32nd Annual Research Bulletin

Theme I Productivity and Environmental Sustainability for Food Security and Poverty Alleviation

Volume I

April 2015
Haramaya University

Office of the Vice President for Research Affairs

32nd Annual Research and Extension Workshop 2015

Edited and Compiled by:

Wassu Mohammed(PhD)
Prof. Nigussie Dechassa (PhD)
Nega Assefa (PhD)
Mengistu Ketema (PhD)
Kidesena Sebesibe (MSc)

Printed in Addis Ababa, Ethiopia

Inquiries should be addressed to:
Office of Research Affairs
P. O. Box 116, Haramaya University, Ethiopia
Tel: (+251) 25 553 0324 / (+251) 25 553 0329
Fax: (+251) 25 553 0106 / (+251) 25 553 0325

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1. Carrot (Daucus carota L.) Variety Development

Wassu Mohammed Ali

Haramaya University, College of Agriculture and Environmental Sciences, School of Plant Sciences, E-mail:wasmoha@yahoo.com

Abstract: *Haramaya 1* is the common name for the carrot (*Daucus carota* L.) variety with the original collection name AUA-108. The variety was developed through selection in the eastern highlands of Ethiopia. It was selected from 64 carrot genotypes collected from Haramaya woreda (district). The genotypes were maintained by farmers for a long period of time through an open-pollinated seed production system. The released carrot variety was found to be superior in marketable and total root yields and other desirable traits to the commercial Nantes variety, which was used as the standard check, and a famers' open pollinated cultivar, which was used as a local check. Furthermore, this variety was superior to the Nantes variety and the farmers' open-pollinated cultivar in terms of producing lower proportions of small-sized, cracked, forked, and hairy roots. The variety had also a margin of seed production potential amounting to 11.81% over the Nantes variety. Moreover, its root yield was found to be stable over seasons and locations. Therefore, it could be cultivated sustainably by smallholder farmers in the highlands of eastern Ethiopia and in other places with similar agroecology.

Keywords: Core-size; Farmers' Cultivar; Commercial Cultivar; Root Yield; Seed Yield; Yield Stability

1. Introduction

Carrot (*Daucus carota* L.) is a widely grown root vegetable of the Apiaceae family. The first certain recorded use of carrot roots as a vegetable was in the 10th century in what is today known as Afghanistan. Orange carrots first appeared as a genetic variant in Europe in the 16th century and these more refined orange carrots quickly spread around the world, and by the early 20th century they became the predominate carrots in most growing regions of the world (www.seedalliance.org). Carrot is an important source of alpha- and beta-carotene, the precursors of vitamin A in human nutrition in many countries worldwide. The carotenoids contained in the edible portion of carrots can range from 6000 to more than 54,000 µg per 100g (60–540 ppm) (Simon and Wolff, 1987).

Although the exact time of introduction of carrots to Ethiopia is not known, the crop has been known since the early 1960s in the research system. Research on carrots in Ethiopia was started at Alemaya College of Agriculture (now Haramaya University) using imported seeds of eight varieties from Kenya in the early 1960s. Among the eight varieties tested, Nantes and Chantenay were identified as high yielders (Kifle-Iyesus, 1994; Kidanemariam, 1969). Carrot production has been expanding since then and the total production reached 12345.8 tonnes on 2215 hectares of land (CSA, 2010/11). On the other hand, vitamin A deficiency is widespread in the country (Haile-Meskel, 2011). The prevalence is 2 to 15-fold higher than the World Health Organization (WHO) cut-off point (0.5%) for public significance.

The Nantes carrot has become popular in Hararghe Zone of Ethiopia because it produces quality roots as a result of which it obtained niche market in neighbouring Djibouti and Somalia. Farmers also produce seeds of this carrot variety albeit the poor quality of the seed. The crop is cross-pollinated. Although there is a possibility to produce inbred lines for F_1 hybrid production to attain plant uniformity, inbreeding results in severe depression. Therefore, mass selection using root-to-seed production method is preferred to improve the crop. Haramaya University initiated research on carrots two decades ago with the attempt to improve the locally produced Nantes variety for root uniformity, high yield, good root texture, small core diameter, resistance to cracking, and adaptation to different agroecolgical conditions. Eventually, the university has come up with the variety named *Haramaya 1* from the locally collected 64 genotypes through successive selections.

2. Materials and Methods

2.1. Description of the Study Area

The field experiment was conducted for a long period which included all the breeding procedures starting from screening carrot genotypes to verification trial which was conducted at 12 locations starting screening carrot genotypes to verification trial. The screening and multi-location trials were conducted mainly at Haramaya (Raare), Hirna, Kulbi and Chelenko Haramaya University research farm is located at 2022 m.a.s.l., 9°41"N latitude and 42°03"E longitude. The area has a bimodal rainfall distribution with mean annual rainfall of 760 mm. The long rainy season extends from June to October and accounts for about 45% of the total rainfall. The mean maximum temperature is 23.4^{0}C while the mean minimum annual temperature is 8.25^{0}C (Tekalign, 2011). The soil of the experimental site is a well-drained deep alluvial with a sub-soil stratified with loam and sandy loam. Hirna sub-station is situated at a distance of about 134 km to the west of Haramaya. The site is located at 9 ^{o}12' North latitude, 41 ^{o}4'East longitude, and at an altitude of 1870 meters above sea level. The area receives mean annual rainfall ranging from 990 to 1010 mm. The average temperature of the area is 24.0^o C (Tekalign, 2011). The soil of Hirna is vertisol (HURC, 1996). Kulbi is located at 2330 m.a.s.l. with mean annual rainfall of 862 mm, mean annual maximum and minimum temperature of 19.5^{0}C and 7.3^{0}C, respectively(Tekalign, 2011).

2.2. Experimental Materials

Sixty-four carrot genotypes were collected from Haramaya Woreda.These genotypes were originally introduced into the region by overseas seed companies. Farmers maintained and used the genotypes for a long period of time through an open pollinated seed production system. The genotypes were initially evaluated for root yield potential under Haramaya condition using single rows. Seventeen of the genotypes were promoted to replicate yield trials. Trials were conducted for evaluation of total and marketable root yields for a number of years. Finally, two candidate varieties were promoted to a regional trial and evaluated for two years at three locations along with farmers' cultivars and commercial local Nantes. Verification trial was conducted at nine locations using the same genotypes and finally one variety (AUA-108) was approved for release.

3. Results

3.1. Regional Variety Trial

Analysis of variance conducted for six environments (three locations and for two years) during regional trial revealed that there is significant effect of location, growing season (year) and the interaction of location x season (year) on both total and marketable root yield of four carrot genotypes. In addition, significant difference among genotypes was observed for marketable root yield (Table 1). Root length, root diameter and root core diameter were influenced by location during regional trial (Table 2). The released variety *Haramaya 1* (AUA-108) showed superiority for total and marketable root yield as well as for most of the desirable root characters (Table 3 and Table 4). The total yield and marketable root yield increase of *Haramaya 1* (AUA-108) over other three genotypes (other candidate genotype, AUA-22; standard check, Nantes and local check) was up to 16.23% (Table 5 and Table 6).

3.2. Variety Verification Trial

The released variety of *Haramaya 1* (AUA-108) along with standard check (commercial *Nantes*) and local check were evaluated during 2013 cropping season. This was a verification trial conducted at three locations but genotypes were grown at nine sites (three sites for each location). The analysis of variance was conducted for total and marketable root yield; however, non-significant difference was observed among genotypes (Table 7). The released variety exhibited 39.46% total root yield advantage over standard check (commercial *Nantes*) and local check as well as up to 19.53% marketable root yield advantage (Table 8). Similarly, the released variety showed superiority over the standard check (commercial *Nantes*) and local check for all desirable root characters (Table 9).

3.3. Yield Stability Test

The yield stability of the released variety along with the two checks (the commercial *Nantes* variety and the farmers' open pollinated cultivar) and one other candidate variety (AUA-22) was tested using the two stability models. The AMMI model was used since it combines the analysis of variance with the principal component analysis (Zobel *et al*., 1988) and joint linear regression model as proposed by Eberhart and Russell (1966). In addition, AMMI stability value (ASV) was calculated as proposed by Purchase (1997) and Purchase *et al.* (2000). The released variety (*Haramaya 1*) had the first lowest ASV values for both total and marketable root yields, and it produced the highest total and marketable root yields. On the basis of Eberhart and Russel's Model, *Haramaya 1* had the lowest value of deviation from the regression (S^2di) which is near zero (0.16) and regression coefficient (bi) value (0.98) which is near unity for total root yield. Although the deviations from regression stability parameter values for marketable root yield were negative and higher for all genotypes, *Haramaya 1* had relatively lower values of deviation from regression and regression coefficients (Table 11).

Table 1. Mean squares from combined analysis of variance for total and marketable root yield (t ha^{-1}) over three locations (Haramaya, Hirna and Chelenko) and two years (2010/11 and 2011/12 cropping seasons) of regional carrot variety trial.

Source	df	Total root yield t ha^{-1}	Marketable root yield t ha^{-1}
Replication	2	120.1	88.02
Genotype	3	33.91	86.82*
Location	2	4322.25**	3578.3**
Year	1	6835.02**	8244.72**
Genotype x Location	6	38.71	22.92
Genotype x Year	3	120.49	46.74
Location x Year	2	2231.31**	2022.44**
Genotype x Location x Year	6	99.51	72.21
Error	46	37.44	32.74
Grand mean		47.27	38.60
CV (%)		12.94	14.82

Table 2. Mean squares from combined analysis of variance root and leaf characters of four carrot genotypes over three locations (Haramaya, Hirna and Chelenko) and two years (2010/11 and 2011/12 cropping seasons) of regional carrot variety trial .

	Rep (2)	Geno (3)	Loc (5)	Geno x Loc (6)	Error (22)
Root length (cm)	16.24	4.928	18.135*	0.912	2.562
Root diameter (cm)	0.04504	0.14802	0.33787*	0.04011	0.07039
Root core diameter (cm)	0.08569	0.19803	0.26652*	0.02469	0.06989
Root weight (g)	2105.4	1006.2	163	530.2	859.6
Leaf length (cm)	8.54	167.34	23.82	6.39	48.64
Leaf weight (g/plant)	864.9	598	373.9	551.4	468.3

Table 3. Summary of total and marketable root yield of four genotypes in carrot regional variety trial at three locations over two years (2010/11 & 2011/12 cropping season).

Genotype	Total root yield t ha^{-1}									Overall mean
	Haramaya			Hirna			Chelenko			
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	
V1 (Commercial Nantes)	46.61	76.39	61.5	37.74	34.22	35.98	26.93	51.22	39.08	45.52
V2 (AUA-108 candidate variety)	45.99	77.17	61.58	34.42	38.89	36.66	29.64	62.89	46.26	48.17
V3 (AUA-22)	42.4	86.56	64.48	40.61	35.78	38.19	22.97	57.67	40.32	47.66
V4 (open pollinated famers Nantes)	53.39	68.06	60.72	32.63	33.39	33.01	29.01	54.94	41.98	45.24
Mean	47.1	42.47	32.12	38.35	35.57	36.96	27.14	57.68	42.41	47.27
SD	4.59	7.63	1.65	5.99	2.42	2.96	3.01	3.68	2.66	2.3
Genotype	Marketable root yield t ha^{-1}									Overall mean
	Haramaya			Hirna			Chelenko			
1.1.1	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	
V1 (Commercial Nantes)	35.42	67.5	51.46	27.8	28.67	28.24	20	42.56	31.28	36.99b
V2 (AUA-108 candidate variety)	39.94	73.78	56.86	29.18	34.89	32.53	24.21	56.11	38.16	42.52a
V3 (AUA-22)	34.11	69.55	51.83	33.94	29.83	31.88	15.68	48.78	32.23	38.65ab
V4 (open pollinated famers Nantes)	36.98	60.39	48.68	24.66	28.56	26.61	16.77	44.94	30.86	35.38b
Mean	35.61	68.81	52.21	28.4	30.24	29.31	18.17	47.1	32.63	38.6
SD	1.19	7.97	3.41	3.94	2.5	2.35	2.29	4.21	2.42	1.9

Table 4. Summary of root characters of improved carrot candidate varieties (V3= AUA-22 and V2= AUA-108) and the standard check (commercial Nantes) and local check (farmers open pollinated cultivar) in carrot regional variety trial (2010/11-2011/12).

Genotype	RL(cm)	LL(cm)	RW(g)	LW(g)	RD(cm)	CD(cm)
V1 (Commercial Nantes)	18.36ab	55.7a	108a	39.8a	2.83b	1.38b
V2 (AUA-108 candidate variety)	17.12b	48.4b	107.2a	23a	2.88ab	1.41b
V3 (AU-22 candidate variety)	18.89a	58.6a	130a	40.8a	3.12a	1.71a
V4 (farmers open pollinated cultivar)	18.12ab	54.3ab	115.1a	34.6a	2.94ab	1.50ab
Mean	18.12	54.3	115.1	34.6	2.95	1.50
SE	0.76	3.29	13.82	10.2	0.13	0.12
LSD (5%)	1.57	6.82	28.66	21.16	0.26	0.26
CV (%)	8.8	12.9	25.5	24.6	9	17.6

RL (cm) = root length, RD(cm) = root diameter, CD(cm) = root core diameter, RW(g) = root weight, LL(cm) = leaf length & LW(g) = leaf weight.

Table 5. Total root yield advantage of improved carrot candidate varieties over the standard check (commercial Nantes) and local check (farmers' open pollinated cultivar) in carrot regional variety trial (2010/11-2011/12).

		Total root yield (t/ha)				Percent increase over V1		Percent increase over V4	
Location	Year	V3	V1	V2	V4	V3	V2	V3	V2
Haramaya	2010/11	42.4	46.61	45.99	53.39				
	2011/12	86.56	76.39	77.17	68.06				
	Mean	64.48	61.5	61.58	60.72	4.85	0.13	6.19	1.42
Hirna	2010/11	40.61	37.74	34.42	32.63				
	2011/12	35.78	34.22	38.89	33.39				
	Mean	38.19	35.98	36.66	33.01	6.14	1.89	15.69	11.06
Chelenko	2010/11	22.97	26.93	29.64	29.01				
	2011/12	57.67	51.22	62.89	54.94				
	Mean	40.32	39.08	46.26	41.98	3.17	18.37	-3.95	10.20
Overall mean		47.66	45.52	48.17	45.24	4.70	5.82	5.35	6.48

Table 6. Marketable root yield advantage of improved carrot candidate varieties over the standard check (commercial Nantes) and local check (farmers' open pollinated cultivar) in carrot regional variety trial (2010/11-2011/12) .

Location	Year	Marketable root yield (t/ha)				Percent increase over V1		Percent increase over V4	
		V3	V1	V2	V4	V3	V2	V3	V2
Haramaya	2010/11	34.11	35.42	39.34	36.98				
	2011/12	69.55	67.5	73.78	60.39				
	Mean	51.83	51.46	56.86	48.68	0.72	10.49	6.47	16.80
Hirna	2010/11	33.94	27.8	27.18	24.66				
	2011/12	29.83	28.67	33.89	28.56				
	Mean	31.88	28.24	30.53	26.61	12.91	8.13	19.8	14.73
Chelenko	2010/11	15.68	20	20.21	16.77				
	2011/12	48.78	42.56	52.11	44.94				
	Mean	32.23	31.28	36.16	30.86	3.04	15.6	4.44	17.17
Overall mean		40.32	36.99	39.51	35.38	5.56	11.41	10.24	16.23

V1= Commercial Nantes as standard check, V4= open pollinated famers cultivar as local check and V3= AUA-22 and V2= AUA-108 are considered as improved varieties through selection by Haramaya University

Table 7. Mean squares for total and marketable root yield of three carrot genotypes over three locations (Haramaya, Hirna and Chelenko) during 2013 cropping season (verification trial).

Source	df	Total root yield t ha^{-1}	Marketable root yield t ha^{-1}
Replication	2	193	6.5
Genotype	2	220.7	316.9
Genotype x Location	2	350.3	256.5
Error	4	51.3	74.9
Grand mean	16	290.1	169

Table 8. Marketable and total root yield advantage of improved carrot variety (*Haramaya 1*) over the standard check (commercial Nantes) and local check (farmers' open pollinated cultivar) during 2013 cropping season (verification trial).

	Marketable root yield t ha^{-1}			Percent increase over	
Location	*Haramaya 1*	Local	Nantes	Nantes	Local
Haramaya	30.8	17.5	25.8	19.38	76
Hirna	36.7	23.3	25.8	42.25	57.51
Chelenko	41.7	37.5	26.7	56.18	11.2
Grand mean	36.4	26.1	26.1	39.46	39.46
LSD (5%)	12.99				
	Total root yield t ha^{-1}			Percent increase over	
Location	*Haramaya 1*	Local	Nantes	Nantes	Local
Haramaya	54.2	47.2	47.9	13.15	14.83
Hirna	63.3	54.6	49.2	28.66	15.93
Chelenko	64.2	67.5	55	16.73	-4.89
Grand mean	60.6	56.4	50.7	19.53	7.45
LSD (5%)	17.02				

Table 9. Summary of root and leaf characters of *Haramaya 1* carrot variety, Nantes (standard check) and local check over three locations (Haramaya, Hirna and Chelenko) during regional and verification trial (2011-2013).

Character	*Haramaya 1*	Local	*Nantes*	Mean	SE	LSD (5%)	CV (%)
CD_cm	1.38b	1.71a	1.41b	1.50	0.24	0.51	19.8
LL_cm	55.71a	58.65a	48.39b	54.3	5.96	12.63	13.4
LW_g	39.8a	40.83a	23.05a	34.6	9.81	21.99	28.35
RD_cm	2.83a	3.12a	2.88a	2.95	0.24	0.52	10.2
RL_cm	18.89a	18.36a	17.12a	18.12	1.45	3.07	9.8
RW_g	108a	130a	107.2a	115.1	26.49	56.16	28.2
SSR	32.67a	40.78b	67.22c	46.89	4.27	6.29	9.07
Cracked	0.22b	3.22a	1.89ab	1.78	1.22	1.59	68.53
Forked	2.56b	8.56a	6ab	5.7	1.73	2.59	30.43
Hairy	8.33ab	12a	12.67a	11	1.53	6.32	13.91
Twisted	25.22a	24.11a	17.56a	22.3	2.04	8.01	18.56

Means with the same letters in the column not significantly different at P<0.05. CD (cm) =root core diameter, LL (cm)= leaf length, LW (g)= leaf weight, RD (cm)= root diameter, RL (cm)= root length, RW (g)= root weight, SSR=proportion of small size root production

3.4. Agronomic and Morphological Characteristics

The released variety with local name *Haramaya 1* can be grown medium to high altitudes of eastern Ethiopia (1600-2400 m.a.s.l.) and similar areas of the country either under rain-fed or irrigation. It had deep orange root color. The released variety has long roots with small cores and smaller proportions of small-size roots, cracked roots, forked, and hairy roots. The released variety has attractive root size, colour, and shape. In addition to these, the variety is mainly released for its total root yield advantage of 11.41 and 16.23% over commercial variety "Nantes" and farmers' open pollinated cultivar, respectively. It has also 5.82 and 6.48% marketable root yield advantage over commercial variety "Nantes" and farmers' open pollinated cultivar, respectively. The seed production of *Haramaya 1* was 5.87 g/plant and had an advantage of 11.81% increase from the commercial variety. The yield and some agronomic and morphological characteristics of the released variety are given in Table 10.

Table 10. Agronomic characters of *Haramaya 1* carrot variety.

Characteristic	Description
Adaptation area	Medium to high altitudes of eastern Ethiopia (1600-2400 m.a.s.l.)
Rainfall	760-1010 mm
Planting season	All year round both under rain-fed and irrigation
Planting date	At the start of main rainy season and at any time with irrigation
Seeding rate (kg ha^{-1})	3.5 to 5
Row spacing (cm)	25
Spacing between plant (cm)	5
Fertilizer rate (kg ha^{-1})	46 kg P_2O_5 (100 kg DAP) and 64 kg N (100 kg Urea)
Fertilizer application time	All DAP at planting but half N rate at planting and half at active growth stage
Fertilizer application method	Drilling in row
Leaf length (cm)	55.71
Leaf width (cm)	39.8
Root colour	Deep orange
Root core diameter (cm)	2.83
Root length (cm)	18.89
Root weight (gm)	108
Proportion of small size roots (%)	32.67
Proportion of cracked roots (%)	0.22
Proportion of forked roots (%)	2.56
Proportion of hairy roots (%)	8.33
Proportion of twisted roots (%)	17.56
Root yield (t ha^{-1}) at research field	52.65 (total root yield)
Root yield (t ha^{-1}) at farmers' field	42.52 (marketable root yield) and 48.17 (total root yield)
Seed yield (g/plant)	5.87g per plant
Release year	2014
Breeder/Maintainer	Haramaya University

Table 11. Stability parameters for total and marketable root yield from AMMI analysis (environment and genotypes IPCA 1 & 2 scores, ASV, and ASV based rank) and from Eberhart and Russel's Model (regression coefficient (b_i) and deviation from regression (S^2di) of four carrot genotypes tested at three locations and two cropping seasons

Trait	Genotype	2011 cropping season			2012 cropping season			Pooled Mean & Rank	AMMI model stability parameters				ER's stability Model	
		Haramaya	Hirna	Chelenko	Haramaya	Hirna	Chelenko		IPCA 1	IPCA 2	ASV	ASV rank	b_i	S^2di
Total root Yield	Commercial *Nantes*	46.61	37.74	26.93	76.39	34.22	51.22	45.52 (3)	-1.06	-2.02	2.21	2	0.98	1.76
	Haramaya 1	45.99	34.42	29.64	77.17	38.89	62.89	48.17 (1)	0.66	2.18	2.16	1	0.98	0.16
	AU-22	42.4	40.61	22.97	86.56	35.78	57.67	47.66 (2)	-2.58	0.56	5.51	3	1.19	0.47
	Local check	53.39	32.63	29.01	68.06	33.39	54.94	45.24 (4)	2.97	-0.72	5.99	4	0.82	13.38
Environment	Mean	47.10	36.35	27.14	77.05	35.57	56.68	46.65						
	IPCA1	2.22	-1.53	1.49	-2.72	0.23	0.31							
Marketable root yield	Commercial *Nantes*	35.42	27.8	20	67.5	28.67	42.56	36.99 (3)	-0.59	1.59	1.55	2	0.97	-6.28
	Haramaya 1	39.34	27.18	20.21	73.78	33.89	52.11	42.52 (1)	1.25	-1.64	1.22	1	0.95	-2.51
	AU-22	34.11	33.94	15.68	69.55	29.83	48.78	40.32 (2)	-2.75	-0.59	5.97	4	1.21	-2.55
	Local check	36.98	24.66	16.77	60.39	28.56	44.94	35.38 (4)	2.09	0.64	3.83	3	0.86	-3.26
Environment	Mean	36.46	28.40	18.17	67.81	30.24	47.10	38.05						
	IPCA1	1.31	-1.24	1.16	-2.82	0.99	0.59							

Numbers in parenthesis are mean yield rank of genotypes. IPCA1 and IPCA2 = the first and the second interaction principal component scores, respectively, ASV = AMMI stability value, ER's= Eberhart and Russel's, b_i = regression coefficient and S^2di = deviation from linear regression.

4. Discussion and Recommendation

Carrot (*Daucus carota* L.) is a widely grown root vegetable in eastern Ethiopia. Carrot is grown as an annual for its fleshy root, but it is a true biennial requiring two seasons for flowering and seed production. The eastern Ethiopia farmers produce carrot from their own seeds for longer period of time. This gives the opportunity for breeders/horticulturist to collect seeds from farmers and select genotypes for uniformity of the roots and other desirable traits to develop better variety. After a number of years selection, it was possible to develop *Haramaya 1* carrot variety with deep orange root colour, higher total and marketable root yield than the commercial variety Nantes. The variety was developed through mass selection using root-to-seed production method. The released variety has many desirable traits as compared the commercial variety Nantes and farmers cultivars. Moreover, this variety has a seed production potential of 5.87g/plant. The carrot seed production spacing in the world is in the range between 75 and 95 cm between row and 20 to 30 between plants. Open pollinated carrot cultivars produced about 600 to 1000 kg ha^{-1} in the temperate regions while about 300 kg ha^{-1} in the tropical regions. The 1000 grain weight is 0.8g (George, 1999). The released variety *Haramaya 1* has a seed production potential of 391.33 kg ha^{-1} at the lower spacing of 75 and 20cm between rows and plants, respectively.

Carrot roots have highest content of carotenes (alpha- and beta-carotene) which are cleaved in the human body to create Vitamin A molecules. It is an important source of vitamin A in human nutrition in many cultures worldwide (www.seedalliance.org). For instance, in the USA, carrots are the single most important source of dietary pro-vitamin A carotenoids accounting for 30% of the total vitamin A available to consumers (Simon, 1992). In Ethiopia, malnutrition of vitamin A in the country was estimated as high which is 2 to 15-fold higher than the World Health Organization (WHO) cut-off point (0.5%) for public health significance (Haile-Meskel, 2011). This might be due to the low production and consumption of vegetables rich in Vitamin A content such as carrots. The carrot production has been expanding in eastern Ethiopia starting in the early 1960s at the start of carrot research in Alemaya College of Agriculture (now Haramaya University), however, the region is known with high prevalence of vitamin A malnutrition. This indicated that the potential of the crop to overcome the public health problem is not well exploited. This might be due to the low production and consumption of carrot in the region. The lower productivity of the crop might be due to the use of low yielding genotypes grown from farmers saved seed in the region. Therefore, the newly released variety (*Haramaya 1*) may be as one of the remedy measure to alleviate the problem since it had total root yield margins of 11.41 and 16.23% over the commercial Nantes variety and the farmers' open pollinated cultivar, respectively. Moreover, the variety is stable for root yield and could be recommended for cultivation in a wider range of environments.

The variety *Haramaya 1* has been released in 2014 after decades of researchers' effort. The variety has root yield and root quality attributes advantages over the commercial variety and farmers' cultivars. However, this superiority of the variety over existing cultivars may not be sufficient to exploit the genetic potential of the variety. The proper seed production and distribution, appropriate agronomic managements recommendations are required to increase the productivity of the variety. But, the proper plant spacing to obtain optimum seed yield, proper isolation distance from other cultivars to maintain the genetic identity of the variety and other agronomic managements for the production of higher root yield are not studied. Therefore, the future research must focus on these areas to make recommendations to exploit the genetic potential of the variety in the region or elsewhere in the country. Carrot is a cross pollinated crop and there is the highest probability of losing its identity with short period of time. Therefore, it is necessary to maintain the identity of the variety and improve the variety every time through mass selection breeding method using root-to-seed production.

5. Conclusion

The results of the long period research have demonstrated that the released variety Haramaya 1 is superior to the commercial Nantes variety as well as the farmers' open-pollinated cultivar in terms of root and seed production potential. The results have also revealed the variety was stable over locations and seasons for root yield, and has desirable root quality attributes and higher seed production potential. The high seed production potential of the variety implies the higher possibility of reducing the purchase of unknown quality imported carrot seeds with high price from the market since farmers could produce and save seeds easily from this variety. In conclusion, the newly released variety Haramaya 1 could be cultivated profitably and sustainably in the highlands of Hararghe zones and other places with similar agroecologies, and could lead to enhancing income of smallholder farmers.

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2. Collection and Evaluation of Eastern Ethiopia Hot Pepper (*Capsicum* spp.) for Yield and Yield Components

Wassu Mohammed Ali

Haramaya University, College of Agriculture and Environmental Sciences, School of Plant Sciences, E-mail:wasmoha@yahoo.com

Abstract: Seventy hot pepper (Capsicum spp.) collections obtained by single plant selection from eastern Ethiopia and four improved varieties used as checks were planted at Haramaya University research field during 2013/14 cropping season using Augmented design with five blocks and each block consisted of 14 new entries and five checks. Data were collected for growth, yield and yield components but the evaluation of accessions were made for major yield and yield components (total and marketable dry pod yield t/ha, number of dry pod/plant, number of marketable dry pod/plant and average dry pod weight in grams). The differences among the tested genotypes were significant ($P<0.05$) for total and marketable dry pod yield t/ha while significant differences were observed between test vs. control, among tests and checks for all traits. The Hararghe hot pepper collections exhibited up to 3.26 and 2.56 total and marketable dry pod yield t/ha, respectively, while the high yielding variety produced 1.91 and 1.22 t/ha total and marketable dry pod yield, respectively. A total of 22 and 20 accessions exhibited higher total and marketable dry pod yield, respectively, over yields of high yielding variety. The high yielding accessions total and marketable dry pod yield advantages ranged from 0.26 to 70.5 and 2.95 to 110.5%, respectively. The new selections showed superiority over the improved varieties not only for dry pod yields but also for other traits. It was computed as highest (21.16%) genetic advance that could be made through selection of 5% of the accessions for marketable dry pod yield t/ha. Genetic variability among collections and improved varieties was observed and high genetic distances were computed. The observed high genetic distance, advance and high marketable dry pod yield in eastern Ethiopia hot pepper collections was encouraging to continue collection and selection to improve the crop for yield and other desirable traits in the region.

Keywords: Collections; Genetic Distance; Genetic gain; Genetic variability; Hot pepper

1. Introduction

Hot pepper (*Capsicum annuum* L.) is a new world crop that belongs to the *Solanaceae* family, and the genus *Capsicum*. Capsicums or red peppers are the berries of capsicum plant and they form an indispensable ingredient of the culinary throughout the world. It is closely related to tomato, eggplant, potato and tobacco. The genus *Capsicum* is the second most important vegetable crop of the family after tomato (Rubatzky and Yamaguchi, 1997). Hot pepper is produced in all the continents of the world except Antarctica and historically associated with the voyage of Columbus (Heiser, 1976). Columbus has been given credit for introducing hot pepper to Europe, and subsequently to Africa and Asia.

Production of pepper is also well known in Ethiopia (Rehima, 2006). The history of pepper in Ethiopia is perhaps the most ancient than the history of any other vegetable product (EEPA, 2003). Ethiopians has strong attachment to dark red pepper, which has high value principally for its high pungency. The fine powdered pungent product is an indispensable flavoring and coloring ingredient in the common traditional sauce "wot" whereas the green pod is consumed as a vegetable with other food items. There is a general belief among Ethiopians that a person who frequently consumes hot pepper has resistance to various diseases. It is in the daily diet of most Ethiopians. The average daily consumption of hot pepper by Ethiopian adult is estimated 15 gram, which is higher than tomatoes and most other vegetables (Rehima, 2006).

Hararghe is one of the main centers of cultivation (Alkamper, 1972 cited by Jansen, 1981), where diversity of the crop is expected. Therefore, ccollection, evaluation and selection of farmers *Capsicum* cultivars in eastern Ethiopia may be one of the preferable breeding methods to improve the crop for the region. Thus collection on plant basis of capsicum plants is necessary in the region. Therefore, this research was initiated to collect and evaluate Hararghe hot pepper.

2. Materials and Methods

2.1. Experimental Materials and Design

Seeds of *Capsicum* spp. cultivars were collected from western Hararghe around Hirna and grown at Haramaya University during 2012/13 cropping season. Selection was practiced on the single plant basis at nursery where plants were grown very closely and severely competed for growth resources. Seventy hot pepper (*Capsicum* spp.) accessions were selected based on fruit characteristics, plant growth, and reaction to diseases (Powdery and Downey mildew). The seeds of selected plants were raised at nursery and planted at field at Haramaya research field during 2013/14 cropping season using Augmented design in five blocks which each block consists of 14 new entries and five varieties as a check.

Four improved varieties viz. Marko Fana, Marko Dima, Melka Eshet and PBC-660 (Melka Awaze) were obtained from National Vegetable Research Project and the local cultivar from the region were used as checks. The selected 70 accessions and the five checks were planted using unreplicated design (Augmented) where the checks were replicated five times while the new entries were not replicated. The unreplicated design

Augmented consisted of five blocks which each block consisted of 14 new entries and five checks. One block consisted of 19 genotypes and each genotype was planted in one plot with three rows. Twelve plants were planted in one row at spacing of 75 cm between rows and 30 cm between plants.

The accessions were planted at Haramaya University research field. The testing site is located at 9 ^{o}26' N latitude, 42 ^{o}3' E longitudes and at an altitude of 2020 m.a.s.l. The mean annual rainfall is 760 mm (Belay *et al.*, 1998). The mean maximum temperature is 23.4^{0}C while the mean minimum annual temperature is 8.25^{0}C. The soil of the experimental site is a well-drained deep alluvial with a sub-soil stratified with loam and sandy loam. Previous work showed it has organic carbon content of 1.15%, total nitrogen content of 0.11%, available phosphorus content of 18.2 mg kg soil^{-1}, exchangeable potassium content of 0.65 cmolc kg soil^{-1} (255 mg K kg soil^{-1}), pH of 8.0, and percent sand, silt, and clay contents of 63, 20, and 17, respectively (Simret, 2010).

2.2. Data Collection and Analysis

Data were collected for fruit, growth, yield and yield components but the report included major yield and yield components; total dry pod yield tons per hectare, marketable dry pod yield tons per hectare, number of dry pod/plant, number of marketable dry pod/plant and average dry pod weight in grams. Total and marketable yield t/ha were estimated from plants grown in the central row of each plot (10 plants) left the two plants grown at both end of the row in each block and other yield components were estimated from five randomly selected plants in the central row of each plot.

Data were subjected to analysis of variance for Augmented design using SPAD statistical software. The genetic advance that can be made also computed along with heritability, genotypic and phenotypic coefficient of variation. The yield advantage of the new selection over the checks was also computed to evaluate the extent of yield advantage of the high yielding accessions.

The phenotypic and genotypic variance and coefficient of variation were estimated according to the methods suggested by Burton and Devane (1953). Heritability (H_2) in broad sense was computed using the formula adopted by Allard (1960) and Falconer (1990) as: H_2 = [□ ^{2}g/ □ ^{2}p] x 100, where,□ □^{2}g=genotypic variance, □ ^{2}p= phenotypic variance and □ ^{2}e= error variance. Genetic advance/gain as percent of the mean (GA) for each trait was computed using the formula adopted by Johnson *et al.*, (1955) and Allard (1960) as: GA= (k) (□ □p)* (H_2), and GA (as % of the mean) = $\left[\frac{(GA)}{X}\right] x100$, where, k= selection differential (k=2.06 at 5% selection intensity), □ p= phenotypic standard deviation, H_2= heritability in broad sense and x□ □grand mean.

Euclidean distance (ED) was computed from the five yield and yield components of 75 hot pepper accessions after standardization (subtracting the mean value and dividing it by the standard deviation) as:

EDjk = $\sqrt{\sum_{i=1}^{n}(Xij - Xik)[\ ]^{2}_{2}}$ (Sneath and Sokal, 1973), where EDjk = distance between accessions j and k; xij and xik = yield and yield components values of the ith trait for accession j and k, respectively; and n = number of yield and yield component traits used to calculate the distance. The distance matrix from yield and yield components was used to construct dendrograms based on the Unweighted Pair-group Method with Arithmetic means (UPGMA) and the results were presented in the form of dendrogram.

3. Results

3.1. Analysis of Variance and Mean Performance of Accessions

3.1.1. Analysis of variance

The analysis of variance (ANOVA) for dry pod yield (t/ha) and yield components of pepper collections revealed that the presence of significant (P<0.05) variation among accessions for total and marketable dry pod yield (t/ha). But non-significant variation was observed for other yield components viz. number of dry pod/plant, number of marketable dry pod/plant and average dry pod weight (g) (Table 1).

Table 1. Mean squares from analysis of variance (ANOVA) for dry pod yield (t/ha) and yield components of pepper collections under preliminary yield trial (2013/14).

Trait	Block(Adj.)(4)	Genotype (Adj.) (74)	Error (16)
Marketable dry pod yield (t/ha)	0.130	0.256*	0.082
Total dry pod yield (t/ha)	0.387	0.375*	0.250
Number of dry pod/plant	59.260	33.49ns	32.985
Number of marketable dry pod/plant	19.840	11.534ns	9.840
Average dry pod weight (g)	1.100	1.282ns	0.575

** & ns, significant at P<0.05 and non-significant, respectively.*

Table 2. Adjusted mean yield and yield components of pepper collections and improved varieties.

Block		MDPYt/ha	TDPYt/ha	ADPW (g)	NTDP/pl	NMDP/plant
	Marako Fana	1.22	1.91	2.4	16	8
	Marako Dima	0.73	1.11	3	8	4
Checks	PBC-660	0.91	1.34	1.4	21	13
	Melka Eshet	1.11	1.62	3	11	6
	Local cultivar	0.69	1.43	2.2	17	9
	Mean check	0.93	1.48	2.40	15	8
	HU11	1.43	2.50	3.4	17	8
	HU10	1.98	2.29	4.4	14	8
Block I	HU12	1.08	1.58	1.4	20	11
	HU9	0.78	1.20	3.4	9	4
	HU14	2.41	2.92	5.4	14	9
	HU4	1.00	1.92	3.4	13	5
	HU8	0.91	1.61	2.4	13	5
	HU7	1.26	1.49	2.4	12	8
	HU13	0.49	1.03	3.4	8	2
	HU1	1.27	1.92	1.4	19	9
	HU2	0.61	1.01	1.4	11	5
	HU5	1.01	1.48	5.4	9	4
	HU3	1.75	2.34	6.4	10	5
	HU6	0.47	0.94	2.4	9	3
	Block Mean	1.17	1.73	3.33	12	6
	HU27	0.85	1.53	1.4	36	1
	HU26	0.56	0.94	2.4	5	1
	HU25	0.59	1.22	2.4	11	3
	HU24	1.93	2.92	6.4	7	2
Block II	HU23	1.19	1.74	3.4	10	4
	HU22	1.77	2.59	4.4	9	3
	HU21	1.27	2.22	2.4	14	5
	HU20	0.60	1.35	3.4	7	1
	HU19	1.15	1.88	4.4	7	1
	HU17	0.80	1.63	4.4	5	1
	HU18	1.19	1.98	4.4	6	1
	HU15	1.00	1.72	1.4	19	5
	HU16	0.91	1.65	2.4	14	4
	Eshet-01	1.41	2.15	4.4	9	3
	Block Mean	1.09	1.82	3.40	11	3

Table 2. Continued.

Block	Acession	MDPYt/ha	TDPYt/ha	ADPW (g)	NTDP/pl	NMDP/plant
	HU28	0.76	1.34	3.6	11	7
	HU29	0.35	0.90	1.6	16	7
	HU30	0.25	0.68	1.6	12	6
	HU31	0.99	2.09	2.6	18	9
	HU32	1.56	2.50	2.6	23	13
Block III	HU33	2.56	3.26	3.6	21	13
	HU34	0.84	1.80	2.6	20	8
	HU35	0.33	1.08	1.6	16	6
	HU36	1.37	2.10	1.6	24	14
	HU37	0.94	1.30	2.6	13	8
	HU38	0.41	1.09	1.6	16	7
	HU39	1.30	1.95	2.6	21	12
	HU40	0.24	0.58	1.6	10	5
	HU41	0.79	1.18	2.6	13	9
	Block Mean	0.91	1.56	2.31	16	8
	HU55	0.87	1.11	2.2	9	8
	HU54	0.34	0.69	2.2	10	4
	HU53	1.18	1.56	3.2	11	8
	HU52	0.55	0.81	2.2	7	5
	HU51	1.35	1.77	2.2	16	11
	HU50	1.08	1.43	2.2	21	13
Block IV	HU49	0.61	0.85	2.2	9	5
	HU48	1.17	1.62	2.2	17	11
	HU47	1.09	1.22	2.2	12	10
	HU46	1.29	1.94	3.2	11	6
	HU45	1.11	1.53	4.2	8	7
	HU44	0.72	0.96	2.2	10	7
	HU43	0.16	0.27	2.2	5	3
	HU42	0.52	0.77	3.2	3	3
	Block Mean	0.86	1.18	2.56	10	7

Table 2. Continued.

