremely dominating crop production activity in the area, different suitable technologies such as crop residue utilization, grazing land improvement, fodder crop productivity improvement research and its pre-extension activities has been carried out by Sinana Agricultural Research Center. One of the recommended alternatives to improve livestock feeding, and thereby their productivity was cultivation of improved forage crops. Fodder oats (*Avena sativa*), was among forage species that has been promoted for cereal dominated production system of Bale highland. Bonsa and Bonabas fodder oat varieties of SARC having 11.5% and 12.4% CP (Abate *et.al.* 2011), respectively, and can yield more than 10tone DM/ha are the promising varieties particularly released for wheat and barley belt areas of Arsi and Bale highland.

By their nature fodder oat (*Avena sativa*) varieties are adapted to a wide range of soil types, altitudes and rainfall conditions, and tolerate water logging than most of the other cereals (Alemayehu, 1997). Currently it is the most common forage choice among the smallholder farmers of Bale highland. These two fodder oat varieties have a little bit variation depending on their age of maturity and their preference by the farmers also varies based on the length of rain fall receiving period. Oat varieties which require long rainfall duration for maturation are referred as late maturing types whereas the varieties with relatively require short rainfall period called as early maturing ones. All types of oats are cultivated both in Bona and Ganna seasons of a double-cropping system of Bale highlands. Planting season can be considered as crucial factors that determines herbage yield and quality of cultivated forage crops. Studies also indicated that herbage yield and quality of oats are determined by environment, management practices, and genetics (Firdous and Gilani 2001; Yu et al., 2004). Environmental factors such as temperature and precipitation which strongly influenced by the seasons has great role for yield and quality of forage (Kim et al., 2001). Kim *et al, (*2001) also indicated that growing season and variety differences have significant effect on the DM content, CP and TDN of fodder oats. For instance, CP content of the oat variety at spring season was lower than during the autumn season and CP content of late-maturing varieties was higher than the early-maturing variety

On the other hand fodder oats is usually recommended to be harvested for feeding at the dough stage of maturity. Study indicated that the differences in yield and feeding value of fodder oats harvested at different stages of maturity: boot, flower, milk and dough (Meyer *et al.,* 1975). Within each of the forage species there are many varied cultivars which have unique agronomic characteristics. Smallholder farmers of Bale highlands have been recognized the difference in feeding value of forage (fodder oats) harvested at different stage maturity. Studies also indicated that there are tremendous differences in yield and feeding value of forage depending on which growth stage is chosen for harvest (Orloff, S. and D. Drake, 1998). Maturity of forage is closely related to its crude protein and fiber content, digestibility, dry matter yield. For instance in alfalfa, as the stage of maturity increases, so does its fiber content and digestibility decreases. It was indicated that there was a greater digestibility, faster weight gains, and higher milk production from cattle fed alfalfa harvested at an immature stage (Robinson, 2001).

Hence, in agro-ecologies like the highlands of Bale where there is two important cropping seasons, there is a need to determine the more suitable season for good yield and quality fodder oats production. Likewise, determination of optimum stage of harvest to obtain maximum yield and quality is very important. Yet, studies were not conducted with regard to management practices such as the best season of planting and optimum stage of harvest of fodder oats varieties for the highland of Bale. Thus, the intention of this study was to investigate the effect of planting season and stage of harvesting on forage yield and quality of fodder oat (Bonsa and Bonabas) varieties.

Material and Methods

The experiment was conducted in highly cereal crop dominated, crop-livestock mixed production system area of Bale highland at Sinana on-station and Agarfa (sub-site). The Two newly released varieties of fodder oat (Bonsa and Bonabas) were used for the study. The treatments were sown in two cropping seasons locally called ‘Bona’ (from August to December) and ‘Ganna’ (March to July) with varieties as main plot and stage of harvest as sub plot (boot, heading, milk, and soft dough stage) using split plot design replicated three times. Row planting with 20cm between rows using a plot size 2mx1.8m and seed rate of 80kg/ha fertilized by 100kg/ha DAP and 50kg/ha UREA were used.

Agronomic and yield parameters such as percent of lodging, plant height at different harvest stage, herbage dry matter yield at different harvesting stage, leaf to stem ration, and days to different harvesting stage were collected. Two middle rows per different stage were harvested to measure herbage yields at different harvesting stage. The total fresh biomass were recorded in the field and about 500gm and 200gm forage samples were collected in paper bag for determination of dry matter percentage and leaf to stem ratio, respectively. To determine dry matter content of the samples, the samples were oven dried at 65^0C for 72 hours. The Feed sample was analyzed for DM, CP and Ash content according to the standard methods of

AOAC (1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) analysis was followed the procedures of Van Soest *et al*, (1991). *In vitro* DM digestibility was also determine by the Tilley and Terry method as modified by Van Soest and Robertson (1985). Analysis of variance was performed using the statistical analysis system (SAS 1999) software and mean separation was carried out using the Least Significant Difference (LSD) test.

Result and desiccation

Agronomic and yield performances of early (Bonsa) and late (Bonabas) maturing oat varieties during *Bona* (*Meher)* season are presented in Table 1. There were significant difference ($P \leq 0.05$) in plant height, leaf to stem ration, green forage and dry matter yield for both varieties with harvest stages (Table 1). Plant height increased by 42 and 40.4% from boot to soft dough stage for early and late maturing varieties of oat, respectively. The increment was uniform despite the varieties. Leaf to stem ratio (0.95 and 0.79, respectively, for early and late maturing oat varieties) at boot stage had greater ($P<0.05$) than all other harvesting stages. This shows the proportion of leaf increased at immature stage and declines as its age advances. Similarly, green forage yield decreased with harvesting stages. Dry matter yield were lowest at boot stage and highest at soft dough stage for both varieties. Dry matter yield increased by 5.1 and 4.4 tha^{-1}, respectively, for early and late maturing oat varieties at soft dough than boot stage. Besides harvesting stage, location and plating year affects agronomic and yield performances. Plant height, Fresh biomass forage and dry matter yield were significantly higher ($P \leq 0.05$) at Sinana on station than Agarfa sub site. This is related to low temperature and soil character (water logging) at Agarfa.

Table 1. Three years data analysis of agronomic and yield performances of early and late maturing fodder oat varieties during *Bona (Mehar*) season

Harvesting Stages	Bonsa				Bonabas			
	PH (cm)	LSR	GFY (t/ha)	DM (t/ha)	PH (cm)	LSR	GFY (t/ha)	DM (t/ha)
Boot	96.1^{c}	0.95^{a}	49.3^{a}	9.7^{c}	108.8^{c}	0.79^{a}	48.6^{a}	10.9^{b}
Heading	114.7^{b}	0.66^{b}	53^{a}	12.5^{b}	127.8^{b}	0.57^{b}	47.9^{ab}	14.2^{ab}
Milk	130.4^{a}	0.51^{c}	49.4^{a}	12.9^{a}	147.3^{a}	0.42^{c}	37.9^{c}	12.8^{ab}
Soft dough	136.8^{a}	0.47^{c}	39.5^{b}	14.8^{a}	152.8^{a}	0.41^{c}	39.6^{bc}	15.3^{a}
Mean	119.5	0.65	47.8	12.5	134.2	0.55	43.5	13.3
CV (%)	14.2	30	20.5	25.5	12.9	35.8	29.7	39.6
lsd	11.3	0.13	6.5	2.1	11.6	0.13	8.6	3.5
Sinana on station	142.4^{a}	0.61	63.6^{a}	14.3^{a}	148.3^{a}	0.44^{b}	56.8^{a}	15.9^{a}
Agarfa sub site	96.6^{b}	0.69	32^{b}	10.6^{b}	120^{b}	0.66^{a}	30.2^{b}	10.6^{b}
Lsd	7.9	0.09	4.6	1.5	8.2	0.09	6.1	2.5

Key: CV=coefficient of variation, GFY=green forage yield, lsd=least significant difference, LSR=leaf to stem ration, PH=plant height, Means within a column with different superscript differ significantly (P<0.05)

Agronomic and yield performances of Bonsa and Bonabas fodder oat varieties during *Gana* (*Belg)* season are presented in Table 2. There were significance differences (P<0.05) among the parameters from boot to soft dough harvesting stages. The variations for plant height, leaf to stem ratio and dry matter yield for both early and late maturing oat varieties follows the same trend as that of *Meher* season except the green forage yield, which showed the reverse pattern. Green forage yield was significantly (P<0.05) higher at soft dough stage than other stages for early maturing variety and at boot stage for late maturing oat variety. This is due to the short period overlapping of *Mehar* and *Belg* seasons i.e. when oat variety reached at soft dough stage during the *Belg* season, the first rain for *Mehar* season starts and the variety continue vegetative growth stages without seed filling. Due to this, seed quality was poor and yield was very low for both varieties during *Belg* season at all location during the experimental periods.

When we compare the agronomic and yield performances of the varieties across season, the performances during *Meher* season are much better than *Belg* season (Table 1 and 2). The highest green forage yield obtained was 53 and 48.6 t/ha for *Meher* and 24.6 and 27.3 t/ha for *Belg* season for Bonsa and Bonabas, respectively. Similarly, the highest dry matter yield obtained was 14.8 and 15.3 t/ha for *Meher* and 5.5 and 7.3 t/ha for *Belg* season for Bonsa and Bonabas respectively. This indicated that yield performances were doubled for *Meher* season compared to *Belg* season which might be due to favorable environmental condition for *Meher* as compared to Belg season.

Table 2. Three years analysis of agronomic and yield performances of early and late maturing oat varieties during *Gena (Belg)* season.

Harvesting	**Bonsa**				**Bonabas**			
Stages	**PH (cm)**	**LSR**	**GFY(t/ha)**	**DM (t/ha)**	**PH (cm)**	**LSR**	**GFY(t/ha)**	**DM (t/ha)**
Boot	50.8^{d}	0.99^{a}	14.1^{b}	2.9^{b}	67.5^{c}	0.86^{a}	16.5^{b}	3.9^{c}
Heading	63.4^{c}	0.89^{a}	16.5^{b}	4.0^{b}	94.4^{b}	0.71^{b}	23.4^{a}	5.8^{b}
Milk	74.3^{b}	0.73^{b}	21.0^{a}	5.5^{a}	107.4^{a}	0.41^{c}	26.8^{a}	6.4^{ab}
Soft dough	83.9^{a}	0.38^{c}	24.6^{a}	5.4^{a}	110.9^{a}	0.27^{d}	27.3^{a}	7.3^{a}
Mean	68.1	0.75	19.1	4.5	95.1	0.56	23.5	5.8
CV (%)	18.4	29.8	35.1	46.9	16.1	25.5	26.2	39.2
Lsd	8.4	0.15	4.5	1.4	10.2	0.09	4.1	1.5
Location								
Sinana	68.6	0.72	21.2^{a}	4.2	95.6	0.55	26.6^{a}	5.6
Agarfa	67.7	0.78	16.9^{b}	4.7	94.6	0.56	20.5^{b}	6.1
Lsd	5.9	0.11	3.2	0.99	7.2	0.07	2.9	1.1

Key: CV=coefficient of variation, GFY=green forage yield, LSD=least significant difference, LSR=leaf to stem ration, PH=plant height, Means within a column with different superscript differ significantly (P<0.05)

The effect of stage of harvesting on quality parameters such as OM, CP, fiber and IVOMD during *Meher* is shown on Table 3. The Quality parameters were significantly varied (p<0.05) with different stage of harvesting during different season of planting. The lowest DM percentage was obtained at early (boot stage) but its value increased as plant maturity advance though not statistically significant among the three later stages. On the contrary, ash and crude protein percentage sharply decline as plant maturity advanced. This agrees with the result of Corleto *et al*. (2004) Conducted on safflower and Jagadeesh *et al*. (2016) done on hybrid Napier grass (*Penniserum purpureum L.*). This is due to the facts of leafy material generally has higher ash content than stem material (Monti *et al*., 2008) and decreasing of leaf to stem ratio as the plant maturity stage advances. Decline in total ash content is also related to earlier dilution and translocation of minerals from vegetative portion of the plant to roots at late stage of maturity Maynard *et al*. (1981). In addition, Study by Gezahagn *et al. (*2014) and Kitaba *et al*. (2007) also indicated that Crud protein content is positively correlated with ash content. Considerably ($p<0.05$) the lowest fiber content (NDF, ADF and ADL) was noted at boot stage for both varieties and the value increased as the plant advanced in maturity for Bonabas.

The highest contents of NDF % and ADF % was observed at milk stage and then decreasing pattern for Bonsa which is due to early seed feeling character of the variety. This is related to total fiber content declining of the cereal plant at the dough stage, resulting in a curvilinear relationship between fiber and maturity (Corleto *et al,* 2004). This is due to the grain, being very low in fiber, dilutes the increasing fiber of the stem, resulting in little change in total plant fiber as the plant matures. In-vitro organic matter digestibility (TIOMD) and metabolizable energy (ME) contents were higher at early stage (at boot stage) and declined as stage of growth increased for both varieties as expected.

Table 3. Quality analysis of early and late maturing oat varieties during *Bona (Meher)* season

Varieties	**Parameters**	**Harvesting stages**				**Mean**	**CV**	**Lsd**
		Boot	**Heading**	**Milk**	**Soft dough**		**(%)**	**(0.05)**
	DM (%)	88.6^{b}	89.8^{a}	90.2^{a}	89.9^{a}	89.4	0.57	0.62
	Ash (%)	8.6^{a}	6.7^{b}	6.1^{bc}	5.6^{c}	6.7	12.3	1.0
Bonsa	CP (%)	10.6^{a}	8.0^{b}	7.1^{c}	7.0^{c}	8.2	5.3	0.53
	NDF (%)	57.6^{c}	65.9^{b}	68.6^{a}	67.2^{ab}	64.8	3.3	2.6
	ADF (%)	31.9^{c}	40.0^{b}	42.7^{a}	39.3^{b}	38.5	5.3	2.5
	ADL (%)	2.3^{c}	4.3^{b}	5.2^{a}	5.1^{a}	4.2	11.7	0.59
	TIVOMD (%)	58.8^{a}	54.9^{b}	53.5^{c}	53.3^{c}	55.1	1.3	0.84
	ME(MJ/kg DM)	8.7^{a}	8.4^{b}	8.3^{b}	8.3^{b}	8.4	1.4	0.14
	DM (%)	89.6^{b}	90.2^{ab}	90.6^{a}	90.6^{a}	90.2	0.85	0.93
	Ash (%)	8.7^{a}	6.3^{b}	5.1^{b}	4.8^{b}	6.2	26.6	1.9
	CP (%)	10.4^{a}	8.0^{b}	6.6^{c}	5.9^{c}	7.7	10.9	1.0
Bonabas	NDF (%)	62.1^{c}	67.8^{b}	70.3^{ab}	72.1^{a}	68.1	4.8	3.9
	ADF (%)	36.9^{c}	41.7^{b}	45.3^{ab}	46.8^{a}	42.7	8.6	4.4
	ADL (%)	4.1^{c}	4.9^{bc}	5.9^{ab}	6.5^{a}	5.4	19.1	1.2
	TIVOMD (%)	58.5^{a}	54.9^{b}	52.7^{c}	51.6^{c}	54.4	2.3	1.5
	ME(MJ/kg DM)	8.7^{a}	8.4^{b}	8.2^{bc}	8.1^{c}	8.4	2.1	0.21

Key: ADF=acid detergent fiber, ADL=acid detergent lignin, CP=crude protein, CV=coefficient of variation, DM=dry matter, IVOMD=invitro organic matter digestibility, lsd=least significant difference, ME=metabolizable energy, NDF=neutral detergent fiber,

Means within a column with different superscript differ significantly (P<0.05)

The effect of stage of harvest on quality parameters such as OM, N, fiber and IVOMD during *Belg* season is shown on Table 4. Stage of harvesting significantly (p<0.05) affected the quality of both varieties. All parameters showed similar trend of change by the influence of maturity of plant as observed in Bona season except ash content which was not affected by stage of maturity. The variation was similar with variation observed during *Bona* season. Except the percentage of CP and TIVOMD, which were higher during *Belg* season compared to *Meher* season, the percentage of the rest quality parameters were remain unchanged due to season variation.

Table 4. Quality analysis of early and late maturing oat varieties during *Gena (Belg)* season

Varieties	Parameters	Harvesting stages				Mean	CV	Lsd
		Boot	Heading	Milk	Soft dough		(%)	(0.05)
	DM (%)	88.4[b]	88.7[b]	88.9[b]	90.4[a]	89.1	0.59	0.64
	Ash (%)	8.7	8.7	8.5	8.8	8.3	21.1	2.1
Bonsa	CP (%)	13.2[a]	12.1[b]	10.2[c]	8.4[d]	10.9	7.8	1.0
	NDF (%)	57.6[d]	60.7[c]	63.5[b]	70.3[a]	63.0	2.8	2.1
	ADF (%)	28.8[c]	31.3[bc]	33.5[b]	41.4[a]	33.7	7.8	3.1
	ADL (%)	2.0[c]	2.5[bc]	3.2[b]	5.8[a]	3.4	19.1	0.78
	TIVOMD (%)	62.9[a]	61.2[b]	58.2[c]	55.5[d]	59.4	2.2	1.6
	ME(MJ/kg DM)	9.3[a]	9.1[b]	8.8[c]	8.3[d]	8.9	1.6	0.17
	DM (%)	89.0[c]	89.4[c]	90.2[b]	90.7[a]	89.8	0.44	0.48
	Ash (%)	8.0	6.7	7.0	7.9	7.4	17.9	1.6
	CP (%)	13.0[a]	10.6[b]	9.4[b]	7.9[c]	10.3	11.3	1.4
Bonabas	NDF (%)	61.8[c]	65.9[b]	70.1[a]	72.3[a]	67.5	3.2	2.6
	ADF (%)	31.6[d]	35.4[c]	40.6[b]	44.6[a]	38.1	8.3	3.8
	ADL (%)	2.9[d]	3.8[c]	4.9[b]	6.5[a]	4.5	17.3	0.94
	TIVOMD (%)	62.6[a]	58.9[b]	57.1[b]	54.7[c]	58.3	3.0	2.1
	ME(MJ/kg DM)	9.3[a]	8.9[b]	8.6[c]	8.2[d]	8.8	2.2	0.24

Key: ADF=acid detergent fiber, ADL=acid detergent lignin, CP=crude protein, CV=coefficient of variation, DM=dry matter, IVOMD=invtro organic matter digestibility, lsd=least significant difference, ME= metabolizable energy, NDF=neutral detergent fiber, Means within a column with different superscript differ significantly ($P<0.05$).

Conclusion and recommendations

The result of the experiment showed that varieties and harvesting stages significantly ($P<0.05$) affected leaf to stem ratio (LSR), total dry matter yield (DM) and other quality parameters. As the age of the crop advances biomass yield, Organic matter (OM %), Neutral detergent fiber (NDF %) and Acid detergent fiber (ADF %) indicated increment, but quality parameters such as Crude Protein (CP %), and invitro organic matter digestibility (TIVOMD %) indicated decreasing. The earlier harvesting time the better in nutrition quality but the lowest DM yield was observed. Accordingly, the highest DM (13.2 t/ha) and lowest CP% (7.0 ton/ha) was recorded for Bonabas harvested at soft dough stage. The chemical analysis of the sample indicated that varieties and harvesting stages was significantly affected (P<0.05) Dry matter (DM %), Ash (Ash %), Organic matter (OM %), Crude Protein (CP %), Neutral detergent fiber (NDF %), Acid detergent fiber (ADF %). Ganna season is not appropriate for seed production probably due to the long rainy season that damage the seed quality. In general, to attain both high quality and high biomass yield, harvesting at milk stage during Gana season and also relatively better variety for fodder production is Bonsa. Bona season is preferably better than Gana season on seed production for both tested varieties.