Block	Acession	MDPYt/ha	TDPYt/ha	ADPW (g)	NTDP/pl	NMDP/plant
	HU57	0.08	0.73	2.4	7	1
	HU58	1.20	1.92	3.4	13	7
	HU59	0.77	1.19	2.4	11	4
	HU60	1.50	2.32	2.4	19	9
	HU61	2.32	3.09	4.4	15	9
	HU62	0.86	1.77	2.4	15	6
Block V	HU63	0.84	1.37	2.4	11	5
	HU64	1.12	1.60	3.4	8	5
	HU65	1.36	2.39	3.4	16	6
	HU66	0.89	1.47	2.4	11	5
	HU67	0.82	1.42	2.4	12	6
	HU68	0.46	1.22	1.4	17	4
	HU69	0.66	1.23	3.4	7	3
	HU56	1.54	2.74	3.4	16	8
	Block Mean	1.030	1.748	2.829	13	6
	Grand mean	1.011	1.608	2.886	13	6
Critical difference						
	5%	0.74	0.90	1.10	7.70	5.97
Two Control Treatments	1%	1.02	1.24	1.52	10.61	8.23
	5%	1.66	2.01	2.46	17.22	13.35
Two Test Treatments (Same Block)	1%	2.29	2.77	3.39	23.72	18.40
	5%	2.35	2.84	3.48	24.35	18.89
Two Test Treatments(Different Blocks)	1%	3.24	3.92	4.80	33.55	26.02
	5%	1.66	2.01	2.46	17.22	13.35
A Test Treatment and A Control Treatment	1%	2.29	2.77	3.39	23.72	18.40

3.1.2. Mean performance of accessions

The adjusted mean yield and yield components of pepper collections and improved varieties is presented in Table 2. The minimum and maximum total and marketable dry pod yield (t/ha) were 0.27 & 3.26 and 0.08 & 2.56 with the grand mean of 1.6 and 1.01 t/ha, respectively. Average dry pod weight was recorded as low as 1.4 and as high as 6.4 g with the overall mean of 2.85 g. Number of total dry pods per plant was ranged from 3 to 36 and number of marketable dry pods/plant recorded as high as 14 and as low as 1 (Table 3). Moreover, 13 accessions were performing higher than the best yielding checks for all the three important yield and yield component (average dry pod weight, total and marketable dry pod yield t/ha).

Comparison of accessions on the basis of mean performance with the mean dry pod yield and yield components of improved varieties and high performing improved variety was made and presented in Table 4. The mean total and marketable dry pod yield t/ha were 1.48 and 0.93, respectively. The high yielding variety was Marako Fana which produced 1.91 and 1.22 t/ha total and marketable dry pod yield, respectively. Considerable numbers of new selections were performing better than the high yielding variety; 22 and 20 accessions exhibited higher total and marketable dry pod yield, respectively, over yields of Marako Fana. These accession total and marketable dry pod yield advantages ranged from 0.26 to 70.5 and 2.95 to 110.5%, respectively. The absolute total and marketable dry pod yield advantages were as high as 1.35 and 1.34 t/ha, respectively. Similarly, 28 and 3 accessions recorded higher average dry pod weight and number of total dry pods/plant, respectively, over the high performing improved varieties in the experiment. The accessions average dry pod weight and number of total dry pods/plant advantages ranged from 6.67 to133.33 and 7 to 72%, respectively. The observed dry pod weight advantage was as high as 3.4 g and the advantage of 5 and 6 dry pods per plant.

Table 3. Comparison of accessions with the mean dry pod yield and yield components of pepper collections.

	Mean and range of entries				Number of accessions	
Trait	Mean	Minimum	Maximum	SD	Above mean	Below Mean
Marketable dry pod yield (t/ha)	1.01	0.08	2.56	0.5	32	38
Total dry pod yield (t/ha)	1.60	0.27	3.26	0.62	33	37
Average dry pod weight	2.85	1.4	6.4	1.13	28	42
Number of total dry pods per plant	13	3	36	5	30	40
Number of marketable dry pods/plant	6	1	14	3	29	41

Table 4. Comparison of accessions means with the mean dry pod yield and yield components of improved varieties and high performing improved variety.

		No. accessions		Above high performing check		
Trait	Mean of Checks	Above checks mean	Below checks mean	No. of accessions	Absolute advantage range	Percent Advantages range
Marketable dry pod yield (t/ha)	0.93	35	35	20	0.04-1.34	2.95-110.5
Total dry pod yield (t/ha)	1.48	40	30	22	0.01-1.35	0.26-70.5
Average dry pod weight (g)	2.40	34	36	28	0.2-3.4	6.67-133.33
Number of total dry pods/plant	15	24	46	3	5 & 6	7 to 72
Number of marketable dry pods/plant	8	23	47	1	1	7.69

3.2. Genetic Advance

Genetic advance as percent mean that could be made through selection at 5% selection intensity for dry pod yield (t/ha) and yield components of pepper collections along with heritability estimate, phenotypic (PCV) and genotypic (GCV) coefficient of variation are presented in Table 5. The highest genetic advance as per cent mean was recorded for marketable dry pod yield (t/ha) followed by average dry pod weight (g) with 21.16 and 12.48%, respectively. The lowest genetic advance as per cent mean was recorded for number of dry pod/plant followed by marketable dry pod number/plant with 0.27 and 3.37%, respectively. Similar trend was observed for the heritability of traits where higher broad sense heritability was computed for marketable dry pod yield (t/ha) followed by average dry pod weight (g) with 29.76 and 19.74%, respectively. Higher phenotypic and environmental coefficients of variation than genotypic coefficient of variation were computed for all traits.

Table 5. Genetic advance through selection of pepper collections for dry pod yield (t/ha) and yield components.

Trait	GCV	PCV	ECV	H^2	GAM
Marketable dry pod yield (t/ha)	18.83	34.52	28.93	29.76	21.16
Total dry pod yield (t/ha)	10.05	33.30	31.75	9.11	6.25
Number of dry pod/plant	2.41	43.65	43.58	0.31	0.27
Marketable dry pod number/plant	8.96	49.12	48.30	3.33	3.37
Average dry pod weight (g)	13.64	30.69	27.50	19.74	12.48

3.3. Clustering of Accessions

The dendrograms from UPGMA cluster analysis based on Euclidean distance (ED) matrixes are presented in Figure 1. The clustering resulted in the formation of six clusters of which the first cluster was comprised high yielding varieties Marko Fana, PBC-660 and other 17 accessions.

The second and the third clusters comprised of 20 and 23 accessions including the low yielding variety Marko Dima and processing variety Melka Eshet, respectively. Cluster IV, V and VI comprised of 8, 4 and 1 accessions, respectively.

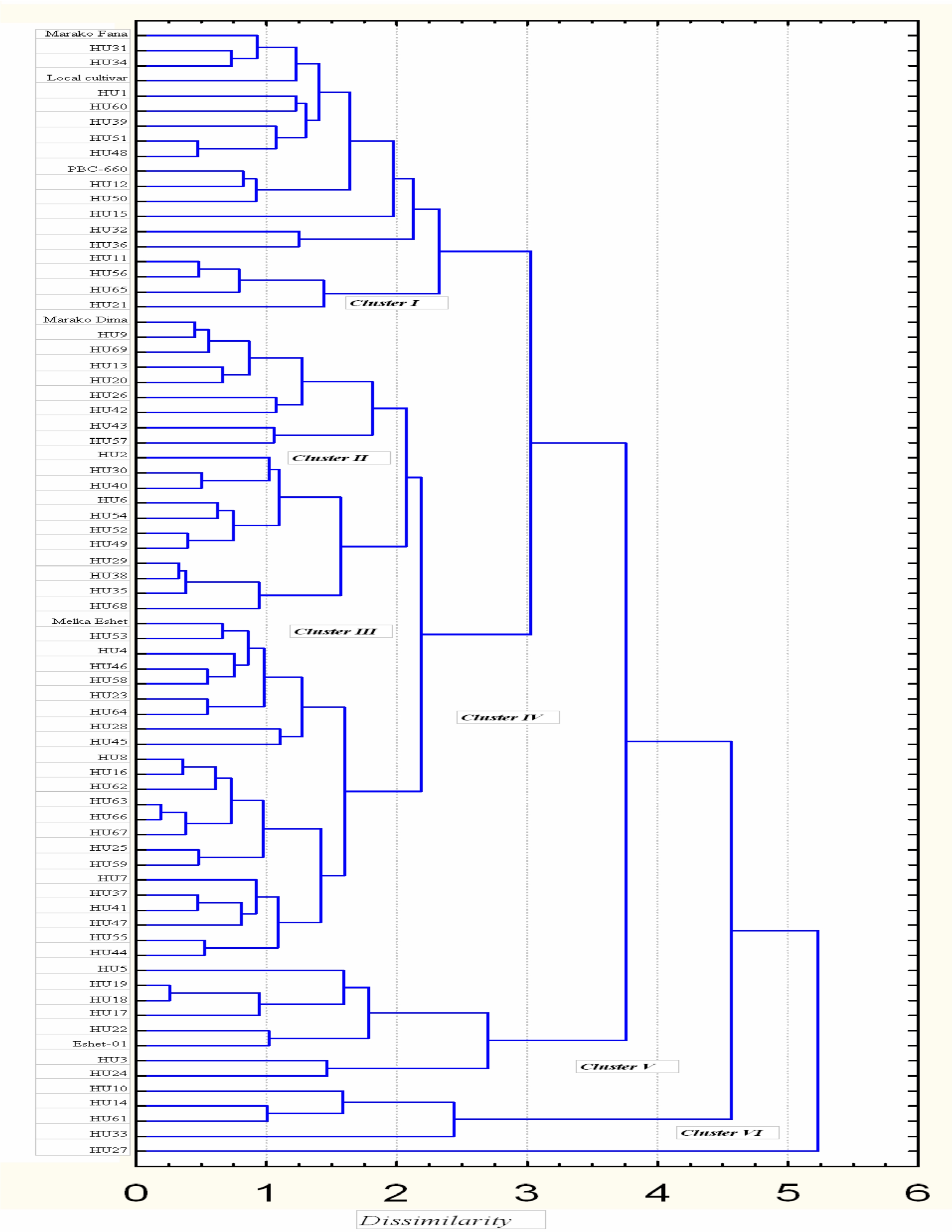
Table 6. List of peeper accessions in six clusters.

Cluster I	Cluster II	Cluster III	Cluster IV
Marako Fana	Marako Dima	Melka Eshet	HU5
HU31	HU9	HU53	HU19
HU34	HU69	HU4	HU18
Local cultivar	HU13	HU46	HU17
HU1	HU20	HU58	HU22
HU60	HU26	HU23	Eshet-01
HU39	HU42	HU64	HU3
HU51	HU43	HU28	HU24
HU48	HU57	HU45	Cluster V
PBC-660	HU2	HU8	HU10
HU12	HU30	HU16	HU14
HU50	HU40	HU62	HU61
HU15	HU6	HU63	HU33
HU32	HU54	HU66	Cluster VI
HU36	HU52	HU67	HU27
HU11	HU49	HU25	
HU56	HU29	HU59	
HU65	HU38	HU7	
HU21	HU35	HU37	
	HU68	HU41	
		HU47	
		HU55	
		HU44	

The first cluster was characterized by containing accessions which had higher marketable and total dry pod number/plant more than the mean pod number of the accessions while majority of the accessions had lower average dry pod weight and majority of the accessions had marketable and total dry pod yield (t/ha) above the mean yield of accessions. Cluster II was characterized by producing marketable and total dry pod yield than lower than the mean of the accessions also produced lower number of total and marketable dry pod/plant than the mean. Cluster III was characterized by containing accessions with higher total dry pod yield t/ha but lower marketable dry pod yield t/ha than mean of accessions except few number of accessions. The member of this cluster had also lower marketable and total dry pod number/plant than mean of the accessions. The member of the Cluster IV except one accessions had higher marketable and total dry pod yield t/ha than mean of accessions higher average dry pod weight but lower marketable and total dry pod number/plant than mean of the accessions. Cluster V was characterized by containing accessions which had highest yield in the experiment and higher mean values for all other traits. Cluster VI which represented one accession characterized with extremely lower mean values for all traits except extremely highest total dry pod number/plant. The mean of the accessions in each cluster and the range as well as the list of the members in each cluster are presented in Table 6 and 7.

Table 7. Range and mean values of the six clusters for yield and yield components of pepper accessions

Trait	Marketable dry pod yield (t/ha)		Total dry pod yield (t/ha)		Average dry pod weight (g)		Number of dry pod/plant		Marketable dry pod number/plant	
Cluster	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Cluster I	1.21	0.69-1.56	1.96	1.43.-2.74	2.31	1.4-3.4	18.63	14-24	1.09	5 - 14
Cluster II	0.47	0.08-0.91	0.95	0.27-1.65	2.29	1.4-3.4	9.95	3 -17	4.00	1- 7
ClusterIII	0.93	0.59-1.29	1.43	0.96-1.94	2.71	2.2-4.2	11.42	8 -15	6.21	3 - 10
Cluster IV	1.09	0.8-1.93	1.63	1.48-2.92	3.51	4.4-6.4	9.86	5 -10	4.96	1 -5
Cluster V	2.32	1.98-2.56	2.89	2.29-3.26	4.45	3.6-5.4	16	14-21	9.75	8-13
Cluster VI	0.85		1.53		1.4		36		1	
Grand mean	1.011		1.608		2.886		13		6	


Marako Fana
HU31
HU34
Local cultivar
HU1
HU60
HU39
HU51
HU48
PBC-660
HU12
HU50
HU15
HU32
HU36
HU11
HU56
HU65
HU21
Marako Dima
HU9
HU69
HU13
HU20
HU26
HU42
HU43
HU57
HU2
HU30
HU40
HU6
HU54
HU52
HU49
HU29
HU38
HU35
HU68
Melka Eshet
HU53
HU4
HU46
HU58
HU23
HU64
HU28
HU45
HU8
HU16
HU62
HU63
HU66
HU67
HU25
HU59
HU7
HU37
HU41
HU47
HU55
HU44
HU5
HU19
HU18
HU17
HU22
Eshet-01
HU3
HU24
HU10
HU14
HU61
HU33
HU27
Cluster I
Cluster II
Cluster III
Cluster IV
Cluster V
Cluster VI
0
1
2
3
4
5
6
Dissimilarity

4. Discussion

In this experiment, the Hararghe hot pepper collections exhibited up to 3.26 and 2.56 total and marketable dry pod yield t/ha, respectively, while the high yielding variety produced 1.91 and 1.22 t/ha total and marketable dry pod yield, respectively. A total of 22 and 20 accessions exhibited higher total and marketable dry pod yield, respectively, over yields of high yielding variety. Generally, the high yielding accessions total and marketable dry pod yield advantages ranged from 0.26 to 70.5 and 2.95 to 110.5%, respectively. The yields obtained from the new selections were better than the improved varieties and the national average yields indicating the possibility of improving dry pod yield through collection and selection of hot pepper in the region. The national average yields have been reported that 7.6 t ha^{-1} for green and 1.6 t ha^{-1} for the dry pods (CSA, 2006). FAO (2009) report also indicated that the estimated production of peppers in Ethiopia were 220,791 t from 97,712 ha in green form and 118,514 t of dry pepper from an area of 300,000 ha. This means that the average production of pepper was 2.26 t ha^{-1} green and 0.395 t ha^{-1} for dry pepper production in the country. On the other hand, other researchers reported the highest dry pod yield of 3000 kg/ ha (Jansen, 1981).

The new selections showed superiority over the improved varieties not only for dry pod yields but also for other traits. About 28 and 3 accessions recorded higher average dry pod weight and number of total dry pods/plant, respectively, over the high performing improved varieties in the experiment. The accessions average dry pod weight and number of total dry pods/plant advantages ranged from 6.67 to133.33 and 7 to 72%, respectively. The Hararghe collections showed superiority over the improved varieties, it is possible to improve hot pepper yields and other desirable traits through collection and selection. Donald (1968) describes two basic principles for plant breeding, 'selection for yield' and 'defect elimination'. Therefore, the basic principles behind plant breeding programme are to develop cultivars with better yield potential and to develop cultivars that have genetic resistance against production hazards that can prevent a cultivar from expressing its yield potential (Acquaah , 2007). Based on these principles, the hot pepper breeding programme in eastern Ethiopia relies on improvement of dry pod yield, improved quality, resistance to frost, drought, disease and pests through collection and selection of local cultivars in the region.

In this experiment, it was computed as high 21.16 and as low as 0.27% for marketable dry pod yield t/ha and number of dry pod/plant, respectively, for the genetic advance that could be made. Similar trend was also observed for the heritability of traits where higher broad sense heritability was computed for marketable dry pod yield t/ha. However, higher phenotypic and environmental coefficients of variation than genotypic coefficient of variation were computed for all traits. Heritability is the proportion of the observed variation in a progeny that is inherited (Acquaah, 2007). Heritability in broad sense is the proportion of the genotypic variability to the total variance (Allard, 1960). It is a measure of the degree to which a phenotype is genetically influenced and can be modified by selection (Schlegel, 2010). In crop improvement, only the genetic component of variation is important since only this component is transmitted to the next generation. Therefore, the observed high genetic advance and heritability for marketable dry pod yield t/ha is encouraging to continue collection and selection to improve the crop in the region.

Selection for a particular trait depends largely upon the genetic and non-genetic factors that affect the expression of phenotypic differences among genotypes. Therefore, heritability is an important estimate for the selection of traits in improving crop. Single plant selection is much effective for a trait that is highly heritable as compared to the trait which is less heritable. Heritability estimates would be reliable if accompanied by a high estimate genetic advance (Singh and Choudhry, 1985). Though, low genetic advance and heritability were computed for three traits in the present study, genetic advance and heritability were in the combinations of high and moderate for marketable dry pod yield t/ha and average dry pod weight which was an indication of more additive gene action (Panse, 1957) and suggested that these traits are amenable for selection. However, the estimated phenotypic and environmental coefficients of variations were relatively greater than the genotypic coefficient of variation in magnitude for all the traits. This indicates the higher sensitivity of traits to environmental modifications which the improvement of traits through selection may be complicated.

The presence of significant differences among collections and between collections and improved varieties was evident from analysis of variance results. It was calculated large genetic distance between local collections and between collections and improved varieties and among improved varieties (results not presented because of its bulkiness). The accessions were grouped into six clusters where none of the improved varieties were a member of Cluster V which comprised collections with highest yield and yield components. Moreover, the overall mean values of local collections within considerable numbers in each trait were performed greater than the high performing improved varieties. This indicated that the presence of considerable genetic divergence between local collections and improved varieties which encourage breeders to commence collection and selection of local materials to improve yield and other desirable traits of hot pepper.

The genetic divergence analysis result was in line with other researcher who reported that Hararghe is one of the main centers of cultivation (Alkamper, 1972 cited by Jansen, 1981), which diversity of the crop is expected. Variation and/or genetic divergence are the occurrence of difference among individuals due to difference in their genetic composition and/or the environment in which they are raised (Falconer., 1990; Allard, 1960; Welsh, 1990). If the character expression of two individuals could be measured in an environment exactly identical for both, difference in expression would result from genetic control and hence such variation is called genetic variation (Falconer, 1990). The presence of variation in the germplasm for the trait of interest is, therefore, very important. Information on the nature and magnitude of genetic variability greatly helps in formulating sound crop breeding and improvement program (Welsh, 1990). Genetic variability, which is due to genetic differences among individuals within a population, is the core of plant breeding because proper management of diversity can produce permanent gain in the performance of plant and can buffer against seasonal fluctuations (Welsh, 1981). In addition, estimation of the magnitude of variation within germplasm collections for important plant attributes will enable breeders to exploit genetic diversity more efficiently. Therefore, the observed variation among collections was due to genetic factors and showed the higher possibilities of collecting distant accessions in eastern Ethiopia that could be used to improve yield and other desirable traits of hot pepper.

5. Summary and Conclusion

This study showed that the presence of considerable genetic distance among eastern Ethiopian hot pepper collections and improved varieties. In both the local collections and improved varieties, large genetic distances were computed. Relatively, large number of local collections showed superiority over improved varieties for yield and yield components. Moreover, clustering of accessions showed that the possibility of obtaining group of local collections with highest yield and yield components which were genetically distinct from improved varieties and other collections. This indicates the need to collect, evaluate and characterize large number of local collections to improve yield and other traits of desirable traits of hot pepper as well as to maintain the genetic resource in eastern Ethiopia.

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3. Impacts of Invasive Plants (*Lantana camara* and *Parthenium hysterophoru*) on Livestock and Rangeland Production in Pastoral and Agro Pastoral Areas of Somali Region, Ethiopia

Dawit Terefe

Haramaya University, School of Animal and Range Sciences, P. O. Box: 138, Dire Dawa, Ethiopia
E-mail: dadibam@gmail.com

Abstract: This study was conducted to assess the impact of invasive plants: Lantana camara and Parthenium hysterophoru on livestock production and feed resources in Jijiga Zone of Somali National Regional State. Three districts Gursum, Jijiga and Tulugulade were purposively selected to represent L. camara, P. hysterophoru and none invaded study sites/areas, respectively. Studies on primary livelihood options were assessed. The socio-economic study revealed changes in major livelihood means of pastoralists. Significant difference ($P<0.05$) were observed in the primary means of livelihood as well as in livestock holding per household across the three study sites. Herd diversification was lesser in Tulugulade district with a Simpson index (SI) of 0.65, than that of Gursum and Jijiga districts where the SI values were 0.49 and 0.40, respectively. Majority of the respondents (66.7%) of Jijiga and all (100%) of Gursum districts believed that the rate of P. hysterophoru and L. camara invasion was still increasing in their respective districts. Most of the respondents (94%) in Jijiga district believed that invasion control strategies were partially effective. However, 60% of the respondents in Gursum district believed that invasion control strategies were failed. Majority of the respondents in Gursum (96.7%) and Tulugulade (100%) districts responded that they had ceased mobility. However, most of the respondents (93.3%) in Jijiga district responded that they practice mobility so far. The average loss of animals per household due to consumption of L. camara was found to be 0.92 TLU. Almost all of the respondents of Gursum and Jijiga districts agreed on adverse effects of these invasive plants on the qualities of animal products as well as their suppressive effect on the growth of valuable forage plants. L. camara and P. hysterophoru posed a serious problem on pastoralist livelihood strategies, livestock production and feed resources availability in Jijiga Zone. Therefore, prompt interventions to curb the expansion of these invasive plants are inevitable.

1. Introduction

Invasive alien species (IAS) are those plants, animals, and microbes which are introduced to new regions, mainly through human activities, where they establish and spread impacting negatively on biodiversity, agriculture, water resources, and human health that directly and/or indirectly affect economic growth and livelihoods of exposed communities. With an estimated number of 480,000 alien species that have been introduced to various ecosystems around the world, majority of them have been contributing significantly to human welfare. However, only a few introduced species actually become problematic (Arne Witt, 2004).

Poor rangeland management in Ethiopia has resulted in serious land degradation, reduced biodiversity, and decline in both quality and quantity of feed production, and gradual replacement of important plant species by unpalatable and noxious ones (Alemayehu, 2004). Foremost among these, *Parthenium* weed (*Parthenium hysterophorus*), mesquite (*Prosopis juliflora*), water hyacinth (*Eichhornia crassipes*), cactus (*Euphorbia stricta*) and lantana weed (*L. camara*) are commonly reported in different parts of the country (EIB, 2012).

The Somali National Regional State (SNRS), which is the second largest regional state, is found in the south eastern part of Ethiopia, covering about 281,900 km^2. The biodiversity of the region has recently been threatened by encroaching weeds and woody plants (EARO, 2003). Increasing deforestation, recurrent droughts and over-grazing might have caused the deterioration of the rangeland vegetation, thereby weakening the grazing and browsing capacities of the rangelands (Belaynesh, 2006). At present, most of the rangelands in SNRS are invaded by noxious weeds/invasive plant species such as: *Parthenium hysterophorus*, *Xanthium spinosum*, *Prosopis juliflora, L.camara* (SERP, 1995). *P. hysterophorus* and *L.camara* has been threatening the rangeland ecology of the region in general, and that of Jijiga Zone in particular, for over three decades now. However, little attempt has been made so far in terms of research and management of such IAS (Taye, 2007).

Parthenium hysterophorus (Asteraceae), is an annual herb with a deep taproot and an erect stem that becomes woody with age. It was first reported at Dire-Dawa, , Eastern Ethiopia in 1988. As an exotic invasive weed, *P. hysterophorus* is expected to continue its invasion until all suitable habitats are occupied, unless suitable measures taken timely. The expansion of *P. hysterophorus* on grazing lands has critically endangered the biodiversity, particularly grass and forb species in North-Eastern Ethiopia (Lisanework *et al.*, 2010).

Another case in point is that of *Lantana camara*, an ornamental shrub, introduced to all parts of the tropics. *L.camara* is well-known in Ethiopia especially as a showy garden plant. Until now, this species had not been perceived as a problem in Ethiopia although it is known as one of the most troublesome weeds in much of the tropics. Studies reported that the species has the capacity to transform productive land into lantana scrub (wasteland), while it is unpalatable to animals, and prevents grass growth (Binggeli and Desalegn, 2002).

All the above mentioned effects of the Alien Invasive Species (AIS) contribute to increased pressure on grazing land that has been frequently threatened by recurrent drought, and thereby affect livestock production and productivity in the pastoral and agro pastoral areas. Though this is the general fact, so far, only few and scattered researches have been done regarding the impacts of these two AIS in some pastoral areas; while no research has been undertaken so far in the Somali Region particularly on the impact of invasive plants in relation to livestock and rangeland production. Thus, this research aimed to study the impacts of two invasive plants (*L.camara* and *P. hysterophorus*) on livestock, and rangeland feed resources in Somali Region with the following specific objectives.

Objectives

The objectives of this study were to:

- assess the impacts of *L. Camara* and *P. Hysterophoru* on livestock management and herd structure and health in Somali region; and.
- assess the impacts of *L. Camara* and *P. hysterophoru* on rangeland feed resources in Somali region.

2. Materials and Methods

2.1. Description of the Study Area

Jijiga Zone is one of the nine administrative Zones of the Somali National Regional State (SNRS).It is located at 750 km southeast of Addis Ababa. The Zone is situated in the northern part of SNRS and neighbors in the east with the Republic of Somalia, in the west with Oromia Regional State and Fik Zone of the SRS, and in the south with Degahbour Zone. The Zone is divided into seven administrative districts: Jijiga, Kebribeyah, Harshin, Babile, Awbare, Tulgulade and Gursum. The total land cover of Jijiga Zone is 40,861 km^2 of which the rangeland extends over 36,629 km^2 (World Bank, 2001).

The Somali Regional State has a bimodal pattern of rainfall regime (IPS, 2002). According to the National Meteorological Service Agency (NMSA, 2000), in Jijiga Zone, there is generally low, unreliable and uneven distribution of rainfall. The mean annual rainfall in this area is 660 ml. The mean minimum and the mean maximum temperature in this area are 20^{0}C and 35^{0}C, respectively. Potential evapo-transpiration (PET) is always high ranging from 1,800 to 2,500 mm of annual PET (IPS, 2002).

2.2. Data Collection

The survey was conducted in three districts of Jigjiga Zone of Somali Regional State The study areas were selected based on secondary information. Purposive sampling technique was used to select the districts with the intention of covering those invaded areas .

2.2.1. Selection of the study sites

Out of the seven districts in Jijiga Zone, three districts were selected for the study. The three districts selected were Gursum, Jijiga and Tulgulade representing *L.camara* invaded, *P. hysterophorus* invaded and none invaded woredas, respectively. Thus, from Jijiga Haroris, from Gursum woreda kubijaro and from Tulgulade woreda Chefe Lega kebeles were selected for the survey.

Haroris kebele is found at 37 km from the Zone capital Jijiga, 09^0 21 274 N and 043^0 05. 520 E and has an altitude of 1813 m.a.s.l. Kubijaro is found at 50 km from the Zone capital Jijiga, about 09^0 21 274 N and 042^0 31. 301 E and has an altitude of 1533 m.a.s.l. Chefe Lega is found at 42 km from the Zone capital Jijiga, about 09^0 32.208 N and 042^{0}32.311 E and has an altitude of 2119 m.a.s.l.

2.2.2. Sampling and data collection procedure

Questionnaire that consisted of a wide range of questions was prepared in both open-ended and close-ended form. It was divided into components to cover the following major themes: household characteristics, rangeland resources, livestock management practices, livestock composition, local people's perception towards the impacts of the invasive plants on livestock management practices and pastoral and agro pastoral livelihood and invasive plants control interventions. The questionnaire was administered by 6 enumerators who have knowledge about the study areas and familiarity with the local language.

Interviews were also conducted with key informants. Participatory rural appraisal (PRA) techniques were used and administered on group discussions (group discussions were held with 9-12 individuals in each kebeles). In addition, information relevant for this study were collected from secondary sources, and used to make comparison between *Parthenuim* and *L.camara* invaded and none invaded kebeles.

2.3. Data Analysis

To assess the socioeconomic characteristics of households and their perception on *Parthenuim* and *Lantana* invasion, information which was gathered through questionnaire based formal survey was analyzed using Statistical Package for Social Sciences (SPSS) version 16. Livestock compositions (diversity) among the three selected kebeles were performed using the Simpson Index (SI).The calculation of SI involves first converting the number of animals into Tropical Livestock Unit (TLU) equivalents (FAO, 1987).

$$SI = [(\text{TLU cattle})^2 + (\text{TLU camels})^2 + (\text{TLU goats})^2 + (\text{TLU sheep})^2 + (\text{TLU donkey})^2]/(\text{TLU total})^2$$

3. Results and Discussion

3.1. Socio-Economic Conditions and Households Characteristics

3.1.1. Family size and age composition

Overall, family size in the study areas was found to be 8.2 ± 3.8. The mean household size in the non invaded kebele was found to be relatively higher (11.67) than the other two, *L.camara* invaded (5.8) and *Parthenium* invaded (7.1). With regard to the mean age categories of family members in all the study kebeles, large numbers of the family members were found to be in the active age category (15-64 years) whereas very few members of the families were found to be elder (> 65 years) (Appendix Table 1). The presence of large number of the family members in the active age category tells as the available labour in the area to practice the simplest and cheapest (manual clearing) invasive plants control method. The difference in mean age categories of family members in active age category was significant ($P< 0.05$).

3.1.2. Livelihood means

Pastoralism is the most prevalent livelihood strategy comprising about 60% of the region's rural population (SRAR, 2012). However, information obtained from the formal survey (Table 1) shows the change in livelihood means of pastoralists in the study areas. For instance,67% of the pastoralists in *L.camara* invaded and and 93% in none invaded kebeles use crop farming as a primary livelihood means. Whereas in *Parthenium* invaded kebele, 100% of the respondents reported that their primary livelihood means is livestock production, though they also produce crops.

Livestock production is the second livelihood means in the *L. camara* invaded kebele (70 %). But in none invaded kebeles, the second livelihood means is trading (50%) followed by work in government (30%). The x^2 test shows significant difference ($P<0.05$) in the importance of livestock as primary livelihood means in the three districts (Appendix Table 2). This shows the changes in livelihood means of pastoralists, for which 90% of household income was expected to come from livestock production.

Table 1. Livelihood means of respondents.

Livelihood means		Invasion status					
		Lantana (N=30)		*Parthenium* (N=30)		none (N=30)	
Primary		fq	%	fq	%	fq	%
	Livestock production	10	33	30	100	1	3
	Crop farming	20	67	0	0	28	93
	Trading	0	0	0	0	1	3
Secondary	Livestock production	21	70	0	0	4	13
	Work in government	0	0	0	0	9	30
	Crop farming	9	30	30	100	1	3
	Trading	0	0	0	0	15	50
	Contractor	0	0	0	0	1	3

fq = frequency,

3.2. Land Ownership and Land Use Systems

Unlike other pastoralists/ agro-pastoralists in Ethiopia, land is not a clan (common) property in the study area. In the Zone, every household has its own private land. infact, there is a little clan interference in decision making over land related issues. For example if an individual wants to rent his land, the organization or individual who is going to rent the land should be accepted by the clan, otherwise the person can't make decision by himself. Land area measured locally by 'KOTI' which is equivalent to 22 X 22 adult pace or ≈ 0.049 hectare.

Large area of land was band from cultivation or devoid of grazing due to the seriousness of both invasive plants. For instance, on average, every household in *Lantana* and *Parthenium* invaded areas lost 3.4 and 2.3 koti of farming land, respectively (Table 2). This observable fact results a serious threat for the emerging crop farming activity (agro-pastoralism) in Jijiga Zone.

Table 2. Average land holding and farming land lost due to invasion per house hold.

Land use type		Farm land*	Invaded land*
Lantana invaded	Mean	11.6	3.4
	Std. Deviation	8.0	1.6
Parthenium invaded	Mean	19.9	2.3
	Std. Deviation	1.0	1.2
None invaded	Mean	40.3	-
	Std. Deviation	9.6	-

**Area in Koti*

3.3. Livestock Production Constraints

Pastoralists mentioned different factors as constraints to livestock production in their respective areas. According to respondents, in the *Parthenium* invaded district the main livestock production constraints were reported to be water shortage, subsequent feed shortage, expansion of crop production, animal diseases, *Parthenium* invasion and predators' attack. According to the respondents *Parthenium* invasion doesn't impose a serious problem in livestock production activity. However, it is the main challenge for crop production. On the other hand, *Lantana* invasion was mentioned as the second major constraint for livestock production in the *Lantana* invaded district. Predators attack was mentioned as the main threat for livestock production. Animal disease and feed shortage were ranked 3rd and 4th, respectively. In the non invaded kebeles, feed shortage, animal disease and water shortage were listed as 1st, 2nd and 3rd, threat, respectively (Table 3).

Table 3. Livestock production constraints.

Problem	*Parthenium* invaded	*Lantana* invaded	Non invaded
	Rank		
Feed shortage	2	4	1
Animal disease	4	3	2
Invasion	5	2	-
Expansion of crop production	3	5	4
Predators	6	1	5
Water shortage	1	6	3

3.4. Pastoralists' Perceptions towards *Lantana* and *Parthenium* Invasion

Pastoralists in the study area suffer from invasive plants. Particularly three invasive plants: *Parthenium*, *L.camara* and cactus (in Gursum district) are the main threats for pastoralists/agro-pastoralists livelihood in Jijiga Zone. All of the respondents in invaded as well as non invaded areas heard about both invasive plants and they do have information about their impacts on the livestock and crop farming activities. Most of the respondents (60% and 83.3% in *L. camara* and *P. hysterophorus* invaded areas, respectively) rate the current invasion level in their respective areas as heavy.

In Jijiga district, Haroris kebele *Parthenium* was first seen during Ethio-Somali war (40 years ago). Pastoralists in the woreda believed that this invasive plant was introduced by Cuba solders. In Somali, the local name of *P. hysterophorus* is 'Shuk Shuk' (which means problem creator). The local name indicates how pastoralists suffer because of this invasive plant. All of the household respondents in *Parthenium* invaded areas and 90% of the households in *Lantana* invaded areas reported that invasive plants have been creating serious problem in their livelihood activities and perceived them totally harmful. However, 10% of the respondents in Gursum woreda, kubijaro kebele said that *L.camara* has some uses and should not be seen as a harmful plant.

Most of the respondents reported that *L.camara* has been seen in their area four decades ago during the ethio-Somali war. Locally Somali pastoralists call *L.camara* as "Berkalet".All of the respondents in Gursum woreda said that *L.camara* is a harmful plant and since its introduction into the area, it posed lots of problem on Agricultural activities.

The main seed dispersion mechanisms of *L. camara* reported in descending order were flood (56%), wind (26.7%), and human being (10%). Whereas in *Parthenium* invaded area, majority of the respondents (63.3%) said that livestock and flood are the main seed dispersion mechanisms. Only about 36.7% of them put flood as the main way of the dispersion (Appendix Table 3).

3.4.1. Perceived harmful effects of *L. Camara* and *P. Hysterophorus*

Perceptions towards the harmfulness of *L. camara* and *P. hysterophorus* invasion do not vary between *L. camara* and *P. Hysterophorus* invaded areas. All of the respondents reported that both invasive plants are not used for income generation in one way or in the other. However, the respondents pointed out that starved animals often forced to feed on these weeds during periods of feed scarcity. Besides, *L. Camara* has been used as a fuel wood, if these could be mentioned as uses. Nevertheless, all respondents do not like to mention the benefits.

In both areas (*L. camara* and *P. hysterophorus* invaded) the most severe problem caused by invasive plants is their impact on crop production. In *Parthenium* invaded kebele, the impact of the *Parthenium* on livestock was reported as a second problem associated with *P. hysterophorus* invasion,(Affect livestock health), whereas in *L. camara* invaded kebele the second problems was its impact on feed resources through its suppressive effect on herbaceous plant growth. Pastoralists also reported that *Parthenium* affect human health and it causes itching, allergy, and asthma. A study in the same region have also revealed that *P. hysterophorus* causes asthma, bronchitis, dermatitis, and high fever (Shashe, 2007). By and large, the two invasive plants *L.camara* and *Parthenium* have imposed a serious challenge on agro-pastorals livelihood by affecting theier main activities (crop and livestock production). The overall harmful effects of *L. camara* and *Parthenium* on the pastoral livelihood were ranked in Table 4.

Table 4. Perceived harmful effects of *Lantana* and *Parthenium*.

Problems associated with invasive plants	*Parthenium* invaded rank	*Lantana* invaded
Affect livestock health	2	4
Affect feed resources	3	2
Affect human health	4	*
Affect Crop production	1	1
Affect Water points	*	3

** = not mentioned and ranked in group discussion.*

3.4.2. Effectiveness of *Lantana* and *Parthenium* control programs

Most of the respondents (94%) in *Parthenium* invaded kebele believed that invasion control strategies were partially effective. For the effectiveness of the control program, the nature of the plant has played significant role. According to pastoralists, *Parthenium* plant root is shallow and it is easy to uproot it from the soil. Therefore, it can be controlled using simple hand tools or even with a bare hand. However, 60% of the respondents in lantana invaded area believe that invasion control strategies were failed.

In addition, majority of the respondents (66.7%) and 100% of the respondents from *Parthenium* and *Lantana* areas, respectively, believed that the rate of *Parthenium* and *Lantana* invasion is still increasing. There have been little or no traditional practices used to limit the infestation of *Lantana* and *Parthenium* in the study districts. Only few respondents practiced to get rid off the weed when it occurs in the farm land or residential area. Most of the respondents (53.3%) expressed that cutting is an effective method to control Lantana infestation. While, for *Parthenium* control clearing (hand weeding) and Burning were indicated by most of the respondents (75%) to curb the spread of the weed (Appendix Table 4).

3.5. Impact of *Lantana* and *Parthenium* Invasion on Livestock Holding

Livestock holding per household declined over time in the study sites (Appendix Table 5). A comparison made between the current livestock holding and that of 10 years ago has shown significant difference ($P< 0.05$) except for donkey and camel (Appendix Table 6). In both *Lantana* and *Parthenium* invaded kebeles, the average livestock holding per household at present has shown a declining trend than before ten years; however, in the non invaded area, the average holding of cattle, sheep and donkey shown an increasing trend. This shows that in the non invaded area, people become more agrarians and sedentary than they used to be.Respondents in *L. camara* invaded area reported that from all livestock species, the impact of invasive plant is higher on cattle. Normally cattle do not graze *Parthenium* since it is not palatable due to its bad taste. However, they eat it while they are starved in dry season.

This study also revealed that the number of camel per house hold is one and this is below the zonal average which is nine camels per household. The highest camel holding was found in *L.camara* invaded area. Form the result, it can be conclude that the impact of invasive plants on livestock holding per household as well as on a particular animal species is minimal. Other factors like the change in browse species is much more pronounced. For example in *Parthenium* invaded area, the grazing land has become open grassland, available browse species in the area were eroded through time and the area is no more suitable for camel and goat rearing.

3.5.1. Impact of *Lantana* and *Parthenium* Invasion on livestock composition /Herd Structure

The computation for the current herd diversification gave SI value of 0.49, 0.40, and 0.65 for *Lantana*, *Parthenium* invaded and non invaded areas, respectively (Table 5). The lower index values 0.40 and 0.49 for *Parthenium* and *L. camara* invaded areas, respectively implies the greater species diversity in the household. The higher index values SI (0.65) in the non invaded area shows that herd diversification is low at present. This implies that herd composition tends to be dominated by a single animal species than in the non invaded kebeles, because, pastoralists in these kebeles keep higher number of cattle to use them as a source of power to cultivate their land.However, the SI value before 10 years were 0.58, 0.46 and 0.57 for *L. camara* invaded, *Parthenium* invaded and none invaded areas, respectively. This shows that there was a better herd diversification at present than before ten years in *L. camara* invaded and none invaded areas. However, there was a better herd diversification before ten years and at present in the non invaded area. In general,herd diversification is lower in the non invaded area than in invaded areas.

Table 5. Livestock diversity of the study area.

Invasion state	Current SI	Before 10 years SI
Lantana invaded	0.49	0.58
Parthenium invaded	0.40	0.46
None invaded	0.65	0.57

SI= Simpson index

Thus, we can conclude that people in the non invaded area are more dependent on cattle and sheep rearing than their forefathers. Thus, from this result, it can be concluded that herd diversification begin to fade as a herd management tool to cope with livestock production constraints in the non invaded area, but it is still practiced in invaded areas.

3.5.2. Impact of *Lantana* and *Parthenium* on livestock management practices

Related to the arid nature of the study Zone, water resources both for human being as well as for livestock were scarce. Both invaded districts have been challenged with severe shortage of water resources. Pastoralists in *Parthenium* invaded area obtain water from *birka*/pond and ration during dry season/, while in wet season, they harvest rain water and use it for livestock for some time. Water shortage is a serious problem in haroris kebele, particularly during drought season the problem is severe and the regional government distribute water by trucks in the district.

Availability of water is better in *L. camara* invaded and uninvaded areas. Pastoralists in *L. camara* invaded areas obtain water from *ela*/pond/ during dry season and in wet season river and rain water is available. While, pastoralists in none invaded kebeles obtain water from river, streams and springs.

Encroachment of invasive plants around water points has direct and indirect consequences. Directly, it causes loss of drinking water and indirectly it increases predators attack on livestock by serving as hideout for predators and by narrowing paths to water points. It also affects species composition and the mobility of livestock and people by closing paths, grazing areas and colonizing temporary settlement areas (Dawit, 2010). The same phenomenon has been seen in *Lantana* invaded area. Unlike in the *Parthenium* invaded *Haroris* kebele, water sources were considered to be highly affected by *lantana* invasion in Kubijaro kebele (*Lantana* invaded). Pastoralists indicated that many streams such as: Setale, Elgore and Bedigudot were lost due to *Lantana* invasion.

Majority of the respondents (63.3%) said that the average distance livestock travel for watering is less than 1 km;33.3% of the respondents said it is between 1 and 5 km;2.2% of the respondents said it is between 6 and 10 km; and 1.1% said it is greater than 10 km (Appendix Table 7). Majority of the respondents get water for their livestock in 5km radius. Therefore, *Lantana* and *Parthenium* invasion seems not that much pronounced impact on increasing livestock trekking distance to get water and on livestock watering frequency.

3.5.3. Livestock injuries and death in *Lantana* and *Parthenium* invaded areas

Pastoralists in Gursum woreda blame *Lantana* invasion for the increased attack by predators and feed shortage. They put lantana invasion as the second threat of livestock production in their area. Respondents also said that thickets of *Lantana* not only shelter predators in the grazing land but also allows them to hide around residential areas without being noticed by people. *Lantana* has been implicated in poisoning of a number of animals including cattle, sheep and goats since its leaves and seeds contain toxic substances. Ingestion of the plant parts can cause pink nose disease, jaundice and muzzle in cattle. Heavy outbreaks of *Lantana* poisoning occur during drought times (Sankaran, 2007). Respondents in Gursum wereda also reported that consumption of *Lantana* plant parts cause metabolic disorder, muzzle and nose wound and if it is consumed as sole feed it causes death to cattle.

Considerable amount of animals were also lost due to *Lantana* invasion directly by the consumption of the plant and indirectly by predators attack. The average loss of animals per household due to consumption of *Lantana* was found to be 0.92 TLU. However, loss of animals in TLU per household due to predators attack accounts 1.05 (Table 6). Respondents in *Parthenium* invaded area did not report loss of animal due to *Parthenium* consumption. In the contrary, animals consume *Parthenium* during dry season and if it is in small proportion, it has no effect on health of animals. However, they said that calves consumed *Parthenium* at young stage will not able to stand (suffer from lameness).

Table 6. Lost animals in *Lantana* invaded area.

Cause of loss	Mean animal loss in TLU
Consumption of *Lantana*	0.92
Predators attack	1.05
Total	1.97

3.5.4. Impact of *Lantana* and *Parthenium* Invasion on livestock products quality

In the study area, the pastoralists expressed their views concerning the quality of animal Products. According to them, consumption of *Lantana* and *Parthenium* plant parts has adverse effect on livestock products. Respondents also reported that selling milk from animals that fed *Lantana* and *Parthenium* plant parts would face a market problem. They indicated that nobody would purchase the milk because it tests bitter/bad. Goat and camel milk from *Parthenium* fed animal has a bitter taste. They also claim that meat from *Parthenium* fed animal has poor quality in terms of appearance and flavor. Trounce (1998) reported that meat from animals that graze the *Parthenium* is badly tainted and unfit for the table unless the animals grazed on *Parthenium*-free paddocks for at least a month prior to slaughter.

Consumption of *L camara* also gives milk that have a bitter taste and causes the meat to be tasteless. Pastoralists also said that consumption of both *Lantana* and *Parthenium* plant parts reduce milk yield. By and large, these invasive plants are unpalatable to livestock when there is enough grazing (feed). However, during dry season or in drought time, feed shortage is inevitable and animals are obliged to eat the plants, but their productivity will be poor.

3.6. Impact of *Lantana* and *Parthenium* Invasion on Feed Resources

Research has shown that the allelopathic effect of *Lantana* reduces the vigour of native plant species and limits their productivity. *P. hysterophorus* invasion also causes changes in above-ground vegetation and below-ground soil nutrient contents, disturbing the entire grassland ecosystem. *Parthenium* is a menace to agriculture because it competes with pastures and reduces carrying capacity (Trounce, 1998; Sankaran, 2007). In this study, during group discussion, respondents mentioned that some of the valuable browses and grasses have been disappearing due to *Lantana* and *Parthenium* invasion (Table 8). However, species that have disappeared in the infested area are still in existence in areas that are not yet infested by *Lantana* and *Parthenium* (group discussion). Similarly, Belaynesh (2006) and Shashie (2007) indicated that due to invasive plants, in Jijiga Zone most of the valuable species are disappearing and as a result there is forage scarcity in the area.

Extensive area of land in the study area have been infested and covered by *Lantana*, *Parthenium*, cactus and *Prosopis*. Thus, invasive plants indiscriminately suppress the growth of grass, forb and legume plants and cause declined in herbaceous cover and disappearance of the most essential palatable species. These plants are basically main feed items, and their unavailability will influence the livestock production system of the area. Therefore, if not appropriate grazing management practices are implemented promptly, the impact of invasive plants will greatly hamper livestock production in the area.Respondents listed valuable species which were essential for livestock production in the area, but have already been disappeared due to the continued increase of *Lantana* and *Parthenium* invasion (Table 7).

Table 7a. Endangered plant species due to *Parthenium* invasion.

Grass name		Legume name	
Somali	Scientific	Somali	Scientific
Ris		Harama Anole	
Burhan	*Panicum coloratum*	Mujili	*Solanum nigrum*
Serdi	*Chloris gayana*	Anjil	
Derema	*Chrysopogon plumulosus*	Kerendo	
		Beresh	
		Shufaah	

Table 7b. Endangered plant species due to *Lantana* invasion.

Grass name		Legume name		Tree name	
Somali	Scientific	Somali	Scientific	Somali	Scientific
Harfo	*Aristida adoenis* Hochst.	Gerewa		Wadi	
Serdi		Nyla Kobis		Tenharir	
Burawlet	*Pennisetum sp.*	Barti		Eswodwd	
Gergor	*Elusine spp.*	Furelay	*Ipomea eriocarpa*	Agemse	
Awast		Uspodenan		Debi	
Kelebe (Qalabe)	*Hyparrhenia hirta*			Methekom	
Burhan				Debobes	
Ebetiti				Medeyo	

Respondents from *L. camara* and *Parthenium* invaded areas reported that the status of grasses and legume plants shows a decreasing trend. However, respondents in the non invaded area have different perception on the status of browse plants. The majority of these respondents (73.4%) believe that there is no change in the browse plants status (Appendix Table 8). Others (23.3%) said that it shows a decreasing trend while the remaining (3.3%) of them said browse plants are increasing in their area.

All of the respondents in *L. camara* invaded kebeles said that there were enough feed in their kebele for livestock before *L. camara* invasion, however, only 36.7% of the respondents in *Parthenium* invaded area said *Parthenium* invasion has created feed shortage in their kebele.

4. Summary and Conclusion

The result of this study indicated that pastoralists have similar perception towards invasive plants in this study area. Most of the respondents (60% and 83.3% from *L.camara* and *Parthenium* invaded areas, respectively) rate the current invasion level as heavy. The main seed dispersion mechanisms in *L.camara* and *Parthenium* invaded areas were flood (56.7%) and (63.3%) livestock, and flood, All of the respondents opted for complete eradication of invasive plants from their district. Majority of the respondents, 66.7% and 100% for *Parthenium* and *Lantana* areas, respectively believed that the rate of *Parthenium* and *Lantana* invasion is still increasing. Only few respondents practiced to get rid off the weed when it occurs in the farm land or residential area. Most of the respondents (53.3%) expressed that cutting is an effective method to control *Lantana* infestation. While, for *Parthenium* control clearing (hand weeding) and burning were indicated by most of the respondents (75%) to curb the spread of the weed.

The computation for the current herd diversification gave SI value of 0.49, 0.40, and 0.65 for *Lantana*, *Parthenium,* and non invaded areas, respectively (Table 6). The lower index values 0.40 and 0.49 for *Parthenium* and *L.camara* invaded areas, respectively implies the greater species diversity in the household. The higher index values SI (0.65) in the non invaded area shows herd diversification is low at present. Thus, from this result, it can be concluded that herd diversification begins to fade as a herd management tool to cope with livestock production constraints in the non invaded area…, but it is still practiced in invaded areas.

Majority of the respondents in *Lantana* invaded and none invaded areas were 96.7% and 100%, respectively said that they had ceased mobility. The major reasons for abandoning mobility were shortage of grazing land mainly due to invasive plants and some of them due to the possession of small numbers of livestock. However, most of the respondents (93.3%)' in *Parthenium* invaded kebele still practice mobility.

Respondents in Gursum wereda also reported that consumption of *Lantana* plant parts causes metabolic disorder, muzzle and nose wound and if it is consumed as sole feed it causes death to cattle. Animals consume *Parthenium* during dry season and if it is in small proportion it has no effect on health of animal. However, they said that calves consumed *Parthenium* at young stage will not able to stand (suffer from *Lameness*). Considerable amount of animals lost due to *Lantana* invasion directly by the consumption of the plant and indirectly by predators attack. The average loss of animals per household due to consumption of Lantana was found to be 0.92 TLU.

In the study area, the pastoralists expressed their views concerning the quality of animal Products. According to them, consumption of *Lantana* and *Parthenium* plant parts has adverse effect on livestock products. Respondents also reported that selling milk from animals that fed *Lantana* and *Parthenium* plant parts would face a market problem.. Goat and camel milk from *Parthenium* fed animal has a bitter taste.However, respondets also claimed that meat from *Parthenium* fed animal has poor quality in terms of appearance and flavor.

Respondents during group discussion mentioned that most of the valuable species are disappearing in the area, some of valuable browses and grasses have been disappearing due to *Lantana* and *Parthenium* invasion. However, species that have disappeared in the infested area are still in existence in areas that are not yet infested by *Lantana* and *Parthenium* (group discussion).

5. Recommendation

Past invasive plants control endeavours need to be revised to achieve better result in the area. Becides, new invasive plants control plans need to be designed not to affect livestock herding and mobility and need to be participatory. The exact impact of both invasives on:

- Grasses and browse plants;
- Livestock productivity; and
- Livestock products quality

need to be investigated in a laboratory/by feeding trials/ under nursery condition (for the allelopathic effect) to get empirical evidences and better explain the impact based on statistical results.

6. Acknowledgements

This research was funded by Ethiopian agricultural research organization. Additional support was provided by Haramaya University Research and Extension Office. I would like to thank Dr. Mengistu and Mrs. Hirut Yirga for their valuable support

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4. Beekeeping Practices, Production, Potential, and Challenges of Beekeeping among Beekeepers in Haramaya District, Eastern Ethiopia

Biressaw Serda[1], Tessema Zewudu[2], Moges Dereje[2] and Mohammed Aman[2]

[1]Haramaya University, College of Veterinary Medicine;
[2]College of Agriculture and Environmental Sciences, P. O. Box: 138, Dire Dawa, Ethiopia,
Corresponding author: biressawserda2011@gmail.com

Abstract: Beekeeping is a long-standing practice in the rural communities of Ethiopia and appears as ancient history of the country. A cross sectional study, in which 97 households were purposively included, was conducted in Haramaya district to assess the current beekeeping practices, production potentials and production constraints. Most (99%) of the beekeepers in the study area have owned only traditional hives and produce honey for home consumption. The beekeeping practice was dominated by male. A mild stimulant, K*ate edulis* (khat), is the main income source for the residents. Lack of adequate bee forages, poor market, lack of trained development agents and bee pests are the major problems facing the beekeeping sub sector in the area. The most important constraints of beekeeping in the study area were insecticides, birds and bee diseases (1st), Misuse of pesticides (2nd), Insecticides, birds and pesticides together (3rd), Pests, insecticides and predators (4th), lack of training (5th), shortage of bee forage (6th), shortage of water (7th) and absconding (8th). There are enormous opportunities to boost the production of honey in the villages. Thus, introducing modern beehives, limiting the use of pesticides in 'khat' production and awareness creation and assistance to empower women in the beekeeping activity are needed interventions.

Keywords: Beekeeping; Constraints; Pests; Production; Traditional Hives

1. Introduction

In Ethiopia, beekeeping has been practiced for centuries and its potential is well documented. Of all the countries in the world, no country has such a long tradition of beekeeping than Ethiopia (Nebiyu and Messele, 2000). Despite its long history, beekeeping in Ethiopia is still an undeveloped sector of agriculture. The knowledge and skill of honey production and honey and beeswax extraction of Ethiopian farmers is still very traditional (MoARD, 2006).

Most of local beehives are hanged over tall trees. Productivity of the hives is very low and averaged 5-6 kg of honey per hive per year, while from the improved one average of 15-20 kg even more is possible. Honey and beeswax collected after the rainy season starts in October and extends until December. In the South and Eastern parts, in addition to the main, there is minor harvesting period during May-June. According to CSA, (2001) the major honey and beeswax producing regions in Ethiopia are Oromia (41%), SNNPR (22%), Amhara (21%) and Tigray (5%). However, the country is suffering from the ecological degradation of its natural resources and this means the basis for any honey production is threatened and affected. In many regions of the country, beekeeping is considered as one of the income-generating activities for resource-poor farmers including women, youth, and the unemployed sectors of the community (Gezahegn, 2001).

About 10% of the honey produced in the country is consumed by beekeeping households. The remaining 90% is sold for income generation; of this amount, it is estimated that 70% is used for brewing '*Tej*' (local alcoholic beverage) and the balance is consumed as table honey. Additionally, beeswax is collected and traded. Honey is a vital factor in job creation and maintaining livelihoods. However, current honey production estimate represents only 8.6% of the country's production potential. Productivity from traditional hives is very low, with an average of 5-6 kg per year, while production from improved hives (including transitional hives) reaches 18-30 kg per year (Nebiyu and Messele, 2000; Paulos, 2011; ARSD, 2000; MoRAD, 2006).

Beekeeping is still operating in the old traditional ways implying the need for modernization. Low productivity and poor quality of bee products are the major economic impediments for rural beekeepers (Nuru, 1999); however, they face another primary economic concern; i.e. lack of skill to manage their bees and bee products. Most of the rural beekeepers cannot afford to invest in modern beekeeping inputs, processing, packaging, and transport their products to market to maximize profit. They produce a low quality product that they are forced to sell locally to wholesale buyers at prices much lower than in domestic commercial markets (Amsalu *et al*., 2004). The major constraints that hinder beekeeping development in Ethiopia can be stringent rules and conditions set by honey importing countries (MoRAD, 2003), very limited domestic market, only basic knowledge of honey production and limited access to market information and technologies, unreliable transport, poor storage of products, lack of quality monitoring and control plan in place and inadequate laboratory facilities and poor institutional set-up for assuring quality (Nebiyu and Messele, 2000; Paulos, 2011;. MoRAD, 2003). In line with this, the government of Oromia region recently identified potential areas for beekeeping. According to Haramaya district bureau of Agriculture, there is no well-established study on the potential and challenges of beekeeping in the district. Therefore, the objective of this study is to identify the current practices, production potentials, and constraints of beekeeping in Haramaya District, Eastern Ethiopia.

2. Materials and Method

2.1. Study Area

The study was conducted in Haramaya district (East Oromia National Regional State) which is found at 508 km east of Addis Ababa and 19 km to reach Harar on the high way from Addis Ababa to Harar. 90% of the area is classified as midland and 10% as lowland. The estimated animal population in the area is about 63,723 cattle, 13,612 sheep, 20,350 goats, 15,978 donkeys, 530 camels, 42,035 chickens and 3331 bee colonies. The production system of the district is mixed type. Topographically, it is situated at an altitude of 1400 to 2340 m above sea level with the mean annual temperature and relative humidity of 18°C and 65%, respectively. There are four seasons; a short rain season (from March to mid May), a short dry season (from end of May to end of June), a long wet season (early July to mid October) and a long dry season (end of October to end of February) (Haramaya Bureau of Agricultural Development, 2010-personal communication; CSA, 2011).

2.2. Study Design and Sampling Procedure

Cross-sectional study was conducted to collect data using questionnaire survey. Beekeepers in the district represented the study population. The sampling units were households keeping honeybee colony. Using a purposive sampling procedure, a total of twelve kebeles (villages) were selected based on agro-ecology representation (high-land, mid-land and low-land), honey production potential and accessibility. Information about the type of hives used, the number of bee colonies owned, the purpose of keeping honey bees, the marketing system of honey and other hive products, the rate of absconding and swarming and harvesting and processing of hive products and major constraints of beekeeping were collected through interviews using a semi-structured questionnaire.

3. Results and Discussion

3.1. Distribution of the Respondents in Agro-climatic Zones and Gender

Almost all (99%) of the respondents were located in *weyana dega* (midland) agro-climatic zone. As far as ownership of the beekeeping across gender was concerned, the activity is dominated by male. This indicates the gender disparity in owning the beekeeping economic task in the study area (Table 1). This finding is contradicted with the results of Amsalu *et al.*, (2004) and Gezahig (2001) that pinpoint beekeeping as one of the income-generating activities for resource-poor farmers including women, youth and the unemployed sectors of the community.

3.2. Placement of Hives and Beekeepers Preference of Hives

Table 1. Agro-climatic zones, gender distribution of respondents, Hive placement and preferences, Haramaya district, 2014.

	Frequency (%)
Agro-climatic zone	
Weyna Dega (mid-land)	99.0
Dega (high-land)	1.0
Kola (low-land)	0.0
Total	100.0
Ownership in gender	
Male	99.00
Female	1.00
Total	100.00
Variables	**Frequency (%)**
Hive placement	
Back yard of the house	51.0
Inside a simple shelter	32.0
Under the eaves of the house	1.6
Trees in forests	10.5
Trees near home stead	4.9
Total	100.00
Preferred hives by the beekeepers	
Traditional	75.0
Transitional	20.5
Modern	4.5
Total	100.0

3.2. Placement of Hives and Beekeepers Preference of Hives

Most (51%) of the beekeepers in the study area kept the traditional bee hives at the back yard of the house, 32 % kept inside a simple shed built for hive placement, 1.6% kept under the eaves of the house, 10.5% kept on trees in forests and 4.9% kept on trees near home stead (Table 1). Some of the traditional bee hives placement are presented in figure 1. According to Kerealem (2005), most beekeepers of Amaro wereda kept their bee colonies by hanging on trees near homestead and in forest areas. Majority (75%) of the beekeepers of the study area preferred traditional hives over transitional (20.5%) and modern hives (5.5%). This is mainly because of the high cost of constructing and purchasing of modern and transitional hives and due to lack of harvesting and processing equipment's to use modern and improved hives. Similarly, Mahari (2007) reported that in east Tigray modern beekeeping require more expensive establishment cost, accessories, (further cost) and skill training, though they yield better quality and quantity of honey.

A. Hives under shed B. hives under tree

Figure 1. Placement of traditional hive in Haramaya District, 2014.

3.3. Feed Source for Bees and Trend of Colony Population

As the type and source of feed determines the success of beekeeping, the respondents were asked to indicate the source of feed for their bees. Accordingly, 94% of them indicated foraging as the main source of feed for their bees. As far as the colony population is concerned, only 45.4% of them indicated a decreasing trend (Table 2). The trend of colony population is decreasing over the years due to absconding, lack of using improved bee hives, pests and predators, drought and lack of bee forage. Similarly, a result reported by Tessega (2009) in Bure district indicated that hive products were in a decreasing trend due to shortage of bee forages, drought, pesticides and herbicide application, lack of water and poor management in order of importance.

3.4. Harvesting and Processing of Hive Products

This study pointed out that the only hive product harvested and utilized by beekeepers of the study area was honey. During harvesting they mainly use fire as a smoking material. None of the beekeepers in the study area strain the harvested crude honey. Their main reasons for not straining were due to the reduction in the amount of honey after harvesting (55%), lack of knowledge on how to strain crude honey (20.5%) and lack of straining materials (24.5%). None of the beekeepers of the study area collect crude beeswax. According to the respondents the main reasons for not collecting beeswax were lack of knowledge on the importance of bees wax as an income generating hive product unlike honey (77.7%), lack of processing skills (12%), lack of market for wax in their locality (5.3%) and lack of processing material (9.6%) (Table 2). The finding was similar to that of Wilson (2006) and Tallonitire (2006) that lack of appropriate production technologies, weak market and absence of value chain development largely resulted in much lower contribution of the honey production sub-sector and much lower than its potential.

Table 2. Frequency distribution of feed source colony population and reasons for not straining honey and collecting bees wax.

Feed sources	Frequency	Percent
Foraging	91	93.8
Supplementary feeding	3	3.1
Others	3	3.1
Total	97	100.0
Trend of colony population		
Decreasing	44	45.4
Increasing	45	46.4
No difference	8	8.2
Total	97	100.0

Reason for not straining honey (n=97)	%	Reason for not collecting Beeswax (n=97)	%
Amount of honey will be reduced	55.0	Lack of knowledge	77.7
Lack of material	24.5	Lack of processing skills	12.0
Lack of knowledge	20.5	Lack of market	5.3
		Lack of processing material	5.0
Total	100.0		100.0

3.5. Economic Dependence and Major Constraints

The result of this study identified beekeeping practices is very traditional in Haramaya district with very low production, which is produced only for home consumption. Thus, economically, the respondents depend mainly on non-beekeeping activities (Table 3). Since the product is insufficient, there is no market chain for honey and honey products in the district. According to Tessega (2009) in Bure district of Amhara region, the main purposes of keeping bees were for source of income and home consumption. Apart from this statement, Paulos (2011) stated that pollination of crops and natural vegetation yields more than honey, both per hive and per hectare. Moreover; even if more than half of the respondents are having different sources of income, most of them (44.3%) were relying on '*Khat*'. Besides, there is no household that indicated beekeeping as the only income source. Rather, it is used as a supplementary to livestock, vegetable and fruits, and poultry income sources. Major constraints in beekeeping were also identified as, insecticide usage and birds constitute the highest share followed by misuse of pesticides. This is mainly due to expansion in '*Khat*' production which uses heavy application of pesticides that adversely affect the beekeeping practices. Therefore, the most important constraints of beekeeping in the study area were insecticides, birds and diseases (1st), misuse of pesticides (2nd), insecticides, birds and pesticides together (3rd), pests, insecticides and predators (4th), lack of training (5th), shortage of bee forage (6th), shortage of water (7th) and absconding (8th) (Table 4). According to SOS-Sahel-Ethiopia (2006), the major constraints in Ethiopia are lack of beekeeping knowledge, shortage of trained manpower, shortage of beekeeping equipment, pests and predators and inadequate research and extension services to support apiculture development programmes.

3.6. Opportunities of Beekeeping

Currently, Ethiopian government is highly supporting self contained watershed developing program in which beekeeping is part and parcel the program. Low cost modern hives is being produced using locally available materials and efforts are being made to organize farmers in groups and link them with local carpenters who produce modern bee hive. Farmers from selected kebeles of the study area are currently obtaining beekeeping training by the community development works of Haramaya University. There is an increasing demand for honey for domestic consumption and export by different customers and organizations. Though scarce in dry seasons, there are many bee forage species throughout the year in most part of the study area. Availability of rich culture and tradition of beekeeping, suitable environment with different agro ecology, availability of farmers having indigenous knowledge, skills and keen interest to adopt improved technologies and to undertake beekeeping as a way of life are among the few to mention.

Table 3. Economic dependence of activities in the villages, Haramaya district, 2014.

	Non-beekeeping Economic activities					
Kebeles/villages	Crop	Crop and livestock	Trade	Crop and trade	All	Total
Amuma		4			2	6
Baatee	5	2	1	1		9
Fandisha Leencaa	1					1
Daamota	4					4
Iffa Oromia	18	6				24
T/Gabisaa	19					19
B/Gadaa		9				9
I/Balinaa		7				7
Haaqa	1	12				13
A/Baatee	1					1
Kuroo	1					1
Bacaqee	3					3
Total	53	40	1	1	2	97

Table 4. Major beekeeping problems in the Haramaya district, 2014.

Major problems	Frequency	Percent
Insecticides	9	9.3
Birds	2	2.1
Misuse of pesticides	17	17.5
Lack of bee forage	6	6.2
"Hamma" (honey badger)	1	1.0
Insecticide, birds and diseases	27	27.8
Insecticides and pesticides	3	3.1
Insecticides and lack of bee forage	5	5.2
Insecticides and dry spell	2	2.1
Birds and pesticides	1	1.0
Pesticides and lack of bee forage	9	9.3
Insecticides, birds and pesticides	12	12.4
Insecticides, birds and "Hamma" (honey badger)	1	1.0
Insecticides, pesticides and dry spell	2	2.1
Total	97	100.0

4. Conclusion and Recommendations

Majority of the beekeepers in the study district produce honey for home consumption than for the market. The most widely used type of beekeeping in the study area is traditional due to the high cost of the improved hives and their accessories. From the study, it was understood that the colony population is decreasing from time to time due to destruction of forest areas for crop cultivation and different constraints particularly insecticides, predators and bee diseases. With the expansion and reliance of the households in '*Khat*' production in the study area, insecticide and birds as well as misuse of pesticides are constraining the beekeeping practices. Unless some measures and regulations are put in place on type of pesticides to be used for '*Khat*' production, the continuity of beekeeping remains in challenge. There is a need of intervention in introducing modern beehives that can make households produce more for market than home consumption. Awareness creation and assistance is needed to empower women in the beekeeping activity. Introducing the modern beehives in the study district is needed to supplement the households' income sources from beekeeping. Finally, there is a need for limiting the use of pesticides in '*Khat*' production and proper identification of bee diseases and their prevention measures to sustain the beekeeping activity.

5. Acknowledgement

The research was funded by Haramaya University Research Office to which we are grateful. We would like to express our thanks to Haramaya Woreda Agricultural offices for their assistance during data collection. The research team is also grateful to study participants for their collaboration, enthusiasm and willingness to share us information.

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5. Influence of Nitrogen Application Rates and Maize Varieties on the Grain Yield and Some Agronomic Traits of Maize (*Zea mays* L.)

Habtamu Zeleke

Haramaya University, College of Agriculture and Environmental Science, Department of Natural Resource Management, P. O. Box 38, Dire Dawa, Ethiopia
Author Email: wubeno@yahoo.com.

Abstract: A study was made on the effects of different rates of nitrogen and maize varieties at Haramaya University main campus, eastern Ethiopia for two years (2012/13 and 2013/14 cropping seasons). The purpose of the study was to determine the effects of the application different rates of nitrogen and maize varieties on yield and some yield related traits. The nitrogen application rates were 18, 36, 72, 108 and 144 kg/ha nitrogen and the four late maturing maize varieties were Jibat, AMH 760Q, BH 660 and BH 661A. The experiment was laid out 5 x 4 factorial arrangements in randomized complete block design (RCBD) with three replications. Statistically significant difference for grain yield was found between the varieties in their response due to treatment combinations. Significant and increasing trend of grain yield when the nitrogen dose increased. The interaction effect of nitrogen rates and maize varieties were also highly significant. All the four varieties included in the study gave relatively similar yield and over 10000 kg/ha of grain yield when 72 kg/ha of N/ha was applied indicating the already recommended rate nitrogen is still valid for maize production under similar soil types in Haramaya area.

Keywords: Nitrogen Application; Rate; Late Maturing; Agronomic Trait; *Zea Mays* L.

1. Introduction

According to a 2012 FAO report, Ethiopia is the fourth largest maize producing country in Africa, and first in the East African region. It is also significant that Ethiopia produces non-genetically modified (GMO) of mainly kernel white maize, the preferred type of maize in neighboring markets as cited in (CSA, 2014). According to Tadesse *et al.* (2011) maize is also most dominant and known cereal crop of in areas such as West Oromia zones.

Hybrid cultivars have played a vital role in increasing acreage and productivity of maize. In Ethiopia, Maize production was boosted by 9.1% in 2005-2013, whereas averages yield t/ha at national level was increased by 4.8% in the same years. Ethiopia's current national maize yield is 3.25 metric tons per hectare, 28% above the developing world average of 2.5 MT/ha. The 'developed' world, however, see average yields of 6.2 MT/ha, with some countries actually exceeding 10 MT/ha (CSA, 2014).

Maize (*Zea mays* L.) is one of the three most important cereal crops in the world together with wheat and rice in terms of area of production. However, maize surpasses both wheat and rice (FAOSTAT, 2012) in terms of total grain production. The current productivity of the crop in developed countries such as in USA is 10.3 t/ha; in Germany 9.7 t/ha; in Canada 8.4 t/ha and South Africa 4.96 t/ha with the world average grain yield of 5.1 t/ha (FAOSTAT, 2010).

Hybrid cultivars have played a vital role in increasing acreage and productivity of maize.Currently, in Ethiopia, Maize production was boosted by 9.1% in 2005-2013, whereas averages yield t/ha at national level was increased by 4.8% in the same years. Ethiopia's current national maize yield is 3.25 metric tons per hectare, 28% above the developing world average of 2.5 MT/ha. The 'developed' world, however, see average yields of 6.2 MT/ha, with some countries actually exceeding 10 MT/ha (CSA, 2014).

It can be seen that despite the large are allocated for maize production in Ethiopia, the productivity is very low contributing to low total production due to both biotic stresses (diseases, insect pests and weeds) and abiotic stresses such as drought; declining soil fertility, poor agronomic practices, limited use inputs as well as insufficient technology generation including nutrient efficient improved varieties.

According to Hefny and Aly (2008), nitrogen along with phosphorus, is one of the most limiting macronutrients to maize grain yield. Nitrogen availability influences the uptake, not only of itself, but also of other nutrients (Onasanya *et al.*, 2009), as N-fertilized plants usually have larger root systems, which enhances the capture of other nutrients (Masaka, 2006). According to Abd El-Lattief (2011), since nitrogen is highly mobile, its use and demand is continuously increasing as it is subjected to high loss from the soil plant system. Even under the best management practices 30-50% of applied N is lost through different agencies and hence farmers are forced to apply sufficient to meet the amount of nitrogen to meet demand of the maize crop for increased nitrogen. In high and medium altitude maize growing areas of Ethiopia, where rainfall is high, most of the nitrogen is lost through leaching and most also probably due to denitrification making the nutrient unavailable during the critical stages of crop growth.

Different strategies have been used in order to mitigate nutrient leaching and improve the nutrient use efficiency (NUE). Nitrification inhibitors, which slow the oxidation of NH_4, and enhance slow and controlled release fertilizers, have been used to reduce N leaching (Sitthaphanit *et al.*, 2010). Furthermore, soil management practices, such as incorporating straw with a high C: N ratio and minimum tillage can reduce N leaching.

Currently, more or less similar dose of N is used as a blanket recommendation for most soil types and also for different varieties. In principle, it is advised to determine nutrient requirement for different varieties and also revisit the past recommendations in light of the changing climatic conditions. Thus, this experiment was conducted with the objective to determine the optimum nitrogen fertilizer for maize varieties Jibat, AMH 760Q, BH 660 and BH 661 and to assess the interaction effects of maize varieties on yield and yield related characters of maize.

2. Materials and Methods

The experiment was conducted at Haramaya University main campus Raare research site, eastern Ethiopia during 2012/13 and 2013/14 cropping seasons. The geographical coordinate of the site is 9 °26'N latitude, 42°3'E longitude, and it is situated at an altitude of 1980 meters above sea level. The weather condition during the cropping seasons was favorable for crop development, except during the month of June where there was dry spell (Appendix table 1). The soil of the experimental site is a well-drained deep alluvial with a sub-soil stratified with loam and sandy loam.

The experiment consisted of a factorial combination of five levels of N (18, 36, 72, 108 and 144kg ha^{-1}) and four maize varieties (Jibat, AMH 760Q, BH 660 and BH 661) arranged in randomized complete block design (RCBD) with three replications. The major sources of N were urea (46% N). Phosphorus was applied uniformly to all plots at the rate of 46 kg/ha at planting.

The land was prepared by tractor driven tilling equipment to obtain proper seed bed. There were four rows per plot with 5.1m row length. The middle two rows were used for data collection. The distance between rows and plants within the row were 0.75m and 0.30m, respectively. Plots within a replication were separated by 1.5m space and blocks were spaced 1.5 m apart. Half dose of N applied at planting and the remaining half was applied close to flowering stage of the maize crop. All other cultural practices including application of chemical (Cypermethrin granule) against stalk were done as required.

Data were collected on plant height, ear height, the ratio between plant height (cm) and ear height (cm), rust, blight, stand count at harvest, 1000 kernel weight (g) and grain yield (kg/ha). Statistical analysis was done for the data using Statistical Analysis System (SAS) Version 9.2 (SAS Inc., 2002) following the procedures suggested by Gomez and Gomez (1984) and mean separation was done using least significant difference (LSD) at 5% level of significance.

3. Results and Discussion

The analysis of variance indicated that grain yield (kg/ha) was highly significantly ($P<0.01$) influenced by the combination of variety and nitrogen fertilizer rates and growing season (year). The interaction of year and combination of treatments (variety and nitrogen fertilizer rates) had also highly significantly influence on grain yield of maize (Table 1).

The obtained results showed in general there is increasing trend of grain yield when the rates of nitrogen increased from 18 kg N/ha to 144 kg/ha (Table 2). Variety Jibat produced the lowest (6563.00 kg/ha) at 18 kg N/ha and high at 36 and 72 kg/ha N with 11400.00 and 11030.00 kg/ha of grain yield, respectively. Similarly variety AMH 760Q produced the lowest grain yield per hectare (6987.00 kg/ha) at 18 kg N/ha and highest at 72 kg/ha (10440.00 kg/ha). Varieties BH 660 and BH 661 produced (7363.00 and 8272.00 kg/ha, respectively) a bit better yield at 18 kg N/ha level compared to Jibat and AMH 760Q, except that variety BH 660 gave consistently over 10000.00 kg/ha of grain yield starting 36 kg N per ha rate indicating that this hybrid may be considered as nitrogen se efficient variety. The results obtained by different authors in their study on different levels of nitrogen in maize was similar to the findings of this study (Thair *et al.*, 2001; Muhammad *et al.*, 2012; FarshadSorkhi; Tilahun *et al.*, 2013 and MojtabaFateh, 2014).

Table 1. Analysis of Variance for Grain Yield of Nitrogen Fertilizer Trial on Maize (Haramaya, 2012/13 and 2013/14.

Source of variation	Degrees of freedom	Sum of squares	Mean square
Replication	2	55474320.787	27737160.394
Treatments(T)	19	316766810.414	16671937.390**
Year (Y)	1	1752498727.620	1752498727.620**
T x Y	19	278260186.079	14645272.952**
Error	78	462552467.471	5930159.839
Total	119	2865552512.371	

Coefficient of Variation: 22.99%

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Table 2. Influence of Variety and N Fertilizer on Yield Related Traits and Yield of Maize at Haramaya Eastern Ethiopia.

Treatment No.	Treatment Combination		Traits							
	Variety	N rate (kg/ha)	PHT	EHT	EHT/PHT	RUST	BLIGHT	STH	1000 Kernel weight (g)	Grail yield (kg/ha)
1	Jibat	18 kg/ha	202	97.5	0.48	1.5	1.5	43	420.73	6563.00
2	Jibat	36 kg/ha	198	94	0.47	1.5	1.5	48	423.43	11400.00
3	Jibat	72 kg/ha	186	83	0.45	1.5	1.5	41	434.80	11030.00
4	Jibat	108 kg/ha	195	87	0.45	1.5	1.5	38	426.07	9424.00
5	Jibat	144 kg/ha	186	92	0.50	1.5	1.5	40	423.40	9714.00
6	AMH 760Q	18 kg/ha	209	119	0.57	1.5	1.5	42	397.23	6987.00
7	AMH 760Q	36 /kg/ha	210	126	0.60	1.5	1.5	40	425.10	9341.00
8	AMH 760Q	72 kg/ha	198	112	0.57	1.5	1.5	36	413.77	10440.00
9	AMH 760Q	108 73 kg/ha	203	114	0.56	1.5	1.5	37	406.83	9415.00
10	AMH 760Q	144 kg/ha	209	123	0.59	1.5	1.5	40	394.33	9806.00
11	BH 660	18 kg/ha	222	120	0.54	1.5	1.5	39	458.70	7363.00
12	BH 660	36 kg/ha	241	137	0.57	1.5	1.5	38	466.60	11260.00
13	BH 660	72 kg/ha	239	140	0.59	1.5	1.5	42	460.83	11550.00
14	BH 660	108 kg/ha	242	143	0.59	1.5	1.5	39	501.50	9106.00
15	BH 660	144 kg/ha	230	124	0.54	1.5	1.5	39	447.50	8925.00
16	BH 661	18 kg/ha	228	122	0.54	1.5	1.5	47	433.10	8272.00
17	BH 661	36 kg/ha	227	115	0.51	1.5	1.5	44	418.33	11400.00
18	BH 661	72 kg/ha	221	114	0.52	1.5	1.5	42	456.60	14050.00
19	BH 661	108 kg/ha	230	119	0.52	1.5	1.5	44	453.83	13620.00
20	BH 661	144 kg/ha	220	114	0.52	1.5	1.5	47	457.03	11600.00
C.V			8.03	11.40	1.42	NS	NS	NS	15.39	22.99
LSD (5%)										3491.00

4. Recommendation

From the results obtained in this study, it can be concluded that farmers in Haramaya woreda and areas with similar soil type in eastern Ethiopia may apply 72 kg N/ha to get good grain yield from maize, particularly hybrid varieties Jibat, AMH 760Q, BH 660 and BH 661.

5. Acknowledgement

The author is grateful to Haramaya University for providing the research grant and all other supports during execution of the research. The contribution of all technical assistants of Maize Research Program at Haramaya University, particularly, Mr. Elias Abrahim is highly acknowledged. Without their assistance, the successful completion of this research might have been impossible.

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6. Genetic Gain of Tuber Yield and Late Blight [*Phytophthora infestans* (Mont.) de Bary] Resistance in Potato (*Solanum tuberosum* L.) Varieties in Ethiopia from 1987 to 2011

Wassu Mohammed Ali

Haramaya University, College of Agriculture and Environmental Sciences, School of Plant Sciences
Author E-mail: wasmoha@yahoo.com

Abstract: Since the introduction of potato, it has been considered as a strategic crop aiming at enhancing food security and economic benefits to Ethiopia. Potato improvement program has been started in 1975 and the first variety was released in 1987. Periodic evaluation of improvements in economic importance traits is necessary to assess breeding progress over time; however, no study has been attempted in Ethiopia. Therefore, this study was conducted with the objectives of determining the rate and magnitude of progress in tuber yield and resistant to late blight in historical potato varieties and to determine the contribution of late blight disease to tuber yield variation. Sixteen improved varieties released between 1987 and 2011 and two farmers' cultivars were planted in three environments with randomized complete block design with three replications. The combined analysis of variance revealed the presence of significant difference among varieties for tuber yield and resistant to late blight due to genotype, location and genotype x location interaction. Total and marketable tuber yield increased linearly with year of varieties release at a rate of 0.14 and 0.18 t ha^{-1}, respectively, per year. Late blight severity score reduced at a rate of -0.31% year^{-1}. Late blight severity score explained total tuber yield variations between 31.39 to 80.1% across environments. The research revealed progressive improvement of the crop over 25 years in the country for tuber yield and controlling late blight disease through use of resistant varieties. However, most of the varieties became susceptible for late blight in favourable environment for the pathogen and only few varieties performed better for tuber yield and late blight resistance across environments. This suggested the need to change the existing potato breeding approach that depends on separate efforts of breeders at different research centers to develop varieties for specific agro-ecologies. This call for the organized and complementary efforts of researchers in the country to develop high yielding varieties that match the changing market and end-user demands, and resistance to the new virulent pathogen races for larger target areas of Ethiopia.