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Effect of planting season and stage of harvesting on forage yield and quality of Vetch varieties in the highland of Bale, Ethiopia

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Abstract

The experiment was conducted for three consecutive years at Sinana on-station and Agarfa (sub site) of Bale highland with the objective of determining the appropriate planting season and optimum stage of harvesting for forage yield and quality of vetch varieties. The area is crop-livestock mixed with cereal crop dominating production system. Two newly released varieties of fodder vetch (Gabisa and Lalisa) were used for the study. The material was sown in both bona and Gena cropping seasons with varieties as main plot and stage of harvest as sub plot (beginning of flowering, full flowering and Seed filling*). Three years (Six seasons) data analysis showed that varieties and harvesting stages significantly affected (P<0.05) leaf to stem ratio (LSR) and total dry matter yield (DM). The highest DM (10.4 t/ha) were recorded for Lalisa harvested at seed filling stage during Bona, while the highest LSR about (1.0) were obtained from Bonsa at beginning of flowering and full flowering harvesting stages of both season. The chemical analysis revealed that varieties and harvesting stages significantly affected (P<0.05) Dry matter (DM %), Ash (Ash %), Crude Protein (CP %), Neutral detergent fiber (NDF %), Acid detergent fiber (ADF %), Acid detergent lignin (ADL %) during both season. The intermediate point negotiating Biomass yield and quality hay is harvesting at flowering stage to obtain better LSR and CP of 13.7% and 14.4% during Bona and 15.9% and 14.3% during Gena for Lalisa and Gabisa respectively. Ganna season is not appropriate for seed production due to long rain damaging the seed quality.*

Key words*: Crude protein, Biomass, fodder vetch*

Introduction

Feed shortage is repeatedly reported as one of the major constraint of livestock production in highlands of Bale. Improved forage legumes crops such as vetch are recognized for their potential to produce good feed resource to solve the feed shortage. Vetch is one of annual forage legume adapted to a wide range of soil types, altitudes and rainfall conditions (Alemayehu 1997). It is found to be with high herbage yield under low input condition such as fertilizer and can be used for livestock feeding in the form of green or conserved for dry season use. It is also a highly efficient N fixer and can replace much of the N fertilizer. Some of its agronomic traits are its competitiveness with weeds, growth under local management condition. Vetch cropping promotes yields above those attainable from conventional cropping system largely through improved soil quality. Including vetch into the cropping system provides an environmentally friendly solution to reducing use of N fertilizer while improving soil fertility and enhancing crop yield.

In Bale highland there is two important cropping seasons suitable for forage production. Forage legumes such as vetch fit well in double cropping systems of Bale highland and provide an important source of feed. The herbage yield and quality of forage can be affected by growing season and harvesting stages. The performance of individual variety could also vary from season to season. Environmental factors such as temperature, water stress, light, and soil nutrients are well known to have a significant impact on the quality of forage plants, particularly those grown in environments with varying degrees of different stresses. These stresses can result in large variations, mainly between seasons in forage yield and quality. Stress occurs when an environmental factor is not ideal for plant growth, for example, too low or too high a temperature, water logging, drought, a soil nutrient deficiency (Buxton and Fales, 1994).

Studies show that the effects of condensed tannin (CT) in forage legumes have been related to the species (Jackson *et al*., 1996), plant part (Barahona *et al*., 1997), genotype within species (Schultze-Kraft and Benavides, 1988), plant maturity (Lees *et al*., 1995), and environmental factors (Barry and Forss, 1983; Anuraga *et al*., 1993). The variation of CT levels with plant genotype and environmental conditions suggests that CT accumulation can be regulated through selection or breeding, and through targeting legumes to specific environmental “niches” that favor low CT concentration in edible forage.

This needs the selection of the variety for its suitable cultivation season. Hence, depending on which cultivar or variety is chosen, and how it is managed, it is possible to utilize the maximum advantage of the forage for our animals. However, there is lack of adequate information on the herbage yield and quality produced during these two different cropping seasons. As the result the suitable cropping season for good herbage yield and quality not clearly identified. Moreover, the appropriate stage of harvesting for optimum herbage yield and quality of vetch is not yet determined. Hence, determination of appropriate planting season and optimum harvesting stage of vetch varieties (Gabisa and Lalisa) for the highlands of Bale is very crucial. Therefore; this activity was carried out to determine the appropriate planting season and optimum stage of harvesting for forage yield and quality of vetch varieties.

Material and Methods

The experiment was conducted at Sinana On station and Agarfa (sub-site) of Bale highland for three consecutive years. The area is crop-livestock mixed with cereal crop dominating production system characterized by bimodal rain fall resulting in two cropping seasons locally called ‘Bona’(from August to December) and ‘Ganna’ (March to July). Two newly released varieties of vetch (Gabisa and Lalisa) were used for the study. The experiment was arranged in split plot design, replicated three times and sown in two cropping seasons with varieties as main plot and stage of harvest as sub plot (beginning of flowering, full flowering and seed filling). Recommended seed rate 30kg/ha and 100kg DAP/ha fertilizer were used on plot size 2*2.1 $m^{2.}$

Data for grain yield and other agronomic traits such as plant height at different harvest stage, days to beginning of flowering, full flowering and seed setting, herbage yield at different harvesting stage, and leaf to stem ration were collected. For herbage yield, two middle rows were harvested at different harvesting stage. At harvest, total fresh biomass was recorded at field and 500gm and 200gm forage samples were collect to paper bag for determination of dry matter percentage and leaf to stem ratio respectively.

To determine dry matter content, the samples were oven dried at 65^0C for 72 hours and weighted for DM yield estimation. The feed sample was analyzed for DM, CP and Ash content according to the standard methods of AOAC (1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) analysis was followed the procedures of Van Soest *et al.* (1991). *In vitro* DM digestibility was also determined by the Tilley and Terry method as modified by Van Soest and Robertson (1985). Least Significant Difference (LSD) of Mean separation of different agronomic and yield parameters of different harvesting stage to dry matter yield was carry out using statistical analysis system (SAS 1999) software.

Result and Discussion

The agronomic and yield performances of vetch (Gebisa and Lalisa) varieties during *Bona* (*Meher)* season are presented in Table 1. Leaf to stem ratio harvested at beginning of flowering stage was significantly (P≤0.05) greater than that obtained at seed filling stage for both varieties. The proportion of leaf was decreased as plants age increased for both varieties. Green forage yield obtained at seed filling stage is higher (P<0.05) than that obtained at beginning of flowering stage for Gebisa and remain unchanged for Lalisa variety. DM yield harvested at seed filling stage had greater by 132% and 73%, respectively, for Gebisa and Lalisa than harvested at beginning of flowering stage. This showed that the highest yield was obtained at later harvesting stage and early immature harvest result in a loss in dry matter yield. Plant height obtained at Sinana on station was significantly greater (P<0.05) than Agarfa sub site for both varieties (Table 1).

Table 1: The three years data analysis of agronomic and yield performances of vetch varieties during *Bona (Mehar*) season

Harvesting stages	Gebisa				Lalisa			
	PH (cm)	LSR	GFY (t/ha)	DM (t/ha)	PH (cm)	LSR	GFY (t/ha)	DM (t/ha)
Beginning of flowering	85.7[b]	0.98[a]	19.6[b]	3.1[b]	129.7[b]	0.89[a]	37.1	6.0[b]
Full flowering	87.9[b]	0.95[a]	21.5[ab]	3.8[b]	140.5[ab]	0.77[a]	39.7	8.6[ab]
Seed filling	117.9[a]	0.73[b]	28.1[a]	7.2[a]	160.8[a]	0.46[b]	35.8	10.4[a]
Mena	97.2	0.88	23.1	4.7	143.7	0.71	37.5	8.3
CV (%)	31	23.5	50.8	56.7	24.8	41.9	38.7	45.5
lsd(0.05)	20.2	0.14	7.9	1.8	23.8	0.19	9.7	2.5
Sinana on station	116.3[a]	0.82	24.2	4.9	169.1[a]	0.56[b]	41.3	8.3
Agarfa sub site	78.0[b]	0.94	22	4.5	118.2[b]	0.86[a]	33.7	8.3
LSD (0.05)	16.5	0.11	6.4	1.5	19.5	0.16	7.9	2.1

Key: CV=coefficient of variation, DM=dry matter, GFY=green forage yield, lsd=least significant difference, LSR=leaf to stem ratio, PH=plant height

Agronomic and yield performances of vetch varieties during *Gena* (*Belg)* season are presented in Table 2. Despite the higher performances of the agronomic parameters during *Bona (meher)* season, the trends of their changes with harvesting stages were alike. Plant height at seed filling stage increased by 67% and 66%, respectively for Gebisa and Lalisa than beginning of flowering stage and on the contrary, leaf to stem ratio decreased as harvesting delayed. Green forage and dry matter yield obtained at seed filling stage was significantly greater ($P<0.05$) than beginning of flowering stage for both varieties. There were no significant ($P>0.05$) difference observed for all agronomic parameters considered across location.

Table 2: The agronomic and yield performances of vetch varieties during *Gena (Belg)* season

Harvesting stages	Gebisa				Lalisa			
	PH (cm)	LSR	GFY (t/ha)	DM (t/ha)	PH (cm)	LSR	GFY t/ha)	DM(t/ha)
Beginning of flowering	42.4[c]	1.0[a]	6.0[b]	0.99[b]	60.1[b]	1.12[a]	7.2[b]	1.5[b]
Full flowering	55.8[b]	0.9[a]	7.1[ab]	1.4[b]	75.4[b]	1.01[a]	11.6[ab]	2.4[ab]
Seed filling	70.9[a]	0.64[b]	9.7[a]	2.7[a]	99.9[a]	0.55[b]	17.7[a]	3.3[a]
Mena	56.4	0.85	7.6	1.7	78.5	0.89	12.2	2.4

CV (%)	34.3	30.5	55.3	64	32.5	34.3	83.8	58.5
LSD (0.05)	12.9	0.17	2.8	0.73	17.1	0.21	6.8	0.93
Sinana on station	55.3	0.87	7.6	1.7	78.1	0.87	9.8	2.3
Agarfa sub site	57.4	0.83	7.6	1.7	78.8	0.93	14.6	2.5
LSD (0.05)	10.6	0.14	2.3	0.59	13.9	0.17	5.6	0.76

Key: CV=coefficient of variation, DM=dry matter, GFY=green forage yield, lsd=least significant difference, LSR=leaf to stem ratio, PH=plant height

Early cutting had significantly higher ($p<0.05$) mineral and crude protein content compared to late cutting as presented on Table 3. Ash and crude protein percentage obtained from cut at the beginning of flowering stage is significantly ($P<0.05$) higher than seed filling harvest for both varieties. This agrees with the result of C.H. Jagadeesh *et al*, (2016) done on hybrid Napier grass (*Penniserum purpureum*). This is due to the facts of leaf material generally has higher ash content than stem material (Monti *et al*., 2008) and decreasing of life to stem ratio as the plant maturity stage advances. Decline in total ash content is also related to earlier dilution and translocation of minerals from vegetative portion of the plant to roots at late stage of maturity Maynard *et al*. (1981). In addition, Study by Gezahagn *et al., (*2014) and Kitaba *et al*., (2007) also indicated that Crud protein content is positively correlated with ash content.

The Percentage of fiber contents (neutral detergent fiber, acid detergent fiber and acid detergent lignin) did not significantly increased as harvesting delayed and was maximum at fully flowering stage for Gebisa varieties and there is slight decrease in some of these parameters at seed filling stage. This is due to the grain, being very low in fiber, dilutes the increasing fiber of the stem, resulting in little decrease in total plant fiber as the plant matures (seed filling stage). True *in vitro* organic matter digestibility (TIVOMD) and metabolizable energy (ME) content decreased as harvesting stage delayed. TIVOMD percentage for both varieties and metabolizable energy for Gebisa variety had higher ($P<0.05$) for early cut (beginning of flowering) compared to late cut (seed filling stage). Generally quality parameters decreased as stage of forage harvest advanced.

Table 3. The analysis of quality of early and late maturing oat varieties during *Bona (Meher)* season

Varieties	Parameters	Harvesting stages			Mean	CV (%)	Lsd
		Beginning of flowering	Full flowering	Seed filling			
Gebisa	DM (%)	89.9[a]	89.9[a]	89.6[b]	89.8	0.08	0.09
	Ash (%)	10.5[a]	9.7[b]	7.6[c]	9.3	4.5	0.52
	CP (%)	15.9[a]	14.4[b]	12.2[c]	14.2	5.9	1.03
	NDF (%)	48.8[b]	50.7[a]	48.1[b]	49.2	3.2	1.96
	ADF (%)	38.9[ab]	41.7[a]	37.0[b]	39.2	6.0	2.93
	ADL (%)	7.1[a]	7.3[a]	6.3[b]	6.9	7.1	0.61
	TIVOMD (%)	75.6[a]	73.0[b]	71.9[b]	73.5	2.6	2.4
	ME (MJ/kg DM)	10.8	10.6	10.7	10.7	2.6	0.34
Lalisa	DM (%)	90.1	90.1	90.1	90.1	0.06	0.07
	Ash (%)	10.0[a]	9.1[b]	7.6[c]	8.9	5.9	0.65
	CP (%)	16.2[a]	13.7[b]	10.7[c]	13.5	10.1	1.69
	NDF (%)	53.8[b]	55.4[ab]	58.3[a]	55.8	4.6	3.2
	ADF (%)	47.8	47.6	48.7	48.0	4.9	2.9
	ADL (%)	8.5	8.6	8.6	8.6	5.6	0.59
	TIVOMD (%)	69.9[a]	67.8[ab]	65.2[b]	67.7	3.1	2.6
	ME (MJ/kg DM)	10.1[a]	9.9[ab]	9.7[b]	9.9	2.5	0.31

Key: ADF=acid detergent fiber, ADL=acid detergent lignin, CP=crude protein, CV=coefficient of variation, DM=dry matter, IVOMD=invitro organic matter digestibility, lsd=least significant difference, ME=metabolizable energy, NDF=neutral detergent fiber

There was a significant difference for quality parameters considered with delayed harvesting stages presented in table 4. The variation was similar with variation observed during *Bona* season. Except the percentage of CP and TIVOMD, which were higher during *Belg* season compared to *Meher* season, the percentage of the rest quality parameters were remain unchanged due to season variation.

Table 4. Analysis of quality of early and late maturing oat varieties during *Gena (Belg)* season

Varieties	Parameters	Harvesting stages			Mean	CV (%)	lsd
		Beginning of flowering	Full flowering	Seed filling			
Gebisa	DM (%)	89.9[a]	89.8[b]	89.7[b]	89.8	0.07	0.08
	Ash (%)	11.8[a]	11.3[a]	9.1[b]	10.7	9.6	1.29
	CP (%)	15.8[a]	14.3[b]	13.7[b]	14.6	7.8	1.4
	NDF (%)	48.6[ab]	47.5[b]	49.7[a]	48.6	3.3	1.9
	ADF (%)	38.1	37.2	37.4	37.5	5.9	2.8
	ADL (%)	6.7[ab]	6.5[b]	7.1[a]	6.8	7.1	0.59
	TIVOMD (%)	78.6[a]	76.6[b]	73.6[c]	76.3	1.9	1.78
	ME (MJ/kg DM)	11.0[a]	10.8[ab]	10.7[b]	10.8	1.8	0.24
Lalisa	DM (%)	90.0[a]	90.0[a]	89.9[b]	89.9	0.04	0.05
	Ash (%)	11.4[a]	10.9[ab]	10.8[b]	11.0	3.1	0.42
	CP (%)	17.3[a]	15.9[b]	15.4[b]	16.2	2.8	0.55
	NDF (%)	47.9[b]	50.0[a]	49.2[ab]	49	3.0	1.8
	ADF (%)	39.3[b]	42.0[a]	40.3[ab]	40.5	4.2	2.1
	ADL (%)	7.3	7.6	7.4	7.4	4.7	0.43
	TIVOMD (%)	74.7[a]	72.1[b]	70.8[b]	72.5	2.2	1.95
	ME (MJ/kg DM)	10.6[a]	10.3[b]	10.1[b]	10.3	1.8	0.24

Key: ADF=acid detergent fiber, ADL=acid detergent lignin, CP=crude protein, CV=coefficient of variation, DM=dry matter, IVOMD=*invitro* organic matter digestibility, lsd=least significant difference, ME=metabolizable energy, NDF=neutral detergent fiber

Conclusion and recommendations

Dry matter yield harvested at seed filling stage had greater by 132% and 73%, respectively for Gebisa and Lalisa than harvested at beginning of flowering stage. This showed that the highest DM yield was obtained at late harvest stage but early immature harvest is a loss of huge dry matter yield. Leaf to stem ratio which is the highest indicator of quality, harvested at the beginning of flowering stage is significantly higher (P<0.05) than that obtained at seed filling stage uniformly for both varieties. One of the important quality parameter CP percent was also indicated decreasing pattern as the plant age advances. The intermediate point negotiating Biomass yield and quality hay is harvesting at flowering stage to obtain better leaf to shoot raition (LSR) and crude protein (CP) of 13.7% and 14.4% during Bona and 15.9% and 14.3% during Gena for Lalisa and Gabisa, respectively. Ganna season is not appropriate for seed production due to long rain damaging the seed quality. Therefore; the ideal harvesting time and season for both high quality and high biomass yield is harvesting at full flowering stage during Bona season. Depending on biomass yield and quality data the relatively better variety for fodder production is Lalisa.

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Evaluation of effective microbe treated barely straw supplemented with bypass protein as intervention diet for cross breed dairy animal under small scale farmer's condition

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Abstract

The study was conducted at on farm level with crossbred lactating dairy cows, maintained under small scale mixed farming system at Kofele district, in West Arsi zone, Ethiopia to assess the effect of feeding intervention diet (EM treated barley straw) supplemented with a concentrate mixture (linseed cake 48%; wheat bran 50% and salt 2%). The study was conducted to asses feed intake, milk yield and profitability during the dry season. A total of 26 households having one or two lactating cows per house hold were selected. Twenty six cows in mid-to late lactation with an average body weight of 315.8±52.05 kg were selected and balanced for their parity, stage of lactation, level of milk yield and divided into two groups (13 cows per group). Thirteen cows were fed EM treated barley straw in addition to grazing and supplemented with a concentrate mixture at 0.5 kg /kg of milk yield/cow/day (T1), and the other 13 cows of one group were maintained as usually practiced by farmers (control) (T2). Feeding EM treated barley straw supplemented with linseed cake and wheat bran concentrate mixture significantly (P<0.01) increased feed intake and milk yield of the cows. Due to the improvement in daily milk yield by 2.31 kg (4.98 vs. 2.65 kg), the net profit increased from

ETB 39.24/cow/day in the control group to ETB 49.05/cow/day in T1 group. This study indicated that the intervention diet increased the net profit for farmers to ETB 9.81/cow/day. Feeding EM treated barley straw with bypass protein source was found to be an effective approach to maximize the utilization of locally available feed resources for better animal productivity during the dry season in mixed farming system of Ethiopia.

Key words: *Effective Micro-organism, barley straw treatment, economic analysis, milk yield*

Introduction

Crop and livestock production are commonly integrated in the mixed farming system of the mid and high lands of Ethiopia. In such systems the land is dominantly utilized by smallholder farmers for production of cereal and pulse crops and grazing land for livestock through rain fed agriculture. As more and more land is put under crop production, livestock feed becomes scarce and crop residues particularly cereal straws remain the major feed source for the animals particularly during the dry period of the year (Solomon, 2004). Crop residues such as cereal straws are low quality feeds which forms the basal feed in most parts of Ethiopia. They are deficient in nitrogen, energy, vitamins and minerals, of which fermentable nitrogen is usually the first limiting (Girma *et al*. 2014, Zewudie, 2010). The nutrient deficiencies affect microbial growth, microbial protein synthesis and overall fermentation in the rumen that further result in low voluntary intake and fiber fermentation and digestibility.