Keywords: Genetic gain; Genotype x Location; Late blight severity; Potato varieties

1. Introduction

Food security is a key priority for ever increasing population in Eastern Africa. The need to feed this population puts increasing pressure on the fixed land for food production. This is further aggravated by the increasingly degraded environment and the uncertainties resulting from climate change. This declining and variable environment requires robust crops adapted to a wide range of agro-ecologies in the region. Potato is the best crop for food and nutrition security in the sub-region because of its plasticity to environmental regimes and higher yield per unit area (Kyamanywa *et al.,* 2011). Potato is considered as cheap source of human diet in many countries, because it is a high-energy staple food, provides high productivity per unit area and time, supply carbohydrates, quality protein (lysine), minerals, nutrient salts and several vitamins from group B and large amount of vitamin C (Horton, 1987).

Potato was introduced to Ethiopia in 1858 by the German botanist Schimper (Pankhurst, 1964). Since its introduction, potato has been considered as a strategic crop aiming at enhancing food security and economic benefits to the country. Ethiopia is one of the principal potato producing countries in Africa. Approximately, 1.3 million farmers (CSA, 2011) grow potato in mid and highlands of Ethiopia. The country has a potential to grow potato in 70% of the 10 million hectares of arable land of the country (FAO, 2008). The area planted with potato increased from 30,000 to about 164,146 hectares between 2002 and 2007. In the last 10 years, potato productivity has progressed from 7 to 11 t ha^{-1}. Nevertheless, the current area cropped with potato and the average yield (< 10 t ha^{-1}) far below the country's potential (Baye and Gebremedhin, 2013). The low acreage and yield are attributed to many factors, but lack of high quality seed potatoes, proper management of the crop and high yielding varieties are the major factors (Gildemacher *et al.*, 2009; Endale *et al.*, 2008). Of these, developing crop varieties which withstand the changing climate is becoming a priority activity for breeders.

In Ethiopia, strategic research for potato variety development and other agronomic managements began in 1975 (Gebremedhin, 2013). Starting the release of the first potato variety (987), more than 27 potato varieties were developed and registered by the government research institutions (MoA, 2013; MoA, 2012). The major focus was developing varieties for high yield and resistant to late blight for different agroecologies of the country by separate effort of different research centers and Haramaya University. However, considerable number of released varieties becomes susceptible to late blight (lost their resistant) due to the pathogen [*Phytophthora infestans* (Mont.) de Bary] has the ability to rapidly evolve to overcome resistance major genes (Stewart *et. al.,* 2003, Wastie, 1991).

The major task of the breeders is to develop high yielding varieties, resistance or tolerance to stress and varieties that match the existing end use of the crop. Breeders have often been unable to forecast future cropping scenarios and the economics of production. Therefore, periodic evaluation of potato varieties for yield and disease resistance is necessary to assess breeding progress over time. The generated genetic gain information from such experiment helps plant breeders to know how much the varieties match the changing cropping scenarios and the economics of production. However, such research has not been attempted in the country for the last 25 years of potato variety development. Therefore, this experiment was conducted; i) to determine the rate and magnitude of progress for tuber yield in historic potato varieties in Ethiopia; ii) to evaluate varieties resistant to late blight and progress made in selection of resistant varieties in the last 25 years and iii) to determine the contribution of late blight to tuber yield variation..

2. Materials and Methods

2.1. Description of the Study Sites

The field experiment was carried out at three environments namely; Haramaya, Hirna and Arberkete which are considered as the representative mid and highland potato growing areas of eastern and western Hararghe. The experiment was conducted for one cropping season in 2013.

Haramaya University, Rare research farm is located at 2020 m.a.s.l., 9°41"N latitude and 42°03"E longitude. The area has a bimodal rainfall distribution and is representative of a sub-humid mid altitude agro-climatic zone. The mean annual rainfall is 760 mm. The short rainy season extends from March to April and constitutes about 25% of the annual rainfall whereas the long rainy season extends from June to October and accounts for about 45% of the total rainfall (Belay *et al.*, 1998). The mean maximum temperature is 23.4^{0}C while the mean minimum annual temperature is 8.25^{0}C (Tekalign, 2011). The soil of the experimental site is a well-drained deep alluvial with a sub-soil stratified with loam and sandy loam. Previous work showed that it has organic carbon content of 1.15%, total nitrogen content of 0.11%, available phosphorus content of 18.2 mg kg soil^{-1}, exchangeable potassium content of 0.65 cmolc kg soil^{-1} (255 mg K kg soil^{-1}), pH of 8.0, and percent sand, silt, and clay contents of 63, 20, and 17, respectively (Simret, 2010).

Hirna research sub-station of Haramaya University is located at 9 ^{o}12' North latitude, 41 ^{o}4' East longitude, and at an altitude of 1870 metres above sea level. The area receives mean annual rainfall of 990 to 1010 mm (HURC, 1996). The mean maximum and minimum annual temperatures are 21.8°C and 8.6°C, respectively (Tekalign, 2011). The soil of Hirna is vertisol type with silty clay in texture, which contain organic carbon 1.75%, total Nitrogen 0.18%, available Phosphorus 32 mg kg soil^{-1}, exchangeable Potassium 0.68 cmol$_c$ kg soil^{-1}and pH of 7.09 (Nebret , 2011). The third site was Arberekete, which is located at a distance of about 171 km to the west of Haramaya. The site is located at 9 ^{o}14' North latitude, 41 ^{o}2'East longitude, and at an altitude of 2280 meters above sea level.

2.2. Experimental Materials

A total of 16 potato varieties were used. These varieties were released by five research centers and Haramaya University during 1987 to 2011. In addition, two farmers' cultivars were included. The description of the varieties including the recommended growing altitudes is given in Table 1.

2.3. Experimental Design and Procedures

The experiment was laid out as a Randomized Complete Block Design (RCBD) with three replications in each environment. Each potato genotype was assigned to one plot in each replication and six rows with 12 plants. The gross plot size was 16.2 m^2 with 75 and 30 cm between rows and within plant spacing, respectively. The spacing of 1.5m and 1m was maintained between plots and replications, respectively.

The experimental fields except at Arberekete were cultivated by a tractor to a depth of 25-30 cm and levelled then after ridges were made by hand. Medium sized (39-75g) and well sprouted tubers were planted at the sides of ridges (Lung'aho *et al.*, 2007). Tubers was planted at the end of June and first week of July during the main growing season after the rain commenced and when the soil was moist enough to support emergence. The planting depth was maintained at 10 cm.

Fertilizer was applied as the recommendation made by Haramaya University at the rate of 75 kg N and 92 kg P_2O_5 ha^{-1}. The source of N and P_2O_5 were DAP (18% N, 46% P_2O_5), and Urea (46 % N). The entire DAP fertilizer rate was applied at the depth of 10 cm below the seed tuber at planting, while Urea was applied 7-10 cm away from the plant as two side dressings for subsequent split applications (50% + 50% in two installment of 30 and 50 day after planting). Other agronomic managements were applied as per the recommendation made for the crop.

The haulm was mowed two weeks before harvesting to thicken tuber periderm; as yellowing or senescence observed apparent on the lower leaves. For yield estimation, tubers were harvested from forty plants from the four middle rows, leaving the plants growing in the two border rows as well as those plants growing at both ends of each row to avoid edge effects.

Table 1. Name, accession code, year of release, maintainer center of potato varieties.

No.	Variety	Accession code	Year of release	Breeding Center	Recommended Altitude (m.a.s.l.)
1	Alemaya 624	Al-624	1987	Haramaya University	1700 - 2400
2	Chirro	AL-111	1998	Haramaya University	2700 - 3200
3	Zemen	AL-105	2001	Haramaya University	1700 - 2000
4	Bedasa	AL-114	2001	Haramaya University	2400 - 3350
5	Gorebela	CIP-382173.12	2002	Sheno Research Center	1700 - 2400
6	Guasa	CIP-384321.9	2002	Adet Research Center	2000 - 2800
7	Jalenie	CIP-37792-5	2002	Holeta Research Center	1600 - 2800
8	Gera	KP-90134.2	2003	Sheno Research Center	2700 - 3200
9	Chala	CIP-387412-2	2005	Haramaya University	1700 - 2000
10	Bulle	CIP-387224-25	2005	Hwassa Research Center	1700 - 2700
11	Gabbisa	CIP-3870-96-11	2005	Haramaya University	1700 - 2000
12	Mara Charre	CIP-389701-3	2005	Hwassa Research Center	1700 - 2700
13	Gudanie	CIP-386423.13	2006	Holeta Research Center	1600 - 2800
14	Araarsaa	CIP-90138.12	2006	Sinnana Research Center	2400 - 3350
15	Belete	CIP-393371.58	2009	Holeta Research Center	1600 - 2800
16	Bubu	CIP-384321-3	2011	Haramaya University	1700 - 2000
17	Bete	Local cultivar			
18	Jarso	Local cultivar			

*** Plant Variety Release, Protection and Seed Quality Control Directorate, Crop Variety Register Issue No.16 (MoA, 2013, June, Addis Abeba, Ethiopia), pp.161-164.*

2.4. Data Collection

Total tuber yield of each genotype was estimated from plants counted at harvest in the four middle rows. Tubers were carefully collected after the hills were hand dug. The collected total tubers in each plot were weighted and converted to yield tons per hectare. Tubers which were free from diseases, insect pests and greater than or equal to 20g in weight were sorted, weighted for each plot and recorded as marketable yield (t ha^{-1}).

Disease assessment was conducted starting 30 August 2013 after 46 days of planting as soon as disease symptoms appear in susceptible genotypes and then after every 20 days until majority of the genotypes attained physiological maturity. Disease incidence and severity were assessed following CIP (2006) guideline and other established procedures. Assessment of severity late blight under field conditions in percent was recorded on plot basis taking in account the number of plants developing disease symptoms in a leaf and/or many leaves and plants free from disease Henfing (1987) as described in Table 2. Disease assessment was done by the same three evaluators without knowing the value given at the previous reading.

2.5. Data Analysis

Data were subjected to analysis of variance (ANOVA) for each location and combined over environments following the standard procedure for RCBD given by Gomez and Gomez (1984) using the General Linear Model (GLM) of the SAS procedure of version 9.1 (SAS, 2007). Significant genotypes x environment mean squares were observed for tuber yield and disease severity parameters. For these traits homogeneity of variances were tested using Bartlett's test. Heterogeneity of the error variances of the individual environment experiments was observed and analysis was made for each environment.

Linear regression analysis was used to calculate the genetic gain of yield potential and disease resistance (disease severity reduction). The average annual rate of genetic gain for each trait was estimated by regressing of the mean value of each trait against the corresponding year of release of each variety (Singh and Chaudhary, 2007). Linear regression analysis was also used to estimate disease severity as cause of genetic gain in tuber yield. In this regression analysis tuber yield was considered as independent variable while disease severity was considered as dependent variables. Correlation of year of release and mean value of each variety for each trait was also calculated to understand the association of year of release and the mean performance of varieties. The annual rate of genetic gain achieved over the last 25 years of potato improvement was determined as the ratio of genetic gain to the corresponding mean value of the oldest variety and expressed as percentage.

Annual rate of gain = Cov (X, Y)/Var (X), where, X is the year of variety release, Y is the mean value of each trait for each variety; Cov is the covariance of X and Y and Var is variance of X (year of variety release). Percent genetic gain per year for each variety was calculated as Percent Genetic Gain $Year^{-1}$ = {[(XG-XAL-624)/XAL-624]/YG-YAL-624*100, where, X is the mean value of observations for a given trait and Y is the year of release of each variety (G) and Alemaya 624 (AL-624). The increment over farmers' cultivars for each trait was calculated as Percent

Increment of Variety (%) = XG – XFC/XFC*100, where, XG is the mean value of each variety for each trait and XFC is the mean value of the two farmers' cultivars (Jarso and Bete) in eastern Ethiopia. In this experiment, Alemaya 624 was considered as the oldest variety since it was the first potato variety released in the country in 1987.

Table 2. Assessment of severity late blight (%) under field conditions Henfing (1987).

Phytophthora infestans (%)		
Average	Boundaries	Symptoms
0	0	P. infestans not observed
2.5	Trace < 5	P. infestans present. Maximum 10 injuries per plant
10	5 < 15	Plants seem to be healthy, but injuries can be easily observed. There are no more than 20 affected leaves
25	15< 35	P. infestans is easily observed on the plants. About 25% of the leaf area is affected by injuries.
50	35< 65	Plants look green, but each one is affected by the pathogen, lower leaves are necrotic. About 50% of the leaf area is destroyed
75	65< 85	Plants look green with brown spots. About 75% of the leaf area is affected. Leaves in the middle of the plant are destroyed
90	85< 95	Only upper leaves are green. Most of leaves are affected and many stems have external injuries
97.5	95< 100	Plants look brown, few upper leaves are green and most of the stems are hardly affected or dead
100		Leaves and stems are destroyed

3. Results

3.1. Analysis of Variance and Mean Performance of Varieties

The analysis of variance for total and marketable tuber yield and t ha^{-1} as well as late blight severity score in each environment/location revealed significant differences (P<0.01) among genotypes (Table 3). The combined analysis across the three environments revealed the presence of significant differences among environments, genotypes and environment x variety interaction for all traits (Table 4). Absence of homogeneity of error variances for these traits leads to conduct the analysis separately for each environment.

Table 3. Mean square from the analyses of variance for tuber yields and late blight severity score of potato varieties at three locations during the 2013 cropping season.

		Trait		
Location	Source of Variation	Total tuber yield t ha^{-1}	Marketable tuber yield t ha^{-1}	Late blight severity (%)
Haramaya	Replication (2)	40.35	27.12	267.13
	Variety (17)	295.48**	236.63**	2430.94**
	Error (34)	8.82	7.61	62.23
Hirna	Replication (2)	4.95	6.43	15.7
	Variety (17)	269.38**	254.36**	1889.3**
	Error (34)	7.58	7.43	252
Arberkete	Replication (2)	4.06	3.02	162.02
	Variety (17)	134.95**	112.86**	1298.1**
	Error (34)	2.59	2.39	83.65

** and ** = significant at P<0.05 and P<0.01, respectively. Numbers in parenthesis are degrees of freedom.*

At Haramaya, all varieties except five (Mara Charre, Gudanie, Bubu, Belete and Gera) produced lower total and marketable tuber yield than the oldest variety (Alemaya 624). At Arberekete, five varieties including Belete (released in 2009) had lower total and marketable tuber yield (t ha^{-1}) than the oldest variety. On the other hand, all varieties except Gorebela (released in 2002) produced total tuber yield higher than the old and farmers varieties at Hirna. All improved varieties except two at Haramaya and Arberekete exceeded the mean tuber yield of farmers' cultivars. Considering the performance of varieties across environments, most varieties except four exceeded the oldest variety in producing tuber yield. Particularly, Mara Charre, Bubu, Gudanie and Gera exceeded the oldest variety by about 6.67 to 18.73 t ha^{-1} (Table 5 and 6).

Eight out of 16 varieties scored lower late blight severity than the oldest variety at Haramaya. All varieties except one (Chirro) had lower late blight severity scores than the mean of two farmers cultivars. In this environment, only 4 out of 11 varieties released between 1998 and 2005 scored lower late blight severity than the oldest variety (Alemaya 624). At Hirna all varieties except Gorebela and at Arberkete all varieties except Bedasa and Gorebela recorded lower late blight severity scores than the oldest variety (Alemaya 624). At Hirna all varieties but at Arberkete all varieties except Bedasa and Gorebela recorded lower late blight severity scores than mean late blight severity score of the two farmers cultivars. The two recently released varieties (Bubu and Belete) consistently recorded lowest late blight severity scores ($\leq$15%) in all the three environments. Other four varieties, Gera, Bulle, Mara Charre and Araarsaa had late blight severity scores not more than 30% in all environments (Table 7).

Table 4. Mean squares from combined analysis of variance for tuber yield and quality attributes of potato varieties tested at three locations during the 2013 cropping season.

	Trait		
Source of Variation	Total tuber yield t ha^{-1}	Marketable tuber yield t ha^{-1}	Late blight severity (%)
Replication (2)	18.37	16.35	267.7
Variety (17)	444.13**	386.59**	4468.4**
Environment (2)	3965.18**	3281.24**	11460.4**
Variety x Environment (34)	127.85**	108.63**	575.12**
Error (106)	6.68	5.97	130.9

** and ** = significant at P<0.05 and P<0.01, respectively. Numbers in parenthesis are degrees of freedom.*

Table 5. Trends of genetic gain in potato varieties released in each year (1987-2011) for total tuber yield (t ha^{-1}): percent genetic gain year^{-1} over AL-624 (oldest variety) and percent increment over mean of the two farmers' cultivars.

Variety	Year of release	Haramaya Mean TTY	Haramaya PGGY AL-624	Haramaya PIMFC	Hirna Mean TTY	Hirna PGGY AL-624	Hirna PIMFC	Arberkete Mean TTY	Arberkete PGGY AL-624	Arberkete PIMFC	Average PGGY AL-624
Alemaya 624	1987	27.26cd		62.55	33.53hi		14.09	33.6d		19.66	
Chirro	1998	17.19hij	-3.36	2.50	44.64de	3.01	51.89	41.96ab	2.26	49.43	0.91
Zemen	2001	16.89ij	-2.72	0.72	45.21de	2.49	53.83	34.8d	0.26	23.93	0.19
Bedasa	2001	23.12deg	-1.08	37.87	38.52fg	1.06	31.06	27.08f	-1.39	-3.56	-0.43
Gorebela	2002	19.27ghi	-1.95	14.91	21.15k	-2.46	-28.04	18.36h	-3.02	-34.62	-2.52
Guasa	2002	15.44ij	-2.89	-7.93	50.45c	3.36	71.66	40.15bc	1.30	42.98	0.82
Jalenie	2002	16.59ij	-2.61	-1.07	42.93ef	1.87	46.07	34.18d	0.12	21.72	-0.05
Gera	2003	28.47c	0.28	69.77	55.27ab	4.05	88.06	30.67e	-0.55	9.22	1.33
Chala	2005	26.07cde	-0.24	55.46	51.49bc	2.98	75.20	34.8d	0.20	23.93	1.06
Bulle	2005	25.78cde	-0.30	53.73	35.13gh	0.27	19.53	22.73g	-1.80	-19.05	-0.63
Gabbisa	2005	21.93e-h	-1.09	30.77	47.64cd	2.34	62.10	37.75c	0.69	34.44	0.76
Mara Charre	2005	54.31a	5.51	223.85	56.52a	3.81	92.31	39.79bc	1.02	41.70	3.31
Gudanie	2006	38.58b	2.19	130.05	43.95de	1.64	49.54	34.09d	0.08	21.40	1.24
Araarsaa	2006	24.3c-f	-0.57	44.90	43.63de	1.59	48.45	37.5c	0.61	33.55	0.62
Belete	2009	28.76c	0.25	71.50	45.54de	1.63	54.95	30.25e	-0.45	7.73	0.49
Bubu	2011	35.56b	1.27	112.05	46.94cde	1.67	59.71	43.2a	1.19	53.85	1.38
Jarso		13.94j			30.52il			25.32fg			
Bete		19.59f-i			28.26j			30.83e			
Mean released varieties		26.22	-0.49	56.35	43.91	1.95	49.40	33.81	0.03	20.39	0.56
Mean farmers cultivars		16.77			29.39			28.08			
LSD (5%)		4.93			4.57			2.67			
CV (%)		11.8			6.5			4.8			

Means with the same letters are not significantly different at P<0.05. LSD = least significant difference, TTY = total tuber yield tons per hectare, PGGY AL-624 = percent genetic gain year^{-1} over AL-624, PIMFC = percent increment over mean of farmers cultivars, CV = coefficient of variation in percent, Average PGGY AL-624 = average percent genetic gain year^{-1} over AL-624 over three locations.

Table 6. Trends of genetic gain in potato varieties released in each year (1987-2011) for marketable tuber yield (t ha^{-1}): percent genetic gain year^{-1} over AL-624 (oldest variety) and percent increment over mean of the two farmers' cultivars

Variety	Year of release	Haramaya Mean MTY	Haramaya PGGY AL-624	Haramaya PIMFC	Hirna Mean MTY	Hirna PGGY AL-624	Hirna PIMFC	Arberkete Mean MTY	Arberkete PGGY AL-624	Arberkete PIMFC	Average PGGY AL-624
Alemaya 624	1987	24.59cd		68.89	28.69hi		12.33	29.89gh		22.65	
Chirro	1998	15.94fgh	-3.43	9.48	41.45de	4.04	62.29	37.84ab	2.42	55.27	1.32
Zemen	2001	15.85fgh	-2.72	8.86	43.59cd	3.71	70.67	31.71efg	0.43	30.12	0.69
Bedasa	2001	21.33de	-1.19	46.50	35.12fg	1.60	37.51	24.6j	-1.26	0.94	-0.18
Gorebela	2002	17.78efg	-2.03	22.12	18.44j	-2.38	-27.80	16.82l	-2.92	-30.98	-2.41
Guasa	2002	13.92gh	-3.04	-4.40	46.73bc	4.19	82.97	36.33bc	1.44	49.08	1.11
Jalenie	2002	15.66fgh	-2.59	7.55	38.43ef	2.26	50.47	31.02g	0.25	27.29	0.16
Gera	2003	26.59c	0.24	82.62	51.38a	4.94	101.17	27.98hi	-0.40	14.81	1.71
Chala	2005	24.52cd	-0.23	68.41	47.07abc	3.56	84.30	32.28efg	0.44	32.46	1.38
Bulle	2005	23.63cd	-0.43	62.29	32.22gh	0.68	26.16	20.41k	-1.76	-16.25	-0.46
Gabbisa	2005	20.14def	-1.18	38.32	43.21cd	2.81	69.19	34.06cde	0.78	39.76	0.95
Mara Charre	2005	47.48a	4.75	226.10	50.11ab	4.15	96.20	35.07cd	0.96	43.91	3.31
Gudanie	2006	35.85b	2.11	146.22	41.41de	2.33	62.14	31.23fg	0.24	28.15	1.60
Araarsaa	2006	22.81cd	-0.57	56.66	41.25de	2.30	61.51	33.64def	0.66	38.04	0.92
Belete	2009	27.26c	0.30	87.23	41.82de	2.08	63.74	28.16hi	-0.26	15.55	0.77
Bubu	2011	33.48b	1.28	129.95	43.91cd	2.21	71.93	39.54a	1.35	62.25	1.69
Jarso		12.07h			26.41i			21.62k			
Bete		17.04efg			24.67i			27.11ij			
Mean released varieties		24.18	-0.58	66.05	40.30	2.57	57.80	30.66	0.16	25.82	0.84
Mean farmers cultivars		14.56			25.54			24.37			
LSD (5%)		11.9			4.52			2.57			
CV (%)		4.58			7.1			5.2			

Means with the same letters are not significantly different at P<0.05. LSD = least significant difference, MTY = marketable tuber yield tons per hectare, PGGY AL-624 = percent genetic gain year^{-1} over AL-624, PIMFC = percent increment over mean of farmers cultivars, CV = coefficient of variation in percent, Average PGGY AL-624 = average percent genetic gain year^{-1} over AL-624 over three locations.

Table 7. Trends of genetic gain in potato varieties released in each year (1987-2010) for late blight severity: percent genetic gain year^{-1} over AL-624 (oldest variety) and percent increment over mean of the two farmers' cultivars

Variety	Year of release	Haramaya			Hirna			Arberkete			Average PGGY AL-624
		Mean Severity	PGGY AL-624	PIMFC	Mean Severity	PGGY AL-624	PIMFC	Mean Severity	PGGY AL-624	PIMFC	
Alemaya 624	1987	50cd		-45.05	32b		-48.39	23d		-36.11	
Chirro	1998	95a	8.18	4.40	12cd	-5.68	-80.65	13def	-3.95	-63.89	1.30
Zemen	2001	87a	5.29	-4.40	12cd	-4.46	-80.65	18def	-1.55	-50.00	0.82
Bedasa	2001	68b	2.57	-25.27	23bc	-2.01	-62.90	37bc	4.35	2.78	1.56
Gorebela	2002	48d	-0.27	-47.25	60a	5.83	-3.23	60a	10.72	66.67	4.00
Guasa	2002	67b	2.27	-26.37	8cd	-5.00	-87.10	10ef	-3.77	-72.22	-1.27
Jalenie	2002	62bc	1.60	-31.87	17bcd	-3.13	-72.58	20def	-0.87	-44.44	-0.38
Gera	2003	25fg	-3.13	-72.53	5d	-5.27	-91.94	23d	0.00	-36.11	-3.10
Chala	2005	70b	2.22	-23.08	8cd	-4.17	-87.10	20def	-0.72	-44.44	-0.37
Bulle	2005	10h	-4.44	-89.01	15cd	-2.95	-75.81	22de	-0.24	-38.89	-3.07
Gabbisa	2005	50cd	0.00	-45.05	15cd	-2.95	-75.81	20def	-0.72	-44.44	-1.06
Mara Charre	2005	30ef	-2.22	-67.03	5d	-4.69	-91.94	13def	-2.42	-63.89	-3.02
Gudanie	2006	40de	-1.05	-56.04	12cd	-3.29	-80.65	23d	0.00	-36.11	-1.50
Araarsaa	2006	27f	-2.42	-70.33	10cd	-3.62	-83.87	18def	-1.14	-50.00	-2.51
Belete	2009	13gh	-3.36	-85.71	8cd	-3.41	-87.10	15def	-1.58	-58.33	-2.99
Bubu	2011	13gh	-3.08	-85.71	4d	-3.65	-93.55	8f	-2.72	-77.78	-3.17
Jarso		95a			60a			47b			
Bete		86.67a			63a			25cd			
Mean released varieties		47	0.14	-48.15	15	-3.23	-75.20	21	-0.31	-40.45	-0.98
Mean farmers cultivars		91			62			36			
LSD (5%)		13.09			15.47			12.46			
CV (%)		15.2			45.4			32.4			

Means with the same letters are not significantly different at P<0.05. LSD = least significant difference, Mean severity = severity of late blight in percent, PGGY AL-624 = percent genetic gain year^{-1} over AL-624, PIMFC = percent increment over mean of farmers cultivars, CV = coefficient of variation in percent, Average PGGY AL-624 = average percent genetic gain year^{-1} over AL-624 over three locations.

3.2. Estimates of Gain for Tuber Yield

The highest estimates for annual percent genetic gain of total tuber yield was noted at Hirna (Gera= 4.05%) and the lowest was -3.02% at Arberkete for Gorebela (released in 2002). Mara Charre and Bubu which were released in 2005 and 2011, respectively, had highest percent genetic gain over the oldest variety (Alemaya 624) for total tuber yield across the three environments (Table 5). These varieties also exhibited consistently higher percent genetic gain across three environments while Gorebela recorded consistently lower genetic gain for marketable tuber yield (t ha^{-1}). Chirro had lowest (-3.43%) at Haramaya and Gera (4.94%) at Hirna had highest percent genetic gain relative oldest variety for marketable tuber yield (t ha-1) (Table 6). The annual rate of gain over the oldest variety (Alemaya 624) in percent ranged between -1.62 (Haramaya) and 2.44% (Hirna) for total tuber yield while it was in the range between -1.77 and 2.68% for marketable tuber yield t ha^{-1}. The overall annual rate of gain over the oldest variety in percent was 1.79 and 1.86% for total and marketable tuber yield, respectively (Table 8).

Total tuber yield and varieties year of release had positive but weak (r = 0.09) association at Arberkete while relatively strong (r = 0.39) for total and marketable tuber yield at Hirna. The coefficient of determination (R^2) was as low as 0.079 for total tuber yield at Arberkete and high (R^2 = 0.1523) for marketable tuber yield at Hirna (Figure 1 and 2). It was observed the reduction of -0.04 and -0.02 t ha^{-1} year^{-1} of total and marketable tuber yield, respectively, at Haramaya while the highest increase of 0.46 and 0.58 t ha^{-1} year^{-1} of total and marketable tuber yield, respectively, at Hirna. The absolute reduction and increase of tuber yields t ha^{-1} year^{-1} were computed as absolute reduction and increase of 15 varieties mean yield over Alemaya 624 divided by 25 years (starting 1987 the first variety release year) to 2011 (the year of recently released variety, Bubu in the experiment) (Table 8).

Table 8. Estimation of coefficient of determination (R^2), average rate of gain (b), the annual absolute and relative genetic gain (RGG) for average tuber weight and quality related traits of potato varieties

Trait	CD (R^2)	AAGG-AL-624	RAGG AL-624 (%)	AGIFC	RGIFC (%)	Annual rate of gain (b) (%)
HU TTY t ha^{-1}	10.49	-0.04	-0.16	0.06	0.24	-1.62
Hirna TTY t ha^{-1}	14.78	0.46	1.38	0.38	2.25	2.44
Arber TTY t ha^{-1}	7.9	0.01	0.03	0.23	0.68	0.34
Average TTY t ha^{-1}	11.86	0.14	0.45	0.23	1.06	1.79
HU MTY t ha^{-1}	10.16	-0.02	-0.07	0.11	0.50	-1.77
Hirna MTY t ha^{-1}	15.23	0.58	2.11	0.59	2.31	2.68
Arber MTY t ha^{-1}	9.8	0.03	0.11	0.25	0.82	0.38
Average MTY t ha^{-1}	15.77	0.18	0.64	0.32	1.21	1.86
HULB Severity	25.24	-0.13	-0.25	-1.76	-1.93	-10.40
Hirna LB Severity	7.4	-0.74	-2.31	-1.88	-3.03	-1.00
Arberkete LB Severity	26.94	-0.07	-0.30	-0.60	-2.86	-8.30
Average LB Severity	32.21	-0.31	-0.89	-1.39	-2.22	-5.74

CD (R^2) = Coefficient of determination, AAGG-AL-624 = absolute annual average genetic gain over Alemaya 624 (oldest variety), RAGG-AL-624 (%) = relative annual average genetic gain over Alemaya 624 (oldest variety), AGIFC = absolute annual average increment over mean of farmers cultivars, RGIFC (%) = relative annual average increment over mean of farmers cultivars

The lowest absolute increase of total tuber yield (0.06 t ha^{-1} year^{-1}) over the mean of two farmers' cultivars was recorded at Haramaya while the highest (0.38 t ha^{-1} year^{-1}) was registered at Hirna. The lowest (0.11 t ha^{-1} year^{-1}) and highest (0.59 t ha^{-1} year^{-1}) absolute increase of marketable tuber yield over the mean of two farmers' cultivars was recorded for the same locations over the last 25 years (Table 8).

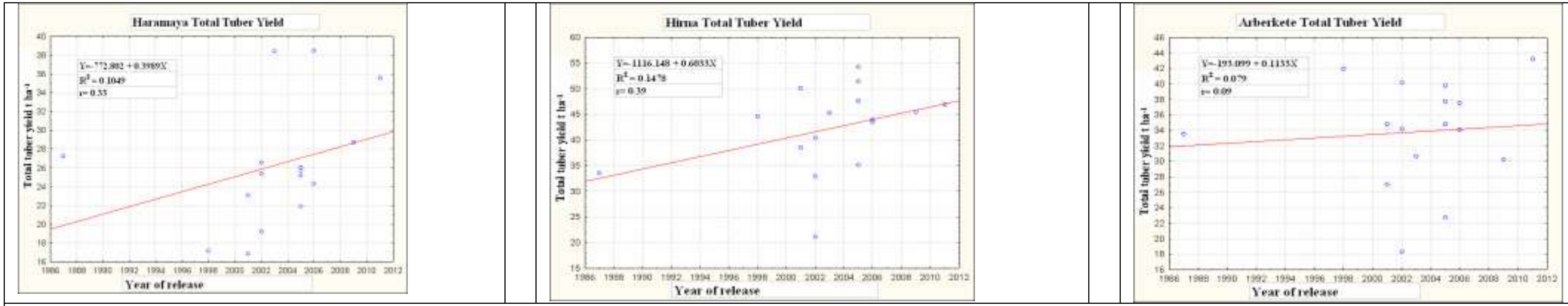

Figure 1. Linear regression of potato total tuber yield on year of variety release with equation of best-fit line for three environments.

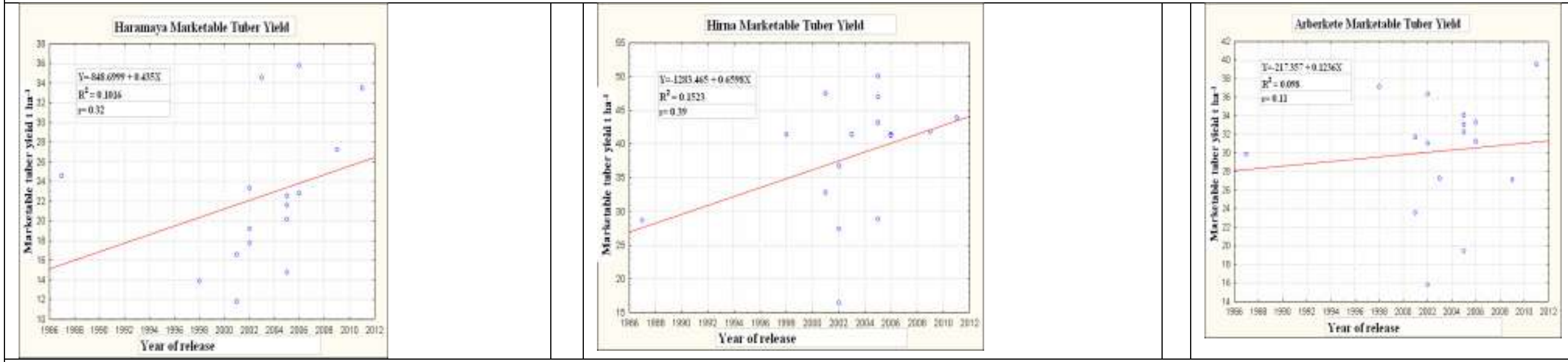

Figure 2. Linear regression of potato marketable tuber yield on year of variety release with equation of best-fit line for three environments.

3.3. Estimates of Gain for Late blight Resistance

Late blight severity score was higher than the oldest variety at Haramaya while all varieties except Gorebela both at Hirna and Arberkete and Bedasa at Arberkete had lower percent late blight severity score. Percent genetic gain relative to Alemaya 624 ranged from the increase of 10.72% (Gorebela) at Arberkete to the reduction of 5.68% late blight severity year^{-1} (Chirro) at Hirna. The two farmers' cultivars recorded the highest percent late blight severity in all environments except Chirro at Haramaya, Bedasa at Arberkete and Gorebela at Hirna and Arberkete. Percent reduction of late blight severity ranged from -4.4% (Zemen) at Haramaya to -93.55% (Bubu) at Hirna as compared to mean late blight severity score of farmers' cultivars (Table 8).

The absolute reduction of late blight severity was as high as 0.74% at Hirna and as low as -0.07% year^{-1} at Arberkete over Alemaya 624 (oldest variety) with average annual absolute reduction of 5.74%. Improved varieties absolute reduction of late blight severity for the last 25 years was highest (-1.88% year^{-1}) at Hirna and lowest (--0.60% year^{-1}) at Arberkete as compared to the mean of two farmers cultivars. Annual rate of gain (b) reduction of late blight severity due to the improved and released varieties for the last 25 years was highest (-10.4%) at Haramaya but it was lowest (-1%) at Hirna with average Annual rate of reduction of 5.74% (Table 8).

The late blight severity score for varieties showed negative association with release year of varieties and had strong negative association at Arberkete (r=-0.52) and Haramaya (r=-0.51) and weak association at Hirna (r=-0.086). The R^2 was as high as 0.2694 and as low as 0.0074 at Arberkete and at Hirna, respectively (Figure 4). Late blight severity scores explained the observed yield variations by about 31.39, 80.1 and 67.89% at Haramaya, Hirna and Arberkete, respectively (Figure 5). Mean total tuber yield variation over environments was also explained by about 43.71% due to late blight severity. Late blight severity score and tuber yield had negative association ranged from r = -0.024 (Haramaya) to r = -0.895 (Hirna) (Figure 3).

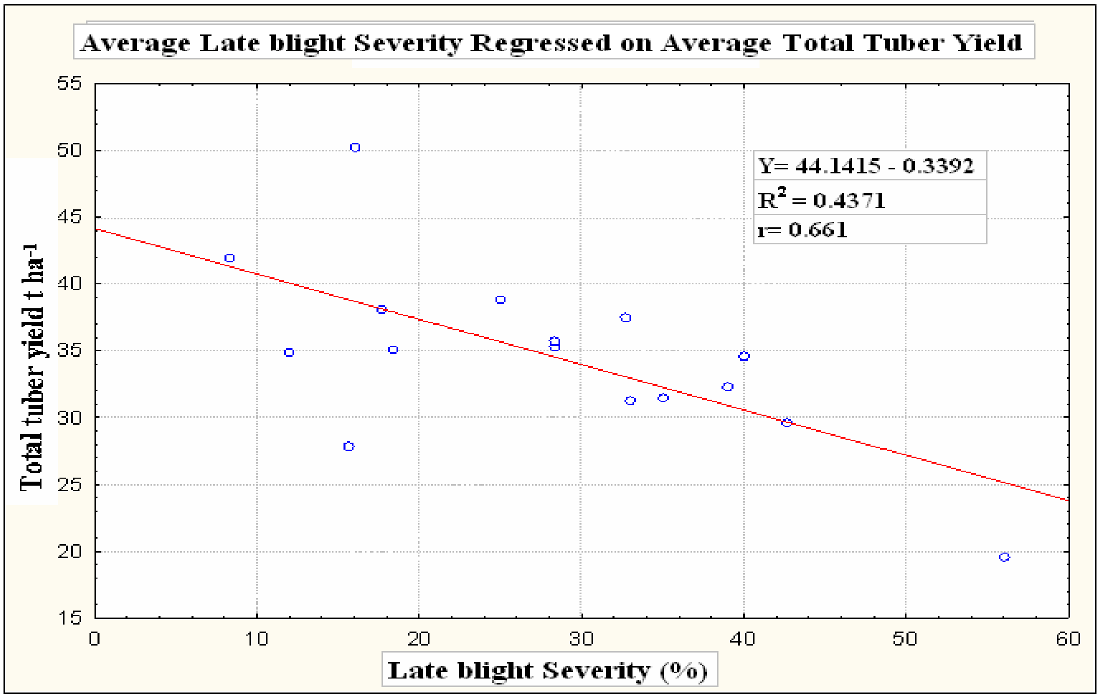

Figure 3. Linear regression of average late blight severity over three locations on average total tuber yield of varieties with equation of best-fit line

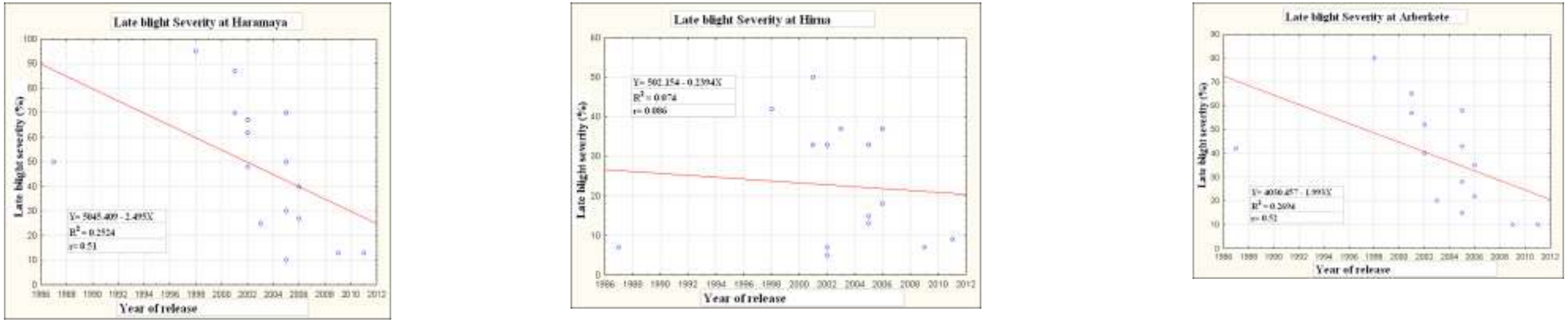

Figure 4. Linear regression of potato late blight severity on year of variety release with equation of best-fit line for three environments

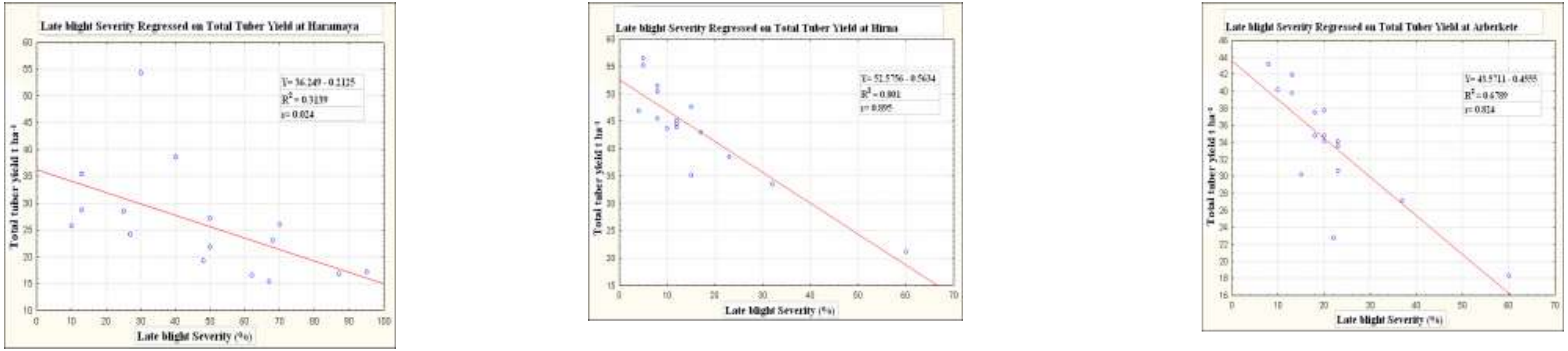

Figure 5. Linear regression of average late blight severity on total tuber yield of varieties of at three environments with equation of best-fit line.