Barley straw is one of the major crop residues available in most cereal producing mixed farming systems. However, it contain high fiber and hence has low degradability in the rumen (530g/kg) (Zewudie, 2010). Therefore, the nutrient derived by feeding of barely straw hardly supports the maintenance requirement and leading to low production and productivity of dairy animals. There are various options reported to alleviate these constraints such as supplementation, chemical treatment, biological treatment and manipulation of the rumen ecosystem. Recently the treatment of crop residue with effective microbes (EM) is becomes one of the biological methods of improving feed quality. The treatment of crop residues with

EM and supplementation with escape protein resulted in remarkable results in improving intake, digestibility and performances of animals.

Effective Microbes (EM) treated hay led to increased feed efficiency in stationed lactating dairy cows under Ethiopian condition (Mulugeta, 2015). Although such information was generated on research station, the efficacy of EM, particularly when used as under small scale farmers condition and treating or ensiling crop residues has not been well evaluated. Therefore, this study was aimed to evaluate the effect of EM-treated barely straw supplemented with bypass protein feed on feed intake and milk yield and economic benefit under on farm condition of small scale crossbreed dairy producers.

Materials and methods

Description of the study area

The study was carried out on-farm at West Arsi zone Kofele district, Wamigne Abosa Kebele which located 285 km to the South East of Addis Ababa along the main road from Shashamane to Bale Robe at 7^{o} 7’ N latitude and 38^{o} 30’ E longitudes. It has an altitude of 2670 meters above sea level (m.a.s.l). The area is a typical mixed crop livestock production system, where small scale dairying based on crossbred animals are found here and there. Cattle are dominant livestock species in the area while wheat, barley, potato, cabbage and Inset are the major crops produced.

Experimental Animal, Design and Treatments

The experiment was conducted on mid to late lactating dairy animals of interested sixteen farmers in the study area. Totally twenty six lactating cross breed dairy animals with average body weight of 315.8±52.05 kg and an average milk yield of 2.67±0.41 kg/cow/day were categorized equally in to two treatments to participate in the experiment.

The experimental cows were divided into two treatment groups (thirteen cows in each group). Cows of the first group (T1) graze for 8 hours and supplanted with intervention diet (EM2 treated barley straw supplemented with a concentrate mixture composed of 48% linseed cake, 50% wheat bran and 2% salt). Cows in the second group (T2, control) graze for eight hours and they feed on untreated barley straw with wheat bran as supplements which is common practices in the study area. During allocation of animals into experimental treatments the level of milk yield, stage of lactation, body condition and parity were also considered. All the cows were weighed and drenched with broad-spectrum anti-helminthes (Albendazole 2500mg) prior to the start of the experiment.

Preparation of EM2 treated Barley straw

To prepare EM2 solution for ensiling barley straw; 1liter of EM1 (stock solution) was mixed with 1liter of molasses and 18 liters of chlorine free water. The solution was then stored in an air tight plastic container of capacity 20 litter for 12 days. After 12 days the activated EM2 solution was thoroughly mixed with chopped barely straw (in the ratio of 1liter EM2:1kg straw) and compacted in an airtight plastic bag of capacity 20 kg. The mix was allowed to ferment for 10 hours before fed to the animals. Stock EM solution (EM1) to be used for this study was purchased from the recognized distributer (Woljejii PLC, Debrie-Zeit, Ethiopia).

The supplement in the intervention diet was fed at the level required to fulfill nutrient requirement of the cows based on NRC (1989). The amount of supplement fed to each cow in T1 during the adaptation period of two weeks was at the rate of 0.5 kg per kg of milk production/day and 4kg of EM2 mixed barley straw early in the morning before grazing and 2kg in the afternoon. Hence, adjustment of the concentrate supplement and mixed straw was made weekly based on the milk yield of each cow and voluntary intake at the rate of 0.5kg per kg of milk production/day. It was fed in the morning and evening milking times, by dividing the daily allowances into two equal parts.

Data collection, monitoring of experimental animals

The data was recorded over a period of 105 days including an adaptation period of two weeks. Field visits were carried out every two weeks to monitor the feed intake and milk yield of the animals. The body weights of cows were measured each fifteen days by using heart girth measurement. Adjustment of roughage offered was made weekly based on the amount of refusal weighed and recorded every morning. All the cows were hand milked twice a day, in the morning and in the evening. Milk yield was measured daily and recorded right at milking. The animals had free access to water throughout the experimental period. The enumerators daily recorded the intake of roughage and concentrate and milk yield on pre-designed data recording sheet. These sheets were checked at each visit for precision and regularity.

Statistical and economic analysis

General Linear Model (GLM) procedure of SAS (2004) was used for analyzing data collected during monitoring. Mean comparison was done using the Least Significant Difference (LSD) for parameters with significant difference. Differences were considered statistically significant at 5% level of significant. Data generated form monitoring study was analyzed using the following model:

$Y_{ij} = \mu + r_i + e_{ij}$

Yij is the dependent variable (feed intake, milk yield, body weight gain),

μ overall mean, r_i effect of diet

Xij the record of live weight/milk yield of the jth cow on the ith diet,

eij random variation.

The economic analysis was based on calculations of the total cost of production and the income from milk sales. The price of feeds and the price of milk were obtained from the market price prevail in the area during experimental period. The net profit/cow/day was calculated for the whole experimental period by reducing the cost of production from income generated from milk sales.

Results and discussion

Socio-economic characteristics of participating farmers

The average family size of the selected farmers was 8.42 members per household out of which 48.2% were male and 51.8% were female members. Among the participant farmers, 92.3% were male headed households while 7.7% were female headed households.

The size of land holding of the participant farmers ranged from 10 ha to 14 ha. The average land holding 12.58ha out of which 62% is allocated for grazing and the rest 38% was used for crop production.

Available Feeds and feeding systems of milking dairy animals

In this study three major feed types used by dairy producers were identified: natural grazing, crop residue (barley straw and wheat straw) and agro-industrial by product (wheat bran). Two types of feeding systems (Extensive and semi-intensive) were used by dairy producers in the area.

Chemical composition and in-vitro organic matter digestibility (IVOMD) of feeds

The chemical composition and in-vitro organic matter digestibility (IVOMD) of feeds offered to experimental animals is presented in Table 1. The basal diet (natural pasture and untreated barley straw) available for feeding during the dry season was low quality and do not meet production requirement of animals (Table 1).

Table 1: Chemical composition, in-vitro organic matter digestibility and estimated metabolizable energy of feeds (Mean ± standard deviation)

Variables	Untreated barley straw	Treated barley straw	Wheat bran	Linseed cake
Dry matter %	93.4	90.09	90.06	93.23

Organic matter	92.39	89.93	95.72	91.5
Crude protein	2.3	4.95	16.98	29.8
NDF	80.05	57.97	38.19	25.1
ADF	59.56	40.66	9.39	9.52
ADL	11.05	8.03	2.52	5.14
IVOMD (%)	33.1	51.7	77.7	67.1
EME(MJ/kg)	5.29	8.27	11.65	10.06

Source: Mulugeta Abera (2015) and Girma Chalchissa (2014)

CP= crude protein; ADF=acid detergent fiber; NDF=Neutral detergent fiber; MJ=Mega joule; IVOMD =In vitro organic matter digestibility; EME= Estimated metabolizable energy (0.16*IVOMD)

Dry matter intake (DMI)

The daily feed intake and milk yield of cross breed cows treated in the experiment is presented in table 2.

Table 2: Effect of feeding EM treated barley straw supplemented with concentrate on feed intake and milk yield of lactating crossbred dairy cows (LS-means and SE)

Variables	**Intervention diet (T1)**	**Control (T2)**	**SE**
Dry matter intake (DMI), kg/day			
Grazing, hour/day	8h	8h	±0.081
EM treated /untreated barley straw	6.68[a]	4.64[b]	±0.152
Concentrates	3.25[a]	1.56[b]	±0.021
Total DMI, kg/day	9.93[a]	6.20[b]	±0.072
% Roughage	67.2[b]	74.8[a]	±0.015
% Concentrate	32.8[a]	25.2[b]	±0.012

Average milk yield, kg/cow/day	4.98[a]	2.65[b]	±0.470
Increase in milk yield, kg/cow/day	2.31	-	

a,b means in the same row for each parameter with different superscripts are significantly different (P<0.05); LS-means: Least square means; SE: Standard error

*The dry matter intake through grazing was not considered

Significant (P<0.01) improvement in DMI was observed due to feeding of the intervention diet in lactating crossbred cows over farmers practice or control diet. This was in agreement with the observation reported by Adebabay (2009) in treated rice fed indigenous breed cows, which may be due to improved palatability.

Milk yield

There was no variation between the two treatments in initial average milk but treating barely straw with bypass protein supplementation improved the performance of cross breed dairy animals. Feeding of intervention diet resulted in a significant (P<0.01) increased in daily milk yield by 2.31 kg (4.98 vs. 2.67 kg). Similar results also reported Dejene *et al*. (2009) indicated that cows in urea treated *teff* straw supplemented diet had significantly higher milk yield than for un-supplemented animals. This is due to the bypass protein through linseed cake supplementation in addition to increased palatability, N content, digestibility, nutritive value of the straw as a result of EM treatment. It has been accepted that intake and exploitation efficiency of crop residues are influenced by the rate of rumen fermentation (Van Soest, 1982) and the balance of nutrients absorbed in the intestines.

Economic analysis

The cost of grazing for the control groups was not considered while the total cost of production (feeds, EM, labor for treating straw and material including plastic sheet used for sealing the treated straw) was considered since other variable cost (medicaments) was the same for both groups. The net profit increased from ETB 39.24/cow/day in the control group (T2) to ETB 49.05/cow/day in T1 group due to the improvement in milk yield. Hence, this study demonstrated that feeding the intervention diet to crossbred dairy cows increased the net profit for farmers to ETB 9.81/cow/day over the farmers' practice (Table 3).

Costs of barley straw and grazing cost were not considered because farmers produce barley straw and uses their own grazing lands. Participants observed that besides increase in milk production, most of the cows in intervention diet showed symptoms of heat at the proper time in contrast to the cows in T2. Considering the positive long-term impact of the intervention diet on production, reproduction, body condition and general health of the animals, the economic returns may be higher by using the intervention diet. Furthermore, considering the cost of production and the market price of milk prevailed in the area during experimental period, the intervention diet was found to be economical compared to farmers practice.

Table 3: Economic evaluation of feeding EM treated barley straw supplemented with concentrates in lactating crossbred dairy cows

Variables	**Intervention diet (T1)**	**Untreated diet (T2)**
Cost of untreated straw, Ethiopian birr (ETB)	0	0
Cost of straw treatment		
Cost of molasses	103.85	0
Cost of EM	576	0
Cost of plastic	54	0
Cost of labor	315	0
Cost of grazing	0	0
Cost of supplement (linseed cake & wheat bran), ETB[#]	2166.45	0
Total Variable cost, ETB	3215.3	819
Cost /cow/day	30.62	7.8
Cost /cow/kg of milk	6.14	2.94
Gross income from sale of milk, ETB["]	8366.4	4939.2
Net profit, ETB	5151.1	4120.2

Net profit/cow/day, ETB	49.05	39.24
Net profit over control, ETB	9.81	

Remark: cost of concentrate: 8 ETB/kg of linseed cake, 5 ETB/kg of wheat bran, 1.50 ETB/kg of molasses, 3 ETB/kg of salt, labor cost (man day) was 35 ETB while cost of plastic sheet per meter was 18 ETB, Selling price of milk was 16 ETB/kg of milk, $1 USD~ 24 ETB

Conclusion

Substantial increase in milk production per animal per day and net benefit derived from the increased milk produced indicated that the use intervention diet is a sound technology for cross breed dairy animals under small scale farmer's condition. Thus it is possible to substantially improve the productivity of crossbred dairy cows in similar production systems by feeding EM2 treated cereal straw and supplementing with bypass protein. However, the extent of improvement might need further investigation. The effect of EM on digestibility of OM or fermentation of fiber should be investigated further. Finally, promotion of effective infrastructure for technology transfer, further refinement of EM treatment technique and ensuring either on-farm or nearby availability of supplies necessary for straw treatment are important elements for ensuring impact of the technology.

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AGRICULTURAL ENGINEERING

On farm evaluation and verification of tef grain and chaff separator machine

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Abstract

Tef grain separating and cleaning activities are predominantly traditional methods that depend on naturally blowing air and threshed grain thrown using flat materials such as shovel. This method is time and labor consuming, and often lead to contamination of the grain with foreign materials such as dust and silt. To this end, small engine driven tef grain and chaff separator and cleaning machine was designed and manufactured to alleviate the problems. The performance of the machine was evaluated interms of separation efficiency and separation losses at different feed rate, sieves oscillations and sieves inclinations. The test result showed that maximum separation efficiency and minimum separation loss of the machine as 97.94, 0.71, respectively, with the output capacity of 8-10 quintals per hour.

Key words: efficiencies, feed rate, losses, Sieve oscillation, sieve slope, Tef separation

Introduction

Tef [*Eragrostis tef* (Zucc.) Trotter] is a cereal crop extensively cultivated in Ethiopia as a major staple crop. It is one of the economical cereal crops in Ethiopia (Bekabil *et al.*, 2011). However, as most of its production systems are traditional process, the teff grain losses occurred during grain is separated from chaff, winnowed and further cleaning. Research result in this field showed that utilizing agricultural mechanization technology can reduce post-harvests losses of teff by up to 30% (NAMS, 2014). So, to reduce this loss Asalla Agricultural Engineering Research Center (AAERC) and Sasakawa Global Africa 2000 (SGA2000) were developed tef thresher. Despite having a fan, the developed thresher had failed due to the small size of tef grain and its low terminal velocity. As a result, AAERC designed and fabricated another machine with acceptable efficiency but this wacc s also restricted to small scale level and manually operated belt conveyor feeding mechanism. Therefore, this study was aimed to resize and modify the AAERC tef and chaff separating and cleaning machine in order to avail it for tef producer farmers of selected AGP-II districts of Arsi zone, Oromia.

Material and method

Machine specifications and description

In this study, construction and testing of the machine was conducted based on the design of Abayineh and Abebe (2015). The machine consists of a frame, an oscillating triple-screen assembly, a centrifugal blower and diesel engine as shown in fig. 1.

Figure 1: Experimental tef chaff separating and cleaning machine

General specifications of machine are: overall length 152cm, overall width 80 cm, overall height 133cm, power of 5hp, easy operation; minimum adjustments, reduced repairs and maintenance problems. Multi crop capability includes three interchangeable screens. Simple design of the machine includes shaft for horizontal oscillating screen drive and fan.

Measured Parameters

Performance evaluation of the machine was made on the basis of the following parameters; separating efficiency and separation loss as suggested by Amer (2009) using Equation 1 & 2.

$$SE = \frac{M_1}{M_2} X100\%$$

$$SL = \frac{M_4 - M_3}{M_4} X100\%$$

Where: M_1 = mass of impurities after separation and cleaning (kg), M_2 = mass of impurities before separation and cleaning (kg), M_3 = mass of grains after separation and cleaning (kg), M_4 = mass of grains before separation and cleaning (kg), SE = separation efficiency (%) and SL = separation loss (%)

Experimental Design and Treatment

To evaluate the separating and cleaning performance of the machine, three levels of sieve slopes (0, 5 and 10^o), four levels of sieve oscillation (5, 10, 15 and 20 Hz) and four levels of feed rates (3, 6, 9 and 12 kg/minut) were used. The experimental design was factorial in split-split plot, 3 x 4 x 4 having 48 experimental units. Each combination of an experiment (slope x oscillation x feed rate) was replicated three times and the total numbers of test runs were 144. The sieve slope was taken as main plot while sieve oscillation and feed rate were taken as sub-plot and as sub-sub plot, respectively.

Result and Discussion

Effect of sieve slope on separation efficiency and separation loss

As can be seen from figure 3 (a) increase in sieve slope from 0 to 5 degrees increased separation efficiency from 74.72 to 83.37%; but further increase in sieve slope to 10 degrees resulted in decreasing separation efficiency to 71.39%. This was due to the very fact that the grains moved out of the separation unit with the materials out of grains (MOG), because the greater force (*mgSinα*) acting on the entire material, grain and chaff, down the slope and the difference between gravity component and inertia component of forces ($mgCos\alpha < m\omega^2 r$) that lead to sliding rather than tossing and flailing the grain and chaff Figure 2.

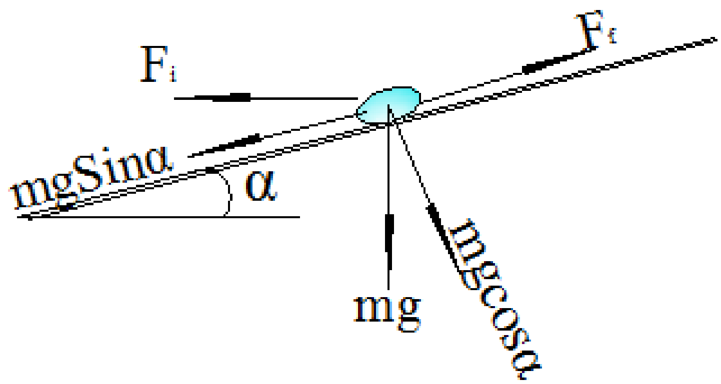


Figure 1: Forces acting on materials and their direction over the sieve surface (F_i = inertia force and Ff =friction force)

Effect of sieve oscillation on separation efficiency and separation loss

Separation efficiency tended to decrease with increasing sieve oscillation while separation loss increased with increasing sieve oscillation (Fig 3b). The increase in the separation loss was from 4.93 to 22.64 % as sieve oscillation increased from 5 to 20 Hz. The decrease in separation efficiency and increase of separation loss with increasing sieve oscillations may be due to less resident time of materials to be separated on the sieve.

Effect of feed rate on separation efficiency and separation loss

Figure 3(c) indicates that separation efficiency decreased with increasing feed rate while the separation loss increased with increasing feed rate. Increasing feeding rate from 6 to 12 kg/min decreased the separation efficiency from 72.69 to 55.98% while separation loss increased from 10.6 to 20.66% and effect was highly significant at ($P < 1\%$) (Table 1).

Combined effects of sieve slope, sieve oscillation and feed rate on separation efficiency and separation losses

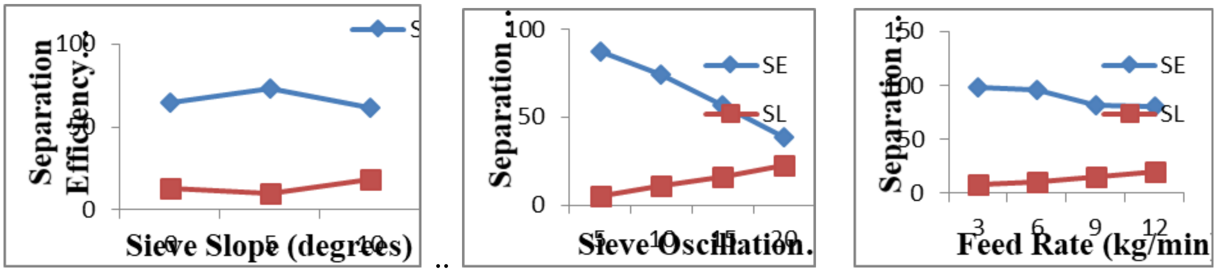
Analysis of variance indicated that the effect of sieve slope, sieve oscillation and feed rate were highly significant (P<0.01) on both separation efficiency and separation loss. Sieve slope and sieve oscillation (SS x SO), sieve slope and feed rate (SS x FR) and sieve oscillation and feed rate (SO x FR) combinations had highly significant (P<0.01) effect on both separation efficiency and separation loss except that SS x FR combination had significant effect at P<0.05 on separation loss. Separation efficiency and separation loss were dominantly affected by sieve slope and sieve oscillation and followed by sieve slope and feed rate and sieve oscillation and feed rate.

Table 1: Mean squares for the performance of the machine

Source of variation	DF	Mean squares	
		Separation Efficiency	Separation Loss
Replication	2		
SS	2	1685.4**	225.76**
SO	3	26063.02**	455.03**
FR	3	1965.44**	265.47**
SS x SO	6	2081.2**	24.49**
SS x FR	6	46.69**	7.55*
SO x FR	9	38.43**	7.52**
SS x SO x FR	18	44.14**	3.7**
Error	72		

Key: *, **; significant at 5% and 1% probability level, respectively; D.F degree of freedom, SS= Sieve slope, SO= sieve oscillation, FR= feed rate

The high separation efficiency and low separation loss were obtained at 3 kg/min feed rate, 5^{o} sieve slope and 5 Hz of sieve oscillation. The combined effect of sieve slope, sieve oscillation and feed rate (SS x SO x FR) was also highly significant (p<0.01) on separation efficiency and separation loss. In generally, separation efficiency decreased with increasing sieve oscillation and feed rate while separation loss was increased with increasing feed rate and sieve oscillation.



(a), (b) (c)

Figure 3: Effect of sieve slope, sieve oscillation and feed rate on separation efficiency and separation loss

Multiple Regression Analysis

This analysis was made to identify parameters that had a dominant effect on separation and cleaning efficiencies and associated losses. Accordingly, dominant effect of feed rate was resulted in all, except on separation efficiency (Table 2).

Table 2: Multiple regression equation of parameters studied

Regression	Equation	R^2
SE Vs SS, SO and FR	SE = 133.044 -0.52xSS -3.21xSO -2.593xFR	0.934
SL Vs SS, SO and FR	SL = -19.231 +0.513xSS +1.163xSO +1.45xFR	0.924

Conclusion

Based on the performance evaluation made and results obtained, the performances of the machine was significantly affected by feed rate, sieve oscillation and sieve slope in that order of dominancy and the minimum losses and the maximum efficiency were achieved at 5^0 sieve slope for all sieve oscillations and feed rates. The maximum separation efficiency and minimum separation loss were 97.94, 0.71, respectively. Separation efficiencies in general decreased with the increasing sieve oscillation and feed rate, while separation losses increased with the increasing sieve oscillation and feed rate. The separation efficiency was slightly increase as sieve slope increase from 0 to 5 degrees but further increase of sieve slopes up to 10 degrees kept on reducing the efficiencies of separation. The separation losses were decreased as sieve slope increased from 0 to 5 degrees and increased as sieve slope increased to 10 degrees. In addition, the multiple regression analyses model developed can be used as corner stones and spring boards to select optimum combination of the variable parameters to further develop and/or improve seeds and grains separating and cleaning machine. The output of the machine is estimated at 8-10 qt/ha, which depends on nature of input materials (mixture of grain and straw/chaff).

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Adaptation and Verification of Improved Row Crop Cultivator for Equine Animals

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Abstract

Weeding is one of the critical stages in crop cultivation and affects quantity and quality of the yield. In Arsi Zones of Oromia state, weeding is done tiresomely either manually uprooting or using simple hand hoe. Thus, this activity was conducted to adapt and evaluate field performance of row crop cultivator for Equine Animals and to compare with hand weeding and hand hoe in local condition. Performance parameters such as field capacity, weeding efficiency and plant damage of the row cultivator were considered during the performance test at farmers' field. The test results showed that, the developed row cultivator can work up to 5.0 cm depth of operation with 0.075 ha/hr field capacity, 80.66% weeding efficiency, 9.65% plant damage and 114birr/ha cost of cultivation was obtained under the field test. Therefore, this implement was recommended for popularization in any row planted crops as it gave better field capacity and highly save the cost of operation.

Keywords: *Row crop cultivator, Manual Weeding, Weeding Efficiency, Field Efficiency*

Introduction

Weeding is one of the critical stages in crop cultivation and affects yield and quality of the yield. It can reduce crop yields from 15 to 50% depending on species, density and weeding time through competition with main crop for light, water and nutrition (Hasanuzzaman *et al*., 2009). Weeding is done either manually uprooted or using simple hand hoe. Timeliness of operations is one of the most important factors which can only be achieved if appropriate uses of simple agricultural tools are made. Majority of crops are planted relatively at the same time and this results in shortages of labor during the peak seasons of weeding. The intensification and modernization of agricultural production is associated with use of better farm implements and increased power utilization. To popularize improved animal-drawn row cultivator, it had been modified to equine animal drawn and evaluated for feasibility on farmers' fields. Therefore, the objective of this study was to evaluate field performance of Horse drawn row crop cultivator and compare to hand weeding and hand hoe for developing appropriate mechanical weed control drawn by Equine Animals.

Materials and Methods

Description of the Row Cultivator

The developed row cultivator is light, simple in design, easy to operate, reduce drudgery and manufactured from locally available materials and can be easily maintained. The constructional details and main components of the row cultivator are main frame, tine and shovel.

Test Conditions

Performances of row cultivator vary with the conditions of the field, soil, weed, crop, operator and the ambient conditions. As the weed condition; type of weed, population density and the height of weed were considered. Plant population and height were measured as crop conditions.

Experimental Field

The practical field tests were conducted during the 2016/17 cropping season on purposely selected farmers' field in West Arsi Zone of Oromia Region. The row cultivator had been evaluated on wheat (Kubsa variety), sown in 0.2m row spacing and single horse was used for test. The test plot was 15 m x 20 m with three replications at each site. Cultivating operations were done after three weeks of sowing with hand weeding, hand hoe and row cultivator.

Performance Indicator

Weeding efficiency, plant damage, field capacity and field efficiency was taken as performance indicator. The weeding efficiency was determined by counting number of weeds before and after the cultivation by throwing a quadrant (metal frame of 1m × 1 m). The weeding efficiency of the row cultivator was calculated by the following equation (Remesan *et al.*, 2007):

$$e = \frac{(W_1 - W_2)}{W_1} x100 \quad 1$$

Where: - e = weeding efficiency in percent, W_1= number of weeds/m^2 before weeding

W_2= number of weeds/m^2 after weeding

To determine the damaged plant, as a quality of work done, number of plants in a 10 m row length before and after weeding was counted and percentage of plant damage was obtained by the following equation (Yadav and Pund, 2007):

$$q = \left[1 - \left(\frac{Q}{P}\right)\right] x100 \quad 2$$

Where: - q = plant damage per cent, Q = Number of plants in a 10 m row length after weeding

P = Number of plants in a 10 m row length before weeding

Field capacity and field efficiency were calculated by the following equations (Hunt, 1995):

$$C_e = \frac{S \times W \times F_e}{10} \quad 3$$

$$F_e = \frac{T_e}{T_t} \times 100 \quad 4$$

Where: - Ce = effective field capacity (hah^{-1}), *S* = the travel speed of the cultivator (kmh^{-1}), *W* = working width (*m*), F_e = field efficiency (%), T_t and T_e are the total and effective time (*h*)

Cost Analysis:

Cost analysis was done on the basis of fixed and variable costs of equipment. The cost items include purchase price of the machine, salvage value of the machine, machine life (year), interest rate (%), yearly repair and maintenance cost and labor cost.

Results and Discussions

The results of field performance of different weeding methods were explained in table 1 below.

Table 1: Field Performance Test Results

No	Particulars	Row cultivator	Hand-hoe	Hand weeding
1.	Area covered (ha)	0.03	0.03	0.03
2.	Test duration (hr)	0.4	6	5.33
3.	Row to row spacing (mm)	200	200	200
4.	Age of the crop (days)	21	21	21
6.	Mean plant population (per M^2)	157.55	161.78	147.11
8.	Plant damage (%)	9.65	8.01	5.43
9.	Mean weed population(No/m2) - Before cultivation - After cultivation	 113.22 21.89	 170.22 24.44	 130.33 23.11
10.	Weeding Efficiency (%)	80.66	85.64	82.27
11.	Depth of operation (cm)	7	4.67	-
12.	Working width (cm)	550	-	-
13.	Mean speed of operation (m/s)	0.74	-	-
14.	Effective field capacity (ha/hr)	0.075	0.005	0.0056
15.	Length of the row (m)	20	20	20
16.	Grain Yield (kg per plots)	175.67	180.99	166.66
17	Grain Yield (Qun/ha)	58.56	60.33	55.55

Weeding Efficiency

The weeding efficiency was determined by considering the number of weed before and after weeding operation. The highest weeding efficiency was observed for hand hoeing (Table 1), which may be due to the fact that more precisely intra row area could be covered. Average value of the row cultivator weeding efficiency was found to be 80.66%. It can be concluded that the row cultivator is efficient because efficiency is more than 80% and also easy in operation.

Plant Damage

There was plant damage due to animal behavior while cultivation. Guiding Animal to follow plant rows was tiresome because they don't move straight forward while field operations. So that higher percentage of plant damage was found in case of row cultivator (9.65%) followed by hand hoe (8.01%) and hand weeding (5.43%) (Table1). The higher recorded percentage of plant damage for row cultivator might be because of the higher speed of operation, width of cultivator and depth of operation, caused injury to the plants by cutting either their roots or stem.

Field Capacity

The field capacity of developed row cultivator was calculated by selecting respective plots of size 15 × 20 m the row cultivator was operated and different observations were recorded. The mean field capacity of the developed row cultivator was found 0.075 ha/h (table 1). This test result indicates, the row cultivator was easy to operate and outcome of field capacity also satisfactory.

Cost Analysis

On average, it took 59 and 67 hours for three people to weed a hectare of wheat land by hand and hand hoe, respectively, while the time required for weeding a hectare of land using a row cultivator was 13 hours. On average weeding with a row cultivator was 5 times faster than hand and hand hoe weeding. Hence, one can note that the time requirement per hectare is reduced by one-fifth and labor requirement reduced by the same amount. This clearly indicates that total labor cost of weeding a hectare of land can be reduced to one-fifth.

Conclusion and Recommendations

The developed row cultivator attained satisfactory field performances of 0.075ha/hr effective field capacity, 81.11% field efficiency, 80.66% weeding efficiency, 9.65% plant damaged, 58.56 qt/ha of wheat yield and also total labor cost of weeding a hectare of land with row cultivator was only 114birr. Besides, tests did not reported any ergonomics defect or part breakdown throughout the test and it was easy to operate. In general, field performance test results indicated satisfactory result for adopting this row crop cultivator and it can also be used for other crops as row spacing can be adjusted. Thus, it can be concluded that newly developed row crop cultivator could be recommended as the appropriate solution for the weeding problem of small and medium scale farmers. Therefore, it can be recommended for popularization for any row planted crops as it gave a better field capacity and higher saving in the cost of operation and labor requirement as compared to traditional practices. Besides, the newly developed row crop cultivator should also further modified to reduce percentage of plant damage and better performance.

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Participatory on Farm Evaluation and Verification of Poultry Feed Mixer

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Abstract

On farm evaluation and verification of poultry feed mixer was done using sodium chloride (NaCl) as tracer. The machine was tested using a feed composed of 40.05 kg cracked corn, 18 kg wheat bran, 7.50 kg noug cake, 3.75 kg cracked soybean, 3.75 kg fish meal, 0.75 kg lime stone, 0.75 kg premix, 0.075 kg methionine, 0.15 kg lysine and 0.225 kg salt (NaCl) replicated thrice at four mixing durations of 10, 15, 20 and 25 minutes and screw shaft speed of 100, 150 and 250 rpm. The effectiveness of mixing was assessed on the basis of percent salt content, and percent coefficient of variation (CV %) and degree of mixing of sample collected at the end of each test. The best values of coefficient of variation (8.42%) and degree of mixing (91.58%) were obtained at mixing screw shaft speed of 150 rpm and holding time of 20.minutes. Hence, it can be concluded that the poultry feed mixer, should be operated at speed of 150 rpm with maximum holding time of 20 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.

Keywords: Poultry, poultry feeds, feed mixer

Background and Justification

Feed production for livestock, poultry or aquatic life involves a range of activities, which include grinding, mixing, pelleting and drying operations. New (1987) gave a summary of the different types of machinery needed for the production of various types of feeds and they include grinders, mixers, elevators and conveyors, extruders, cookers, driers, fat sprayers and steam boilers. 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).

Essentially, feed mixing can be done either manually or mechanically. The use of manual labour to mix crushed poultry feed by the traditional agricultural sector that is characterized by subsistence farming was perhaps the first form of poultry feed mixer. The manual method of mixing feed ingredients is generally developed to characterized by low output, less efficient, labour intensive and may prove unsafe, hence, hazardous to the health of the intended animals, birds or fishes for which the feed is prepared. If feed is not completely mixed, portions of the feed will contain either too much or too little of the formulated ingredients. This excess variability causes economic losses to users of the feed (Barashkov *et al*., 2007). Therefore, the objective of the study was to evaluate and verify the developed vertical screw type poultry feed mixer amenable to local condition economically, socially and technically.

Materials and Methods

Materials and instruments

Materials and instruments that used during on farm evaluation of the poultry feed mixer were: feed mixer, taco meter, digital balance, stop watch, graduated cylinder, and sample holding bags and others.

Mixer Performance Evaluation

The poultry feed mixer was loaded with all the feed ingredients` prepared on the basis of required amount. A 100 g sample was taken during the discharge of the mixed feed. Herrman and Behnke (1994) suggested that ten samples per batch per mixing time and speed would yield sufficient and satisfactory coefficient of variance. The sodium chloride concentration was determined according to the method developed by FAO (1981) for concentration analysis as following equation:

$$NaCl_{cons} = \frac{Titre \times factor \times 0.1}{weight\,of\;\; sample} \times 100\% \qquad (1)$$

Where: Titre value = volume of the titre used, factor = 0. 0058 and 0.1 = concentration of $AgNO_3$

The performance of the feed mixer assessed on the basis of salt concentration as analyzed in the laboratory and its mean concentration, variation between samples (standard deviation) and coefficient of variation (CV) and degree of mixing using the following equations as recommended by Herrman and Behnke (1994).

$$\%CV = \frac{SD}{\bar{y}} \times 100; \quad \bar{y} = \frac{\sum y_i}{n}\; ; \quad SD = \sqrt{\sum\left(y_i - \bar{y}\right)^2 \big/ (n-1)} \text{ and } \%DM = 100 - \%CV \qquad (2)$$

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 and n = total number of samples

Experimental Design

The experimental design was randomized complete block design with three replications. Treatments consisted of factorial combinations of three mixing speeds and four holding. Analysis of variance appropriate to the design of the experiment to evaluate the significance of the factors on mean salt concentration, coefficient of variation and percent mixing were tested using Geanstat 15th software. Test at 0.05 probability level was computed to delineate the significance differences between and/or among treatment means.

Result and Discussion

Tests were carried out at four mixing periods (holding time) and three mixing speeds (auger shaft speeds, rpm) to evaluate the mixing performance of feed mixer based on salt concentration of mixed feed as measured by mean value of concentration, standard deviation, coefficient of variability and degree of mixing. Table 1 gives the mean concentration of salt (sodium chloride, NaCl), mean percent coefficient of variation and mean percent degree of mixing of feed ration mixed using the prototype poultry feed mixer developed at the auger shaft speed of 100 rpm and various levels of holding/mixing time.

Table 1**:** Mean prototype poultry feed mixer performance at mixing time of 10, 15, 20 and 25 minutes for each auger shaft of 100, 150 and250 rpm.

Mixing dur. (min)	**Shaft Speed (rpm)**	**Mean NaCl Conctrn (%)**	**Mean CV %**	**DM(%)**
10	100	0.250	20.27	79.73
15	100	0.241	14.37	85.63
20	100	0.24	12.79	87.21
25	100	0.243	11.25	88.75
Mean	**-**	**0.244**	**14.67**	**85.33**
10	150	0.24	17.43	82.57
15	150	0.235	14.54	85.46
20	150	0.25	8.42	91.58
25	150	0.248	10.42	89.58
Mean	**-**	**0.243**	**12.70**	**87.30**
10	250	0.232	17.03	82.97
15	250	0.229	14.10	85.90
20	250	0.248	12.64	87.36
25	250	0.237	12.18	87.82
Mean	**-**	**0.236**	**13.99**	**86.01**

From Table 1, it can be seen that, at the mixing auger shaft speed of 150 rpm, holding time of 20 and 25 minutes resulted in percent coefficient variation of 8.42% and 10.42%, respectively. The two values of coefficient variations obtained at holding times 20 and 25 minutes are within upper boundary of rating as indicated by Herrman and Behnke (1994) (values of percent coefficient of variations < 10, 10 – 15, 15 -20 and > 20 are rated excellent, good, fair and poor, respectively, in terms of uniformity of mixing). Hence, the mixing uniformity was superior at the combination of 150 rpm and 20 minutes of mixing time.

The percent coefficients of variation of speeds below and above 150 rpm were higher though the mixing time was increased up to 25 minutes. This is due to the very fact that at low mixing auger shaft speeds (rpm) the magnitudes of both axial and radial acceleration of the feed ingredients were so small that all materials might tend to move as a unit. On the other hand, at high mixing auger shaft speeds (rpm) the magnitudes of both axial and radial acceleration of the feed ingredients were so high that segregation of individual feed ingredient became inevitable; hence increase percent of coefficient of variation is consequence. Results of the analysis of variance (ANOVA) presented in Table 2 and Appendix Table 1 revealed that the mixing screw shaft speed and the interaction of the same with holding time had high significant effect ($p < 0.05$) on degree of mixing.

Table 2: Effects of auger screw shaft revolution and holding time on percent degree of mixing (DM %)

Paramete	**Source of variation**					**Measure of differences**	
	Auger Screw Shaft Speed (R), rpm	**Degree of Mixing (%)**				**LSD (5%)**	**SE(M)**
	100	85.33^{a}				1.067	0.514
	150	87.30^{b}					
	250	86.01^{a}					
	Mixing/holding time (T), min					1.232	0.594
	10	81.75^{a}					
	15	85.66^{b}					
	20	88.72^{c}					
	25	88.72^{c}					
	Interaction (R*T)					2.134	1.029
		10 min	15 min	20 min	25 min		
	100 rpm	79.73^{a}	85.63^{b}	87.21^{be}	88.75^{d}		
	150 rpm	82.57^{c}	85.46^{b}	91.58^{d}	89.58^{d}		
	250 rpm	82.97^{c}	85.90^{b}	87.36^{be}	87.82^{bd}		

Key: Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

Conclusion and Recommendations

The optimum level of mixing with percent coefficient variation of 8.42 and percent degree of mixing of 91.58 were observed at the mixer speed of 150 rpm and holding/mixing time of 20 minutes. Hence, it can be concluded that the machine should be operated at speed of 150 rpm with maximum holding time of 20 minutes. Based on the experimental results, increase in holding time beyond the time indicated above will require the farmers to spend extra money on electrical power and labor costs during feed mixing. This mixer must be operated at mixing auger speed of 150 rpm for a period of 20 minutes per batch of mixing; and the feed ingredients must be prepared correctly by keeping their required size as recommended by mono-gastric nutritionist for specific poultry growth stage.

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Adaptation and verification of wheat row planter for Equine animals

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Abstracts

In an intensive agriculture increase in crop yield, cropping reliability, cropping frequency and crop returns depend on uniformity and timely establishment of optimum plant populations. Because of tillage repetitions, in Arsi and W/Arsi Zones farmers face draft power shortage during plantation days. To tackle this problem they had practice of using equine animals for this operation by local implements. Thus, this work was focused on adaptation of improved row planter for single animal harnessing system. The technology was redesigned, manufactured and comparatively evaluated with local row planting practice. The evaluation parameters used were labor requirements, time of operation, plant distribution uniformity, seed rate and grain yield. From the results obtained, the improved technology performs well within recommended ranges in distribution uniformity, plant population and improved operation time when compared with local practice. With these merits, the technology had recommended for large scale use in the study area.