4. Discussion

Potato varieties developed for different agroecologies of the country by separate efforts of breeders at different research centers exhibited significant differences for tuber yield. Relatively, most of the varieties released in 2005 and onwards produced higher tuber yield across locations while most of other varieties released before 2005 performing highest yield in one environment but low in other environment. The percent genetic gain of varieties calculated relative to varieties year of release and oldest variety and annual rate of gain in percent for tuber yield also varied across locations. However, the average annual rate of gain in percent was 1.79 and 1.86 for total and marketable tuber yield, respectively, which can be consider as highest gain. One of the many potential new cultivars will be best in all environments and selection in one type of environment has consequences for performances in different types of environment (Falconer and Mackay, 1996). This might be due to that quantitative traits such as yield are highly influenced by environment than qualitative traits (Bernardo, 2010). Because, yield depends on many factors which is controlled by many genes and subject to considerable modification by differences in environment (Beukema and Vander Zaag, 1990, Briggs and Knowles, 1985). The significant variation of tuber yields in potato due to variety, environment and genotype x environment interaction were also reported by other researchers (Flis *et al*., 2014; Mulugeta, and Dessalegn, 2013; Elfinesh, 2008; Mulema *et al*., 2008; Mateo *et al*., 2007).

Potato improvement for late blight resistance seems successful in Ethiopia when the successive released varieties were compared to the oldest variety and farmers' cultivars. But, most of the varieties were more susceptible for late blight as compared to oldest variety in hot spot area (Haramaya). On average -5.74% annual rate of gain in percent was computed for late blight severity score, coefficient of determination was relatively higher and the correlation between varieties year of release and severity score was negative and strong in two locations. This showed that the general trend in the last 25 years potato improvement was in developing more resistant varieties. Late blight severity score explained the tuber yield variations as less than 31% and at most 80% across environments with average of 66.1% over locations. This was very high for the single factor contribution to tuber yield and it suggested the impossibility of attaining notable progress in tuber yield without incorporating resistance to late blight in potato varieties. Late blight is the most serious fungal disease, occurs almost everywhere and if not controlled, losses may reach 100 percent (Henfling, 1987). In highland areas of Ethiopia, late blight disease cause potato production loss estimated up to 70% (Mekonen *et al*., 2011). This fact was also observed in this study by the inverse relation of tuber yield and late blight severity score in percent.

The general trend of potato improvement as evaluated from average annual rate of gain in percent for tuber yield and late blight resistance could be considered as high in the country for a quarter of a century. On the other hand, highly significant differences were among varieties for tuber yield and late blight resistance due to environment/location and genotype x environment/location interaction. The annual gain rates of varieties and percent annual genetic gain across environment/locations varied for tuber yield and late blight resistance. Only few varieties developed by three centers consistently performed better for both traits. Majority of varieties (10 out of 16 varieties) had disease score >40% which can be considered as susceptible at disease hot spot area (Haramaya). If genotypes are performing differentially at different environments, it is possible to increase genetic gains in yield from narrowing the environment(s) favourable the varieties and thus maximizing yield in particular areas by exploiting genotype x environment interaction (Teferi, 2009; Dixon *et al.,* 1991). This supported the current potato breeding approach where each research center is developing varieties for their respective agro-ecology for which they are responsible and located.

But, the susceptibility of the majority of the varieties for late blight at environment favorable for the pathogen showed either the appearance of new race of the pathogen (A2 type) because it is not restricted to one region (Drenth *et al*., 1995, Goodwin and Sujkowski, 1995) and can be dispersed anywhere in the country. On the other hand, varieties might loose resistance due to the ability of *P. infestans* to rapidly evolve to overcome resistance major genes (Stewart *et.al.,* 2003, Wastie, 1991) and the new aggressive race of the pathogen can be distributed throughout the country. Varieties might also carry varying number of R-genes, but they were all considered as resistant in the absence of the races or where the environment was not favored the pathogen (Beukema and Van Der Zaag, 1979). But, either the environment is becoming favourable for the pathogen or the races are introduced in the region, the varieties that showed susceptible reaction to the pathogen will not be considered for cultivation unless other disease control measures are employed. Demand is in progress for varieties for large scale production, export and specific processing industries. The evolution of new virulent pathogen races, changing market and end-user demands with larger target areas force breeders to consider a wider range of production constraints, multiple traits and make heavy investments in breeding. The country cannot afford the required huge investment and skill human power for the existing potato breeding approach (development of varieties for different agroecologies) to match the changing cropping scenarios and economics of production. This demands a dynamic cooperation among scientists in the country for complementary efforts to achieve essential operational sizes; draw sound hypotheses and strategies that can be translated into breeding objectives. This includes testing of germplasm across a wide range of environments, exchange information among researchers and develop wide adaptable varieties for all desirable traits.

5. Summary and Conclusion

The understanding of the changes produced by plant breeding on potato tuber yield and yield determinants (mostly late blight), through the study of the behaviour of cultivars released at different times is important. Because it is a useful tool to define and suggest future selection criteria and future breeding approach in the country. This research was conducted for the first time in the country aiming to examine the genetic improvement of potato tuber yield and reduction of late blight severity through successive development and release of varieties for the last 25 years. The research revealed progressive improvement of the crop over years in the country for tuber yield and reduction of late blight severity. Potato improvement achieved highest annual rates of gain in percent for tuber yield and late blight resistance (>1.7%), because raising the rate of genetic gain from 1% to more than 2% annually for a quarter of a century is a key component of agricultural transformation. The change in tuber yield was associated with changes in lower late blight severity score with changing of scores across environments in different varieties. Susceptibility of most of the varieties for late blight in the environment which was favourable for the pathogen and few varieties performed better for tuber yield and late blight resistance across environments. This suggested the need to change the existing potato breeding approach that depends on separate efforts of breeders to develop varieties for specific agro-ecologies and local consumption (traditional meals). This call for the joint and nationally coordinated efforts of researchers to develop wide adaptable varieties that match the changing market and end-user demands, economics of scale and the evolution of new virulent pathogen races for larger target areas.

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7. Genetic Variability in Potato (*Solanum tuberosum* L.) Genotypes for Late blight [*Phytophthora infestans* (Mont.) de Bary] Resistance and Yield at Haramaya, Eastern Ethiopia

Wassu Mohammed

Haramaya University, School of Plant Sciences, P O Box 138, Dire Dawa, Ethiopia
Author Email: wasmoha@yahoo.com

Abstract: Late blight (*Phytophthorainfestans* de Bary) is the most important and destructive disease of potato (*Solanumtuberosum* L). The pathogen has the ability to rapidly evolve and overcome resistance genes, leading commercial potato varieties to succumb to the disease. Therefore, evaluation of commercial varieties for resistance should not be a one time task, but a routine breeding activity. This study was, therefore, conducted to determine the genetic variability of potato varieties in terms of resistance to the late blight and yield potential at Haramaya in 2013/14 cropping season under natural epiphytotic conditions. A total of 21 potato genotypes (Alemaya 624, Araarsaa, Belete, Bubu, Bulle, Chala, Chiro, CIP-384321/3A, CIP-384321/3B, Gabbisa, Gera, Gorebela, Guasa, Gudanie, Jalanie, Jarso, Mara Charre, Moti, and Zemen) were evaluated using a randomized complete block design (RCBD) with three replications. The genotypes showed highly significant (P<0.01) differences in reaction to the disease (disease intensity, severity, score and AUDPC) and yield potential. Only three varieties (Bubu, Belete and Bulle) were found to be resistant to the disease, with the other three varieties (Gera, Araarsaa and Mara Charre) being moderately resistant. High broad sense heritability (H^2) (47.78 to 91.02%) and genetic advance in percent mean (GAM) (58.87 to 96.31%) were computed for both disease and yield parameters. High genotypic and phenotypic variances were recorded with low magnitude of differences for all parameters, and the environmental variance was much lower than the two other variances. Strong and positive genotypic and phenotypic correlations were observed among the disease score parameters and unmarketable tuber yield while strong and negative correlations were observed between disease score and the two yield parameters (total and marketable tuber yields). This indicated that the traits are highly heritable with the involvement of more additive gene action and are amenable for selection. The dendrogram of the 21 potato genotypes using Unweighted Pair-group Method with Arithmetic means (UPGMA) analysis and Euclidean distances separated the genotypes into three clusters and four sub-groups where resistant, moderately resistant, and high yielding varieties were grouped into the first cluster while all susceptible and low yielding genotypes were grouped under Cluster III. The resistant varieties were found to be the most distant from many of the genotypes but were closer to each other. However, genetic similarities were observed among the susceptible genotypes. The presence of genetic variability and the high heritability, coupled with high genetic gain of the traits, suggest the potential of improving for disease resistance and yield through selection. The study also suggests utilization of the identified resistant varieties for producing the crop. However, sustaibable production of thes varieties is unlikely since the disease rapidly evolves to overcome the resistance genes of the plant, impying that integrated management of the diasease is the most practical option.

Keywords: AUDPC (Area under Disease Progress Curve); Broad sense heritability; Euclidean distance; Genetic distance; Genetic variability; Varieties

1. Introduction

Potato (*Solanum tuberosum* L.) is one of the most widely grown food crops after the three cereals viz., maize, rice and wheat (Vleeshouwers *et al.*, 2011). In Eastern Africa, potato is the best crop for food and nutrition security where food security is a key priority for the over 200 million people whose number is predicted to double by 2030 (Kyamanywa *et al.,* 2011). Under such increasing pressure on the fixed land, increasingly degraded environment and uncertainties resulting from climate change, producing crops like potato with high plasticity to environmental regimes and higher yield per unit area is indispensable. However, existing climate change may also increase the risk of epidemic disease development for potato production particularly of late blight of potato which may result in yield reductions (Baker *et al.*, 2005; Hijmans, 2003).

Late blight [*Phytophthorainfestans* (Mont.) de Bary] affects all parts of the crop and can destroy a potato field within a few days (Razukas *et al.*, 2008). Late blight is not only the most serious fungal disease, but it also occurs almost everywhere where potatoes are grown and is especially important in the traditional potato growing areas. If not controlled, losses may reach 100 percent (Rubio-Covarrubias *et al.*, 2005) and even lower infection levels may make the crop unfit for storage (Henfling, 1987). In the highlands of Ethiopia, late blight and bacteria wilt (*Ralstoniasolanacearum*) are the most important economic diseases that cause an estimated yield loss of up to 70% (Mekonen *et al.*, 2011).

Host resistance is the best control measure as compared to fungicide spray since the latter is expensive while the former is more economical and environmentally sustainable. Potato breeding for resistance to late blight has been going on worldwide for several decades. Despite this effort, the majority of commercially grown potato varieties succumb to to late blight too soon. In the early 1900s, potato breeders successfully introgressed resistance from wild species (*Solanum demissum* Lindl.) into the cultivated potato. However, this major gene resistance was quickly overcome by *P. infestans* (Wastie, 1991). Subsequently, a total of 11 major dominant resistance genes (*R* genes) were identified, but these genes have been defeated by *P. infestans*. Even so, there is some evidence that they may be useful when combined with other sources of resistance (Stewart *et al.,* 2003).

In Ethiopia, 30 potato varieties have been released by the research system since 1987; however, considerable number of varieties have become susceptible to late blight and, hence, gone out of production (Gebremedhin, 2013).

However, no attempt has yet been made to assess the variability of potato varieties released in the country for resistance to late blight. The varieties are merely described as resistant or moderately resistant in the variety registry books (issued by the Ministry of Agriculture) as observed at the time of the release. This is because i) the varieties were tested for late blight resistance and released by different research centers at different times for different agro-ecological areas of the country; ii) the varieties may not show differential resistance for they carry different R-genes which confer resistance in the absence of virulent races of the pathogen and environment favourable to the pathogen; iii) each center maintains a portion of the released varieties for its geographic area; iv) centers are located at different agro-ecologies which may not equally favor all races at same cropping season or v) there may be a race change, i.e., the presence of A2 type of the pathogen because this race is dispersed worldwide and not restricted to temperate region (Drenth *et al.*, 1995, Goodwin *et al.*, 1995).

Researchers in Ethiopia obtained the germplasm for selection in the form of advanced clones, tuber families, and true potato seed. The variations were generated by crossing different genotypes and selfing the heterozygotes at International Potato Center (CIP) in Peru. (Gebremedhin *et al.*, 2008). Most of the potato varieties that have been released before 2008 possessgenes for either vertical resistance or horizontal resistance to late blight in the presence of unknown resistance major R genes (Gebremedhin, 2013). Earlier genetic analyses demonstrated that 11 known R genes introgressed from *Solanum demissum* (Black *et al.*, 1953). The clustering of functional genes for qualitative and quantitative resistance to various pathogens suggests their evolution from common ancestors by local gene duplication, followed by functional diversification (Gebhardt and Valkonen, 2001; Oberhagemann *et al.*, 1999; Leister *et al.*, 1996; Leonards-Schippers *et al.*, 1994).

Therefore, varieties released in Ethiopia for different agroecologies at different periods, carrying different genes for resistance and tested at different environments, are expected to have wide genetic variations. However, genetic variability study has not been conducted to estimate the extent of the variations and genetic distance among the released potato varieties in the country.

In addition, the late blight disease of potato has mutable features so that it can overpass any resistance. When limited potato cultivars are used for resistance against it, the disease can violate large potato cultivar groups in different years. As a result, potato cultivars described as resistant to *Phytophtora infestans* today might not be resistant in subsequent season (Song *et al.*, 2003). Therefore, analyzing the late blight resistance helps to determine differences in disease development not only between various susceptibility potato cultivars, but also to find differences in the same potato cultivar every separate research year (Razukas *et al.*, 2008). A group of scientists have opinion that it is necessary to apply few methods for potato cultivars evaluation for susceptibility to the late blight such as testing of all cultivars in area where the environment favours the pathogen (Lee *et al.*, 2001).Therfore, it is believed that potatoes meant for breeding programs have to be tested not only under field conditions with the natural late blight infection, but also in the laboratory making artificial infection settings (Asakaviciute *et al.,* 2006; Razukas and Jundulas, 2005). This is because, in the case of selection for stress conditions, the genotype x environment interaction is of basic importance and the breeder is greatly challenged. Therefore, for stress conditions, direct selection is more effective in the same environment than selection for the mean of both favorable and unfavorable environments (Kirigwi *et al.*, 2004; Cecarelli *et al.*, 1998; Calhoun *et al.*, 1994). Specifically, it is better to conduct studies on genetic variability of potatoes for late blight resistance in one environment where conditions favour the pathogen. Potato late blight occurs when meteorological conditions are suitable (Hansen *et al.*, 2005). The majority of released potato varieties in the country were planted at Haramaya in 2013/14 cropping season when the environmental conditions were luckly most favourable for the occurrence of the disease, which created a good opportunity for evaluating the varieties for resistance to late blight.

Therefore, this study was conducted to determine the degree of resistance to late blight by potato varieties realeased in Ethiopia and to elucidate their genetic variability in terms of resistance to the disease and yield potential.

2. Materials and Methods

2.1. Description of the Study Site

A field experiment was conducted under rain-fed condition during the 2013/14 main cropping season at the research field of Haramaya University on the main campus. The research site is located at 9 °26' N latitude, 42 °3' E longitude and at an altitude of 2022 meters above sea level. The mean annual rainfall is 760 mm (Belay *et al.*, 1998). The mean maximum and minimum annual temperatures are 23.4°C and 8.5°C, respectively (Tekalign, 2011). The mean relative humidity is 50%, varying from 20 to 81%. The soil of the experimental site is a well-drained deep alluvial soil with a sub-soil stratified with loam and sandy loam (Tamire, 1973). The soil has pH of 8.0, organic carbon, total nitrogen, available phosphorus, and exchangeable potassium contents of 1.15%, 0.11%, 18.2 mg kg $soil^{-1}$, 0.65 $cmol_c$ kg $soil^{-1}$, respectively ((Simret, 2010).

2.2. Experimental Materials and Design

A total of 21 potato genotypes i.e. seven potato varieties, which were released by Haramaya University at different times for eastern Ethiopia, 10 potato varieties, which were released by different Research Centers for different agro-ecologies of the country, two local cultivars susceptible to late blight and two potato genotypes which are under yield trial were used for the experiment (Table 1). Two farmers' cultivars (Jarso and Batte) which are known to be susceptible to late blight were used as control plants. The oldest or the first released variety (Al-624) in the country and recently released variety (Moti) were used as having one and more than one resistant genes (R-genes), respectively, which were used to compare other varieties with the oldest and most recently released ones. Other varieties are under cultivation throughout the country and they were evaluated as resistant and moderately resistant to late blight at time of their release in different years.

The experiment was laid out as a Randomized Complete Block Design (RCBD) where each genotype was replicated three times. Each plot was 3.60 m x 4.50 m (16.2 m^2) consisting of six rows, that contained a total of 12 plants per row and 72 plants per plot. The spacing between plots and adjacent replications were 1.0 and 1.5 m, respectively.

Medium-sized and well sprouted potato tubers were planted at the spacing of 75 cm between rows and 30cm between plants. All agronomic practices were applied as per the recommendation made by the Haramaya University for the region.

Table 1. Name, accession code, year of release, and yield potential under researchers' and farmers' management practices, maintainer center of potato varieties and recommended growing altitude.

No.	Variety or genotype	Accession code	Year of release	Yield (t/ha) RM	FM	Breeding Center	Recommended Altitude (m.a.s.l.)
1	Moti	KP-90147-41	2012	4.27-7.98	3.35-6.496	Sinnana Research Center	2350-3350
2	Bubu	CIP-384321-3	2011	39-42	35-39	Haramaya University	1700-2000
3	Belete	CIP-393371.58	2009	47.2	28-33.8	Holeta Research Center	1600-2800
4	Araarsaa	CIP-90138.12	2006	20-42	37-50	Sinnana Research Center	2400-3350
5	Gudanie	CIP-386423.13	2006	29.0	21	Holeta Research Center	1600-2800
6	Mara Charre	CIP-389701-3	2005	33.3	28.4	Hwassa Research Center	1700-2700
7	Gabbisa	CIP-3870-96-11	2005	40.0	31	Haramaya University	1700-2000
8	Bulle	CIP-387224-25	2005	39.3	38.3	Haramaya University	1700-2000
9	Chala	CIP-387412-2	2005	42.0	35	Haramaya University	1700-2000
10	Gera	KP-90134.2	2003	25.9	-----	Sheno Research Center	2700-3200
11	Jalanie	CIP-37792-5	2002	40.3	29.10	Holeta Research Center	1600-2800
12	Guasa	CIP-384321.9	2002	24.4-33.0	22-25	Adet Research Center	2000-2800
13	Gorebela	CIP-382173.12	2002	30-52	26-30	Sheno Research Center	1700-2400
14	Badhasa	AL-114	2001	40.6	-----	Haramaya University	2400-3350
15	Zemen	AL-105	2001	37.2	-----	Haramaya University	1700-2000
16	Chiro	AL-111	1998	32-40	25-35	Haramaya University	2700-3200
17	Alemaya 624	Al-624	1987	-----	-----	Haramaya University	1700-2400
18	Batte	Local cultivar	-----	-----	-----	East Hararghe	
19	Jarso	Local cultivar	-----	-----	-----	East Hararghe	
20	CIP-384321/3A		-----	-----	-----	Under yield trial	
21	CIP-384321/3B		-----	-----	-----	Under yield trial	

Source: MoA, 2013 and 2012. Varieties with initial AL are the old potato genotypes (before 1987) maintained by Haramaya University; varieties with initial CIP are materials introduced from International Center for Potato, Peru after the first release of potato varieties in the country (1987) and varieties with KP initial are introductions other than from CIP.

Table 2. Assessment of late blight severity under field conditions (%) (Henfling, 1987).

Phytophthora infestans (%)		
Average	Boundaries	Symptoms
0	0	P. infestans not observed
2.5	Trace < 5	P. infestans present. Maximum 10 injuries per plant
10	5 < 15	Plants seem to be healthy, but injuries can be easily observed. There are no more than 20 affected leaves
25	15< 35	P. infestans is easily observed on the plants. About 25% of the leaf area is affected.
50	35< 65	Plants look green, but each one is affected by the pathogen, lower leaves are necrotic. About 50% of the leaf area is destroyed.
75	65< 85	Plants look green with brown spots. About 75% of the leaf area is affected. Leaves in the middle of the plant are destroyed
90	85< 95	Only upper leaves are green. Most of leaves are affected and many stems have external injuries
97.5	95< 100	Plants look brown, a few upper leaves are green and most of the stems are affected or dead
100		Leaves and stems are destroyed

2.3. Data Collection and Analysis

2.3.1. Disease assessment and yield data collection

Disease assessment began on 30 August 2013, i.e., 46 days after planting as soon as disease symptoms appeared on susceptible genotypes and then carried every 20 days until the majority of the genotypes attained physiological maturity. Disease incidence and intensity were assessed following CIP (2006) guideline and other established procedures described below. Area under the Disease Progress Curve (AUDPC) was also calculated from disease intensity recorded at different fixed date intervals. Disease assessment was done by the same three evaluators without knowing the value given at the previous reading.

The total tuber yield of each genotype was taken from plants in the four middle rows. Tubers were carefully collected after the hills were dug by hand. The collected total tubers in each plot were weighted and converted to tons per hectare. Tubers which were free from diseases, insect pests, and greater than or equal to 20 g in weight were sorted, and weighed for each plot and converted as marketable yield (t ha^{-1}). The remaining tubers (diseased, insect-attacked and small-sized, i.e.< 20 g) were recorded as unmarketable tuber yield (t ha^{-1}).

Assessment of the severity of late blight under field conditions in percent was recorded on plot basis taking into account the number of plants developing disease symptoms in a leaf and/or many leaves and plants free from disease following the procedures of Henfling (1987).

Disease intensity (percent severity index) was recorded on the basis of the percentage of leaf area affected by late blight and calculated for each disease assessment as follows.

$$\text{Late blight intensity } \% = \frac{\text{Summation of numerical rating}}{\text{No.plants examined} \times \text{Maximum disease score}} \times 100 \qquad 1$$

The intensity of foliar blight that was expressed in percent of the infected leaf area was used for the disease rating scale as suggested by Mohan and Thind (1999). Depending on the final record of disease intensity (%), the genotypes were classified as resistant, moderately resistant, and susceptible as per the scale (Anonymous,1997) (Table 3).

The area under disease progress curve value (AUDPC) was calculated using the following formula (Campbell and Madden, 1990) and it was interpreted directly without transformation as the higher the AUDPC, the more susceptible is the genotype (CIP, 2006).

$$\text{AUDPC} = \sum_{i=1}^{n-1} \left(\frac{y_i + y_i + 1}{2} \right) (t_{i+1} - t_i) \qquad 2$$

Where "t" is the time of each reading, "y" is the percent of affected foliage at each reading and "n" is the number of readings. The variable "t" can represent Julian days, days after planting.

Table 3. Disease score and description, intensity (%), and resistance category.

Disease Score	Score description in terms of foliage infected (%)	Disease intensity (%)	Category
0	No visible symptoms	Up to 5	Highly Resistant
1	1-10	5-20	Resistant
2	11-25	21-40	Moderately Resistant
3	26-50	Above 40	Susceptible
4	51-75		
5	>75		

2.3.2. Data analysis

Data for AUDPC, disease score, severity, and intensity and yield parameters were subjected to analysis of variance (ANOVA). Least significant difference (LSD) at 5% probability) was used to compare the means of the evaluated genotypes. The phenotypic and genotypic variance and coefficients of variation were estimated according to the methods suggested by Burton and Devane (1953). Heritability (H^2) in broad sense was computed using the formula adopted by Allard (1960) and Falconer and Mackay (1996) as: H^2 = [□ ²g/ □ ²p] x 100, where,□ □²g=genotypic variance, □ ²p= phenotypic varianceand □ ²e= error variance. Genetic advance (GA) for each trait was computed using the formula adopted by Johnson *et al.*, (1955) and Allard (1960) as:

GA= (k) (□ ²p) * (H^2), and GA (as % of the mean) $=\left[\frac{(GA)}{X}\right] x100$ 3

Where, k= selection differential (k=2.06 and 1.76 at 5% and 10%, respectively, selection intensity),□ ²p= phenotypicstandard deviation, H^2= heritability in broad sense andx=grand mean. Phenotypic and genotypic correlations between tuber yield and genotype resistance traits were estimated using the method described by Miller *et al.* (1958).

Genetic distance of genotypes was estimated using Euclidean distance (ED) calculated from the seven disease score and yield traits of 21 potato genotypes after standardization (subtracting the mean value and dividing it by the standard deviation) as established by Sneath and Sokal, (1973) as follows:

$$EDjk = \sqrt{\sum_{i=1}^{n}\left(Xij - Xik\right)^{\frac{2}{2}}} \quad 4$$

Where, EDjk = distance between clones j and k; xij and xik= disease score and yield traits mean values of the ith character for genotypes j and k, respectively; and n= number of traits used to calculate the distance. The distance matrix from disease score and yield traits was used to construct dendrograms based on the Unweighted Pair-group Method with Arithmetic means (UPGMA). The results of the cluster analysis were presented in the form of dendrogram. In addition, mean average distance (ED) was calculated for each genotype by averaging the distance of a particular potato genotype over the other 20 genotypes. The calculated average distance was used to estimate which potato genotype is closest or distant to the others.

3. Results

3.1. Analysis of Variance and Mean Performance of Genotypes

Analysis of variance computed for seven late blight disease score and tuber yield parameters of 21 potato genotypes is presented in Table 4. The analysis of variance indicated highly significant (P<0.01) variation among genotypes for all traits. The disease severity computed for each evaluation day and the last evaluation ranged from 14 to 100% (Table 6). The two farmers' cultivars (Batte and Jarso) and the two released varieties; Chiro and Zemen (old varieties, released in 1998 and 2001 next to the first released variety) were evaluated as the most susceptible genotypes with 100% disease severity. The lowest disease severity (14%) was recorded for three varieties, namely, Bubu, Belete and Bulle of which the former two were released as recently as in 2011 and 2009 while the third variety was released in 2005. Disease severity for the other three varieties, namely, Gera, Mara Charre and Araarsaa was calculated as 29% (Table 6).

Table 4. Mean squares from analysis of variance (ANOVA) for yield and late blight as evaluated in 2013/14 cropping seasons at Haramaya.

Traits	Replication (2)	Genotype (20)	Error (40)	SE	CV (%)
Disease severity (%)	213.27	2145.98**	68.32	8.27	16.4
Disease intensity (%)	169.44	2142.90**	73.61	7.01	16.1
Disease score	0.4286	3.83**	0.312	0.56	16.8
AUDPC	135887	2148278**	73263	270.70	20.5
TTY t ha^{-1}	69.99	212.50**	23.05	4.80	20.3
MTY t ha^{-1}	68.06	269.72**	20.06	4.48	22.5
UNMTY t ha^{-1}	0.464	9.629**	1.571	1.60	23.2

*** =Significant at P<0.01;numbers in parenthesis indicates degrees of freedom; SE= standard error; CV (%)= coefficient of variation in percent;AUDPC= area under the disease progress curve;TTY t ha^{-1} = total tuber yield tons per hectare; MTY t ha^{-1} = marketable tuber yield tons per hectare; UNMTY t ha^{-1} = unmarketable tuber yield tons per hectare.*

Table 5. Mean disease severity, score, AUDPC and tuber yield (t ha^{-1}) of 21 potato genotypes as evaluated in 2013/14 cropping season at Haramaya.

Genotype	Disease severity (%)	Disease score	AUDPC	TTY t ha^{-1}	MTY t ha^{-1}	UNMTY t ha^{-1}
Moti	51cd	3bc	1788de	9.48i	5.04k	4.44bcde
Bubu	13hi	2c	225j	35.56ab	33.48ab	2.07ef
Belete	13hi	2c	225j	28.74bcd	27.26bc	1.48f
Araarsaa	27fgh	3bc	507ij	24.3def	22.81cde	1.48f
Gudanie	40def	3bc	704ghi	38.52a	35.85a	2.67def
Mara Charre	30efg	2c	736ghi	25.18de	20.15cdefg	5.04abcd
Gabbisa	50cd	3bc	1146fg	21.93defg	14.81fghij	7.11a
Bulle	10i	1cd	125j	25.78de	21.63cdef	4.15bcde
Chala	70b	4b	1955cd	26.07de	22.52cde	3.56def
Gera	25gh	2c	544hij	28.44bcd	24.59cd	3.85cdef
Jalanie	62bc	4b	1535def	16.59fghi	13.33ghij	3.26def
Guasa	67b	4b	1546def	15.41ghi	9.19jk	6.22abc
Gorebela	48cd	3bc	1133fg	19.26efgh	17.78defgh	1.48f
Badhasa	69b	4b	1445ef	23.11defg	16.59efghi	6.52ab
Zemen	87a	5a	2341bc	16.89fghi	11.85hijk	5.04abcd
Chiro	95a	5a	2761ab	17.19fghi	13.93ghij	3.26def
Alemaya 624	50cd	3bc	957gh	27.26cd	24.59cd	2.67def
Batte	87a	5a	2553ab	11.26i	5.04k	6.22abc
Jarso	95a	5a	2994a	13.93hi	10.07ijk	3.85cdef
CIP-384321/3A	30efg	3bc	993g	34.37abc	32.89ab	1.48f
CIP-384321/3B	42de	3bc	1498ef	37.33a	35.26a	2.07ef
LSD (5%)	13.64	0.9216	446.7	7.922	7.392	2.646

Means followed by the same letter with in a column are not significantly different at 5% level of significance; AUDPC= area under the disease progress curve;TTY t ha^{-1} = total tuber yield tons per hectare; MTY t ha^{-1} = marketable tuber yield tons per hectare; UNMTY t ha^{-1} = unmarketable tuber yield tons per hectare.

The varieties were grouped according to their year of release and their disease severity was compared with the mean of the two farmers' cultivars and the variety released for the first time in the county (AL-624 in 1987), which is the oldest variety. All genotypes except Chiro and Zemen had reduced disease severity varying from 10 to 86% as compared to the two farmers' cultivars. When the genotypes were compared to the oldest variety, only eight genotypes had lower disease severity. Among the varieties released from 2003 onwards, only Chala and Moti had higher disease severity than the oldest variety (Table 6).

Based on the calculated AUDPC, the five varieties, namely, Bulle, Bubu, Belete, Araarsaa and Gera had the lowest AUDPC ranging from 125 to 544 while the others had the highest range, i.e., 704 to 2994. None of the genotypes had a disease score 1 except Bulle. Only four varieties (Bubu, Belete, Araarsaa and Gera) had a disease score of 2 and the remaining ones had a score of 3 and above (Table 5).

The mean marketable tuber yield ranged from 5.04 to 35.85 t ha^{-1} (Table 5). The highest total tuber yield was recorded for Gudanie (35.85 t ha^{-1}) and CIP-384321/3B (35.26 t ha^{-1}) while the lowest marketable tuber yield (5.04 t ha^{-1}) was obtained from Moti (released in 2012) and Batte (farmers' cultivar).

The varieties which scored lower disease severity and AUDPC had also higher marketable tuber yields. The lowest unmarketable tuber yields were registered for Belete, Gorebela, Araarsaa and CIP-384321/3-A while the highest was recorded for Gabbisa (7.11 t ha^{-1}) followed by Jarso (6.52 t ha^{-1}), Badhasa (6.52 t ha^{-1}), Batte (6.22 t ha^{-1}), and Guasa (6.22 t ha^{-1}).

Table 6. Disease intensity (%) in four different disease assessments and disease resistant category of potato genotypes.

Genotype		Days after planting				Decrease/increase intensity (%) over		Disease resistance category
		46	62	77	92	Farmers	First released	
Batte		14	38	90	100a			Susceptible
Jarso		17	38	100	100a			Susceptible
Mean farmers		16	38	95	100			
AL-624	1987	3	11	33	56c	-44		Susceptible
Chiro	1998	14	33	100	100a	0	44	Susceptible
Zemen	2001	4	29	100	100a	0	44	Susceptible
Badhasa	2001	0	14	38	67b	-33	44	Susceptible
Mean (2001)		2	21.5	69	84	-16	44	
Gorebela	2002	4	11	38	56c	-44	0	Susceptible
Guasa	2002	1	14	56	90a	-10	34	Susceptible
Jalenie	2002	4	14	56	61b	-39	5	Susceptible
Mean (2002)		3	13	50	69	-31	13	
Gera	2003	0	4	17	29e	-71	-27	Moderately resistant
Chala	2004	4	33	61	67b	-33	11	Susceptible
Bulle	2005	0	0	1	14f	-86	-42	Resistant
Gabbisa	2005	4	11	38	56c	-44	0	Susceptible
Mara Charre	2005	1	3	29	29e	-71	-27	Moderately resistant
Mean (2005)		2	5	23	33	-67	-23	
Gudanie	2006	0	4	17	38d	-62	-18	Susceptible
Araarsaa	2006	0	4	14	29e	-71	-27	Moderately resistant
Mean (2006)		0	4	15	34	-66	-22	
Belete	2009	0	0	4	14f	-86	-42	Resistant
Bubu	2011	0	0	4	14f	-86	-42	Resistant
Mean (2010)		0	0	4	14	-86	-42	
Moti	2012	4	21	76	90a	-10	34	Susceptible
CIP-384321/3 A	1	11	38	42	42cd	-58	-14	Susceptible
CIP-384321/3 B	4	14	56	90	90a	-10	34	Susceptible
LSD (5%)					14.16			

3.2. Genetic Variability Components

Genetic variability estimates including genotypic and phenotypic variances, phenotypic (PCV) and genotypic (GCV) coefficients of variation, heritability, and genetic advance as percent mean were computed for disease score and yield parameters (Table 7). The results of the study revealed the presence of considerable variations among genotypes for the seven parameters considered. The phenotypic variances were higher than the genotypic variances for all the traits studied. Although the phenotypic coefficients of variation were higher than the genotypic coefficients of variation, the differences were low in magnitude.

Table 7. Variability components for late blight resistance and tuber yield parameters in 21 potato genotypes as evaluated in 2013/14 cropping season at Haramaya.

Traits	Mean	GV	PV	EV	GVC (%)	PCV (%)	ECV (%)	H^2 (%)	GAM (5%)
Disease severity (%)	60.4	692.55	760.87	68.32	43.57	45.67	13.68	91.02	85.63
Disease intensity (%)	53.4	689.76	763.37	73.61	49.18	51.74	16.07	90.36	96.31
Disease score	3	1.17	1.48	0.312	36.10	40.62	18.62	78.99	66.09
AUDPC	1980	691671	764934	73263	42.00	44.17	13.67	90.42	82.28
TTY t ha^{-1}	23.65	63.15	86.20	23.05	33.60	39.26	20.30	73.26	59.25
MTY t ha^{-1}	19.94	83.22	103.28	20.06	45.75	50.97	22.46	80.58	84.60
UNMTY t ha^{-1}	3.71	2.35	4.92	2.571	41.34	59.81	43.22	47.78	58.87

GV = genetic variance; PV = phenotypic variance; EV = environmental variance; GCV = genotypic coefficient of variation; PCV = phenotypic coefficient of variation; ECV = environmental coefficient of variation; H^2 = heritability in broad sense in percent; GAM (5%) = genetic advance in percent mean at 5% selection intensity; AUDPC= area under the disease progress curve;TTY t ha^{-1} = total tuber yield tons per hectare; MTY t ha^{-1} = marketable tuber yield tons per hectare; UNMTY t ha^{-1} = unmarketable tuber yield tons per hectare.

High heritability in broad sense was computed for disease severity (91.02%), AUDPC (90.42%), disease intensity (90.36%), while relatively low heritability was estimated for unmarketable tuber yield (47.78%) and total tuber yield (73.26%). Similarly, the highest genetic advances as a percent mean (96.31%) was recorded for disease intensity while the lowest was recorded for unmarketable tuber yield (58.87). Among the yield parameters, marketable tuber yield exhibited higher heritability (80.58%) and genetic advance as a percent mean (84.6%).

3.3. Phenotypic and Genotypic Correlations

According to the procedures for standard evaluation trials of advanced potato clones (CIP, 2006), correlation between yield and genotype resistance can be calculated if yield has been evaluated in addition to the AUDPC. In this study, genotypic correlation coefficients were computed in addition to phenotypic correlation coefficients to obtain better estimates of the associations between tuber yield and disease resistance (Table 8).

Positive and highly significant (rg=0.96) genetic correlation was observed between late blight intensity and AUDPC, whereas the two disease scores had negative and highly significant (rg=-0.97) correlations with marketable tuber yield. The AUDPC exhibited significant but negative correlations with total tuber yield (rg=-0.66) and marketable tuber yield (rg=-0.58), but positive and significant correlation with unmarketable tuber yield (rg=0.62). In general, total and marketable tuber yield were negatively and highly significantly correlated with disease parameters, while unmarketable tuber yield was positively correlated. The two yield parameters also exhibited negative genotypic correlation with unmarketable tuber yield.

Disease intensity showed positive and highly significantly phenotypic correlation with other disease parameters but highest with AUDPC (rp=0.96). Unmarketable tuber yield showed positive and significant phenotypic correlation with disease intensity while total and marketable tuber yield showed negative correlations. AUDPC also showed negative and highly significantly phenotypic correlation with total and marketable tuber yield (rp=-0.63).

Table 8. Genotypic and phenotypic correlation coefficients above and below diagonal, respectively, for late blight and yield parameters in 21 potato genotypes as evaluated in 2013/14 cropping season at Haramaya.