Key words: Equine animals, Row planting

Background and justification

Under intensive cropping, timeliness of operations is one of the most important factors which can only be achieved if appropriate uses of agricultural machines are advocated (Salokhe and Oida, 2003). Increases in crop yield, cropping reliability, cropping frequency and crop returns all depend on the uniform and timely establishment of optimum plant populations. A meaningful selection, setting and management of all farm machinery, especially the planting operation is one of the most important agronomic requirements for optimum plant establishment associated with crop production (Murray *et al*., 2006).

In wheat belt Woredas of Arsi and West Arsi, farmers repeat tillage several times to prepare seed bed, usually from 3 to 6 before plantation. This activity is performed in 90 to 100 days. During months of this operation, there is scarcity of draft animal in the area as well as forage except plant residue. As per the information collected from Zonal Bureau of Agriculture, 5 to 10% of farmers face challenge of oxen because of long continuous operation time and inadequate forage availability. To tackle these problems, farmers are practicing the use of equine animals for sowing activities. Since the use of these animals is being practiced for sowing, adapting of improved, proven and effective oxen drown wheat row planter to equine (horse) is essential for farmers in the area.

Accordingly, the objective of this activity was to modify and evaluate the proven oxen drawn wheat row planter for horse so that alternative draft power source with improved technology will be availed for the selected area.

Materials and Methods

Material used to manufacture prototype

Raw materials used for the manufacturing of prototype technology were angle iron, flat iron, sheet metals, aluminum flutes, $1^{1/2}$' galvanized water pipe, different size bolts and nuts, bearings, beam and handle wood.

Parts modified to fit for harnessing system

The following parts of the original planter were modified to decrease the overall weight of planter.

Hopper: It was made up of 1.5mm sheet metal with four compartments. Reducing the overall weight of the technology was mandatory to be pulled by single horse.

***Ground wheel*:** The diameter of the existing wheel was reduced from 60cm dia to 55cm dia which reduces both overall height and weight of the machine.

Technology description

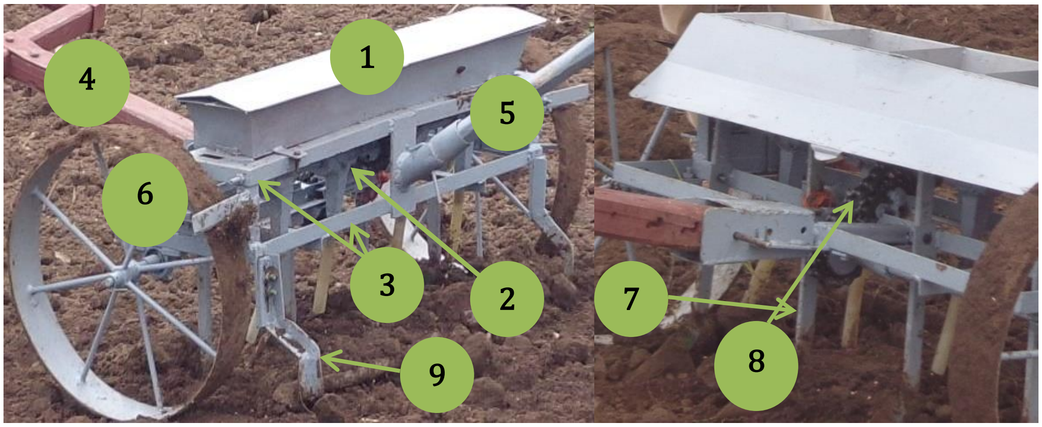

Fig 1: Pictorial description of the planter (1-hopper, 2-seed metering mechanism, 3-frame, 4-beam, 5-handle, 6-wheel, 7-furrow opener, 8-chain and sprocket assembly, 9-furrow cover)

Seed box (hopper): is a box like structure made up of steel sheet metal of 1.5mm thickness with four compartments for seed. Seed metering mechanism is placed at the bottom of the box.

Metering mechanism: it picks up seeds from the seed box and delivers them in to the seed tube. It is fluted roller feed type and provided at the bottom of the box. The numbers of fluted rollers are equal to number of rows. The fluted roller is driven by a steel shaft. There are ten horizontal groves provided along the outer periphery of the rollers and rollers can be shifted along the shaft depending upon the seed rate. These rollers are mounted at the bottom of the seed box. They are made of aluminum material with housing of galvanized water pipe.

Frame**:** Made of mild steel angle section and flats. It is designed in such a way that strong enough to withstand all types of loads in working condition. All other parts of the seed drill are fitted to the frame.

Beam: Made of wood and designed to fit with single animal harnessing mechanism and used to connect the planter with animal.

Wheels: Are fitted on an axle for transporting the drill on roads. Flat iron wheels and or pneumatic tire are used as transport wheels. They are fitted with chain and sprocket attachment to transmit motion of the wheel to the seed metering mechanism when the drill is in operation.

Furrow openers: These are the parts which open up furrows in the soil for placing the seeds. It is shovel structure made up of sheet metal and flat iron.

Covering device or furrow closer: It is a device which closes the furrow with soil after the seed dropped in. The covering device is made in straight bar mode which is connected to frame at the back.

Deriving mechanism: consists of a sprocket-chain assembly and drive and driven shaft that carry the seed picking discs. The chain connects the drive shaft sprocket and the driven shaft sprocket. As the drive shaft rotates with ground wheel, the driven shaft which carries the seed metering discs rotates and picks up seed from hopper.

Experimental detail

The experiment was conducted on sandy loam soil in West Arsi zone of Oromia regional state. It was conducted in 2016/17 cropping season. The wheat variety used was kubsa

. The experimental farmers were purposively selected. Treatments used to evaluate the technology were local row planting practice, broad casting and row planting with improved technology. The plot size was 20m X 5m replicated three times on similar soil types and conditions. Comparative evaluation was done by selecting the following performance indicator parameters.

Labor Requirement: It is the number of person required on operation/during planting time (in person per operation)

Planting time*:* Time taken for sowing by animal drawn planter and manual hr/ plot

Distribution uniformity*:* Percentage of even distribution of plant /plot. The row spacing and plant population in a row are treated here.

Plant population: It is the number of plants per hectare. The optimal yield is the factor of planmt population.

Depth of planting*:* Depth of the hole was measured by scale ruler (cm)

Yield*:* The wheat harvested from each plot harvested, dried, cleaned and weighted to kg per hectare.

Seed rate*:* Amount of seed required for one hectare planting in kg per hectare

Result and discussion

The mean performance indicator parameters test results of the treatments were explained in the following table.

Table 1: Field performance test results

Treatments	**Seed rate (kg/ha)**	**Field capacity (ha/hr)**	**Operational speed (m/sec)**	**Number of rows per pass**	**Depth of plough(m)**	**Labor required per operation**
Broad casting	152	0.044	0.72	1	0.17	3 men
Local row planting practice	146.5	0.04	0.69	1	0.17	3 men
Improved technology	111	0.17	0.85	4	0.05	3 men

Seed rate: It is the amount of seed to plant one hectare in kg/ha. From the performance result indicated in the above table (Table 1), amount of seed saved per hector by improved technology was 41kg and 35.5kg when compared with broad casting and local row planting methods respectively. Comparing seed rate the improved technology was found superior to both local row planting practice and broad casting methods.

Field capacity: It is the amount of work performed in ha/hr. As indicated in the table; 5.88hrs, 25hrs and 22.72hrs were needed to cover one hectare by using improved technology, local row planting practice and broad casting methods respectively.

Working width: It was also compared as 4 rows, 1row and one row for improved technology, local row planting and broad casting respectively. Thus, improved technology drills four rows per single pass while the other methods plants one row per pass.

Depth of planting: Plants as shallow as possible provide seed placed in the moisture zone but deep enough so that the drying front will not reach the seedling roots before leaf emergence. Optimum planting depth for wheat is between 50-70 mm. From test result obtained, the improved technology drills seed within recommended depth range while the local row planting and broad casting ploughs deeper than recommended range.

Operation drudgery: One of the main objectives of engineering technologies is to reduce work drudgery and related hardships to ease intended operation. On operation it was very comfortable for operator to use improved technology while it was painful to use local row planting practice especially, for the one who drops seed and fertilizer in a row. From the comments of farmers and observations, improved technology eases row planting related operational hardships. The following figures describe population density and distribution uniformity of the treatment data taken during germination count.

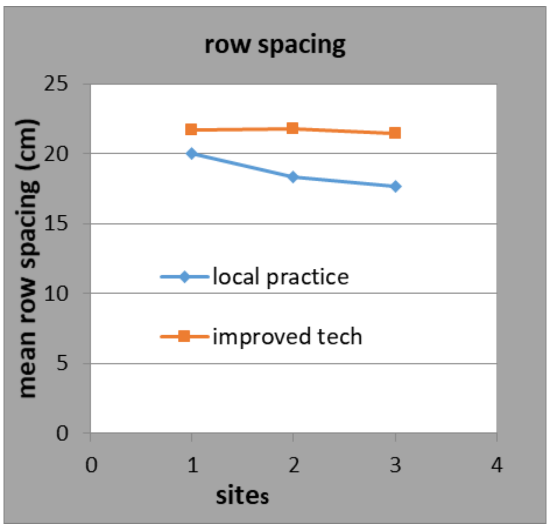

Figure 1: Mean row spacing across sites

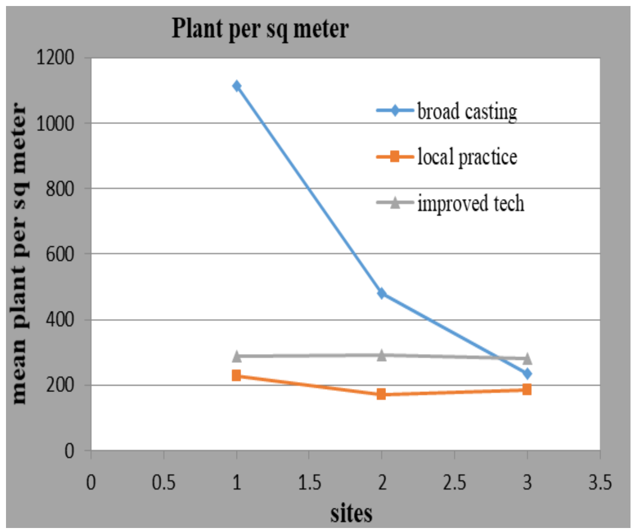

Figure 2: Mean plant population per meter square

The performance results described on Fig 1 and 2 indicated plant population and distribution uniformity. Improved technology (red line) had small variation in mean sample values and that of local row planting technology showed relatively larger variation (Fig 1). The ideal row spacing variation is zero, from the variation figure the superior treatment is improved technology. The mean variation for plant population per meter square of the samples across site indicated that improved row planter performs better than local practice (broadcasting). From the recorded and analyzed data indicated on the same figure, it can be concluded that improved technology performs better than the other two treatments. On figure 3, plant population per square meter was compared. When population density was compared, again the improved technology treatment performs better than the other treatments.

Distribution uniformity indicates variation in delivery between openers. The coefficient of variation (CV) is a mathematical term used to describe distribution uniformity.

$$CV = (StDEV\ sample) * \frac{100}{Average\ sample}$$

Where; CV is Coefficient of Variation, StDEV= Standard Deviation of Sample data and Average sample is arithmetic average of the sample data taken.

The interpretation of coefficient of variation is as characterized by PAMI (Prairie Agricultural Machinery Institute, which is Canadian Company working on machinery research) has been accepted the following scale as its basis for rating distribution uniformity of seeding implements for wheat crop: CV greater than 15% is unacceptable, CV between 10 and 15% is acceptable, CV less than 10% is very good and CV less than 5% is excellent

Table 2: The standard deviation and Coefficient of Variation for improved wheat row planter and local practice

	Of all sample	
	Single animal planter	Local practice
StDEV	5.78	6.51
Sample Average	38.43	34.86
CV (%)	15.04	18.64

The coefficient of variation of the planter is within acceptable range of plant distribution uniformity while that of the local practice is not in the recommended uniformity range. Grain yield by improved technology was 70.21quintal per hectare while that of the local practice and broad casting was 68.18quintal per hectare and 48 quintal per hectare respectively. Thus, grain yield advantages of 4.03 quintal per hectare compared to local row planting practice was recorded by using improved technology.

Conclusion and Recommendation

The improved single animal row planter improves operation timeliness of row planting, removes work drudgery of the operation, saves seed and shows yield advantages over the other treatments. Work drudgery and operation timeliness are the main objectives for both small or large mechanization technologies and this will facilitate the adoption of row planting practice in the area. Generally, the improved single animal drawn technology had superior advantage over local row planting practice in all selected evaluation parameters. Since time operation is reduced by four folds the cost of operation will also reduce. Thus, it is advantageous to multiply and distribute this technology in the study area.

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Adaptation and Verification of Spike Tooth Harrow for Pack Animals

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Abstract

It was observed that, farmers in the test area repeat farm tillage usually from 3 to 6 to prepare seedbed by using oxen and traditional 'Marasha'. But these practices are causing exhaustion for both the farmers and oxen which are less resistive to such conditions. In addition, as the affordability of the oxen is becoming difficult and the traditional 'Marasha' is not suitable for reducing the repetitive tillage. Therefore this activity was aimed at modifying and verifying existing spike tooth harrow for secondary tillage and for donkey and horse harnessing suitability. Field evaluation of the modified implement was carried out to determine plowing width and depth, clod breakage (soil pulverization) and working capacity (hr/ha). Test result of the modified implement showed that 63.4 % clod breakage or soil pulverization within an average time of 3.8 hr/ha, which takes a day by using the ('Marasha'). The average yield of grain worked by spike-tooth harrow was 80 quintal/ha and that of 'Marasha' with oxen was 67quintal/ha.

Key words: clod size, tillage, spikes

Introduction

Optimum tillage to achieve maximum crop yields with minimum energy consumption is the main goal of efficient seedbed preparation. A good seedbed preparation shows finer particles and greater firmness in the vicinity of the seeds (Pandey, 1998). The use of animal traction has enabled farmers to expand their area of farming and contributed to the timeliness of their agricultural operations. The cost of maintaining cattle is often too great to make oxen a feasible source of farm power when compared to pack animals. Donkeys and horses are popular draft animals because they are inexpensive (often less than half the price of oxen on the live market), easy to train, and effective where shallow breaking is practiced before planting begins (Dibbits and Bobobee, 1996)

Spike tooth harrow breaks clods, stirs the soil, uproots the early weeds, levels the ground, and breaks soil crust. It also covers the seeds which usually operate at shallow depths up to 5 cm. It was observed that, farmers around Asassa and Dodola woredas repeat tillage usually from 3 to 6 to prepare seedbed for plantation. This activity is performed in 90 days. During these months of operation, most oxen exhausted and farmers face problem of draft power to overcome the challenge, farmers are practicing the use of pack animals. They use traditional ‘maresha’ to accomplish these tasks. However, this traditional implement used is not suitable for donkey and horse. They cause wounds and sores on the donkeys' necks, making donkeys inflexible and rendering them unusable for several days (Kathy and Zahra, 1983). Therefore the activity was aimed at modifying and verifying existing spike tooth harrow technology used for secondary tillage and further for donkey and horse to overcome the above problems.

Material and methods

The material required to undertake this activity were:- Wheat grain, fertilizer, Harness attached on the back of pack animal, donkey or horse to pull an implement, (150x150x4000) mm and Ø (70, 80)mm eucalyptus tree, Ø (6, 8, 10)mm of round bar, M (10x120) mm bolt and nut and 8mm nail.

Technology adaptation

The attachment of spike tooth harrow were modified and attached to harness system on the back of pack animal that have good draft force and equipped to the beam (Fig 1).

Fig 1: Modified spike tooth harrow

The diagonal dimension before modification of spike tooth harrow is 167cm.These diagonals are designed and modified to 120.9cm. The right and left diagonals are the longest part of spike tooth harrow used to support other parts attached on it. The width of largest bottom before modification is 147cm. It is designed and modified to 101cm.The second part before modification was 127cm and reduced to 85.4cm. The third one was 97cm before modification and minimized to 64.6cm. The top one was 74cm and modified to 49cm.The numbers of spikes available on spike tooth harrow before modification were 29 in numbers and it is reduced to 24 spikes. Weight of modified technology (spike-tooth harrow + harness + 'mofer' attachment was; 40 + 7 + 9=56 kg). Its actual width was 85 cm and height of spikes was 18cm.

Performance evaluation of modified spike tooth harrow

Field test

Field test was done at two different sites of Asassa and Dodola woredas. The evaluation was carried out to determine the following parameters under field conditions: plowing width and depth of a modified spike tooth harrow, clod breakage into finer pieces (soil pulverization) and for good soil bed and maximum working capacity (hr/ha). Total area of the tests was 20mx20m (400m^2) which is divided to 20x10 m plot size for working with the spike-tooth harrow and the other 20x10m for oxen with 'Marasha'. Land preparation of the experimental area before the test was coarse except compacted at Dabara walta'i kebele and soil type is sandy loam.

Result and Discussion

Field test for clod breakage

The clod breakage was measured using Varner caliper in selected 1m x 1m ploughed area.

Table 1- Average clod breakage

No	Test site	Parameter	Tot.average (lxwxt)cm
1	Kachama chare Kebele	Clod diam. Before	25x18x10.5
		Clod diam. After	13x10x6
2	Dabara walta'i kebele	Clod diam. Before	26.5x20.5x10
		Clod diam. After	16x11x7
3	Huruba walkite kebele	Clod diam. Before	26.5x20.5x10
		Clod diam. After	16x11x7

An average actual plowing width per pass for modified spike tooth harrow was 85cm and actual plowing depth was 9.3cm. Clod breakage or soil pulverization of about 54.9 % was done at Kachama chare Kebele, 73.6 % at Dabara walta'i kebele and 61.4 % at Huruba walkite kebele.

An average time used for assembling the modified implement was 4.2 and 2.1 minute for disassembling during field operation. Two persons were used during assembling, operation and disassembling. Generally, we found that an average of 63.4 % clod breakage or soil pulverization was done by the technology modified. Time taken for spike-tooth harrow was 3.8 hr/ha which is approximate to 4 hr/ha.

Grain Yield and yield related data

An experimental crop harvested was taken by placing (1 x 1) m^2 quadrant on the experiment plot at three places.

Table 2- Average yield of experimental crop

No.	Parameter	Average yield for Harrow covered	Average yield for Oxen covered
1	Weight of bundle (qt/ha)	194	166
2	Weight of cleaned grain (qt/ha)	80	67
3	Weight of straw (qt/ha)	125	99
4	Grain straw ratio	0.62	0.68
5	Sheave length (cm)	80.6	81.3

The total average weight of cleaned grain yield was 67 qtl/ha for oxen covered and 80 qtl/ha for spike-tooth harrow. Generally, the average weight of cleaned grain covered by modified technology had good result as compared to oxen covered.

Conclusion and recommendation

Spike tooth harrow is used to break down the clod size and to assist with field leveling after ploughing. The technology recommended was not gender dependent, so that male and female farmers can use equally. An average time used for assembling was 4.2 minute but 2.1 for disassembling during field operation. Time taken for spike-tooth harrow was 3.8 hr/ha. 63.4 % clod breakage or soil pulverization was done by the technology modified. Wheat cleaned grain yield is 67 qtl/ha for oxen covered and 80 qtl/ha for modified spike-tooth harrow. In this test, it has been found that utilizing indigenous knowledge; features of traditional implements and farmers' know how in agricultural technology design, development and testing process is a very effective approach for appropriate technology development.

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NATURAL RESOURCE MANAGEMENT

Verification of Soil test based crop response phosphorous recommendation for Teff at Omo Nada district, western Oromia

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Abstract

On-farm verification trial of soil test based crop response calibrated phosphorus was conducted at Omo Nada district of Jimma Zone during 2016 main cropping seasons. The aims of the study was to verify recommended optimum nitrogen fertilizer rate for the district during the soil test based crop response phosphorus calibration. The treatments were: soil test based crop response phosphorus recommendation (STBCRPR) (T1), farmers' practices or blanket recommendation (T2) and control or without fertilizer (T3). The experiment was conducted across seven sites and thus farmers were used as replication. The Plot size was 48m by 18m for each treatment. Yield data was analyzed using SAS and LSD was used for mean separation. The initial soil reaction pH were strongly acidic ranging from 4.39 to 5.44 and the available P was very low ranged from 1.042 to 3.058 ppm. The results of the study revealed that there were significant differences ($P \leq 0.05$) among the treatments in teff grain yield. The maximum mean grain yield (1047.14 kg ha^{-1}) was recorded from the application of STBCRPR (soil test based crop response phosphorus recommendation whereas the lowest (740.00 kg ha^{-1}) was recorded from the control. Nitrogen fertilizer rate of 23 kg N ha^{-1} showed better grain yield and thus recommended for the area. The study also showed that P-critical value (4.5 ppm) and P- requirement factor (15.12) were determined for the recommended phosphorus in the study area. Economic analysis was performed to compare treatment advantages. The validity of critical value and economic evaluation showed that STBCRPR would yield 2.06 Ethiopian birr for every birr invested. Thus, it is highly advisable *to farmers and other tef growers in the test environment to use soil test based crop response phosphorus recommendation so as to increase the productivity and profitability of teff.*

Key Words: Soil tast based fertilizer recommendation, Phosphorus critical, available phosphorus

Introduction

Providing food for the ever-growing population is one of the critical challenges of today. According to Beets (1982), production can be increased by expanding the area planted to crops, raising the yield per unit area of individual crops or by growing more crops per year. In the future, most of additional food the world needs must come from larger yields on the lands already under cultivation and/or from lands now considered marginal (Chatterjee and Maiti, 1994). A major share of this increase will likely come from the use of irrigation, commercial fertilizers, pesticides, improved crops culture, mechanization and improved soil and water management (FAO, 1984). The demand for fertilization is evident, as growers around the world have already recognized the return, which can be realized from added plant nutrients. Quinenes *et al.* (1992) stated that unless something is done to restore soil fertility first, other efforts to increase crop production could end up with little success. Moreover, using chemical fertilizers that bring more than 100% extra yield is inevitable in most cases (Kelsa *et al*., 1992).

In Ethiopia, low soil fertility is one of the factors limiting the yield of crops, including wheat. It may be caused as a result of removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residue from farmland, and lack of proper crop rotation program (Tamirie, 1982). The results of several studies conducted on the status of P in Ethiopian soils (Tekalign and Haque, 1987) indicated that most of the soils studied require addition of P fertilizer for profitable crop growth.

It is essential that the results of soil tests could be calibrated or correlated against crop responses from applications of plant nutrients in question as it is the ultimate measure of fertilization program. An accurate soil test interpretation requires knowledge of the relationship between the amount of a nutrient extracted by a given soil test and the amount of plant nutrients that should be added to achieve optimum yield for each crop Sound soil test calibration is essential for successful fertilizer program and crop production (Abaidioo et al., 2000). Soil test based phosphorus calibration study was conducted at Omo Nadaa district on Teff for three years. Thus formula comprises critical phosphorus value and phosphorus requirement factor were determined based on initial P level in the soil. Even though critical phosphorus value and phosphorus requirement factor were determined verification trial was not performed. Therefore, the objective of this research were to verify P critical value and P-requirement factors on Teff.

Materials and methods

The study was conducted on farmers' fields in the district. Seven sites were selected based on their willingness, wealthy and initial soil test value. Kuncho variety was used as test crop. Phosphorus recommendation was given according to the formula, P (kg/ha) = (P critical – P ini)*Prf. This recommendation was compared with farmers practice and control. Urea and DAP was used as the source of N and P, respectively. Phosphorus fertilizer was applied at sowing whereas Urea was applied 30 days after planting. The experimental design was simple RCBD replicated per farmers. The treatments were: soil test based crop response phosphorus recommendation (STBCRPR) (T1), farmers' practices (blanket recommendation) (T2) and control (without fertilizer) (T3). The Plot size was 48m by 18m for each plots. Yield data was analyzed using SAS and LSD was used for mean separation. Economic analysis was performed to investigate the economic feasibility of treatments, which were based on CIMMYT, 1988)

Initial soil pH, available phosphorus and EC status of the study area conducted pre-verification season were used a base for the execution of the present study. Accordingly, the pH (H_2O) of the soil samples collected before planting were ranged from (4.39 to 5.44) (Table 1). This showed that the soils were strongly acidic in reaction as the classification made by FAO (FAO, 2008). Continuous cultivation and long-term application of inorganic fertilizers lower soil pH and aggravate the losses of basic cations from highly weathered soils (Mokwunye *et al*. 1996). Available Phosphorus (Olsen method) collected before planting were ranged from (1.042 to 3.058) ppm (Table 1). The available P contents of the soil were very low (Olsen *et al.*, 1954). The Ethiopian agricultural soils particularly the Nitisols and other acid soils have low available P content due to their inherently low P content, high P fixation capacity, crop harvest and soil erosion (Mesfin, 1998; Yihenew, 2002; Dagne, 2016).

Table 1.Initial soil pH, available phosphorus and EC status before planting at Omo Nada district in 20016 cropping season.

Sites	PH(H_2O)	P-ava. (Olsen method)	E.C
Site 1	4.39	1.255	0.054
Site 2	5.13	2.432	0.053
Site 3	4.62	1.986	0.038
Site 4	5.00	1.958	0.057
Site 5	5.44	3.058	0.083
Site 6	4.83	1.042	0.049
Site 7	4.43	2.375	0.034

P-available = available phosphorus

Results and discussions

Verification of Phosphorus Critical value and Requirement Factor

There were significant differences ($P \leq 0.05$) among the treatments in teff grain yield. The maximum mean grain yield (1047.14 kg ha^{-1}) was recorded from the application of soil test based crop response phosphorus recommendation (STBCRPR) whereas the lowest (740.00 kg ha^{-1}) was recorded from the control plot (Table 2). STBCRPR increased yield per hectare by 23% over farmer's practices (Table 2).

Table. 2: Verification of Phosphorus Critical value and Requirement Factor in 2016 cropping season.

Treatments	Yield /ha (kg)
STBCRPR (soil test based crop response fertilizer recommendation	1047.14[a]
Framers Practices (blanket recommendation)	848.57[b]
Control (without fertilizer)	740.00[c]
LSD (5%)	72.76
CV(%)	7.11

LSD = Least Significant Difference, CV = Coefficient of Variation

Economic analysis

In estimating economic parameters, products were valued based on market price collected from local markets during January 2017 where Teff was 16.00 ETB kg^{-1} of grain at field price. Fertilizers price of DAP and Urea, and seed price of Teff were 15.12, 11.26 and 25.91 ETB kg^{-1}, respectively. A wage rate of 50.00 ETB per work-day and oxen plow rate of 150.00 ETB per work day were used.

The partial budget presented in (Table 3) showed that the least total variable cost (TVC) was recorded by control treatment (without fertilizer), while the highest net benefit (NB) was obtained from STBCRPR (10899.16 ETB ha^{-1}), which gave 24.42% higher NB than farmers practices fertilizer application. The analysis of marginal rate of return (MRR), on the other hand, revealed that the rate of return per unit cost of production was highest from STBCRPR

(% MRR = 206.16). This showed that it would yield 2.06 Ethiopian Birr for every Birr invested.

Table **3**. Partial budget with dominance and marginal rate of return analysis to establish the profitability of teff production with Soil Test Based Crop Response Phosphorus Recommendation at Omo Nada district

Partial budget with dominance					
Treatments	Yield (Kg ha^{-1})	GFB (ETB ha^{-1})	VC (ETB ha^{-1})	NB (ETB ha^{-1})	Dominance
Control (without fertilizer)	740.00	11840 .00	3779.60	8060.40	
Blanket recommendation	848.57	13577.12	4817.34	8759.79	Un dominated
STBCRPR	1047.14	16754.24	5855.08	10899.16	Un dominated

Marginal rate of return (MRR %)					
Treatments	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	Incremental cost	benefit	MRR (%)
Control (without fertilizer)	3779.60	8060.40			
Blanket recommendation	4817.34	8759.79	1037.74	699.39	67.40
STBCRPR	5855.08	10899.16	1037.74	21.37	206.16

ETB = Ethiopian Birr; GFB = Gross field benefit; TVC = Total variable cost; NB = Net benefit; MRR = Marginal rate of return; STBCR PR= Soil Test Based Crop Response Phosphorus Recommendation

Conclusion and recommendation

STBCRPR was superior to both farmer' practices and control, Hence STBCRPR is selected for the recommendation on Teff at Omo Nada district. Therefore awareness should be created for farmers through demonstration. To sustain and/or improve the current soil fertility status of the study sites, integrated soil fertility management practices (soil conservation, lime application, crop rotation) can improve the current situation.

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Verification of soil test based crop response phosphorus calibration on maize (Zea mays) at Wayu-Tuka district, Western Oromia.

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Abstract

*The experiment was carried out on nine farmers' field at Wayu-Tuka district, Western Oromia in 2016 cropping season using optimum amount of urea (200kg/ha), critical P-value (4.23ppm) and the phosphorus requirement factor (9.58) determined during soil test based maize crop fertilizer response recommendation study in the years 2014 and 2015. The experiment has three treatment including control (without fertilizer), farmers practices (blanket recommendation) and soil test based crop fertilizer response recommendation (p calculated value from Pc, Pf and initial soil available P). Improved maize variety BH-661were used and sown at 75*30 cm inter and intra row spacing. The experimental design was randomized complete block design with three replication having 10*10m plot size for each treatment. These are zero, farmers practice (50 kg/ha) and recommended rate of P which based on initial soil value. Mean grain yield of maize was highest for plots treated with recommended rate having initial P- value less than critical P-value than farmers practice and control. Whereas, plots having initial soil P-value equal and/or greater than critical P-value gave more or less equal maize grain yield for the three treatments as they were equally treated with the same amount of urea.*

***Key words**: BH-661, critical p-value, phosphorus requirement factor, initial soil p-value*

Introduction

Soil fertility depletion and widespread soil degradation are the major biophysical root causes of declining per- capita food production and natural resource conservation in Sub-Saharan Africa (Sanchez *et al.*, 1997; Farouque and Tekeya, 2008). In Ethiopia, century-long, low-input agricultural production systems and poor agronomic management practices, limited awareness of communities and absence of proper land-use policies have aggravated soil fertility degradation (Getachew and Bekele, 2005). This has also encouraged the expansion of farming to marginal, non-cultivable lands, including steep landscapes and range lands.

Phosphorous is the most yield limiting of soil-supplied elements, and soil P tends to decline when soils are used for agriculture (David and David, 2012). Studies have demonstrated that Nitisol areas in Ethiopia are marginally to severely deficient in P (Bekele *et al*., 1996, 92-99; Regassa and Agegnehu 2011, 103-112). In Ethiopia, the blanket recommendations that are presently in use all over the country were issued several years ago, which may not be suitable for the current production systems (Bekele et al., 2002, Zeleke *et al.*, 2010). Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P fertilizer rate to their fields regardless of soil fertility differences.

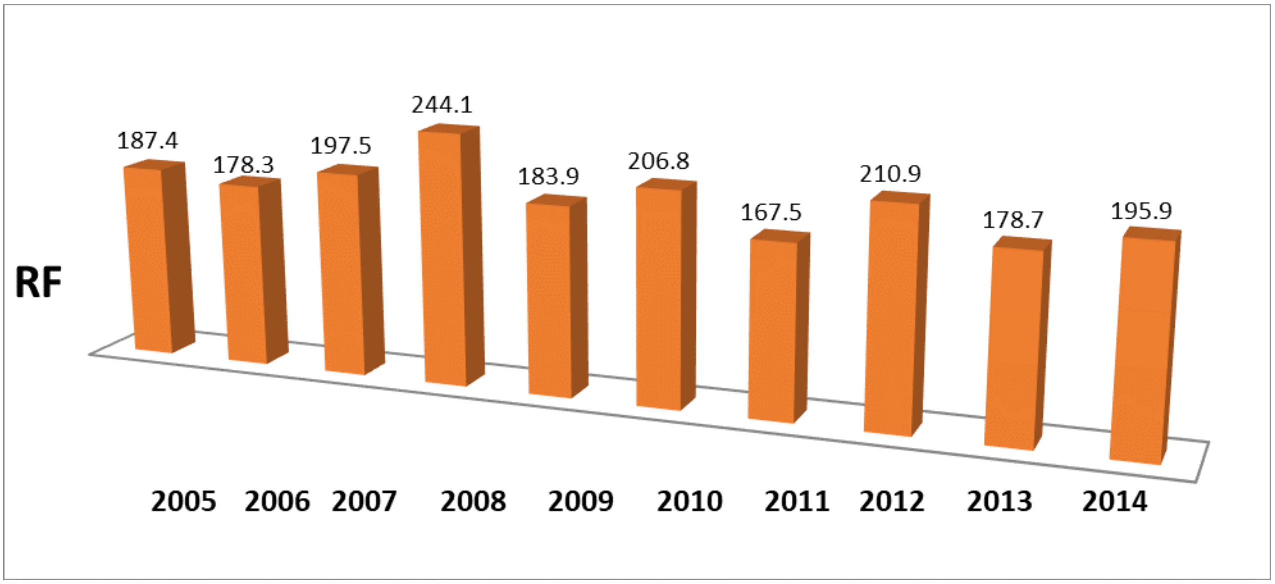
Calibration is a means of establishing a relationship between a given soil test value and the yield response from adding nutrient to the soil as fertilizer. It provides information how much nutrient should be applied at a particular soil test value to optimize crop growth without excessive waste and confirm the validity of current P recommendations (Evans 1987, McKenzeie and Kryzanowski 1997, 17-19). They enable to revise fertilizer recommendations for an area based on soil and crop type, pH and soil moisture content at time of planting. An accurate soil test interpretation requires knowledge of the relationship between the amount of a nutrient extracted by a given soil test and the amount of plant nutrients that should be added to achieve optimum yield for a particular crop (Muir and Hedge 2002, 32-33; Watson and Mullen 2007. Soil tests are designed to help farmers predict the available nutrient status of their soils. Once the existing nutrient levels are established, producers can use the data to best manage what nutrients are applied, decide the application rate and make decisions concerning the profitability of their operations (Agegnehu and Lakew, 2013). However, local assessments for the soil P critical levels and soil P requirement factors even for the major crops of the country are negligible. Currently, soil fertility research improvement is agreed with respect to Site specific fertilizer recommendation in the country.

An accurate soil test interpretation requires knowledge of the relationship between the amount of a nutrient extracted by a given soil test and the amount of plant nutrients that should be added to achieve optimum yield for each crop (Sonon and Zhang, 2008). Calibrations are specific for each crop type and they may also differ by soil type, climate, and the crop variety. Having this knowledge, Nekemte Soil Research Center under taken soil test besed maize crop fertilizer P response calibration study at Wayu-tuka distrcit on Nitosols during the years 2014 and 2015 and determined Optimum nitrogen rate (200 kg/ha), P-critical (4.23 ppm) and P-requirement factor (9.58). But similar to any other investigated or improved technology, to have confidential on technology dissemination to end users, the economic visibility and acceptance of the technology should be verified at the same area. Therefore, the objectives of this study were to verify critical P-value with the relative yield response of maize on Nitisols at Wayu-tuka district of East Wollega Zone and determine the critical P concentration and P requirement factor.

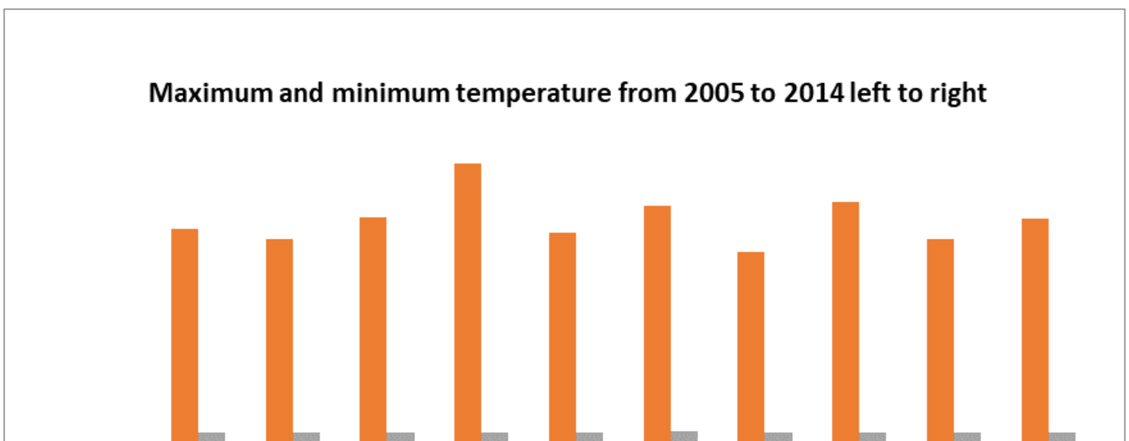
Materials and methods

Experimental Site

Verification of phosphorus response trials with maize was conducted on farmers' fields in 2016 during the main cropping seasons at Wayu-tuka district in East Wollega Zone of Western Ethiopia. Wayu-tuka is located at an altitude of 2080 masl and at geographical location of 36.4622 degree latitude and 9.08833 degree longitude. Rain fall (mm) of the experimental area for the last ten years reveals that highest precipitation was recorded in 2008 while the lowest was recorded in 2011 as shown below. The maximum and minimum temperature of the experimental area for the last ten years (2005-2014) also indicated in fig 2 below. Immense generous



Source: Ethiopian metrological agency,
Fig 1: Rain fall (mm) of the experimental area for the last ten years



	1	2	3	4	5	6	7	8	9	10
max T	187.4	178.3	197.5	244.1	183.9	206.8	167.5	210.9	178.7	195.9
minT	13.3	13.1	12.8	12.7	13.2	13.4	12.9	13.1	13.2	13.0

Source: Ethiopian metrological agency
Fig 2: Maximum and minimum temperature of the experimental area

For the selection of representative trial sites across the area, nine soil samples (0-20 cm depth) were collected from farmers' fields before the onset of the trial in 2016. Soil samples were analyzed for pH using a ratio of 2.5ml water to 1 g of soil and available P using Olsen method. Based on the soil available P content for each site P-fertilizer to be applied was calculated by the formula P (kg/ha) = [Pc-P_0]*P_{rf}.

Experimental Procedures

The experiment was arranged in simple randomized complete block design with three treatments referring phosphorus rates (zero, farmers practice (50 kg/ha) and recommended P which varies from farmer to farmer based on initial soil P-value) and replicated three times. The gross plot size was 10m x 10m (100m^2) with spacing of 75cm*30cm. The harvested plot area measured was 6m*6m (36$m^{2)}$. The sources of N and P were urea and DAP respectively. All agronomic practices were applied based on local research recommendations. Land preparation was done in accordance with a standard practice locally used. The experimental plot was cultivated by an oxen-drawn. An improved maize variety BH-661 was used. Cultivation, weeding, chemical spray and harvesting were done at the appropriate time according to the research recommendations. Application of phosphorus fertilizer was done by banding the granules at the time of planting. Nitrogen at the rate of 92 kg N $ha^{-1}$was applied in the form of urea in two splits [(1/2 at planting, and ½ after first weeding, after 20 days).

Table 1: Initial soil P-value and amount of fertilizers added for maize during the experimental year (2016).

Experimental sites	Initial soil P-value (ppm) (Olsen method	Amount of Urea added (kg/ha)			Amount of DAP added (kg/ha)		
		C	FP	RR	C	FP	RR
Site-I	27	200	200	200	0	50	0
Site-II	4.6	200	200	200	0	50	0
Site-III	4.58	200	200	200	0	50	0
Site-IV	8.24	200	200	200	0	50	0
Site-V	6.49	200	200	200	0	50	0
Site-VI	4.12	200	200	200	0	50	2.29
Site-VII	17	200	200	200	0	50	0
Site-VIII	2.39	200	200	200	0	50	38.32
Site-IX	2.6	200	200	200	0	50	33.95
Grand total	-	1800	1800	1800	0	450	74.56

C=control, FP= farmers practice and RR= recommended rate based on initial soil P-value

Data Collection

As the trial is a verification experiment only maize grain yield was collected.