	Disease intensity	Disease Incidence	Disease Score	AUDPC	TTY t ha^{-1}	MTY t ha^{-1}	UNMTY t ha^{-1}
Disease intensity		0.29*	0.43**	0.96**	-0.64**	-0.97**	0.58**
Disease severity	0.32*		0.31*	0.96**	-0.56**	-0.55**	0.58**
Disease Score	0.34*	0.32		0.38*	-0.54**	-0.57**	0.34**
AUDPC	0.96**	0.96**	0.35*		-0.66**	-0.58**	0.62**
TTY t ha^{-1}	-0.32*	-0.66**	-0.58**	-0.65**		0.89**	-0.43**
MTY t ha^{-1}	-0.54**	-0.67**	-0.57*	-0.65**	0.91**		-0.66**
UNMTY t ha^{-1}	0.59**	0.61**	0.48**	0.63**	-0.53**	-0.81**	

** & ** =significant at P<0.05 and P<0.01, respectively. AUDPC= area under the disease progress curve, TTY t ha^{-1} = total tuber yield tons per hectare, MTY t ha^{-1} = marketable tuber yield tons per hectare, UNMTY t ha^{-1} = unmarketable tuber yield tons per hectare.*

3.4. Genetic Distance and Clustering of Potato Genotypes

Genetic distances among the 21 potato genotypes were estimated using Euclidean distance (Table 9). Euclidean distance ranged from 0.71 (between Chiro and Jarso) to 7.23 (between Bubu and Batte) with a mean and a standard deviation of 3.43 and 1.47, respectively. Bubu and Belete were most distant from Zemen, Chiro, Batte and Jarso with Euclidean distance >6.07. Bulle was also most distant with Batte (6.6), Jarso (6.69), Chiro (6.44) and Zemen (6.1). On the other hand, Belete was close to Bubu, Gera, Bulle, Araarsaa and CIP-384321/3 A and Bubu exhibited closeness to Gudanie, Gera and CIP-384321/3 A with Euclidean distance of <2. Based on average Euclidean distance value, AL-624 (2.67) followed by Jalenie (2.86), Chala (2.87) and Gorebela (2.91) were closest to others while Batte (4.32) and Jarso (4.16) followed by Bubu (3.97), Bulle (3.92), and Chiro (3.92) were the most distant genotypes to others.

The dendrograms from UPGMA cluster analysis based on ED matrixes are presented in Figure 1. When the dendrograms cut at 2, which is above the standard deviation of the genotypic distance, the tested potato genotypes were separated into three clusters (Cluster I, II and II). Cluster I, included five released varieties with sub-group I (Belete and Bubu) and sub-group II (Gera, Mara Charre and Bulle) while Cluster II comprised of one released variety (Gudanie) and the two genotypes (CIP-384321/3-A and CIP-384321/3-B) which are under yield trial. All the other genotypes were grouped in Cluster III with two big sub-groups viz., sub-group III and sub-group IV which consists of 5 and 8 genotypes, respectively. The four out of six old varieties (released by Haramaya University) were grouped in Cluster III sub-group IV with the two farmers' cultivars. In this sub-group, the most recently released variety (Moti) was also included. Sub-group III consists of the first potato variety released in the country and varieties released starting in 2002 to 2006. The first Cluster only included relatively recently released varieties (2005 to 2011) except one variety (Gera) which was released in 2003.

Figure 1. Dendrogram generated based on UPGMA clustering method depicting genetic relationships among 21 potato genotypes based on seven late blight and yield evaluation parameters

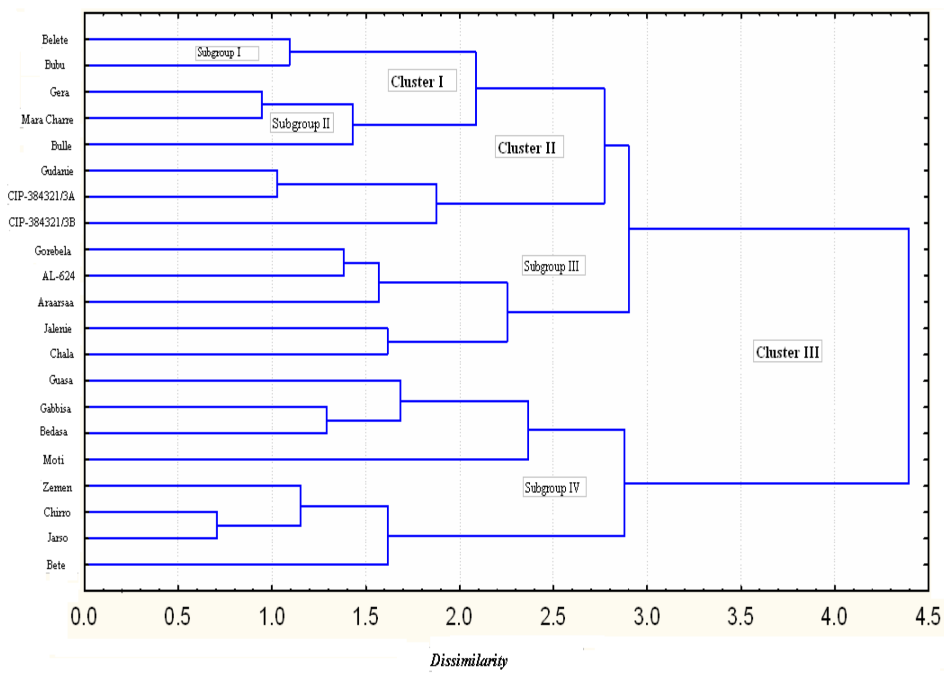

Table 9. Euclidean distance of 21 potato genotypic clones measured from seven late blight and tuber yield evaluation parameters and means Euclidean distance obtained by averaging each genotype distance to other 20 clones.

Genotype	Bubu	Gorebela	Gudanie	Guasa	Gera	Jalenie	Chala	Zemen	Chiro	Bulle	Moti	Batte	Gabbisa	Araarsaa	Mara	Badhasa	Jarso	AL-624	CIP-A	CIP-B (3.68)
Belete(3.7)	1.09	2.78	2.30	5.35	1.55	4.03	4.04	6.07	6.13	1.87	5.06	6.82	4.24	1.37	2.39	4.69	6.53	2.40	1.90	3.47
Bubu(3.97)		3.47	1.73	5.76	1.78	4.59	4.23	6.42	6.50	2.25	5.70	7.23	4.48	2.13	2.69	4.89	6.94	2.68	1.71	3.20
Gorebela(2.91)			3.16	3.28	2.49	1.61	2.18	3.69	3.61	3.36	2.78	4.44	3.18	1.60	2.59	3.13	3.97	1.38	2.54	3.09
Gudanie(3.54)				4.99	2.11	3.93	3.08	5.35	5.38	3.25	5.30	6.31	3.96	2.36	2.83	3.96	5.91	1.94	1.03	1.96
Guasa(3.38)					4.19	1.96	2.57	1.69	2.65	4.97	1.69	1.81	1.94	4.30	3.58	1.43	2.58	3.38	4.88	4.62
Gera (3.09)						3.29	3.20	5.10	5.37	1.33	4.14	5.76	2.80	1.67	0.95	3.42	5.70	1.75	2.06	3.11
Jalenie(2.86)							1.61	2.26	2.44	4.22	1.95	2.92	2.50	2.80	2.99	2.04	2.67	2.14	3.56	3.75
Chala(2.87)								2.37	2.37	4.42	3.06	3.39	2.68	3.02	3.09	1.90	2.84	1.77	2.90	2.64
Zemen(3.69)									1.17	6.10	2.60	1.21	3.27	4.90	4.68	2.22	1.13	3.83	5.17	4.66
Chiro(3.92)										6.44	3.05	2.06	4.05	4.93	5.09	3.02	0.71	3.90	5.09	4.52
Bulle(3.92)											4.70	6.60	3.46	2.48	1.53	4.37	6.69	2.97	3.18	4.29
Moti(3.59)												2.60	2.69	4.04	3.59	2.72	2.92	3.44	4.90	4.80
Batte(4.32)													3.55	5.66	5.18	2.75	1.58	4.72	6.13	5.71
Gabbisa(3.24)														3.57	2.03	1.29	4.13	2.77	4.06	4.17
Araarsaa(3.13)															2.21	3.78	5.33	1.54	1.75	3.13
Mara (3.1)																2.87	5.33	2.04	2.82	3.61
Badhasa(3.12)																	3.17	2.70	4.06	3.90
Jarso(4.16)																		4.35	5.60	5.09
AL-624 (2.67)																			1.64	2.12
CIP-A (3.34)																				1.80

Numbers in parenthesis indicates mean ED of potato genotypes, CIP-A= CIP-384321/3 A, CIP-B= CIP-384321/3 B and Mara= Mara Charre.

4. Discussion

Genetic variability was evident in potato genotypes (the released varieties, farmers' cultivars, and the genotypes under yield trial). Highly significant differences among the genotypes for late blight resistance and yield were revealed by the analysis of variance. This could be attributed to the fact that the released varieties carry varying numbers of R-genes, but were all considered as resistant in the absence of the races or where the environment did not favor the pathogen (Beukema and Van Der Zaag, 1979). This suggestion may be strengthened by the superiority of recently released varieties over the old ones in terms of resistance to late blight and tuber yield potential. In early 1900s, potato breeders successfully introgressed resistance from wild species (*Solanum demissum* Lindl.) into cultivated potato. A total of 11 major dominant resistance genes (*R* genes) were identified although they were later defeated by the disease. However, these genes are still useful when combined with other sources of resistance (Stewart *et al.,* 2003; Wastie, 1991). Most of the potato genotypes that have been released before 2008 were either with major genes for vertical resistance against late blight or were developed for horizontal resistance against the disease in the presence of unknown resistance major R genes (Gebremedhin, 2013), and named population A clones (Landeo *et al.*,1997). However, such resistance was short-lived because of the ability for the causal organism to overcome it (Landeo *et al.*, 2000a, 2000b). But, breeding efforts on population A was stopped at CIP (starting from 1990s), and the emphasis shifted to the formation of a new population where horizontal resistance is improved in the absence of major resistance (R) genes. The new population was named as population B. The main feature of this population is that testing and selection were mainly done for horizontal resistance to late blight (unlike those applied for population A), which are simplified significantly in the absence of major (R) genes. Because of the elimination of the interference effect of major R genes, breeding material can be exposed readily to any local isolates in favorable environments and allow effective screening and selection for horizontal resistance (Landeo *et al.*, 1997). Therefore, the recently released varieties may carry either many R-genes as compared to the old varieties or were improved with horizontal resistance in the absence of major resistance (R) genes.

Many of the released genotypes have become susceptible to the disease and are known either as resistant or moderately resistant. This may be because: i) the mycelia of different types of the fungus (mating types A1 and A2) grow together, one of them may form male cells (antheridia) and the other female cell (oogonia). The fertilized oogonium can resist unfavorable conditions such as drought and low temperatures (Henfling, 1987). This happens because the distribution of *P. infestans* type A2 is worldwide not restricted to the temperate region (Fry and Goodwin, 1997; Drenth *et al.*, 1995, Goodwin *et al.*, 1995), ii) *Phytophtora infestans* have mutable features so that it can overpass any resistance and potato cultivars which were described as resistant to the disease may hardly resist the new late blight race (Song *et al.*, 2003).

As suggested by Sivasubramanina and Madhavamenon (1973), genotypic and phenotypic coefficients of variations can be categorized as low (<10%), medium (10-20%) and high (>20%). In this study, high genotypic and phenotypic coefficients of variations were calculated for both late blight resistance and yield parameters. The estimated phenotypic coefficient of variation was relatively greater than the genotypic coefficient of variation for all the traits; however, the differences were low for most of the traits. This showed that the expressions of the traits were mainly the function of genetic factors with less sensitivity to environmental factors. This in turn indicates the presence of substantial genetic variability among the released potato varieties in the country.

Selection for a particular trait depends largely upon the genetic and non-genetic factors that affect the expression of phenotypic differences among genotypes. Therefore, heritability is an important estimate for the selection of traits in improving crops. Heritability estimates would be reliable if accompanied by a high estimate genetic advance (Singh and Chaudhry, 1985). As demonstrated by Robinson *et al.* (1949), heritability can be categorized as low (0-30%), moderate (30-60%) and high (60% and above) and as Johnson *et al.*, (1955) suggested genetic advance as percent mean can be categorized as low (0-10%), moderate (10-20%) and high (20% and above). In the present study, high heritability (78.99 to 91.02%) and genetic advance as percent of mean (GAM) (66.09 to 96.31%) were computed for disease resistance parameters as compared to yield parameters (H^2, 47.78 to 80.58% and GAM, 58.87 to 84.6%). However, for both parameters a combination of high heritability with high genetic advance was observed, which signifies more additive gene action (Panse, 1957), and suggesting that these traits are amenable for selection.

Positive and highly significant correlations were observed among late blight parameters both at genotypic and phenotypic levels. Late blight intensity and AUDPC exhibited negative and highly significant correlations with total and marketable tuber yields, but positive and highly significant correlations with unmarketable tuber yield. These results suggest that high intensity of the disease reduced marketable yield but favored production of unmarketable tuber yield. If yield has been evaluated in addition to the AUDPC, the correlation between yield and genotypic resistance can be calculated as a value close to unity, indicating a very high linear association between tuber yield and resistance to the disease (CIP, 2006).

The dendrogram efficiently separated the more resistant, higher yielding and recent varieties (Cluster I, sub-group I) than the susceptible and the low yielding genotypes (Cluster III, sub-group IV). This research results are in line with the history of potato improvement in Ethiopia and in the world at large. Researchers in Ethiopia obtained the germplasm for selection in the form of advanced clones, tuber families, and true potato seed from International Potato Center (CIP) in Peru (Gebremedhin *et al.*, 2008). The clones introduced at different time carry varied number and different resistance genes either they were developed for vertical or horizontal resistance.The measured genetic distance was also capable in grouping the old introduction (population A) in separate clusters different from the recently introduced clones. Potato genotypes that have been developed and released before 2008 were from population type A (Gebremedhin, 2013). Other researchers also suggested that the clustering of functional genes for the resistance to various pathogens indicates they were from common ancestors (Gebhardt and Valkonen, 2001; Oberhagemann *et al.*, 1999; Leister *et al.*, 1996; Leonards-Schippers *et al.*, 1994). Most of the varieties released before 2008 lost their resistance and exhibited genetic divergence from the recently released varieties. This might be due to the old varieties carry the race specifc genes for resistance but this might not be true in the recent varieties. The R genes conferring race specific resistance provided only transient resistance to late blight, as new races rapidly overcame the R gene-mediated resistance (Fry and Goodwin, 1997; Wastie, 1991).

The results of this study are in agreement with the findings reported by different researches both for potato and other crops. Consistent with the results of this study, Abou-Taleb *et al*., (2010) found that potatao cultivars with high, moderate, and low late blight resistance were grouped in different categories as estimated from RAPD marker. According to this author, the lowest genetic similarity was obtained with the susceptible cultivars. Pattanayak *et al.* (2002) studied the genetic diversity among resistant and susceptible potato cultivars to late blight using RAPD markers and found no clear groupings based on late blight resistance and susceptibility. But they found that susceptible and resistant potato cultivars showed narrow and wider genetic variations, respectively.

5. Conclusion

The presence of genetic viability was evident in potato genotypes from the analyses of both variance and genetic distance. The recently released varieties (Bubu and Belete) were more resistant to late blight than the others. They were grouped together and found to be most distant from many of the other genotypes, but being close to each other. The identified late blight resistant potato varieties; Bubu, Belete and Bulle could be used for potato production as a management option to control late blight in Ethiopia. High yielding and moderately resistant varieties (Gera, Araarsaa and Mara Charre) may be considered for production with less frequent chemical spray before the disease symptom observed. The high yielding variety (Jalenie) and the two genotypes (CIP-384321/3A and CIP-384321/3B) but susceptible to late blight may be recommend for dry season production under irrigation or during "belg" where environmental conditions are not favourable for the disease if the two genotypes are approved to be released. However, it is hardly possible to make recommendation for the use of resistant varieties alone as best option due to the pathogen ability to rapidly evolve to overcome resistance genes and varieties are not absolutely immune and the observed disease severity was unexpected, which might be due to the presence of the two races. Therefore, it is better to apply integrated disease control method i.e. reduction of primary sources of inoculum and less frequent applications of fungicides on varieties to extend the durable resistance. The application of fungicides must depend on the characteristics of chemicals, disease pressure and growth stage of potato crop, because this integrated approach increases the efficacy of control, reduces the costs and environmental side effects.

6. Acknowledgments

The author thanks Haramaya University for the financial support, Holeta, Adet and Sinna Research Centers for providing planting materials and technical staff of Horticulture Program at Haramaya University for their careful management of the experiment and data recording. Finally, the author thanks Dr. Mashila Dejene, senior Pathologist at Haramaya University for his technical support both in executing the experiment and writing the article.

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8. Effect of Integrated Climate Change Resilience Strategies on Faba Bean Rust (*Uromyces viciae-fabae*) Epidemics in Hararghe Highlands, Ethiopia

Habtamu Terefe[1]*, Chemeda Fininsa[1] and Samuel Sahile[2]

[1]Haramaya University, School of Plant Sciences, P. O. Box 138, Dire Dawa, Ethiopia
[2]College of Natural and Computational Science, University of Gondar, P. O. Box 196, Gondar, Ethiopia
Corresponding Author: Email: habmam21@gmail.com, Tell: +251 910309552 or +251 911590636

Abstract: Field studies were conducted at Haramaya and Arbarakate during 2012 and 2013 to assess effects of integrated climate change resilience strategies on faba bean rust (*Uromyces viciae-fabae*) in Hararghe highlands, Ethiopia. Three on-farm based climate change resilience strategies: species mixture (intercropping), compost application and furrow planting alone and in integration were evaluated using Degaga and Bulga-70 faba bean varieties and Melkassa IV maize variety. Treatments were factorial arranged in a randomized complete block design with three replications. Faba bean with maize row intercropping and intercropping-integrated cropping systems significantly reduced disease severity, AUDPC and disease progress rate and increased grain yield per unit area. These treatments reduced rust mean severity by up to 36.5% (in 2012) and 27.4% (in 2013) at Haramaya, and up to 27% in 2013 at Arbarakate on both faba bean varieties as compared to sole planting. Compost fertilization also slowed epidemic progression of faba bean rust and significantly reduced disease parameters when integrated with maize row intercropping. Compost fertilization in row intercropping recorded the lowest (23.1%) final mean disease severity and the highest (36.5%) percentage reduction in mean disease severity compared to sole cropping in 2012 at Haramaya. The trend was similar in 2013 at both locations. Degaga had the lowest rust disease parameters studied compared to Bulga-70 at both locations over years. The overall results indicated that integrated climate change resilience strategies were effective to slow the epidemics of rust and to maintain and sustainably boost faba bean productivity. Hence, integrated climate change resilience strategies along with other crop management systems are recommended in the study areas.

Keywords: Climate change resilience strategies; Epidemics; Rust; *Uromyces viciae-fabae*; *Vicia faba*

1. Introduction

Faba bean (*Vicia faba* L.) is among the most important pulse crops produced in the world for both human diet and animal feed as source of protein and carbohydrate. It is also an excellent complement of crop rotations for fixing atmospheric N and as green manure (Salmeron *et al.*, 2010). China is the largest producer of faba beans which gives East Asia the largest share in world, followed by Egypt and Ethiopia (Salmeron *et al.*, 2010; Akibode and Maredia, 2011). In Africa, Egypt is the dominant producer of faba bean followed by the Sudan, Ethiopia and Morocco (Akibode and Maredia, 2011). In Ethiopia, faba bean production is estimated to account for 4.7% of the total grain production (CSA, 2013). However, yields of faba beans have seen more fluctuations than area harvested in all the top producers and the world cultivated area has decreased in the last 50 years (Rosegrant, 2010). Climate variability, diseases, weeds and other pests are the major constraints of faba bean production. Diseases have always been the major limiting factors (Agegnehu *et al.*, 2006) and faba bean is susceptible to several pathogenic fungi, the major ones include ascochyta blight (*Ascochyta fabae* Speg.), rust (*Uromyces viciae-fabae* (Pers.) J. SchrÖt.) and chocolate spot (*Botrytis fabae* Sard.) in Ethiopia (Dereje and Tesfaye, 1993).

Faba bean rust is a major disease of faba bean in almost every area in the world where faba bean is grown (Torres *et al.*, 2006; Stoddard *et al.*, 2010) that can cause up to 70% of yield loss in early infection (Torres *et al.*, 2006). The disease is severe and influences yield in areas like the Middle East, North Africa and parts of Australia (Stoddard *et al.*, 2010). It is also widely distributed in Ethiopia (Berhanu *et al.*, 2003). In Ethiopia, rust is devastating next to chocolate spot, and depending on severity of infection, it can cause a seed yield loss ranging from 2 to 15% in lower altitudes and 14-21% for intermediate altitudes (Dereje and Tesfaye, 1993). Yield loss could be even higher when in mixed infection with chocolate spot disease (MacLeod, 2006).

Climate variability due to increased temperature and reduced precipitation over time increase susceptibility of faba bean and could also favour disease development. Faba bean production which is seriously affected by diseases and parasitic weeds are also worsened by climate change (Khan *et al.*, 2010). Food legume growers are experiencing frequent droughts due to climate change and variability. Drought predisposes resistant varieties to be easily attacked by pathogens, which are not problems during normal growing seasons and new diseases may happen (Ahmed *et al.*, 2011) and could decrease yield grains. Thus, climate change and associated changes in disease scenarios will demand changes in crop and disease management strategies in order to respond to changes in environmental conditions for sustainable crop production. But research has concentrated on the impacts of one or two of the changing climatic factors on host, pathogen, or the interaction of the two under-controlled conditions. Others are based on modelling of data from controlled experiments (Coakley *et al.*, 1999; Garett *et al.*, 2006; Newton *et al.*, 2010) far different from those in the field. Such studies could be more difficult in conditions where historical weather and crop disease data are not available and where available facilities are not enabling to generate sound data.

Hence, climate change effects studies could be approached through climate change resilience strategies. These are strategies that enhance the capacity of an ecological system to absorb stresses and maintain functioning in the face of external stresses imposed upon it by climate change and to adapt to reduce harm or risk of harm to improve the sustainability of the system, leaving it better prepared for future climate change impacts. They are generally designed to reduce climate change and its impacts in order to sustain ecosystem functioning/agricultural crop production, as it is part of the ecosystem (used in the sense of mitigating/adaptive strategy in this paper). The most important resilience strategies include enhancing functional crop diversification (Newton *et al*., 2010) through use of species and cultivar mixtures in the form of intercropping (Fininsa and Yuen, 2001; Tamado *et al*., 2007; Tilahun *et al*., 2012), effective soil nutrient management (Katungi *et al*., 2009), and efficient soil moisture conservation via furrow planting and mulching (Wang et *al*., 2008; Zhao *et al*., 2012).

Integrating these on-farm climate change resilience strategies for the management of crop diseases and sustainable crop production has a dual role for understanding the effects of climate change and the role of these cropping strategies for mitigation or adaptation. However, despite the significance of crop diseases in limiting crop productions and food supply, there has been limited field-based empirical research to assess the potential effects of climate change on plant diseases (Coakley and Scherm, 1996; Garrett *et al*., 2006). The integral role of climate change resilience strategies for the management of plant diseases and sustaining crop production in the face of climate change is not well addressed. Therefore, the objective of this study was to assess the effects of integrated climate change resilience strategies on the epidemics of faba bean rust in Hararghe highlands, Ethiopia.

2. Materials and Methods

2.1. Experimental Sites

Field-based experiments were conducted at two locations in 2012 and 2013. The 2012 field experiment was conducted at Haramaya University main campus experimental field station during the main cropping season (June to September) on loam aluvial soil. The station is located at 9°26’N and 42°3’E with an altitude of 1980 m.a.s.l. The highest mean annual rainfall for the location is 790 mm with mean minimum and maximum temperatures of 14.0 °C and 23.4 °C, respectively. The 2013 field experiment was conducted both at Haramaya University and Arbarakate Farmers' Training Center (FTC) on clay vertisol soil during the main cropping season. Arbarakate FTC is located at 9°2.86'N and 40°54.79'E with an altitude of 2274 m.a.s.l. in West Hararghe zone at about 180 km away from Haramaya. Arbarakate was characterized by extended higher precipitation (estimated to exceed 1300 mm per annum) and rainy days than Haramaya during the cropping periods with mean daily temperatures ranging between 13.1 and 17.5 °C.

2.2. Experimental Sites' Weather Data for 2012 and 2013

Daily maximum and minimum temperatures (°C), relative humidity (%), and total rainfall (mm) were obtained for Haramaya University experimental site for both seasons from its weather station. The weather data obtained for Arbarakate from the nearby stations were found unrepresentative. However, the weather trend at Arbarakate was characterized by extended period of rainfall and many rainy days and relatively mild temperature levels. The daily mean minimum and maximum temperatures of Arbarakate were derived using the Adiabatic Lapse Rate Model (Brunt, 2007) from nearby meteorological stations; and the daily minimum temperatures range from 5.31 to 12.43 °C and the daily mean maximum temperatures range from 20.17 to 22.61 ° C (June to November) in 2013.The monthly total rainfall and the monthly average temperature in the cropping seasons are presented in Table 1.

Table 1. Monthly mean temperature (°C) and monthly total rainfall (mm) during faba bean growing periods at Haramaya and Arbarakate, Ethiopia in 2012 and 2013 main cropping seasons.

Cropping month	Mean of temperature (°C)			Monthly rainfall (mm)	
	Haramaya		Arbarakate	Haramaya	
	2012	2013	2013	2012	2013
June	19.97	19.30	17.52	0.00	15.80
July	18.56	17.63	15.81	214.00	215.40
August	18.90	18.25	16.48	149.50	185.10
September	18.73	18.43	16.62	105.00	142.10
October	15.50	16.82	15.47	4.60	71.60
November	14.68	15.04	13.14	0.50	81.70
Mean	17.72	17.58	15.84	78.93	118.62

2.3. Treatments, Experimental Design and Management

Three on-farm based climate change resilience strategies and two faba bean varieties (considered as treatments) were used in this study. They were crop diversification (as species-mixtures of faba bean and maize in row intercropping), moisture conservation (as planting in furrow) and soil nutrient management (as compost application). Thus, the treatments included faba bean-maize row intercropping, furrow planting, compost application and faba bean sole planting. The treatments were applied as sole and in integration using two varieties of faba bean and one variety of maize (Table 2).

Table 2. Treatment combinations used for faba bean field experiments at Haramaya and Arbarakate during 2012 and 2013 main cropping seasons and their respective descriptions.

S.No.	Treatment	Treatment combination description
1	SP	Sole faba bean planting (control)
2	FP	Faba bean furrow planting
3	CA	Planting using compost application (compost fertilization)
4	RI	Faba bean-maize row intercropping
5	FP + CA	Faba bean furrow planting with compost application
6	FP + RI	Faba bean furrow planting in row intercropping
7	CA + RI	Faba bean planting using compost application in row intercropping
8	FP + CA + RI	Faba bean furrow planting with compost application in row intercropping

The two faba bean varieties used were Degaga (moderately resistant to faba bean diseases) and Bulga-70 (moderately susceptible) and their characteristic features are presented in Table 3. Both faba bean varieties were obtained from Holleta Agricultural Research Center, Ethiopia. The maize variety used as a component crop was Melkassa-IV (*ECA-EE-36*), which was obtained from Melkassa Agricultural Research Center, Ethiopia. Melkassa IV was released in 2006 with an agronomic attribute: area of adaptation (1000-1600 m.a.s.l altitude and 500-700 mm annual rainfall), early maturing (105 days) and a production potential of 2-4 t ha^{-1}. The compost used in this study was mainly made of a pile of *khat* (*Catha edulis)* residuals collected from the nearby markets of Awaday, eastern Ethiopia. A well decomposed and matured compost were evacuated air dried and sieved. Composite random samples were taken for chemical analysis before application and hence, it was composed of organic carbon (8.01%), organic matter (13.80%), total nitrogen (0.69%), available phosphorus (234.80 mg kg^{-1}) and C:N ratio of 11.61. Compost was applied at a rate of 8 t ha^{-1}and mixed with the soil a week before maize planting and four weeks before faba bean planting in 2012 and three weeks in 2013 cropping seasons. Furrows were prepared by digging about 20 cm deep rows once faba bean was planted and established to seedling stages in order to harvest rain water.

Table 3. Characteristic features of faba bean varieties used for the field experiment at Haramaya and Arbarakate, Ethiopia during the 2012 and 2013 main cropping seasons.

Variety	Year of release	Area of adaptation		Maturity (days)	Seed size (g)	Yield (kg/ha)	
		Altitude (m)	Rainfall (mm)			On-station	On-farm
Degaga	2002	1800-3000	800-1200	116-135	400-450	25-50	20-45
Bulga-70	1994	2300-3000	800-1100	143-150	400-450	20-45	15-35

A total of 16 treatments (for both faba bean varieties and maize as a component crop) were laid out in a randomized complete block design in a factorial arrangement with three replications. In a gross plot size of 4 m x 3 m, a 1 maize: 1 faba bean planting pattern of row intercropping was maintained by planting maize rows spaced 80 cm apart and planting one row of faba bean between the two maize rows. In row intercropping 5 rows of maize were intercropped with 4 rows of faba bean variety each at the center of the two maize rows per plot. In addition, sole faba bean was included as experimental treatment, which was planted at 40 x 10 cm inter-row and intra-row spacing. In case of sole planting, there were 9 faba bean rows per plot. In species-mixtures, maize was planted three weeks before faba bean planting in 2012 and two weeks before faba bean planting in 2013. Spacing between blocks was 1.5 m and rows was 1 m. Sowing of maize was done manually by planting two seeds per hill and later thinned to one plant per hill. Faba bean varieties were also manually planted. Maize was planted on 21 June 2012 and 27 June 2013 at Haramaya; and 3 July 2013 at Arbarakate. Faba bean was planted on 11 July 2012 at Haramaya; and on 12 July 2013 at Haramaya and 16 July 2013 at Arbarakate. The crops were grown without any chemical fertilizer and no artificial pathogen inoculation was performed relying on the natural onset of the disease. Weeding and other agronomic practices were done properly and uniformly as per the recommendations to grow a successful crop.

2.4. Disease Severity Assessment

Disease severity of faba bean rust was recorded during the disease epidemic period. Disease severity was assessed six times at Haramaya and four times at Arbarakate on weekly intervals on both varieties starting from the first visible disease symptoms in the experimental plots both in 2012 and 2013. For disease severity assessments, 12 plants were randomly selected from central rows of each plot and tagged prior to disease symptom appearance. Disease severity assessment began on 50 days after planting (DAP) in 2012 and 44 DAP in 2013 at Haramaya. At Arbarakate, disease severity recording began from 65 DAP onwards during 2013. Disease severity was scored using a 1-9 scale of ICARDA (1986); where, 1 = no pustules or very small non-sporulating flecks; 3 = few scattered pustules on leaves, few or no pustules on stem; 5 = pustules common on leaves, some pustules on stem; 7 = pustules very common on leaves, many pustules on stem; and 9 = extensive pustules on the leaves, petioles and stem, many leaves dead and plant defoliated. Disease severity scores were converted into percentage severity index (PSI) for analysis (Wheeler, 1969); where,

$$PSI = \frac{\text{Sum of numerical ratings} \times 100}{\text{Number of plants scored} \times \text{Maximum score on scale}} \quad 1$$

From disease severity data, area under disease progress curve (AUDPC) in %-days were calculated as used in Campbell and Madden (1990):

$$AUDPC = \sum_{i=1}^{n-1}(0.5(X_i + X_{i+1}))(t_{i+1} - t_i) \quad 2$$

where, x_i = percentage of disease severity index (PSI) of disease at i^{th} assessment; t_i = time of the i^{th} assessment in days from the first assessment date; and n = total number of disease assessments.

AUDPC was calculated separately for disease assessments made on different DAP for each climate change resilience strategy used and the control treatment. Since the epidemic period of the two locations varied in 2013, AUDPC were standardized by dividing the values by the epidemic period of the respective locations (Campbell and Madden, 1990). The epidemic periods were 35 days at Haramaya and 21 days at Arbarakate; and AUDPC values were standardized accordingly.

2.5. Data Analysis

Analysis of variance (ANOVA) was run for disease severity data and AUDPC values of faba bean rust on both varieties to determine treatment effects on disease severity and AUDPC in each year across locations using SAS GLM Procedure (SAS Institute, 2001). Mean separations were made using LSD at 0.05 probability level. To determine the disease progress rate from the linear regression, a logistic model was used. Logistic model, ln[(y/1-y)] (Van der Plank, 1963) was used to estimate the disease progression from each separate treatment. The transformed data were regressed over time, DAP to determine the disease progress rate. The slope of the regression line estimated the disease progress rate in different climate change resilience strategies. Regression was computed using Minitab (Release 15.0 for windows®, 2007). The two locations and seasons were considered as different environments because of heterogeneity of variances tested using Bartlett's test (Gomez and Gomez, 1984) and the F-test was significant. As a result, data were not combined for analysis.

3. Results

3.1. Rust Severity

Faba bean rust appeared during the flowering growth stage of both faba bean varieties both in 2012 and 2013 at Haramaya and during pod formation growth stage at Arbarakate in 2013 cropping season. The mean disease severity of faba bean rust in the two cropping seasons was significantly different ($P \leq 0.05$) between climate change resilience strategies and the control, among climate change resilience strategies used and between varieties both at Haramaya and Arbarakate experimental areas (Table 4). In both cropping seasons, mean disease severity assessments at different DAP showed significant variation between treatments starting from 57 DAP in 2012 and 51 DAP in 2013 at Haramaya in the disease epidemic periods. Whereas at Arbarakate, it was started from 65 DAP during 2013. Higher rust severity was observed on both faba bean varieties in 2013 than in 2012 and it was severe after pod filling growth stage at Haramaya.

The lowest final mean disease severity on 85 DAP in 2012 was recorded on both faba bean varieties at Haramaya from integrated climate change resilience strategies treated-plots (referring to the combined use of two or more of the strategies hereafter unless stated) as compared to sole planting. A similar trend was obtained in 2013 on both varieties at both experimental locations. Intercropping and intercropping-integrated climate change resilience strategies (referred to furrow planting in row intercropping and/or compost fertilization in row intercropping and/or furrow planting with compost fertilization in row intercropping or intercropping-integrated cropping systems hereafter) had the lowest mean disease severity records on both varieties and locations over years in comparison to sole planting. On the final disease severity assessment days, intercropping-integrated climate change resilience strategies-treated plots recorded up to 23.14% compared to 36.42% of sole plot in 2012 and 32.72% compared to 45.06% of sole plot in 2013 on both faba bean varieties at Haramaya. At Arbarakate, the trend was 16.67% as compared to 22.84% of sole plot on both varieties in 2013.

Thus, intercropping-integrated climate change resilience strategies-treated plots were found to highly reduce disease severity of rust compared to control plots. The highest mean disease severity reductions reached 36.46% (in 2012) and 27.39% (in 2013) on both varieties at Haramaya. Similarly, the reduction was up to 27.01% on both varieties studied at Arbarakate. Moreover, although there was no consistent significant ($p>0.05$) difference among compost fertilization, furrow planting, furrow planting with compost fertilization and sole planting, compost fertilization and furrow planting with compost fertilization had lower faba bean rust severity on both faba bean varieties in 2012 and 2013 at Haramaya. In 2012, compost fertilization and furrow planting along with compost fertilization lowered the final mean disease severity of faba bean rust in the range between 9.31 and 10.16% on both varieties at Haramaya. A similar trend was also indicated in 2013 on both varieties at both locations (Table 4). Furthermore, at both locations and seasons, the overall mean disease severity records showed that the two faba bean varieties were varied significantly. Degaga variety registered lower mean disease severities than Bulga-70 variety studied. The interaction between faba bean varieties and climate change resilience strategies used was not significant during both cropping seasons at both locations.

Table 4. Effects of climate change resilience strategies on faba bean rust (*Uromyces viciae-fabae*) severity (%) and standard area under disease progress curve (%-days) at Haramaya during 2012 and 2013 and at Arbarakate during 2013 main cropping seasons.