Statistical Analysis

The data were subjected to analysis of variance (ANOVA) using the procedure of the SAS statistical package version 9.0 (SAS Institute, 2001). Mean separation for the treatments was done using least significant difference (LSD) test.

Results and discussions

Statistical analysis showed that grain yield of maize was significantly affected by treatments and also by sites at 5% level of significance (Table 2). Analysis of variance show that phosphorous had a highly significant effect on maize yield and yield consistently increased as the rate of P increased to critical value. Highest number of maize grain yield (9966.7 kg/ha) was recorded by treatment three (T3) followed by treatment two (T2), (9537.7 kg/ha) while the lowest maize grain yield (8400 kg/ha) was recorded by treatment one (T1). Regardless of the phosphorus and nitrogen fertilizer rates, sites also showed significant difference on grain yield of maize (Table 2). This might be due to the variation among farmers on their farm land management, cropping history and other cases.

Partial Budget Analysis

Economic analysis was performed to investigate the economic feasibility of the treatments. Partial budget and marginal rate of return analyses were used. The average grain yield was adjusted to 10% downwards to reflect the difference between the experimental yield and the yield farmers will expect from the same treatment. The average open market price (4 Birr kg^{-1}) for maize crop and the official prices of DAP (16 Birr kg^{-1}) and as well as cost for fertilizer transportation and application (40 birr per 100Kg) was used for analysis. A treatment was considered worth to farmers when its minimum acceptable rate of return (MARR) is 100% (CIMMYT, 1988), which is suggested to be realistic.

Table 2: Mean grain yield of maize as affected by phosphorus fertilizer at Wayu Tuka district in 2016 cropping season.

Treatments	**Grain yield (kg/ha)**
T1= control (Zero P)	8400.0[b]
T2= Farmers practice (50 kg DAP/ha)	9537.7[a]
T3=recommended P-which based on initial soil P-value	9966.7[a]
LSD (0.05)	739.25
Sites-I	11146.7[ab]
Sites-II	7366.7[d]
Sites-III	12100.0[a]
Sites-IV	10666.7[b]
Sites-V	9200.0[c]
Sites-VI	7066.7[d]
Sites-VII	11233.3[ab]
Sites-VIII	7299.8[d]
Sites-IX	7633.3[d]
LSD (0.05)	1280.4
CV (%)	14.63

Key: Means followed by the same letter are not significantly differ from each other at 5% of probability level.

Table 3: partial budget analysis

treatments	Yield (kg/ha)	Adjusted grain yield 10%	Farm gate price per kg (birr)	Gross benefit	TCV	Net benefit	MMR ratio	MRR (%)
Control	8400	7560	4	30240	0	30240	-	-
Recommended rate	9966.67	8970	4	35880	1192.96	34687.04	3.73	373
Farmers practice	9537.78	8584	4	34336	7200	27136	-1.26	D

Application of soil test based recommended P-rate when combined with 200 kg/ha urea was significantly increased grain yield of maize compared to the other treatments. The economic analysis also showed that the highest net benefit (34687.04 ETB/ha) was obtained from recommended treatment rate with marginal rate of return (373%) which is greater than the minimum acceptable rate of return (100%).

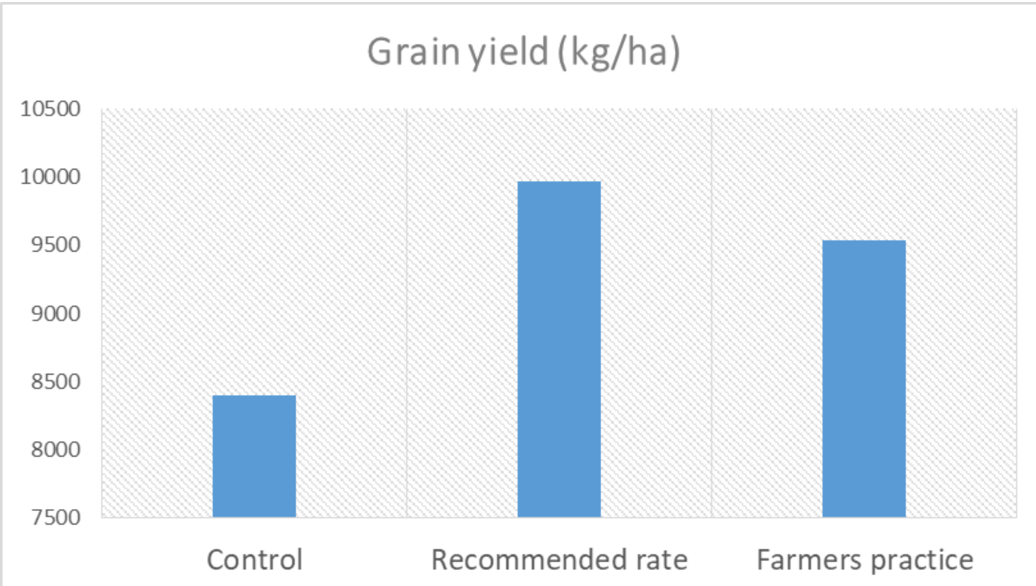


Fig 1: Treand of grain yield of maize for the three treatments

Conclusion and recommendation

There were clear positive effects of P fertilizer on yield of maize on Nitisols of western of Ethiopia. Across all nine sites, the critical soil P concentration was 4.23 mg ka^{-1} (Olsen method). The results may be used as a basis for P fertilizer recommendations for the production of maize on Nitisol areas. It can also be used for future intensification in other areas for developing a system for soil- test P fertilizer recommendations. P fertilizer application could be recommended for a build-up of the soil P to the critical value, or maintaining the soil P at this level. Increasing P beyond this level, the cost of additional P fertilizer to produce extra yield would likely be greater than the value of additional yield.

Thus, as the partial budget analysis reveals in table three and soils with available P status below 4.23 mg kg^{-1}, yield of maize could show a significant response to applications of P fertilizers. Whereas in areas with available P status greater than 4.23 mg kg^{-1}, the P concentration in the soil exceeds crop needs so that further addition of P fertilizer may not result in a profitable yield increase. It can also be used for future intensification in other areas for developing a system for soil test based fertilizer recommendation (Agegnehu *et al*., 2013).

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Evaluation of Different Drainage System on Grain Yield of Bread Wheat in the Waterlogged Vertisol of Adaba & Agarfa District, southeast Ethiopia

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ABSTRACT

Vertisols cover large part of the high rainfall areas of Ethiopia. However, the potential of these soils is not well exploited because of heavy water logging during the main rain season; this problem can be mitigated using different drainage systems. A field experiment was conducted from 2015-2017 G.C. during *"Gena"* (from August to Decemeber) cropping season to investigate the effects of different drainage systems on yield and yield components of bread wheat (“*Madda walabu”*} verities on the waterlogged Vertisols of Adaba and Agarfa districts in the West Arsi and Bale Highlands of Southeastern Ethiopia, respectively. The experimental design was randomized complete block design (RCBD) with treatments (broad bed and furrow (BBF), camber bed land form and a control (farmer practices) were used in three replications. The plot size for the treatments was 7.8 m by 4.5 m (35.1 m^2). Camber beds were formed to make a raised profile 5 m wide and 50 cm high from the furrow to the top of the bed. The broad bed and furrow (BBF) system used an 80 cm wide bed and 40 cm furrow between beds. The result revealed that out of the different proper drainage system used in the present study, camber bed had brought a significant yield improvement over the others viz broad bed furrow (BBF) and the famers’ practice in particular. The highest bread wheat biomass yield of 8.2 t ha^{-1} which is 39% higher over the farmers practice (flat bed) were recorded under camber bed; followed by broad bed and furrow which gave 15% higher biomass yield over the farmers’ practices. Similarly the highest grain yield of 5.8 t ha^{-1} which is 45% higher over the famers’ practice was obtained when the bread wheat was grown using camber bed, followed by broad bed and furrow (4.9 t ha^{-1}) which was 22% higher over the

farmers practices (flat bed). In addition, the application of both camber bed and broad bed and furrow practices resulted in significantly higher values of plant height, spike length, number of seeds per spike, number of tiller and spike lengths of "*Mada walabu*" bread wheat varieties. The current study recommended both camber bed and broad bed and furrow for mitigation of water logging in Vertisols at Adaba and Agarfa for production of bread wheat. As future recommendation need to disseminate the results of the present study to the end users were, high moisture stress is the limiting factor in Vertisols for sustainable crop production in highlands of Bale at large.

Key words: Camber bed, Broad bed and furrow (BBF), bread Wheat, water logging

Introduction

Vertisols cover large part of the high rainfall areas of Ethiopia. However, the potential of these soils is not well exploited because of heavy water logging during the main rainy season. Vertisols are deep black clays which develop cracks when expanding and contracting with changes in moisture content. Vertisol is the fourth soil order in Ethiopia covering about 12.7 million ha or about 10% that distributed in different part of the country (Mesfine, 1998).In addition, there are 2.5 million ha of soils with vertic properties. While about 70% of these soils are in the highlands, and about 25% (1.93 million ha) of the highland Vertisols are cropped (Berhanu Debele, 1985). Vertisols are amongst the most common, high-potential soils in the highlands of Ethiopia, where over 88% of human and 77% of livestock are located (Erkossa, et al. 2005).

Farmers of the Vertisols area have realized the adverse effects of waterlogging on crop productivity and have developed traditional methods for overcoming the problem. Their strategy to utilize Vertisols has always been to plant late in the wet season, which means harvesting a single crop and leaving the land under-utilized or idle (Tedla *et al.,* 1993). Generally, the traditional management of Vertisols in the Ethiopian highlands varies from place to place depending on the amount and duration of rainfall, extent of drainage problems, soil fertility and slope and farm size (Berhanu, 1985; Mesfin, 1998). Because waterlogging resulted in poor aeration, lower soil microbial activities, loss and unavailability of plant nutrients and poor workability (Trough and Drew, 1982). Waterlogging affect the amount of oxygen in the soil,restricting aerobic respiration by growing roots and other living organisms. Hence, soil chemical properties change when anaerobic conditions persist for several days, increasing the availability of some major or minor elements while decreasing the availability of others and which will eventually have a negative effect on grain yield. Waterlogging also denitrifay soil nitrogen and limits the wheat plant's nutrient uptake by reducing plant transpiration and diminishing root

These traditional land preparation techniques include flatbed planting, drainage furrows, ridge and furrows, hand-made broad beds and furrows, post-rainy season planting and soil burning ('guie') (Berhanu, 1985; Mesfin, 1998). Nevertheless, these soils are vastly underutilized due to management difficulties using traditional cultivation practices (Mesfine, 1998). To minimize these difficulties it needs an identification and adoption of appropriate moisture drainage technologies to the study areas for better production up to the potential of the soil. Therefore this project was initiated to select appropriate moisture drainage system through evaluation of the performance of bread wheat on waterlogged Vertisols under different moisture drainage system.

Materials and methods

The experiment was laid out in RCBD with three replications using the following treatments, T_0 = Farmers' practice (FB), T_1= Cumber bed land form (CB) and T_2 = Broad bed furrow (BBF) conditions side by side on a land with uniform slope and similar history. The plot size for all treatment was 7.8 m by 4.5 m (35.1 m^2). Camber beds were formed to make a raised profile 5 m wide and 50 cm high from the furrow to the top of the bed. The BBF system uses an 80cm wide bed and 40 cm furrow between beds. In addition the distance between plots and blocks (1 m) to minimize seed transfer during planting. Seed rate and fertilizer rates were the recommended rates for each crop (41/20 N/P kg ha^{-1}). Initial land preparation, crop management factors was the same for all at each location. Data on plant height, biomass, grain yield and TKW as well as soil sample analysis for pH, OC, total nitrogen and available phosphorous were collected.

Data management and statistical analysis: Data collected was subjected to ANOVA using GLM procedure of statistical analysis system of computer software (SAS, 1998) and LSD was used for mean comparison, and combined analysis over location data was used for interpretation.

Description of the study areas;

The study was conducted at Sinana Agricultural research center Sub-site found at Agarfa and Adaba district in Bale and West Arsi Zone of Oromia Regional State respectively. Agarfa SARC Sub-site is located at 442 km south east of the capital city, Addis Ababa. The mean annual rainfall, maximum and minimum temperature are about 836.1 mm and 22 and 8.6 ˚C, respectively (NMSA, 2010). Based on agro climatic condition the area has three seasons, a short rainy season that extends from March to June, a long rainy season extending from July to October and a dry season that extends from November to February (NMSA, 2010).

On average, the annual rainfall in Adaba district is 913 mm. Temperatures in the high plain range between 10 and 30 degrees Celsius with an average of about 15 degrees. With increasing altitude, the climate gets colder and wetter. SARC Sub-site around Adaba is located at 343 km south east of Addis 220 m above sea level

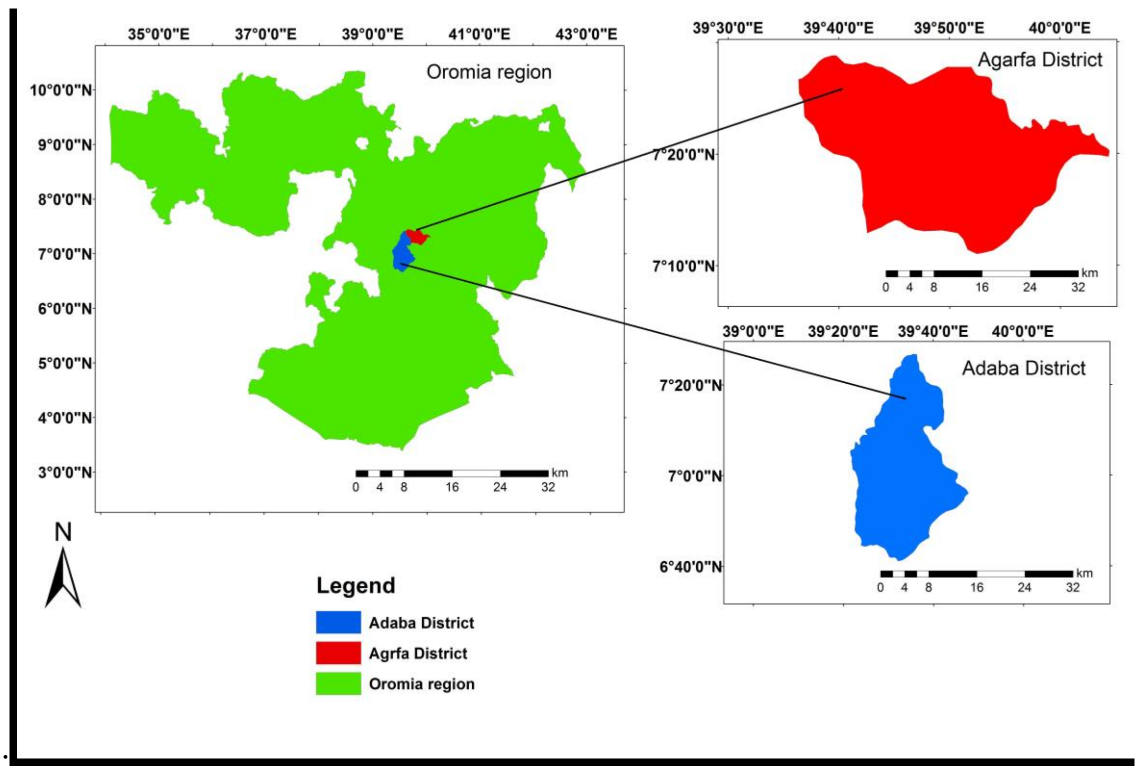

Figure 1 Location of Agarfa & Adaba District

Soil type

The soil map of the area is acquired from the Soil and Terrain database for the northeastern Africa developed by (FAO, 2012) and the soil type of both districts is illustrated as shown on the map below

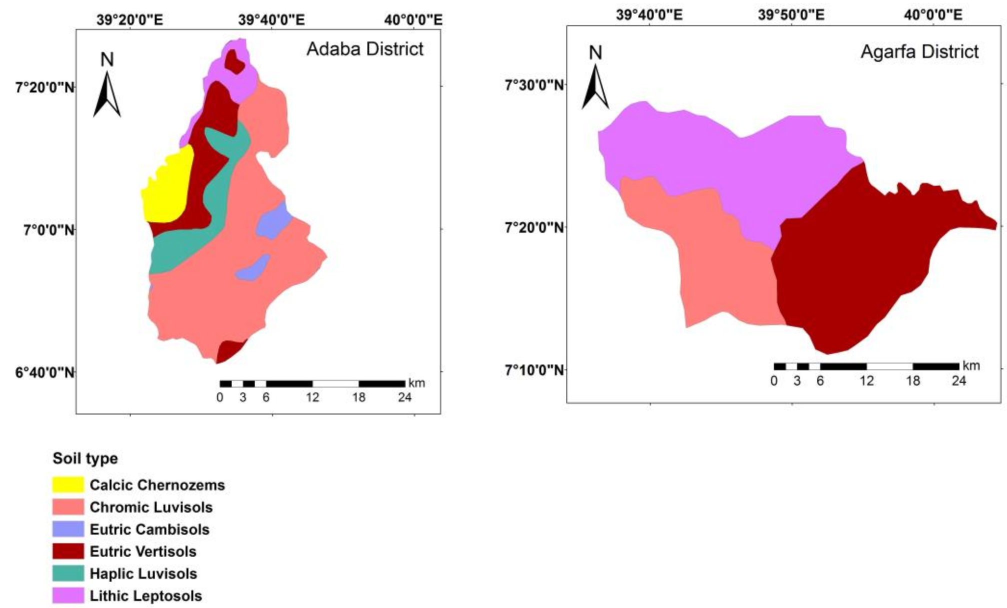

Figure 2.Soil map of Agrfa and and Adaba District

Result and Discussion

The Effect of different drainage system on grain yield and yield components (plant height, number of seed per spikes, spike length, number of tiller, above ground biomass and grain yields) of bread wheat in the waterlogged vertisols of Adaba & Agarfa indicated in Table 1. As indicated in the table there were mean yield and mean yield component differences between different treatments/moisture drainage systems. Accordingly, plants grown on camber beds land forming with fertilizer application had the highest Plant height, number of seeds per spike, spike length, number of tiller, aboveground biomass and grain yields (Table 1). Generally, across all the trial bread wheat grown on improved drainage techniques camber bed and BBF had better yield advantage as compared to farmers' practices. That means farmers' practices had the lowest yield and yield components, which is due to water logging effect on crop performance. On the other hand the result of variance analysis indicated that out of the different proper drainage system used in this study, camber bed had brought a significant yield improvement over the others viz broad bed furrow (BBF) and the famers' practice in particular area.

The highest bread wheat biomass yield of 8.2 t ha^{-1} which is 39% higher over the farmers practice (flat bed), were recorded under camber bed land form of the trial ; followed by broad bed and furrow which gave 15% higher biomass yield over the farmers' practices. Similarly the highest grain yield of 5.8 t ha^{-1} which is 45% higher over the famers' practice was obtained when the bread wheat was grown using camber bed land management, followed by broad bed furrow (4.9 t ha^{-1}) which gave 22% higher over the farmers practices (flat land). The application of both camber bed and broad bed and furrow practices result significantly higher values of plant height, spike length, number of tiller and spike length (Table1.) of "*Mada walabu*" bread wheat over control treatment.

Table1. Results of the effect of different drainage system on grain yield and yield components of bread wheat in the waterlogged Vertisols during "Bona" cropping season 2015- 2017 G.C at Adaba and Agarfa District

Treatments	Plant height (cm)	Spike length (cm)	NSPS	NT	Biomass yield (t ha^{-1})	Grain yield (t ha^{-1})	TKW
Farmer practice	74.9^{b}	6.4^{c}	33.5^{b}	2.0^{b}	5.9^{b}	4.0^{b}	32.3^{b}
Camber bed	93.0^{a}	8.3^{a}	45.6^{a}	2.9^{a}	8.2^{a}	5.8^{a}	39.6^{a}
Broad bed furrow	86.4^{a}	7.4^{b}	40.0^{ba}	2.9^{a}	6.8^{b}	4.9^{ab}	37.4^{a}
Mean	84.7	7.3	39.7	2.6	7.0	4.9	36.5
CV	10.2	7.3	28.0	17.3	21.0	37.9	15.6
LSD(0.05)	7.2	0.5	9.2	0.4	1.2	1.5	4.7

NB: NSPS = Number of seed per spikes, NT =n umber of tillers and TKW = thousand kernel weight

The fact from this experiment is similar with an experiment done by Duah-Yentumi *et al*. (1992) using camber beds and ridges, in comparison with flatland, on the Vertisols in Ghana indicated that the camber beds resulted in highest maize yield of 2215 kg ha^{-1}, followed by that on ridges (1504 kg ha^{-1}) and the lowest on flats (851 kg ha^{-1}),

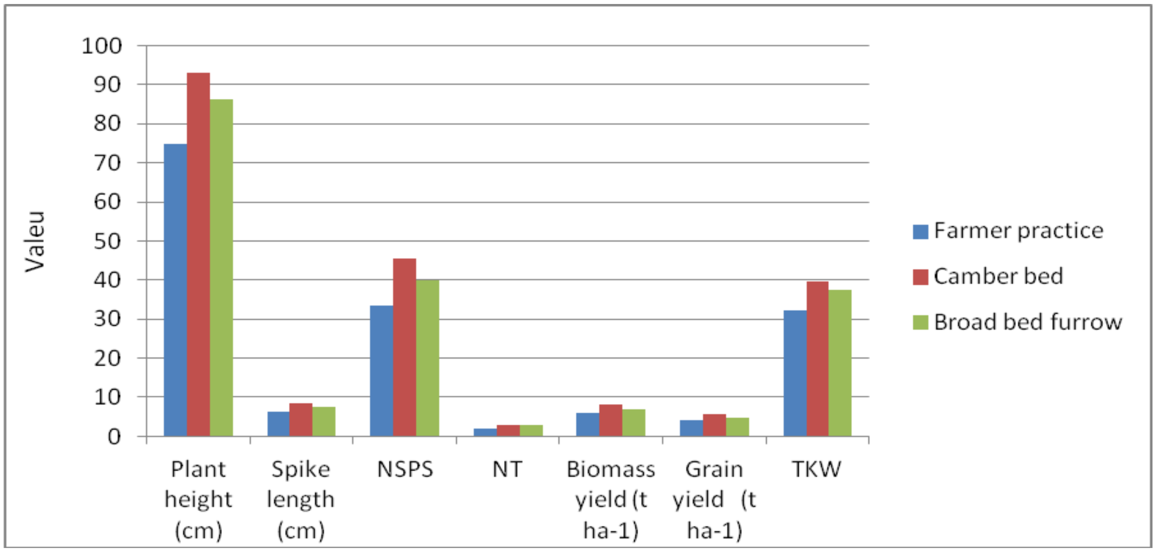

Figure 3.Results of the effect of different drainage system on grain yield and yield components of bread wheat in the waterlogged Vertisol

Conclusion and recommendation

The problem of high waterlogging in vertisol can be mitigated using different drainage systems. In view of the profound influences of climate and crop management practices, the choice and design of the conservation techniques should be done accordingly. As combined analysis over location indicate, the highest bread wheat biomass yield of 8.2 t ha^{-1} which was 39% higher over the farmers practice (flatbed) were recorded under camber bed; followed by broad bed and furrow which gave 15% higher biomass yield over the farmers' practices. Similarly the highest grain yield of 5.8 t ha^{-1} which is 45% higher over the famers' practice was obtained when the bread wheat was grown using camber bed , followed by broad bed furrow (4.9 t ha^{-1}) which gave 22% higher over the farmers practices (flat bed). The application of both camber bed and broad bed and furrow practices resulted in significantly higher plant height, spike length, number of seeds per spike, number of tiller and spike length (Table1.) of "*Mada walabu*" bread wheat varieties over control treatment. The study recommended the use of both camber bed and broad bed and furrow as a drainage technique for mitigation of water logging for production of bread wheat under waterlogged area of Adaba and Agarfa. Finally, disseminating camber bed and broad bed and furrow as future recommendation to the end users is paramount importance at large.

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Moisture Conservation and Management Practices on Yield and yield components of Maize in the Dry land of Bale, Southeastern Ethiopia

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Abstract

Extreme variation in rainfall distribution during the cropping seasons often results in low moisture stress condition which affects crop yields. A field experiment was undertaken from 2015 to 2017 G.C., during *?gana* (from August to December) cropping season to study the effects of *In situ* moisture conservation and management on yield and yield components of improved maize variety (*Melkasa* II) at lowland of Bale *(Goro* and *Ginnir* districts), southeastern Ethiopian. The layout of experimental design was randomized complete block design (RCBD) using three treatments (flat bed, ridging and furrow with ties, and ridging and furrow without ties (open furrow)) with three replications. The plot size for the treatments was 8m x 6m (48 m^2). The results revealed that out of the different *In situ* moisture conservation measures ridging and furrow with ties for Goro District and ridging and furrow without ties (open furrow) for Ginnir district resulted in significantly higher yield improvement over the famers' practice (flatbed). The highest maize biomass yield of 6.0 t ha^{-1} which is 29% higher and grain yield of 5.3 t ha^{-1} which is 28% over flatbed was recorded under ridging and furrow with ties for Goro district. Whereas ridging and furrow without ties (open furrow) gave the highest grain yield of 8.8 t ha^{-1} (64%) and 11.6 t ha^{-1} (28%) for Harawa I and Ebisa of Ginnir district. Moreover, practices of *In situ* moisture conservation of both ridging and furrow with ties for Goro; ridging and open furrow for Ginnir districts resulted in significantly higher plant height, number of ear per plant, ear length, number of kernel per ear (NKPE), biomass, grain yield, thousand kernel weight of "*Malkasa II* " maize variety. The present study recommended both ridging and furrow with ties and furrow, and

furrow without ties (open furrow) for mitigation of low moisture stress at Goro and Ginnir districts, respectively for production of maize. Therefore, demonstrating and popularizing these technologies in low land of Bale zone, where moisture deficit is limiting factor for maize crop production, will be the next measure to be taken by the extensions'.

Key word: moisture conservation, ridging, furrow, ties

Introduction

Periodic low soil moisture due to erratic and poorly distributed rainfall, severe soil erosion and runoff loss of water and the resultant low soil fertility are the prominent causes for the low agricultural productivity in the semi-arid areas of Ethiopia. In addition to accelerated soil erosion and the alarming rate of land degradation, the loss of water as runoff coupled with periodic drought during the cropping season on degraded lands was equally important in rain-fed crop production (Tamirie, 1986; Heluf and Yohannes, 2002). The practice of judicial water conservation undoubtedly plays a significant role in increasing agricultural production in arid, semi-arid and sub-humid areas where agriculture is hampered by periodic droughts and low soil fertility (Tamirie, 1986; Heluf, 1989; Heluf and Yohannes, 2002; Heluf, 2003). Because moisture conservation and management practices provide better nutrient uptake and higher yield as well as improve soil physic-chemical properties apart from reducing water and nutrient losses. But there is no available information in the area to use either of the physical moisture conservation methods available, which is efficient at those specific study areas. Therefore, this experimental design of different structural moisture conservation methods in the study area was intended to address low moisture problem for maize crop production on sustainable bases. Thus, the objective of the experiment was to see the effect of different in situ moisture conservation practices on yield and yield component of maize at Goro and Ginnir districts of Bale Zone.

Materials and Methods

The design used was RCBD in three replications. The treatments included flatbed (T0) as a control treatment that practiced commonly by farming community in the study areas, *In situ* rainwater harvesting practices (flatbed (T0), ridging and furrow with ties (T1), and ridging and furrow without ties (open furrow) (T2).. The treatments identified as T2 and T3 were applied two week before planting; T1 was applied at planting time. Each treatment was applied on a plot size of 8m x 6m (48 m^2), the distance between blocks and within plots are 2m. The spacing between plants within a row 0.25 m, between rows 0.75 m, between tied ridges 0.75 m and between ties was 2 m. An oxen plow tied ridger implement was used for constructing ridges of 0.3 m height. The time of application of all recommended P rate was at planting but N was applied in split: 1/2 at planting, 1/2 after 35 days after sowing. The seeding rate used was 25kg ha^{-1}. All cultural management practices (such as two times hand weeding during the cropping season) were equally made for all plots.

Data of water use efficiency of maize (daily rainfall amount until crop to the harvesting), soil moisture from 0 – 0.3 m soil depth using soil auger at sowing and harvesting of crop, plant height, ear height (PH), number of ears per plant (NEPP), ear length(EL), number of rows per ear (NRPE), number of kernels per row (NKPE), biomass (BY), grain yield (GY), thousand kernel weight (TKW) were collected. Finally, all agronomic data were recorded in EXCEL and subjected to ANOVA using GLM procedures of SAS (2004) and LSD was used to compare treatments mean.

Results and Discussion

Results of the effect of different method of moisture conservation practices on yield and yield components (PH, NEPP, EL, NKPE, BM, GY, and TKW) of maize at Goro district of Bale zone indicated that there were statistically higher significant differences (Table 1). Accordingly, the result of analysis of variance indicated that out of the different *in situ* moisture conservation techniques used in this study treatment, ridging and furrow with ties showed significantly higher yield improvement over ridging and furrow without ties (open furrow) and the farmers' practice at Goro district. On the other hand, ridging and furrow without ties (open furrow) resulted in significantly higher values of "*Malkasa II* " maize yield and yield components at Ginnir district. The highest maize BY of 6.0 t ha^{-1} which is 32.8%

and GY of 5.3 t ha^{-1} which is 28.3% higher were recorded under ridging and furrow with ties over the flat bed. Generally, across all moisture conservation trial areas, maize grown on ridging and furrow with ties, and furrow and ridge without ties had better yield advantage as compared to farmer practices. That means farmers' moisture conservation practices resulted in lowest yield and yield components, which is due to the problem moisture stresses. According to Heluf and Yohannes (2002) findings, which support this experiment result, tied ridge has resulted in yield increments of 15 to 50% on maize and increment of 15 to 38% on sorghum was recorded on different soil types of eastern Ethiopia. Similarly, Heluf (2003) stated that the increased yield of sorghum using tied ridge moisture conservation method could be attributed to the reduced surface runoff, reduced risk of erosion and soil nutrients, and also due to increased water holding capacity of the soil.Another advantage of tied ridge was decreasing surface runoff from the field and increase water retention capacity of the field. Similar finding was reported by Macartney *et al.* (1971) who reported that tied ridging in Tanzania gave higher maize yields in high rainfall areas although this was an exceptional case. According to Et-Swaify *et al* (1985)'s summaries, these system in Africa has been beneficial not only for reducing run-off and soil loss, but also for increasing crop yields.

Table 1. The combined analysis results of the effect of *In-situ* moisture conservation practice on yield and yield components of maize, at Goro District at "*Gana*" cropping seasons during 2015- 2017

Treatments	PH (cm)	NEPP	EL(cm)	NKPE	BY (t ha^{-1})	GY (t ha^{-1})	TKW
Flatbed(control)	145.52^{b}	18.96^{c}	1.0^{c}	33.27^{b}	4.67^{b}	4.13^{b}	221.27^{b}
Ridging and furrow with ties	171.59^{a}	25.11^{a}	1.61^{a}	35.92^{a}	6.0^{a}	5.30^{a}	284.45^{a}
Furrow and Ridge without ties	162.26^{a}	22.18^{b}	1.28^{b}	35.08^{ba}	5.61^{a}	5.08^{ba}	256.19^{a}
Mean	159.79	22.08	1.30	34.76	5.43	4.84	253.97
CV (%)	7.73	13.01	19.89	7.09	12.92	21.78	12.66
LSD(0.05)	12.03	2.80	0.25	2.40	0.68	1.02	31.28

NB: PH = Plant height, NEPP = Number of ear per pant, EL= ear length, NKPE = Number of kernel per ear, By = biomass yield, GY = Grain Yield , TKW = Thousand kernel weight

Effect of moister conservation practices on Soil Moisture (after 75 days of planting)

Different moisture conservation practices were also affected soil water storage at 0.3 m. Greater soil moisture was recorded by tied ridge (17.4%) which was 18% over farmers practice, followed by furrow and ridge 16.2% which is 10% higher moisture content over the flat bed thereby improving growth and yield of maize. At flowering stage maize crop experienced moisture stress in the case of flat bed.

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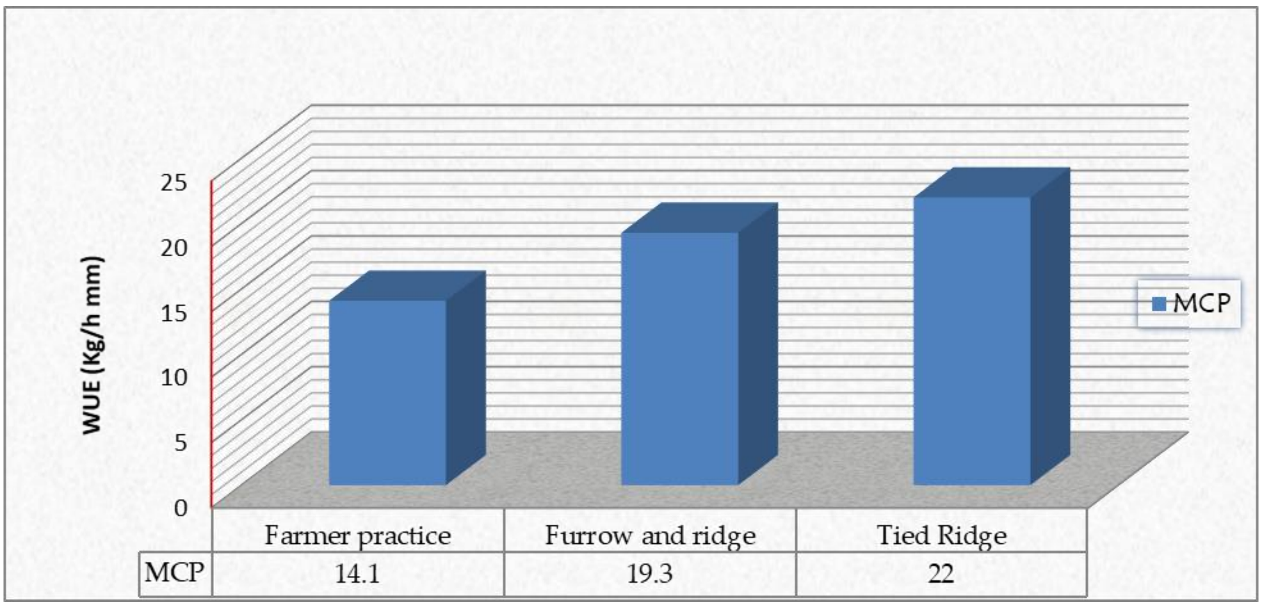

Figure 1**.** Effect of moisture conservation practice on water use efficiency of Maize during 2015 at Goro

As shown in figure 1, water use efficiencies under the different moisture conservation practices differed significantly higher as compared to flat bed. In this study Tied ridge resulted in 56% moisture conservation advantage over the farmers practices; followed by furrow and ridge which is 37% higher water use efficiency. Similarly, Tied-ridging increased sorghum grain yield by more than 40% and soil water by more than 25% in northern Ethiopia (Gebreyesus et al., 2006). The tie act as a barrier for the rain water movement and increases contact time available for infiltration thus enhances the availability of soil moisture to the crops (Rana, 2007). Studies also showed that lack of greater response to applied N and P fertilizer in Ethiopia was probably due to soil water deficit which is the major yield-limiting factor and profitable crop response to applied nutrients depends on soil water availability (Tewodros et al., 2009).

Effect of Moisture Conservation Practice on yield and yield component of Maize at Ginnir district

As indicated in Table 2 and 3, statistically significant diference were recorded on BY and GY for the ridge and furrow treatments at both locations of Ginnir district (at Harawa I during 2015 and 2016, and Ebisa during, 2016 of "*Belg*" (April – July) cropping seasons) ;. Flatbed resulted in lowest grain and biomass yield. From this study results ridging and furrowing increased the yield of maize over the flat bed. Similarly, Channappa and Ashoka (1992) reported that there was 11.67 per cent increase in yield of Sorghum in the ridge and furrow system over the flat method of sowing. There was 40.8 per cent higher yield of pod in the ridge-furrow method than the flat bed sowing systems.

Table 2. Effect of moisture conservation practice on yield and yield component of maize at Harawa one of Ginnir District (*Gana cropping season 2015- 2016)*

Treatments	PH (cm)	NEPP	EL(cm)	NKPE	BY (t ha^{-1})	GY (t ha^{-1})	TKW
Flat bed(control)	157.21^{b}	1.0^{c}	19.82^{b}	26.55^{b}	6.01^{c}	5.39^{c}	305.26^{b}
Ridging and furrow with ties	170.05^{ba}	1.56^{b}	21.72^{b}	33.89^{a}	8.13^{b}	7.47^{b}	347.75^{b}
Furrow and Ridge without ties	196.27^{a}	2.26^{a}	26.85^{a}	37.78^{a}	9.73^{a}	8.81^{a}	437.95^{a}
Mean	174.51	1.61	22.79	32.74	7.96	7.22	363.66
CV	17.24	14.02	14.22	11.34	9.60	13.30	13.40
LSD(0.05)	37.03	0.28	3.99	4.57	0.94	1.18	59.82

Table 2 .Effect of moisture conservation practice on yield and yield component of maize at Ebisa site of Ginnir District during *2016*

Treatments	PH(cm)	NEPP	EL (cm)	NKPE	BM (t ha^{-1})	GY (t ha^{-1})	TKW
Flat bed(control)	186.25	1.25b	28.33	34.25	11.81c	9.04b	259.33
Tied Ridge (with ties)	182.5	1.33ba	29.08	34.04	13.54b	9.92ba	362
Furrow and Ridge (without ties)	188.75	1.63a	28.48	34.71	15.14a	11.57a	370
Mean	185.83	1.40	28.63	34.33	13.49	10.18	330.44
CV	7.55	11.88	3.37	4.19	5.61	10.69	20.96
LSD(0.05)	ns	0.33	Ns	Ns	1.51	2.17	ns

Generally the experiment results indicated that maize yield and yield components were affected by different moisture conservation practices. Hence, significant maize crop yield increament resulted from ridging and furrowing moisture conservation practice.

Conclusion and Recommendation

Moisture stresses caused by shortage of rainfall, irregular distribution of rainfall and erratic rainfall characteristics as well as excessive infiltration rate are the major limiting factor for crop production at rain fed agricultural system. However, the problem of moisture stress for rain fed agricultural systems can be mitigated by moisture conserving practices that improved storage of soil moisture at root zone and by wisely using rain water integrating with different crop management practices. In this respect, the uses of tied ridges showed significant difference at these specific areas (specific climate and soil type). Hence, the use of moisture conservation method might be affected by climatic condition and soil type of the area. . Therefore, the authors' recommend the use of closed end tied ridges and ridges and furrow at Goro and Ginnir districts; respectively. In addition, strong extension work for demonstration and poplarization of the determined technologies should have great attention to overcome problem of moisture stress condition and to improve land productivity for rain fed maize production in the study area. On the other hand the recommended moisture conservation methods can be extrapolated to other area with similar climatic condition and soil type. .

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