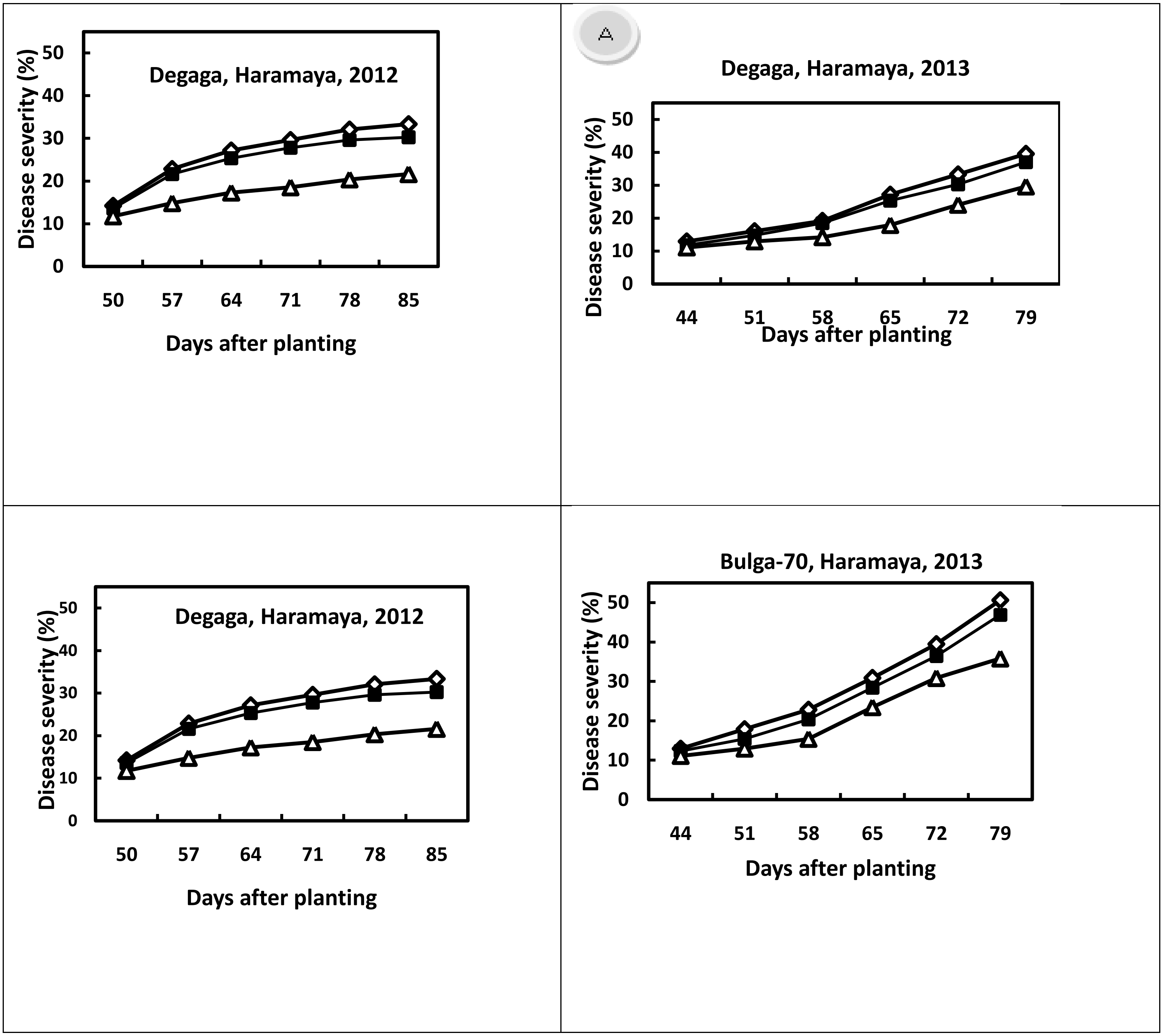
Treatment [a]	Haramaya				Arbarakate	
	2012		2013		2013	
	PSI [b]	rAUDPC [c]	PSI [b]	rAUDPC [c]	PSI [b]	rAUDPC [c]
Variety						
Bulga-70	31.79a	26.07a	42.67a	24.59a	21.99a	16.20a
Degaga	27.01b	22.18b	34.34b	20.92b	17.60b	14.30b
Mean	29.40	24.13	38.51	22.76	19.80	15.25
LSD (0.05)	1.09	0.76	1.14		0.57	0.46
Resilience strategy						
SP	36.42a	29.50a	45.06a	26.48a	22.84a	18.06a
FP	34.57ab	28.30ab	44.45b	25.68a	22.22ab	16.87b
CA	32.72b	27.01b	41.98b	24.54b	21.60b	16.36b
RI	25.00cd	20.37cd	33.95c	20.56c	17.90c	13.94c
FP + CA	33.03b	27.59b	41.98b	24.35b	21.60b	16.05b
FP + RI	26.55c	21.30c	34.57c	20.77c	18.21c	13.99c
CA + RI	23.14d	19.07d	32.72c	19.60d	16.67d	13.17c
FP + CA + RI	23.77d	19.84cd	33.34c	20.05cd	17.29cd	13.58c
Mean	29.40	24.12	38.51	22.75	19.79	15.25
LSD (0.05)	2.19	1.52	2.27	0.93	1.15	0.91
CV (%)	6.31	5.36	5.00	3.48	4.92	5.07

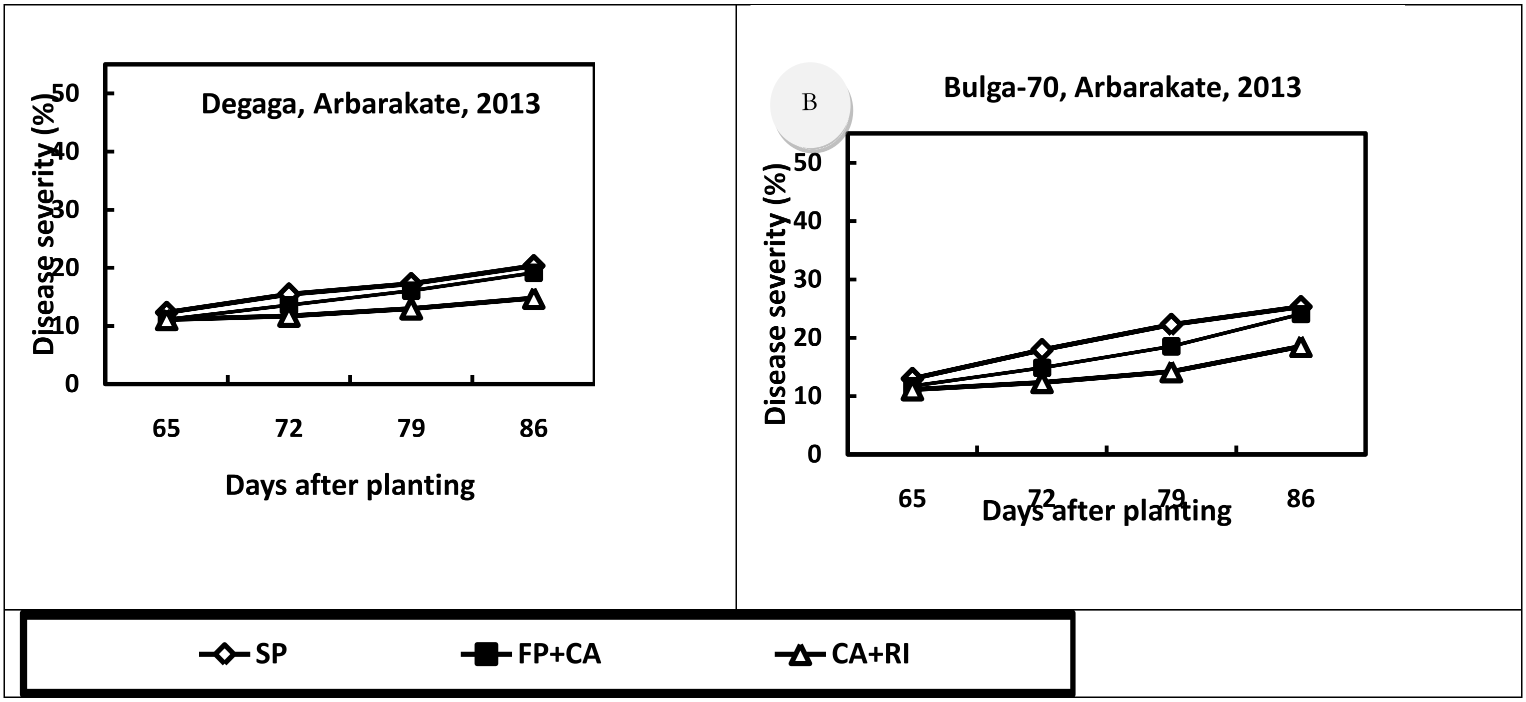
Means in each column followed by the same letter are not significantly different according to the least significant difference test at 5% probability level. [a] *SP, sole planting (control); FP, furrow planting; CA, compost application; RI, row intercropping; FP + CA, furrow planting with compost application; FP + RI, furrow planting in row intercropping; CA + RI, compost application in row intercropping; and FP + CA + RI, furrow plating with compost application in row intercropping.* [b] *Percent severity index on 85 days after planting (DAP) in 2012 and 79 DAP in 2013 at Haramaya and on 86 DAP at Arbarakate during 2013 main cropping season.* [c] *rAUDPC, standard area under disease progress curve of faba bean rust.*

3.2. Disease Progress Curve

The effects of climate change resilience strategies for the management of faba bean rust were also observed on trends of disease progress curves on both faba bean varieties where disease progress curves showed differences among treatments (Figure 1). On both faba bean varieties, disease severity progressed increasingly starting from onset to the final severity at both locations and seasons. The eight disease progress curves for each faba bean variety indicated that the rate of disease progress was not similar for each climate change resilience strategy applied. Disease in sole plots exhibited relatively high progressive curves and displayed the highest levels of faba bean rust. The furrow planting, compost fertilization and furrow planting with compost fertilization-treated plots followed similar curves as sole cropped plots but lied intermediate between sole planting and intercropped and intercropping-integrated climate change resilience strategies-treated plots with intermediate levels of faba bean rust severity. Whereas, disease progress curves of plots treated with intercropping and intercropping-integrated climate change resilience strategies at different levels of integration slowly progressed at both locations on both faba bean varieties over years. Moreover, plots with these integrated climate change resilience strategy treatments displayed the lowest levels of faba bean rust at different DAPs.

The disease progress curve in Figure 1 depicted only three of the main treatment categories (sole planting, furrow planting with compost fertilization and compost fertilization in row intercropping) based on faba bean rust severity levels for the sake of clarity and ease graphic presentation. Accordingly, furrow planting and compost fertilization treatments were lied in between sole planting and furrow planting with compost fertilization whereas treatments like row intercropping, furrow planting in row intercropping and furrow planting with compost fertilization in row intercropping were intermediate between furrow planting with compost fertilization and compost fertilization in row intercropping treatments. However, for Bulga-70, furrow planting with compost fertilization was found intermediate between sole planting and compost fertilization during 2012 at Haramaya.


Degaga, Haramaya, 2012
Disease severity (%)
0 10 20 30 40 50
50 57 64 71 78 85
Days after planting
Degaga, Haramaya, 2013
Disease severity (%)
0 10 20 30 40 50
44 51 58 65 72 79
Days after planting
Degaga, Haramaya, 2012
Disease severity (%)
0 10 20 30 40 50
50 57 64 71 78 85
Days after planting
Bulga-70, Haramaya, 2013
Disease severity (%)
0 10 20 30 40 50
44 51 58 65 72 79
Days after planting



Figur.1. Faba bean rust (*Uromyces viciae-fabae*) disease progress curves as affected by different climate change resilience strategies (FP + CA, furrow planting with compost application and CA + RI, compost application in row intercropping) and SP, sole planting on Degaga and Bulga-70 faba bean varieties at Haramaya in 2012 and 2013 (A) and at Arbarakate in 2013 (B) main cropping seasons

3.3. Area Under Disease Progress Curves (AUDPC)

AUDPC values calculated from disease severity assessed at different DAP on both faba bean varieties for both locations and cropping seasons significantly (*$P \leq 0.05$*) varied between climate change resilience strategies and the control, among climate change resilience strategies used and between faba bean varieties studied (Table 4). AUDPC values were lower on intercropped and intercropping-integrated climate change resilience strategies-treated plots than on other treatments. In 2012, sole plots had the highest AUDPC values, while the lowest AUDPC values were calculated from compost fertilization in row intercropping-treated plots. The values indicated that intercropping and intercropping-integrated climate change resilience strategies-treated plots showed consistent reduction in AUDPC values. In 2013, a similar trend was also calculated for the sole cropped and integrated climate change resilience strategies-treated plots for both varieties and locations.

The reduction in AUDPC values, which were caused by intercropping and intercropping-integrated climate change resilience strategies treatments, was also exhibited by compost fertilization and furrow planting along with compost fertilization treatments, even though there was no significant difference among compost fertilization, furrow planting with compost fertilization and furrow planting treated-plots and sole cropped plots. That is, compost fertilization and furrow planting with compost fertilization treatments generally lowered the AUDPC values of rust on both faba bean varieties at both locations in 2012 and 2013.

3.4. Disease Progress Rate

Disease progress rates and parameter estimates of faba bean rust are tabulated in Tables 5-7. The disease progress rates computed from mean disease severity records showed variations among climate change resilience strategies used in both faba bean varieties, locations and seasons. Disease progress rates calculated from severity records of Degaga variety ranged from 0.0182 to 0.0288 units/day in 2012 and from 0.0340 to 0.0456 units/day in 2013 (Table 5), whereas for Bulga-70, the rates ranged from 0.0234 and 0.0331 units/day in 2012 and 0.0461 and 0.0546 units/day at Haramaya in 2013 (Table 6). The rates computed were also from 0.0158 to 0.0309 units/day for Degaga and 0.0279 to 0.0412 unit/day for Bulga-70 at Arbarakate in 2013 (Table 7). The disease progress rate was relatively higher at Haramaya in 2013 and relatively fast on both varieties in 2012 and 2013 at Haramaya than at Arbarakate. On Bulga-70 variety, at both locations and in both cropping seasons, the disease progress rate was higher as compared to Degaga. It was also observed that disease progressed relatively at faster rates on sole and non intercropped and non intercropping-integrated climate change resilience strategies-treated plots across locations and over years for both faba bean varieties. The results indicated that the rate at which faba bean rust progressed was slower when climate change resilience strategies were applied in integration than the untreated plots to manage the disease.

Table 5. Mean initial (PSI_i) and final (PSI_f) severity index and parameter estimates of faba bean rust (*Uromyces viciae-fabae*) on Degaga variety at Haramaya, Ethiopia during 2012 and 2013 main cropping seasons.

Year	Treatment [a]	Percent severity [b]		Intercept [c]	SE of intercept [d]	Disease progress rate (Logit/day)	SE of Rate [d]	R^2 (%) [e]
		PSI_i	PSI_f					
2012	SP	14.19	33.33	-3.14	0.2439	0.0288	0.0033	81.4
	FP	15.43	31.48	-2.85	0.2131	0.0244	0.0029	80.4
	CA	14.19	29.63	-3.05	0.2036	0.0256	0.0028	83.2
	RI	12.34	22.84	-3.03	0.1647	0.0212	0.0022	83.8
	FP + CA	13.58	30.25	-3.07	0.2586	0.0265	0.0035	76.6
	FP + RI	11.73	24.69	-3.23	0.2213	0.0246	0.0030	79.4
	CA + RI	11.73	21.60	-3.03	0.1762	0.0200	0.0024	80.2
	FP + CA + RI	12.96	22.22	-2.83	0.1817	0.0182	0.0025	75.8
2013	SP	12.96	39.51	-4.36	0.1477	0.0438	0.0020	96.5
	FP	11.73	38.89	-4.54	0.1257	0.0456	0.0017	97.7
	CA	11.73	37.04	-4.41	0.0951	0.0431	0.0013	98.5
	RI	11.11	30.86	-4.22	0.1193	0.0375	0.0016	96.9
	FP + CA	11.73	37.04	-4.42	0.1187	0.0432	0.0016	97.7
	FP + RI	11.73	31.48	-4.13	0.1636	0.0365	0.0022	94.0
	CA + RI	11.73	29.63	-4.01	0.1684	0.0340	0.0023	92.8
	FP + CA + RI	11.11	30.25	-4.15	0.1369	0.0362	0.0019	95.7

[a] SP, sole planting (control); FP, furrow planting; CA, compost application; RI, row intercropping; FP + CA, furrow planting with compost application; FP + RI, furrow planting in row intercropping; CA + RI, compost application in row intercropping; and FP + CA + RI, furrow plating with compost application in row intercropping.

Parameter estimates are from a linear regression of ln(y/(1-y)) disease severity (PSI) proportions at different days after planting (DAP).

[b] Initial and final disease severity (PSI) of chocolate spot recorded at 50 DAP and 85 DAP in 2012 and at 44 DAP and 79 DAP in 2013, respectively.

[c] Intercept of the regression equation.

[d] Standard error of parameter estimates.

[e] Coefficient of determination of the logistic model.

Table 6. Mean initial (PSI_i) and final (PSI_f) severity index and parameter estimates of faba bean rust (*Uromyces viciae-fabae*) on Bulga-70 variety at Haramaya, Ethiopia during 2012 and 2013 main cropping seasons.

Year	Treatment [a]	Percent severity [b]		Intercept [c]	SE of intercept [d]	Disease progress rate (Logit/day)	SE of Rate [d]	R^2 (%) [e]
		PSI_i	PSI_f					
2012	SP	15.43	39.51	-3.23	0.3264	0.0331	0.0044	76.2
	FP	14.81	37.66	-3.18	0.3053	0.0314	0.0042	76.8
	CA	14.81	35.81	-3.07	0.2959	0.0296	0.0040	75.7
	RI	15.43	35.81	-3.01	0.2880	0.0289	0.0039	75.8
	FP + CA	12.96	27.16	-3.21	0.1912	0.0261	0.0026	85.4
	FP + RI	14.20	28.40	-2.98	0.2199	0.0237	0.0030	78.4
	CA + RI	12.34	24.68	-3.09	0.1990	0.0234	0.0027	81.3
	FP + CA + RI	11.73	25.31	-3.20	0.2264	0.0251	0.0031	79.4
2013	SP	12.96	50.62	-4.93	0.1512	0.0546	0.0021	97.6
	FP	12.96	50.00	-4.92	0.1645	0.0538	0.0022	97.1
	CA	12.34	46.92	-4.90	0.1376	0.0527	0.0019	97.9
	RI	11.11	37.04	-4.74	0.1700	0.0471	0.0023	96.1
	FP + CA	12.34	46.91	-4.97	0.1246	0.0534	0.0017	98.3
	FP + RI	11.11	37.66	-4.78	0.1443	0.0480	0.0020	97.2
	CA + RI	11.11	35.80	-4.72	0.1627	0.0461	0.0022	96.2
	FP + CA + RI	11.11	36.42	-4.74	0.1475	0.0467	0.0020	97.0

[a] SP, sole planting (control); FP, furrow planting; CA, compost application; RI, row intercropping; FP + CA, furrow planting with compost application; FP + RI, furrow planting in row intercropping; CA + RI, compost application in row intercropping; and FP + CA + RI, furrow plating with compost application in row intercropping.

Parameter estimates are from a linear regression of ln(y/(1-y)) disease severity (PSI) proportions at different days after planting (DAP).
[b] *Initial and final disease severity (PSI) of chocolate spot recorded at 50 DAP and 85 DAP in 2012 and at 44 DAP and 79 DAP in 2013, respectively.*
[c] *Intercept of the regression equation.*
[d] *Standard error of parameter estimates.*
[e] *Coefficient of determination of the logistic model.*

Table 7. Mean initial (PSI_i) and final (PSI_f) severity index and parameter estimates of faba bean rust (*Uromyces viciae-fabae*) on Degaga and Bulga-70 varieties at Arbarakate, Ethiopia during 2013 main cropping season.

Variety	Treatment [a]	Percent severity [b]		Intercept [c]	SE of intercept [d]	Disease progress rate (Logit/day)	SE of Rate [d]	R^2 (%) [e]
		PSI_i	PSI_f					
Degaga	SP	12.34	20.37	-3.76	0.2052	0.0276	0.0027	90.6
	FP	11.11	19.75	-4.08	0.2319	0.0309	0.0030	90.5
	CA	11.11	19.14	-3.98	0.3233	0.0293	0.0042	81.2
	RI	11.11	16.05	-3.44	0.2021	0.0205	0.0026	84.4
	FP + CA	11.11	19.14	-4.06	0.1770	0.0301	0.0023	93.9
	FP + RI	11.73	16.05	-3.19	0.2609	0.0172	0.0034	69.3
	CA + RI	11.11	14.82	-3.15	0.1490	0.0158	0.0019	85.7
	FP + CA + RI	11.11	15.44	-3.26	0.2021	0.0177	0.0026	80.2
Bulga-70	SP	12.96	25.31	-4.43	0.2423	0.0391	0.0032	93.3
	FP	12.34	24.69	-4.58	0.3533	0.0398	0.0046	87.0
	CA	12.34	24.07	-4.51	0.2838	0.0385	0.0037	90.8
	RI	11.73	19.75	-3.96	0.2796	0.0286	0.0036	84.7
	FP + CA	11.73	24.07	-4.75	0.2097	0.0412	0.0027	95.4
	FP + RI	11.11	20.37	-4.33	0.1676	0.0336	0.0022	95.6
	CA + RI	11.11	18.52	-3.97	0.2360	0.0279	0.0031	88.2
	FP + CA + RI	11.11	19.14	-4.13	0.2865	0.0303	0.0037	85.6

[a] *SP, sole planting (control); FP, furrow planting; CA, compost application; RI, row intercropping; FP + CA, furrow planting with compost application; FP + RI, furrow planting in row intercropping; CA + RI, compost application in row intercropping; and FP + CA + RI, furrow plating with compost application in row intercropping.*
Parameter estimates are from a linear regression of ln(y/(1-y)) disease severity (PSI) proportions at different days after planting (DAP).
[b] *Initial and final disease severity (PSI) of chocolate spot recorded at 65 DAP and 86 DAP in 2012, respectively.*
[c] *Intercept of the regression equation.*
[d] *Standard error of parameter estimates.*
[e] *Coefficient of determination of the logistic model.*

4. Discussion

The overall results of the study indicated that severity of rust was higher and rapidly increasing at the later stages of the epidemic period at Haramaya both in 2012 and 2013. However, in both cropping seasons at Haramaya and Arbarakate, rust severity, AUDPC and disease progress rate were reduced and grain yield per unit area was increased by integrated climate change resilience strategies compared to sole planting. Among the climate change resilience strategies, intercrops and intercropping-integrated cropping systems had the lowest disease parameters of faba bean rust and chocolate spot as well (Habtamu *et al.* submitted) as compared to sole cropping. Such effects could be attributed to effects of intercropping in reducing plant density of component crops and acting as a physical barrier that might hamper inoculum spread and disease progress. In addition, intercrops might have also modified the microclimate by modifying the density of host plants thereby changing canopy microenvironment.

Previous studies indicated that deploying crop diversity is necessary to adapt to climatic changes and to new pathogens that might arise due to changing climates (Fadda, 2011). Intercropping is one way of introducing more biodiversity into agroecosystems and results from intercropping studies showed that increased crop diversity increases the number of ecosystem services provided. Higher species richness may be associated with significant reduction in the negative impacts of diseases (Fininsa, 1996; Bannon and Cooke, 1998) and weeds (Hauggaard-Nielsen *et al.*, 2001). Increasing the complexity of crop environment through intercropping also limits the places where pests can find optimal foraging or reproductive conditions (Lithourgidis *et al.*, 2011). Similarly, mixtures play a major role in reducing the efficiency of the pathogen through the dilution effect (Mundt, 2002) and mixed crop species can also delay the onset of diseases by reducing the spread of disease carrying spores and by modifying environmental conditions to less favorable to the spread of certain pathogens (Altieri, 1999; Lithourgidis *et al.*, 2011). In addition, under Ethiopian conditions, mixed cropping has also been reported to reduce disease severity of faba bean rust (Adet Agricultural Research Center, 2000).

In faba bean-maize intercrops and intercrop-integrated cropping systems of this study, the population of faba bean per plot was reduced by more than half. The microclimate of the faba bean canopy might be modified in such a way that there was free air-circulation, low leaf wetness and reduced damp sites. Likewise, Biddle and Catline (2007) stated that densely planted faba beans encourage humid microclimate within the canopy, thereby, encouraging infection and spore production in the presence of warm temperatures and light film of moisture on the leaf surface. Thus, Fernández-Aparicio *et al.* (2006) noted that intercropping faba bean with cereals has been proposed as a means to lessen the incidence of faba bean rust. The cereal favors aeration and prevents the formation of a dense faba bean canopy that might enhance disease damage. Reddy (2013) also indicated that varietal mixtures reduce disease epidemics by reducing the spatial density of susceptible plants where the deposition probability of released spores on susceptible tissue from a lesion is reduced.

It was also observed that compost fertilization alone and in integration with furrow planting and row intercropping in particular highly reduced faba bean rust and decreased chocolate spot severity and increased grain yield of faba bean (Habtamu *et al.* submitted). In addition to the roles explained by intercropping, possibly compost fertilization could enhance the health and vigority of plants that might have increased plant chances to withstand pathogen attack and to activate the host defense system. Neher *et al.* (2014) found that compost amended soils reduced disease severity of ear blight on brassicas compared to the bare soil. Haggag and Saber (2007) reported that compost teas significantly reduced disease incidence and population counts of alternaria blight and significantly increased the activities of both peroxidase, β-1,3-glucanase and chitinase that could increase plant resistance both under greenhouse and field planted tomato and onion. Similar results were also observed by Sang *et al.* (2010) against *Phytophthora capsici* in pepper plants by compost water extracts and the test again activates expression of pathogenesis-related genes and peroxide generation in the leaves and lignin accumulation in the stems. In addition, composted paper mill residuals suppressed leaf spot of field grown cucumber and bacterial spot of field grown snap bean and anthracnose in greenhouse grown snap beans likely due to induced systemic resistance (Stone *et al.*, 2003). Sang *et al.* (2010) showed the same result on the suppression of *Colletotrichum coccodes* in pepper leaves and *C. orbiculare* in cucumber leaves.

Faba bean rust progressed rapidly from onset to the end of the epidemic period at both locations in 2012 and 2013. The epidemic was appeared early and higher at Haramaya than Arbarakate areas. This could be associated with the weather conditions and the altitude differences of the two locations. Arbarakate was characterized by many rainy days with extended period of rainfall and mild temperature (15.8 to 16.6 ^{o}C) during the cropping season which might have delayed the onset of rust and its epidemics. Haramaya was relatively warm (temperature ranging from 14.7 to 19.8 ^{o}C) with high relative humidity and fair rainfall distribution. Moreover, the results also demonstrated that rust severity was relatively higher late in the epidemic period during 2013 than 2012 at Haramaya. This might be partially explained by early termination of rainfall that would in turn reduce leaf wetness and infection in 2012.

Supporting the current study, Hawthorne *et al.* (2004) stated that rust infection is favored by humid and warm temperatures. This infection can occur following six hours of leaf wetness (so does not require extended wet periods) and humidity plays an important role in causing this epidemic disease (Li-juan *et al.*, 1993). The development of both primary and secondary inoculum sources of faba bean rust are also influenced by environmental factors; cloudy weather with high humidity and 17-22 ^{o}C favors development of the disease (Stoddard *et al.*, 2010). That is, spore production is encouraged by high humidity and warm temperatures and once spores are released and deposited on a susceptible host crop, germination occurs quickly in the presence of a light film of moisture on the leaf surface to cause infection (Biddle and Catline, 2007). Of course, Dipak *et al.* (2012) also found that rainy days are negatively correlated with disease development of *Uromyces viciae-fabae;* which could be the most probably reason for the delayed onset of faba bean rust at Arbarakate in 2013.

Faba bean rust epidemics might also be associated with altitude in which Arbarakate recorded lower rust severity than Haramaya since the former location is more highland than the later. In accordance with this study, a survey conducted by Shifa *et al.* (2011) in Hararghe highlands of Ethiopia in the 2009 cropping season to determine the incidence and severity of faba bean rust, and its association with environmental factors and cultural practices found that the incidence and severity of faba bean rust showed higher association with altitudes. The results indicated that those surveyed locations with an altitude above 2450 m.a.s.l had relatively low incidence and severity than locations below 2450 m.a.s.l. The variation could be partly due to the difference in the relative warmness of locations, as faba bean rust epidemic is lower in lower and intermediate altitudes (<2300m.a.s.l) and usually late in the season (Nigussie, 1991).

5. Conclusions

In conclusion, row intercropping and intercropping-integrated climate change resilience strategies are highly reduced disease parameters of faba bean rust and recommended to manage the disease. Similarly, compost fertilization of the soil also plays an important role to manage faba bean rust; and the role of compost fertilization is highly magnified when integrated in row intercropping. It is, therefore, promising to grow faba bean with maize intercropping, compost fertilization in row intercropping in addition to using host resistance to manage rust of faba bean in Hararghe highlands. Further studies on integrated control of rust should continue that include host resistance and cultivar mixtures in the system. Moreover, much more can be done with compost on quality as well as quantity and the effects on soil physico-chemical properties and the mechanisms through which compost fertilization reduces foliar diseases' severity.

6. Acknowledgements

The study was financed by the Swedish International Development Agency (SIDA) and Haramaya University, Ethiopia. We thank Mr. Getahun Tessema (Farmers' Development Agent, Arbarakate) and Ms. Woinshet Feleke, Mr. Berhanu Asefaw and Tefera Birhanu, School of Plant

Sciences, Haramaya University for their assistance during field follow up and data collection; and staff members of West Hararghe Bureau of Agriculture and Rural Development who facilitated the allotment of experimental land at Arbarakate.

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9. Evaluation and Identification of Potato (*Solanum tuberosum* L.) Varieties for Yield and Resistance to Late Blight [*Phytophthora infestans* (Mont.) de Bary] in Eastern Ethiopia

Wassu Mohammed Ali

Haramaya University, College of Agriculture and Environmental Sciences, School of Plant Sciences, Haramaya, Ethiopia
Author E-mail: wasmoha@yahoo.com

Abstract: Eastern Ethiopia highlands are potentials for potato (*Solanum tuberosum* L.) production. Potato is the second most important crop next to khat (Chata edulis Forsk) in supporting farmers' livelihoods. The production is market oriented with considerable amounts being exported to the neighboring countries; however, the tuber yield is remained low on farmers› field. As one option, the availability of high yielding varieties has given attention to increase the productivity of the crop in the region. Therefore, this research was conducted to evaluate the yield and late blight resistance of majority of the improved potato varieties (15) in the country and two farmers' cultivars as a check under eastern Ethiopia condition to identify high yielding, disease resistance and wide adaptable varieties. The trial was conducted at three locations which are representative of potato growing areas in eastern Ethiopia for two consecutive cropping seasons at Hirna and Arberkete and three seasons at Haramaya. The combined analysis of variance over seasons and locations revealed the presence of significant effects of genotype, environment and location and genotype x environment interaction on late blight resistance, total and marketable tuber yield t ha^{-1}. Therefore, Additive Main Effects and Multiplicative Interaction (AMMI) and Eberhart and Russell models were employed to estimate the contribution of genotype x environment interaction, genotype and environment and to identify high yielding and wide adaptable varieties. However, both models revealed the predominant importance of genotype and environment than genotype x environment interaction for tuber yields while the significant effect of genotype and genotype x environment interaction for late blight resistance. This suggested the varieties can be predictable on their genetic potential and the environments where they grow except few. Considering all stability parameters of the two models, high yield and resistance to late blight, Bubu (38.61 t ha^{-1}) had highest marketable tuber yield and the lowest late blight score. It was identified as stable but responsive to the environments with the tendency of higher performances towards to favourable environments. Belete had the second highest marketable tuber yield (38.26 t ha^{-1}) and disease severity score while Gera (37.34 t ha^{-1}), Mara Charre (36.95 t ha^{-1}) and Gudanie (34.18 t ha^{-1}) had the 3rd, 4th, and 5th highest marketable tuber yield in the trial. The former variety had <30% disease severity score and stable for all traits while the two had >30% severity scores. Based on all analyses results, it is possible to recommend Bubu, Belete and Gera for potato production in eastern Ethiopia even under high pressure of late blight, but it is hardly possible to recommend Mara Charre and Gudanie unless less frequent chemical spray is considered to control the disease late blight.

Keywords: Additive Main effect and Multiplicative Interaction (AMMI); Genotype; Eberhart and Russell Models;, Environment, Late blight; Variety

1. Introduction

Potato has better ability to provide a high yield of high-quality product per unit input with a shorter crop cycle (mostly <120 days) compared to major cereal crops like maize (Hirpa *et al.*, 2010). As a result, the crop is appreciated as a good source of nutritious food and cash by large number of food insecure smallholder farmers and pastoralists in Ethiopia (Haverkort, 2012). Ethiopia has huge potential to produce potato (70% of the 10 million hectares of arable land) (FAO, 2008). The current area covered with potato is very small about 0.16 million hectare and the average yield is below 10 t ha^{-1} (Baye and Gebremedhin, 2013). The Central, the Eastern, the Northwestern and the Southern regions of Ethiopia constitute approximately 83% of the potato farmers. Potato is the second most important crop in eastern Ethiopia next to *khat* (*Chata edulis* Forsk) in supporting farmers' livelihoods with 75.9% increase in income over sorghum [*Sorghum bicolor* (L.) Moench] (Mulatu *et al.*, 2006). The potato production in this region is market oriented with considerable amounts being exported to the neighbouring countries Djibouti and Somalia (Adane *et al.*, 2010).Despite Eastern highlands are agronomic potentials for potato production, the tuber yield is remained low on farmers› field.

In Ethiopia, the low acreage and yield are attributed to many factors, but lack of high quality seed potatoes and high yielding varieties are the major factors (Gildemacher *et al.*, 2009; Endale *et al.*, 2008). More than 27 potato varieties were recommended for production in different regions of Ethiopia. The varieties were developed by different research centers in the country. The total tuber yield of the varieties ranged from 20 to 47 t ha^{-1} (MoA, 2013 and 2012). The differences of varieties for tuber yield might be due to the differences of the varieties genetic potential but also the adaptability of the varieties in the recommended area of cultivation. The role of geographical location in creating varied genetic material even in the absence of genome differentiation was reported in potato (Hawkes, 1990). The difference in tuber yield was also recorded in European Union countries which ranged from 10 to 50 t ha^{-1} (Flis *et al.*, 2014). This difference might be due to the genetic potential of the genotypes, environments and the significant role of genotype × environment interaction. The performance of genotype is determined by its genetic potential, the environment where it grows and the interaction of genotype and environment (Yan *et al.*, 2007; Prabhakaran and Jain, 1994).

The agronomic performance of the recommended potato varieties for different regions of the country has not been tested in eastern Ethiopia. In the absence of genotype x environment interaction, the superior genotype in one environment may be regarded as the superior genotype in all. But, the presence of genotype x environment interaction complicated the selection of superior genotypes for target environments, since the superior genotype in one environment may or may not be superior in other or in all environments. Therefore, evaluation of breeding materials across environments is a must either to select varieties that perform well consistently in all environments or to make specific recommendations of varieties for each environment (Yan *et al.*, 2007; Gauch, 2006). The growing of varieties with stable yield is an advantage for farmers to obtain larger harvest due to large genotypic effect and small genotype x environment interaction (Flis *et al.*, 2014). This suggested that the high mean yield of the variety is not the only criterion for selection unless its high performance is established over the different environmental conditions. The varieties stability test better to be extended to late blight [*Phytophthora infestans* (Mont.) de Bary] resistance in eastern Ethiopia in particular and in the country in general. This is because; the loss of potato production due to this disease is estimated up to 70% in highland areas of Ethiopia (Mekonen *et al.*, 2011). Therefore, the objectives of this research were: (i) to evaluate the performance of improved potato varieties in eastern Ethiopia, thereby to identify high yielding, resistance to disease and stable varieties, and (ii) to determine the environment and genotype x environment interaction on the performance of potato varieties, and iii) to test stability of tuber yield and reaction to late blight across environments.

2. Materials and Methods

2.1. Description of the Study Sites

The field experiment has been carried out at three locations namely; Haramaya, Hirna and Arberkete which are considered the representative potato growing areas of eastern Ethiopia. The experiment was conducted for two cropping season (2012 and 13) in all the three locations while at Haramaya, potato varieties were additionally evaluated during 2014 cropping season to generate reliable information about the late blight resistance of varieties since this location is hot spot area for the disease. This made the total of seven environments considering one location and one cropping season as one environment.

Haramaya University research farm is located at 2022 m.a.s.l., 9°41"N latitude and 42°03"E longitude. The area has a bimodal rainfall distribution with mean annual rainfall of 760 mm. The long rainy season extends from June to October and accounts for about 45% of the total rainfall. The mean maximum temperature is 23.40C while the mean minimum annual temperature is 8.250C. The soil of the experimental site is a well-drained deep alluvial with a sub-soil stratified with loam and sandy loam. Hirna sub-station is situated at a distance of about 134 km to the west of Haramaya. The site is located at 9 o12' North latitude, 41 o4'East longitude, and at an altitude of 1870 meters above sea level. The area receives mean annual rainfall ranging from 990 to 1010 mm. The average temperature of the area is 24.0o C (Tekalign, 2011). The soil of Hirna is vertisol (HURC, 1996). Arberekete field experiment was conducted on farmer's filed, which is located at a distance of about 171 km to the west of Haramaya. The site is located at 9 o14' North latitude, 41 o2'East longitude, and at an altitude of 2280 meters above sea level (CZWADO, 2011).

2.2. Experimental Materials

The experiment included 15 improved potato varieties released for different regions of Ethiopia by five Research Centers and Haramaya University and two farmers' cultivars. The description of the varieties is given in Table 1.

2.3. Experimental Design and Procedures

The experimental was laid out as a Randomized Complete Block Design (RCBD) with three replications in each location and season. Each potato genotype was assigned to one plot in each replication and six rows with 12 plants. The gross plot size was 16.2 m2 with 75 and 30 cm between rows and within plant spacing, respectively. The spacing between plots and replications was maintained at1.5m and 1 m, respectively. For yield estimation, tubers were harvested from forty plants from the four middle rows, leaving the plants growing in the two border rows as well as those growing at both ends of each row to avoid edge effects.

The experimental fields were cultivated by a tractor to a depth of 25-30 cm and ridges were made by hand. Medium sized (39-75 g) and well sprouted tubers were planted at the sides of ridges (Lung'aho *et al.*, 2007). Planting was at the end of June and first week of July during the main growing season after the rain commenced and when the soil was moist enough to support emergence. The planting depth was maintained at 10 cm. The whole recommended rate of Phosphorus fertilizer (92 kg P2O5 ha-1) was applied at planting in the form of Diammonium Phosphate. Nitrogen fertilizer was applied at the rate of 75 kg N ha-1 in the form of Urea in two splits, half rate after full emergence (two weeks after planting) and half rate at the initiation of tubers.

Table 1. Description of potato varieties.

Released/local name of genotype	Release year	Breeder Center	Yield (t ha-1) at research field	Recommended Altitude (m.a.s.l.)
Bubu	2011	Haramaya University	39-42	1700-2000
Belete	2009	Holeta Research Center	47.2	1600-2800
Araarsaa	2006	Sinnana Research Center	20-42	2400-3350
Gudanie	2006	Holeta Research Center	29	1600-2800
Mara Charre	2005	Hwassa Research Center	33.3	1700-2700
Gabbisa	2005	Haramaya University	40	1700-2000

Bulle	2005	Haramaya University	39.3	1700-2000
Chala	2005	Haramaya University	42	1700-2000
Gera	2003	Sheno Research Center	25.9	2700-3200
Jalenie	2002	Holeta Research Center	40.3	1600-2800
Guasa	2002	Adet Research Center	24.4-33	2000-2800
Gorebela	2002	Sheno Research Center	30-52	1700-2400
Bedasa	2001	Haramaya University	40.6	2400-3350
Zemen	2001	Haramaya University	37.2	1700-2000
Chirro	1998	Haramaya University	32-40	2700-3200
Bete (Local cultivar)	----------	----------------------------	-------------------	Eastern Ethiopia
Jarso (Local cultivar)	----------	----------------------------	-------------------	Eastern Ethiopia

Source: MoA, 2013 and 2012. Varieties recommended for Central Ethiopia was by Holeta Agriculture Research Center, for Northern by Adet and Sheno Agriculture Research Centers, for Southern by Hwassa Agriculture Research Center, for Southeastern by Sinnana Agriculture Research Center and for Eastern Ethiopia by Haramaya University.

2.4. Data Collection

Total tuber yield (t ha-1) was calculated and recorded at harvest from the total tuber yield of 40 plants per plot. Marketable tuber yield (t ha-1) was estimated by sorting tubers in each plot which were free from diseases, insect pests and greater than or equal to 20g in weight.

Disease assessment was started after 46 days of planting as soon as disease symptoms appear in susceptible genotypes and then after every 20 days until majority of the genotypes attained physiological maturity. The disease was assessed following CIP (2006) guideline and other established procedures. Assessment of severity late blight under field conditions in percent was recorded on plot basis taking in account the number of plants developing disease symptoms in a leaf and/or many leaves and plants free from disease (Henfing, 1987).

2.5. Data Analysis

Total and marketable tuber yields data were subjected to unbalanced general analysis of variance considering the three seasons and locations. Additive Main Effects and Multiplicative Interaction (AMMI) (Zobel *et al*., 1988) and Eberhart and Russell (1966) models analyses of variances were conducted for seven environments considering each location and one season as one environment. Late blight disease severity data was subjected only for AMMI and Eberhart and Russell analyses of variance for four environments.

Stability parameters of Eberhart and Russell (1966) i.e. regression coefficient (bi) and deviation from linear regression (S2di) were computed using the established procedure for the model. The interaction principal component axes (IPCA) scores of a genotype and an environment were computed in the AMMI analysis. In AMMI biplot, the main effects i.e. genotype and environment means were plotted on the abscissa and the IPCA 1 scores for the same genotypes and environments on the ordinate. In addition, AMMI stability value (ASV) was calculated as proposed by Purchase (1997) and Purchase *et al.* (2000) as follows:

$$\text{ASV}=\sqrt{\left[\frac{\text{IPCAISS}}{\text{IPCA 2SS}}\,(IPCA1score)\right]^2+[\text{IPCA2score})^2}$$

Where, ASV = AMI stability value; SS = sum squares of IPCA1 and IPCA 2 (the first and the second interaction principal component axes, respectively), and thus genotypes with lower ASV was considered more stable than those with higher ASV values.

3. Results

3.1. General Analysis of Variance and Mean Performance of Genotypes

The general analysis of variance results revealed highly significant (P<0.01) effects of the three main factors (genotype, location and season) and all the possible interactions (genotype x location, location x season and genotype x location x season) on total and marketable tuber yield (Table 2a). The combined analysis of variance results from AMMI model revealed the significant effect of all sources of variation (of genotype, environment and genotype x environment interaction) on all traits except nonsignificant influence of environment on late blight severity (Table 3a and 3b). Similar results were obtained from analysis of variance of Eberhart and Russel's Model where sum squares due to genotypes and genotype x environment (linear) were highly significant (P<0.01) for all the traits. Pooled deviation mean square was also significant for all traits except for late blight severity. On the other hand, the mean squares were nonsignificant for all traits and genotypes except for total and marketable tuber yields of Gorebela and late blight severity score of Bete (Table 4a and 4b).

The treatment sum of squares had the highest contribution for total sum squares ranged from 78.48 (late blight severity) to 90.91% (marketable tuber yield) while error sum squares contributed less in the range between 7.98 (total tuber yield) and 12.39% (late blight severity). Genotype sum squares accounted the highest proportion of treatment sum squares for disease severity (71.86%). Environment sum squares contributed the highest share for treatment sum squares of total tuber yield (45.5%) while genotype x environment sum squares had the lowest share of treatment sum squares for all traits. The first principal component axis (IPCA 1) sum square contributed the highest share for genotype x environment sum squares for all traits in the range between 37.04 (total tuber yield) and 66.16% (disease severity) (Table 3a and 3b).

On the basis of pooled mean over locations and seasons showed the wide range of performance of potato genotypes for total tuber yield (21.15 to 41.96 t ha-1) with overall mean of 33.18 t ha-1. Marketable tuber yield was in the range between 16.7 and 38.61 t ha-1 with genotypes overall mean of 29.81 t ha-1. Eight and seven genotypes including farmers' cultivars had mean performance less than the average performance of genotypes for total and marketable tuber yield, respectively (Table 5a). The four varieties, Bubu, Belete, Mara Charre and Gera had highest mean total (>40 t ha-1) and marketable tuber yield (>36 t ha-1). These varieties also had lowest disease severity score where the former two varieties with <20% while the later two varieties <35% (Table 5b).

Growing of the first four AMMI selections in seven environments for total tuber yield t ha-1 has an advantage of 6.16 t ha-1 than growing all genotypes in eastern Ethiopia. Bubu, Belete, Mara Charre and Gera were selected as the first selections by AMMI model in all environments and growing of these three varieties had the advantage of 11.17 t ha-1 total tuber yield than growing of all genotypes and all selected four AMMI selections (Table 6).

Table 2. Mean squares from unbalanced analysis of variance for average tuber weight and tuber yields of 17 potato genotypes as evaluated at seven environments.

Source of variation	DF	TTY t ha-1	MTY t ha-1
Replication	2	21.92	23.10
Genotype (G)	16	751.53**	875.96**
Location (L)	2	7035.52**	7218.94**
Season (S)	2	787.85**	1578.74**
Genotype x Location	32	156.80**	197.70**
Genotype x Season	32	92.89**	81.21**
Location x Season	2	1211.55**	1205.15**
G x L x S	32	50.94**	62.40**
Error	236	16.99	18.85
SE		4.122	4.341
	1.1.2		
CV (%)		12.42	14.56

***, significant at P < 0.01. DF = degree of freedom, ATW (g) = average tuber weight, TTY t ha-1 = total tuber yield tons per hectare and MTY t ha-1 = marketable tuber yield tons per hectare.*

Table 3a. AMMI analysis of variance for total and marketable tuber yield of 17 potato genotypes tested at seven environments.

		Total tuber yield t ha-1				Marketable tuber yield t ha-1			
				Sum of square explained				Sum of square explained	
Sources of variation	DF	Sum of squares	Mean squares	% total	% G x E	Sum of squares	Mean squares	% total	% G x E
Treatment	118	39714	336.6**	90.74		44943	380.9**	90.91	
Genotype	16	12025	751.5**	30.28		14015	876**	31.18	
Environment	6	18070	3011.6**	45.50		20006	3334.3**	44.51	
Rep within E	14	563	40.2	1.42		517	36.9	1.15	
G x E	96	9620	100.2**	24.22		10922	113.8**	24.30	
IPCA 1	21	3563	169.6**		37.04	4740	225.7**		43.40
IPCA 2	19	2902	152.7**		30.17	3014	158.6**		27.60
Residuals	56	3155	56.3		32.80	3169	56.6		29.01
Error	224	3491	15.6	7.98		3977	17.8	8.04	
Total	356	43768	122.9			49437	138.9		

Table 3b. AMMI analysis of variance for late blight disease severity score of 17 potato genotypes tested at four environments.

Sources of variation	DF	Sum of squares	Mean squares	Sum of square explained	
				% total	% G x E
Treatment	67	157794	2355**	78.48	
Genotype	16	113385	7087**	71.86	
Environment	3	15512	5171	9.83	
Rep within E	8	18363	2295	11.64	
G x E	48	28897	602**	18.31	
IPCA 1	18	19117	1062**		66.16
IPCA 2	16	8954	560**		30.99
Residuals	14	827	59		2.86
Error	128	24903	195	12.39	
Total	203	201060	990		

***, significant at P < 0.01. DF = degree of freedom, Rep within E = replication within environments, G x E = genotype by environment interaction, IPCA 1 and 2, interaction principal component axis one and two, respectively.*

Table 4a. Analyses of variance from Eberhart and Russel's Model for tuber yield and average tuber weight of 17 potato genotypes tested at seven environments.

Source of variation	DF	TTY (t ha-1)	MTY (t ha-1)
Genotypes	16	250.51**	291.99**
Environment + (Geno x Env.)	102	90.49**	101.07**
Environment (linear)	1	6023.28	6668.57
Genotypes x Env. (linear)	16	61.55**	82.25**
Pooled Deviation	85	26.14**	27.35**
Bubu	5	7.63	5.68
Belete	5	44.18	42.6
Chala	5	12.83	16.93
Gudanie	5	17.9	16.31
Bulle	5	17	21.09
Chirro	5	28.27	20.86
Araarsaa	5	19.03	17.55
Zemen	5	3.6	6.34
Jalenie	5	2.53	6.43
Jarso	5	27.89	27.45
Gabbisa	5	8.25	8.27
Gorebela	5	75.44**	80.61*
Mara Charre	5	35.79	34.97
Bete	5	35.38	43.45
Bedasa	5	29.83	28.49
Gera	5	50.74	51.34
Guasa	5	28.12	36.61
Pooled Error	238	5.68	6.29

** and **, significant at P < 0.05 and P < 0.01, respectively. TTY (t ha-1) = total tuber yield tons per hectare, MTY (t ha-1) = marketable tuber yield tons per hectare and ATW (g) = average tuber weigh in gram.*

Table 4b. Analyses of variance from Eberhart and Russel's Model for late blight disease severity score of 17 potato genotypes tested at four environments.

Source of variation	DF	Mean square
Genotypes	16	2362.18**
Environment + (Geno x Env.)	51	290.26
Environment (linear)	1	5170.8**
Genotypes x Env. (linear)	16	379.95**
Pooled Deviation	34	104.51
Bubu	2	8.24
Belete	2	223.18
Chala	2	44.30
Gudanie	2	56.84
Bulle	2	14.19
Chirro	2	18.89
Araarsaa	2	311.58
Zemen	2	40.85
Jalenie	2	132.84
Jarso	2	4.54
Gabbisa	2	52.25
Gorebela	2	2.66
Mara Charre	2	132.93
Bete	2	352.29*
Bedasa	2	50.91
Gera	2	47.39
Guasa	2	282.78
Pooled Error	136	106.04

**and **, significant at $P<0.05$ and $P<0.01$, respectively.*

3.3. Stability Analyses from AMMI and Eberhart and Russel's Models

The stability parameters estimated for 17 potato genotypes of total and marketable tuber yields are presented in Table 5a. According to the ASV ranking, Gera, Bete and Mara Charre for total tuber yield; Bedasa, Araarsaa and Bete for marketable tuber yield had lowest ASV. However, Bete and Bedasa had the lowest tuber yields but Gera and Mara Charre were among the four high yielding varieties. The high yielding varieties (Bubu and Belete) had also relatively lower ASV for total and marketable tuber yield. Regression coefficient (bi) was significant and deviation from regression (S2di) was nonsignificant for all genotypes except the two varieties for both total and marketable tuber yields.

In the AMMI biplot, genotype and environment means were plotted on the abscissa and the IPCA 1 scores for the same genotypes and environments on the ordinate. The dotted vertical line shows the grand means of all genotypes whereas the dotted horizontal line shows the zero point for the IPCA scores. Bubu, Chirro and Gudanie distributed in top right quadrant for both total and marketable tuber yields while Mara Charre, Gera, Belete and Gabbisa plotted in bottom right quadrant of both biplots (total and marketable tuber yields) (Figure 1 and Figure 2). Other three varieties viz. Chala, Araarsaa and Zemen also distributed in the right quadrant either for total or marketable tuber yield. Arbrekete in both seasons (2012 and 2013), Hirna in 2013 distributed in top right while Hirna and Haramaya in 2012 cropping season plotted in bottom right in both biplots. Haramaya in 2013 and 2014 cropping seasons distributed in the left quadrants of the two biplots.

The two varieties (Bubu and Bulle) that scored lowest disease severity had relatively higher ASV while seven varieties had low ASV (<1) for late blight severity. Among the seven varieties, Belete had scored lower severity (<20%) while Mara Charre, Gudanie and Araarsaa had disease severity scores in the range between 30 and 35%. All genotypes deviation from regression (S2di) did not show significant difference from zero while nine genotypes had regression coefficient (bi) significantly different from unity (Table 5b). Most of the genotypes with higher and lower disease severity scores were distributed in the right and left side of the biplot, respectively. Bubu and Bule with lowest disease severity scores were plotted in the left bottom while Belete located in the left top quadrant (Figure 3).

Table 5a. Stability parameters for total and marketable tuber yield from AMMI analysis and Eberhart and Russel's Models of 17 potato genotypes tested at three locations and two cropping seasons.

	Total tuber yield t ha-1						Marketable tuber yield t ha-1					
Genotype	Pooled mean	AMMI model stability			ER's Model stability		Pooled mean	AMMI model stability			ER's Model stability	
		IPCA 1	IPCA 2	ASV	bi	S2di		IPCA 1	IPCA 2	ASV	bi	S2di
Bubu	40.55 (3)	0.67	0.92	0.57 (7)	0.54**	1.96	38.61(1)	1.06	0.32	1.92 (9)	0.5**	-0.61
Belete	40.53 (4)	1.35	-2.1	1.09 (9)	1.00**	38.5	38.26 (2)	0.86	-2.15	0.54 (6)	0.95**	36.3
Chala	34.96 (7)	-0.89	-0.1	2.60 (11)	1.33**	7.15	33.29 (6)	-1.56	-0.67	2.37 (11)	1.45**	10.64
Gudanie	36.28 (5)	1.53	1.17	1.76 (10)	0.43*	12.22	34.18 (5)	1.63	0.33	3.62 (15)	0.42*	10.01
Bulle	27.36 (14)	2.22	1.3	2.89 (12)	0.28*	11.32	23.37 (15)	2.71	0.78	5.04 (17)	0.19	14.8
Chirro	33.41 (8)	-2.18	0.26	6.27 (17)	1.55**	22.59	30.15 (9)	-1.81	0.82	2.7 (13)	1.48**	14.56
Araarsaa	32.62 (10)	-0.57	1.26	0.38 (5)	0.89**	13.35	30.64 (8)	0.03	0.92	0.01 (2)	0.8**	11.25
Zemen	32.83 (9)	-1.74	-0.38	3.70 (14)	1.61**	-2.07	30.12 (10)	-1.95	0.31	4.86 (16)	1.68**	0.05
Jalenie	31.1 (13)	-0.99	-0.09	3.26 (13)	1.29**	-3.15	27.15 (12)	-0.59	0.83	0.5 (5)	1.15**	0.13
Jarso	21.15 (17)	0.59	2.38	0.29 (4)	0.58*	22.21	16.7 (17)	1.73	2	1.62 (8)	0.45*	21.15
Gabbisa	36.02 (6)	-0.76	-0.85	0.72 (8)	1.3**	2.57	31.67 (7)	-1.29	-0.5	2.08 (10)	1.45**	1.98
Gorebela	26.2 (16)	2.7	-0.98	4.49 (16)	0.58*	69.76*	23.89 (14)	2.53	-1.46	3.32 (14)	0.55	74.32*
Mara Charre	41.96 (1)	-0.51	-1.7	0.28 (3)	1.19**	30.11	36.95 (4)	-1	-1.51	0.81 (7)	1.22**	28.67
Bete	24.64 (15)	0.36	1.84	0.16 (2)	0.72*	29.71	19.37 (16)	0.58	2.01	0.31 (3)	0.86**	37.16
Bedasa	31.2 (12)	0.65	-1.68	0.40 (6)	1.02**	24.16	26.92 (13)	-0.02	-1.62	0.00 (1)	1.09**	22.19
Gera	40.72 (2)	0.01	-1.99	0.01 (1)	1.17**	45.06	37.34 (3)	-0.62	-2.21	0.33 (4)	1.16**	45.04
Guasa	32.54 (11)	-2.45	0.75	4.44 (15)	1.51**	22.44	28.19 (11)	-2.29	1.8	2.58 (12)	1.59**	30.32
Mean	33.18						29.81					

** and **, significant at P<0.05 and P<0.01, respectively. Numbers in parenthesis represent the mean and ASV rank of genotypes in descending and ascending order, respectively. IPCA 1 and IPCA 1 = interaction principal component axis one and two, respectively, ASV = AMMI stability value, ER's = Eberhart and Russel's mmodel, bi and S2di, regression coefficient and deviation from regression, respectively.*

Table 5b. Stability parameters for late blight disease severity score from AMMI analysis and Eberhart and Russel's Models of 17 potato genotypes.

		Late blight disease severity score (%)				
Genotype	Pooled mean	AMMI model stability			ER's Model stability	
		IPCA 1	IPCA 2	ASV	bi	S2di
Bubu	10 (16)	-1.84	-0.51	3.49 (11)	0.05	-97.8
Belete	18 (14)	0.11	2.85	0.02 (1)	1.04	117.14
Chala	54 (5)	3.33	-0.25	12.29 (16)	2.63**	-61.74
Gudanie	30 (12)	-0.51	-1.39	0.31 (3)	0.7	-49.2
Bulle	11 (15)	-2.4	-0.6	4.79 (13)	-0.29	-91.85
Chirro	79 (2)	3.2	0.04	27.72 (17)	2.60**	-87.15
Araarsaa	35 (10)	-1.46	3.29	0.98 (7)	0.3	205.54
Zemen	71 (3)	3.55	1.18	6.16 (15)	2.84**	-65.2
Jalenie	37 (9)	2.18	-2.22	2.16 (9)	2.14**	26.8
Jarso	95 (1)	-1.41	0.42	2.57 (10)	0.26*	-101.5
Gabbisa	41 (8)	-1.08	-1.37	0.96 (6)	0.44	-53.8
Gorebela	43 (6)	-0.5	0.24	0.72 (5)	0.76**	-103.38
Mara Charre	32 (11)	0.6	2.11	0.32 (4)	1.25*	26.89
Bete	71 (3)	-3.48	-2.84	3.85 (12)	-0.61	246.24
Bedasa	64 (4)	0.28	1.32	0.13 (2)	1.18**	-55.14
Gera	28 (13)	-2.88	0.83	5.36 (14)	-0.42	-58.66
Guasa	42 (7)	2.31	-3.1	1.99 (8)	2.13*	176.74
Mean	45					

** and **, significant at P<0.05 and P<0.01, respectively. Numbers in parenthesis represent the mean and ASV rank of genotypes in descending and ascending order, respectively. IPCA 1 and IPCA 1 = interaction principal component axis one and two, respectively, ASV = AMMI stability value, ER's = Eberhart and Russel's mmodel, bi and S2di, regression coefficient and deviation from regression, respectively.*

Table 6. The first four AMMI selections in seven environments for total and marketable tuber yield t ha-1.

Environment		HU12	HU13	HU14	HIR12	HIR13	AR12	AR13	Advantage t ha-1
	Mean	33.95	22.83	23.89	40.94	43.11	34.41	33.14	33.18
Total tuber yield t ha-1	1st	Be (48.31)	Bu (33.45)	Be (33.56)	Mar (56.75)	Mar (53.39)	Bu (43.7)	Bu (41.28)	11.17
	2nd	Ge (46.1)	Gu (32.01)	Bu (32.79)	Ge (55.78)	Ge (50.51)	Gud (40.48)	Gu (41.1)	9.50
	3rd	Mar (45.83)	Be (31.03)	Mar (31.3)	Be (53.98)	Gua (50.12)	Mar (40.2)	Chir (39.9)	8.59
	4th	Bu (40.28)	Mar (27.68)	Ge (31.06)	Gab (48.07)	Chir (50.12)	Be (39.64)	Mar (38.54)	6.16
Advantage t ha-1		11.18	8.2125	8.2875	12.705	7.925	6.595	7.065	8.85
	Mean	31.73	18.88	19.41	38.54	38.74	31.99	29.4	29.81
	1st	Be (45.62)	Bu (31.1)	Be (31.39)	Ge (54.84)	Mar (47.98)	Bu (42.71)	Ara (37.74)	11.82
Marketable tuber yield t ha-1	2nd	Ge (43.77)	Be (29.94)	Bu (30.61)	Mar (53.29)	Cha (46.84)	Gu (39.03)	Bu (37.66)	10.35
	3rd	Mar (41.55)	Gud (28.52)	Gud (27.58)	Be (51.48)	Ge (46.58)	Be (37.83)	Chir (35.47)	8.62
	4th	Bu (40.56)	Ge (24.27)	Ge (26.87)	Cha (48.53)	Gua (46.07)	Mar (35.24)	Ze (33.89)	6.68
Advantage t ha-1		11.15	9.58	9.70	13.50	8.13	6.71	6.79	9.37

Numbers in parenthesis indicated total and marketable tuber yield t ha-1 varieties in of respective growing site. HU12, HU13 & HU14 = Haramaya site in 2012, 2013 and 2014, respectively, HIR12 and HIR 13 = Hirna site in 2012 and 2013, respectively, AR12 and AR13 = Arberkete in 2012 and 2013, respectively. Be = Belete, Bu = Bubu, Mar = Mara Charre, Ge = Gera, Gu = Gudanie, Chir = Chirro, Gab = Gabbisa, Ara = Araarsaa, Cha = Chala, Gua = Guasa and Ze = Zemen.

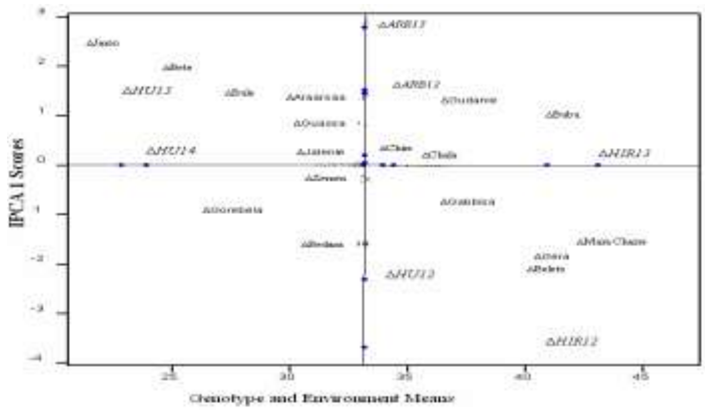

Figure 1. AMMI biplot of 17 potato genotypes evaluated for total tuber yield t ha-1 at seven environments in eastern Ethiopia.

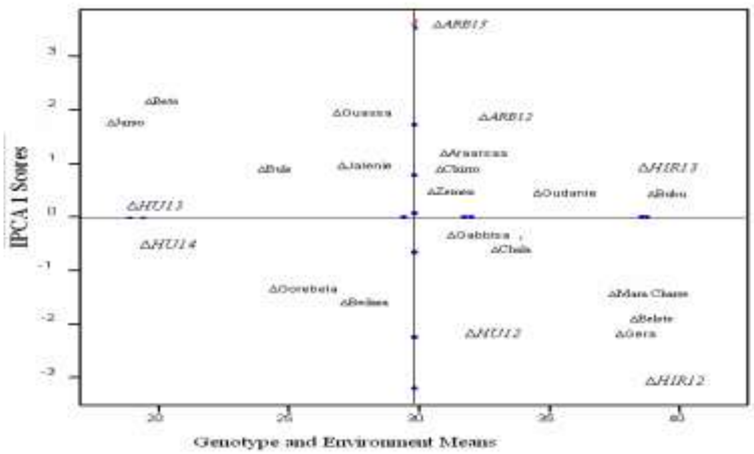

Figure 2. AMMI biplot of 17 potato genotypes evaluated for marketable tuber yield t ha-1 at seven environments in eastern Ethiopia.

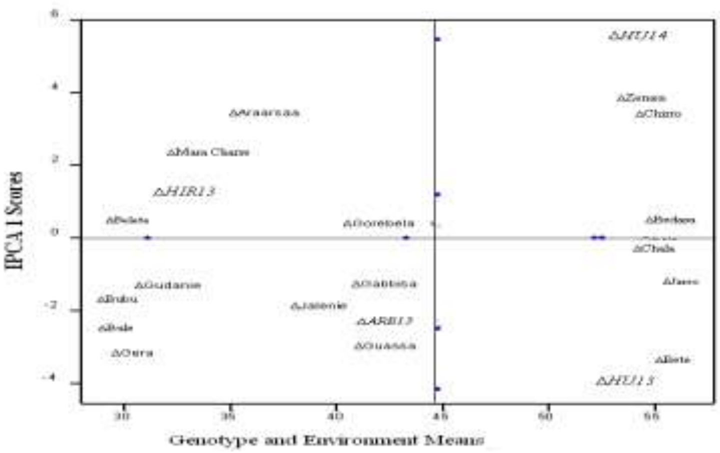

Figure 3. AMMI biplot of 17 potato genotypes evaluated for late blight disease severity at four environments in eastern Ethiopia.

4. Discussion

Highly significant differences among genotypes for tuber yields and late blight resistance showed the presence of wide variations among the varieties for all traits. Environment and genotype x environment interaction had highly significant effect on all traits except late blight resistance was not significantly affected by environment. This indicated the unstable expression of traits across environments. Significant variations among genotypes due to environment and genotype x environment interactions for tuber yields and late blight resistance were also reported by other authors (Flis *et al*., 2014; Mulugeta, and Dessalegn, 2013; Mulema *et al*., 2008; Mateo *et al*., 2007).

The higher contribution of genotype and environment sum squares than genotype x environment interaction to treatment sum squares for total and marketable tuber yields suggested the two components were more important for the observed variations among genotypes. But, the higher contribution of genotype sum square (71.86%) to treatment sum square for late blight severity score as compared to genotype x environment interaction (18.3%) and insignificant mean square of environment in both models indicating the more importance of the resistance gene(s) the genotypes carry. This was also supported by the large share of IPCA 1 sum square (66.16%) to genotype x environment interaction sum square. The significant effect of genotype x environment interaction on yield is a common phenomenon that has been reported in many species of crop plants including potato (Flis *et al*., 2014; Tatarowska *et al.,* 2012; Blanche *et al*., 2009; Mulema et al., 2008; Mallory and Porter 2007).

The mean square deviation from regression (S2di) was nonsignificant from zero for each genotype in all traits except one variety, Gorebela for total and marketable tuber yields indicating the genotypes were not sensitive/stable in the changing environments. However, most of the genotypes regression coefficient (bi) for all traits was significantly different from unity suggested most of genotypes were responsive for the changing environments. According to the Eberhart and Russell (1966) regression coefficient (bi) approximating unity along with deviation from regression (S2di) near zero indicated the average stability of genotypes. The absolute ASV combines IPCA1 and IPCA2 and the genotypes with lower ASV indicate the more stable (Purchase, 1997). Accordingly, Gera followed by Bete Mara Charre for total tuber yield and Bedasa followed by Araarsaa and Bete for marketable tuber yield were the most stable genotypes. Belete followed by Bedasa and Gudanie for late blight disease severity was most stable. However, Bedasa and Bete had the lower tuber yield than average yield of the genotypes while Bedasa had the higher late blight severity score indicating poorly adaptability of the genotypes for the traits which performed low.

Relatively, more number of genotypes had lower IPCA scores (<1) for total and marketable tuber yield (10 and 6 out of 17, respectively) than only 5 out of 17 genotypes for late blight severity. The genotypes that had lower IPCA scores closer to zero are considered the more stable across testing environments (Tarakanovas and Ruzgas, 2006). Accordingly, Gera followed by Bete and Mara Charre had the lowest IPCA score (<0.5) for total tuber yield while Bedasa, Araarsaa, Zemen and Gudanie had the lowest score (<0.35) for marketable tuber yield. Belete and Bedasa had lowest scores (<0.3) for late blight severity. Though these genotypes IPCA scores were not zero, they can be considered as stable because they had the scores approaching to zero. However, Bedasa had high severity score (>40%) indicating this variety was susceptible across the environments. The more the IPCA scores approximate to zero, the more stable the genotypes are over ll environments sampled (Tarakanovas and Ruzgas, 2006; Gauch and Zobel, 1988).

Bubu, Gudanie and Chirro were distributed in top right quadrant of both in total and marketable tuber yield biplots indicating these varieties were high yielding in favourable environment while Belete, Mara Charre, Gera and Gabbisa were plotted in bottom right quadrant of both biplots suggested the varieties were producing tuber more than the favorable environment mean yield. Araarsaa and Zemen for total tuber yield and Chala for marketable tuber yield plotted in top right quadrant, but distributed for marketable tuber either in bottom right (Chala) or left of the biplot indicating the varieties response to environments were different for total and marketable tuber yield. Bubu was plotted at distant top and Mara Charre was at distant bottom right quadrant indicating these varieties were producing highest total and marketable tuber yield more than the mean of favorable environments. On the other hand, Chala and Jalenie for total tuber yield and Zemen for marketable yield plotted close to the centers of biplots indicating the varieties were stable to the respective yields they placed to center of biplots. Varieties being nearest to the origin showed non-sensitivity t the environmental and interactive forces. The stable genotypes are those that are placed near the origin of the axes or score near to zero (Carbonell *et al*., 2004).

Chirro Zemen and Bedasa were distributed in top right and Chala, Jarso and Bete in bottom right quadrants of the biplot indicating the former varieties were highly affected by late blight in an environment with high disease incidence. All these genotypes were either local cultivars or old varieties released before 2001 except one (Chirro) in 2005. This might be due to the genetic structure of the genotypes with low levels of heterogeneity for resistance (Shagol and Tadawan, 2008; Becker and Leon, 1988) or they may not carry as many resistant R genes or the resistance gene were overcome by the pathogen (Beukema and Van Der Zaag, 1979). All the other genotypes (11 out of 17) were distributed in the left side of the biplot indicating the genotypes had lower disease severity scores. Belete plotted at distant in top left quadrant and Bubu and Bule distributed at distant in bottom left quadrant of the biplot indicating the former variety had high disease severity scores in environments with high late blight incidence. But the latter two varieties had the lowest severity score in all environments. Potato genotypes differing in their interaction effects for late blight incidence were also reported (Shagol and Tad-awan, 2008).

Arberkete and Hirna in both seasons (2012 and 2013 and Haramaya in 2012 distributed in right side of both total and marketable yield biplots indicating the environments were good in producing high tuber yields. The tuber yields (both total and marketable) and disease severity score/incidence had inverse relationship. For instance, the lowest tuber yields were produced during 2013 and 2014 seasons at Haramaya, but the disease incidence was high in both seasons (2013 and 2014) at Haramaya. This showed that Haramaya had favourable environment for the pathogen and exerted high pressure on the crop. Yield is controlled by many genes and a product of many factors (Beukema and Vander Zaag, 1990). Characters controlled by many genes with small effects are subject to considerable modification by differences in environments (Briggs and Knowles, 1985). In this research, environments with high disease incidence also produced low tuber yields. This research suggested that tuber yields were most probably affected by late blight more than other environmental factors. Late blight caused by the Phytophthora infestans (Mont.) de Bary is the most important disease of potatoes worldwide (Fry and Goodwin, 1997) which cause up to total loss of yield.

5. Summary and Conclusion

In this trial, the contribution of genotype and environment was much higher than genotype x environment interaction effect for total and marketable tuber yield. This suggested obtaining higher yield is possible through selection of high performing potato varieties. However, the larger effect of environment and the presence of genotype x environment interaction suggested the importance of selecting stable varieties or suitable environment and management for the production of higher yield rather than depending on the overall mean yields due to genotypic difference alone. The late blight resistance of varieties was significantly affected by the genotype and genotype x environment interaction not by environment (AMMI model analysis of variance). The genotype x environment interaction sum square (18.31%) had much lower contribution to the treatment sum square as compared to the largest contribution of genotype (71.86%) sum square. This suggested that late blight resistance of varieties was mainly a function of genetic factor than environment but some of the varieties resistant to the pathogen varied from environment to environment. This suggested that it is possible to select genotypes for late blight resistance at one environment with high disease incidence/favourable environment for the pathogen. The genotypes selected as high resistant to the disease in this environment had the higher chance of being resistant in all environments.

Several models for evaluating stability have been proposed, however, no single model is adequately explains genotype performance across environments. The stability statistics must be combined with performance to be informative and useful in selection. Considering all stability parameters of the two models and the performance of the varieties, Bubu was identified as high performing variety and relatively stable for all the traits measured. Bubu produced the highest marketable tuber yield in the trial and the estimate of stability parameters indicated that it was stable and responsive to environments with the tendency of higher performance in favourable environments. This variety also recorded the lowest severity score for late blight and stable across environments or this variety reaction to late blight was not varied across environments. Belete had the second highest marketable tuber yield and disease severity score but responsive to environment for yield but not late blight. Mara Charre, Gera and Gudanie were among the varieties that had highest total and marketable tuber yields. Gera had <30% disease severity score while Mara Charre and Gudanie had >30% disease severity scores. Therefore, it is possible to recommend Bubu, Belete and Gera for potato production in eastern Ethiopia even under high pressure of late blight, but it is hardly possible to recommend Mara Charre and Gudanie for cultivation in environments that favour late blight unless less frequent chemical spray is also considered.

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10. Maintenance and Enhancement of Sweet potato Accessions at Haramaya University

Wassu Mohammed Ali

Haramaya University, College of Agriculture and Environmental Sciences, School of Plant Sciences, Haramaya, Ethiopia
Author E-mail: wasmoha@yahoo.com

Abstract: Haramaya University maintained 116 sweet potato accessions of which 24, 37and 52 were obtained from Local collections, Nigeria and Asia Vegetable Centers, respectively, The accessions were also maintained for two years (213 and 214) knowing the potential of accessions to be used in improving the crop for eastern Ethiopia, used as germplasm deposit for the Nation and used for a number of scientific researches. Therefore, the objectives of the project were to maintain, characterize, evaluate, and document accessions for future use. The sweet potato accessions were evaluated for phenology, growth, yield, yield components and quality attributes of the crop using Augmented design with 19 replications (blocks) in 2012/13 cropping season. The evaluation revealed significant variations among accessions for most of the traits, which can be exploited for the improvement of the crops. Moreover, 13, 12, and 20 accessions exhibited superiority over the mean of improved varieties for total storage root yield (t/ha), marketable storage root yield (t/ha), and dry matter content (%), respectively. The total and marketable storage root yield advantages of accessions were as high as 87.66 and 75.58, respectively. This indicated the need to study promising accessions in replicated trials and maintaining the rest of accessions for future use.

Keywords: Accessions; Augmented Design; Marketable and Total Storage Root Yield

1. Introduction

Sweet potato is cultivated in Ethiopia mostly for human consumption and as animal feed. It ranks third after Enset [Ensete *ventricosum* (Wele) Cheesman] and Potato (*Solanum tuberosum* L.) which is one of the most important root crops produced in the country. The total area under production reaches 33,070 hectares and the production is estimated to be over 2,628,539 quintals(CSA, 2003). According to FAO (2000) and CSA(2003 and 2006), the Ethiopian national average storage root yield of sweet potato ranges between 8 to 10 t ha^{-1}. Under experimental field, storage root yields ranges between 30 to 73 t ha^{-1} (Hall and Harmon, 1989; Bhansari and Ashley, 1990).

Current knowledge of the distribution of sweet potato genetic resources indicates that maximum diversity of sweet potato in northwestern and southern America and Africa. In the same trend as in other major crop plant, the sweet potato genetic resources are facing a high risk of losing significant amount of variation. (Zosimo, 987). Haramaya University emphasises on the importance of intensive collection of sweet potato germplasm. The University maintained 116 sweet potato germplasm from International and National collections for number of years. The germplasm collections not only used by the University but also by the National research institutes. Therefore, it is necessary to maintain these valuable materials for future use.

There are many reasons for the establishment of a germplasm collection. In many cases a germplasm collection is needed for the crop improvement programme. Plant breeders require genetically diverse material to develop improved crop varieties. The more diverse the gene pool, the higher is the probability that it would contain desirable genes. Germplasm collection is also needed to conserve endangered species. Moreover, it is needed to conserve for future requirements (De Silva *et al*., 1995). Conservation of germplasm has many components including collection, documentation, characterization, evaluation, and maintenance. Systematic conservation of germplasm depends on proper documentation with passport and characterization data. Morphological characterization along with molecular markers helps to identify duplicates. The number of accessions for maintenance can be drastically reduced by eliminating duplicates (Huaman, 1992). Since genetic variability is a prerequisite for the improvement of the crop, it is necessary to maintain sweet potato accessions for long period of the success of the crop improvement. Therefore, this research was initiated with the objectives of maintaining sweet potato genotypes collected by Haramaya University and enhancing through evaluation, characterization and documenting of agronomic and physicochemical attributes of the accessions.

2. Materials and Methods

2.1. General Description of the Research

The research activity consisted of two sub-activities, i.e. i) maintaining of sweet potato collections and accessions introduced from different International Centers and ii) characterizations and evaluation of accessions for further breeding program. One hundred sixteen(116) sweet potato accessions including the two released varieties were planted in a non-replicated trial at Haramaya University for two years to maintain the accessions. The accessions were also planted in separate field using Augmented design to characterize, and evaluate for yield and quality.

One hundred fourteen (114) sweet potato accessions and two released varieties (Adu and Berkome) are listed in Table 1.The accessions were collected from eastern Ethiopia, other regions of the country and International Research Canters. The two varieties, Adu and Berkome were released for eastern Ethiopia by Haramaya University in 2007 after fulfilling the requirements set by the National Variety Release Committee. The accessions were planted at Haramaya University research field using augmented design in 2012/13 main growing season for yield and quality evaluation.

Table 1 List of sweet potato accessions.

No	Accession	No	Accession	No	Accession	No	Accession
1	Tis-8441-3	30	Tis-8441-4	59	CEMSA	88	CN-1753-16
2	Tis-8441-3	31	Tis-9465-2	60	Bacariso	89	CN-1752-14
3	Tis-82/0602-12	32	Tis-80/043-3	61	Awassa-83	90	CN-2065-18
4	Tis-70357-7	33	Tis-9465-10	62	Nefissie	91	CN-2059-9
5	Tis-9465-7	34	Tis-9068-8	63	CN-2065-5A	92	CN-2065-16
6	Tis-8250-9	35	Tis-70357-5	64	CN-2065-11	93	CN-2065-15
7	Tis-9065-5	36	Tis-9465-8	65	CN-2065-1	94	CN-1753-5
8	Tis-82/0602-2	37	Becale type-3	66	CN-2065-11	95	CN-1775-4
9	Tis-80/043-1	38	Koka-26	67	CN-2065-7	96	CN-1775-3
10	Tis-9068-6	39	Wondogenet	68	CN-2065-8	97	CN-1753-1
11	Tis-82/0602-6	40	Tis-9068-2	69	CN-2065-10	98	CN-1753-7
12	Tis-82/0602-1A	41	Koka-9	70	CN-2065-5B	99	CN-1753-8
13	Tis-70357-4	42	Guracha	71	CN-2065-6	100	CN-1754-6
14	Tis-8250-4	43	Arbaminch	72	CN-2066-4	101	CN-1754-5
15	Tis-9465-1	44	Abadiro	73	CN-2066-2	102	CN-1754-3
16	Tis-9465-8	45	Koka-14	74	CN-1752-8	103	CN-1753-11
17	Tis-9065-1	46	Cuba-1	75	CN-1752-9	104	CN-1753-12
18	Tis-8441-1	47	Koka-12	76	CN-1752-15	105	CN-1753-13
19	Tis-9468-7	48	Bacale	77	CN-2059-4	106	CN-1753-14
20	Tis-80/043-2	49	Bacale type-1	78	CN-2059-3	107	CN-1753-17
21	Tis-82/062-11	50	Alemaya-local-2	79	CN-2059-20	108	CN-1753-18
22	Tis-8250-7	51	Alemaya-local-3	80	CN-2059-5	109	CN-1754-12
23	Tis-9465-9	52	Becale-type-1	81	CN-2059-8	110	CN-2054-5
24	Tis-9068-3	53	Lesh type—1	82	CN-1752-5	111	CN-2054-7
25	Tis-8250-8A	54	Korojo-1	83	CN-1752-6	112	CN-1754-11
26	Tis-8250-2	55	Becale-B	84	CN-2054-1	113	CN-1753-20
27	Tis-8250-1	56	Korojo	85	CN-2054-2	114	CN-1753-19
28	Tis-70357-2	57	Becale-B	86	CN-1754-9	115	Adu
29	Tis-82/0602-1B	58	Korojo-2	87	CN-1753-15	116	Berkome

2.2. Experimental Design and Procedure

The Accessions were tested in augmented block design with 19 replications. Each replication contained six accessions and two checks. Each check was appearing once in each block. The checks were replicated 19 times and 114 entries/tests were not replicated. Young portion of 30 cm length of the vine cuttings were planted and 2/3 of their length was covered by soil. 100cm and 30cm were maintained between rows and plant, respectively. Twelve holes per plot were prepared and one vine cutting was planted in each hole of the ridge. Replanting was done to substitute the dead vine after one week of planting. All plots received recommended cultural practices uniformly.

Harvesting was done after 90% of the sweet potato leaves changed into yellowish color. From each plot 10 plants were taken for both physical and proximate analysis. In the field the physical attributes were characterized immediately after harvest. From the total harvest, five sweet potato storage roots were randomly selected for laboratory analysis immediately after physical and yield related data were recorded. Cleaning debris and dust were done before proximate analysis. Hundred fifty two samples were analyzed in laboratory; among those two checks were replicated 19 times. The remaining 114 accessions were not replicated. The optimum temperature during the analysis was estimated 25 ^{o}C.

2.3. Data Collection

Data were not collected from plants grown at maintenance field; however, data were collected from plants grown at evaluation field on both plant and plot basis. The data were collected and recorded according to International Board of Plant Genetic Resource (IPBGR, 1991) to evaluate the sweet potato accessions. Five storage roots were taken for proximate analysis. The physicochemical evaluation was also conducted as per the laboratory procedure (Mazumdar *et al.*, 2003) and according to International Board of Plant Genetic Resource (IPBGR, 1991).

3. Results

3.1. General Description of Accessions under Maintenance

Among 116 accessions, 44.83% were obtained from Asian Vegetable Center which accounted relatively large proportion of accessions and followed by accessions obtained from Nigeria Vegetable Center which accounted 31.93%. The accessions obtained from Asian Vegetable Center had initials Tis and CN, respectively. Sweet potato accessions that were collected from the country accounted 20.69%. Only two accessions (1.72%) were collected from Cuba including one released variety. The number of accessions from different sources is presented in Figure 1.

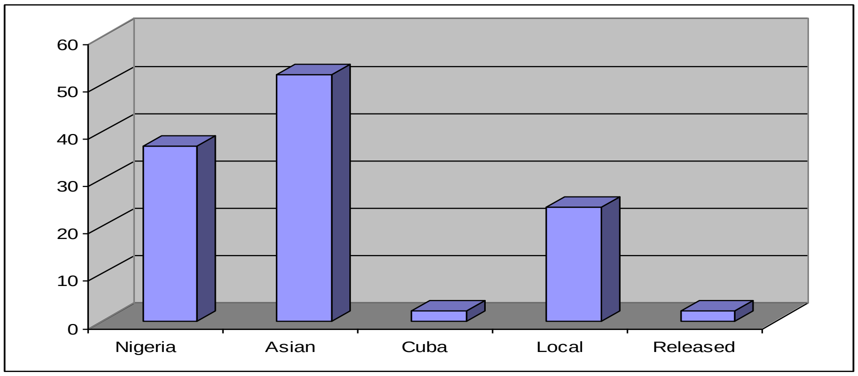

Figure 1. Number of sweet potato accessions from different sources.

3.2. Evaluation of Sweet Potato Accessions

3.2.1. Analysis of variance

Accessions were evaluated for three phenology and growth characters, nine quality related traits and 10 traits of yield and yield components which totally summed to 22 traits. Analysis of variance was computed considering all the collected traits. Analysis of variance computed for 22 phenological, growth, yield, yield components, physical and chemical attributes of sweet potato accessions are presented in Table 2. The result revealed the presence of highly significant differences ($P<0.01$) among accessions for reducing sugar, total sugar, total starch content, pH, total soluble solid, days to physiological maturity and specific gravity. Significant differences ($P<0.5$) were also observed for root fresh weight, total storage root yield, marketable storage root yield, dry matter content and peel content. However, non-significant differences were observed among accessions for number of branches per plant, vine length, above ground dry biomass yield, average number of storage roots per plant, average mass of storage roots, marketable storage root number/plant, unmarketable storage root number/plant and moisture content.

The study also revealed the presence of highly significant ($P<0.01$) differences between the control (check) varieties for days to physiological maturity, storage root fresh weight, dry matter content, reducing sugar, total sugar, total starch content and total soluble solid. Significant ($P<0.5$) differences were also observed for above ground fresh biomass yield, above ground dry biomass yield, marketable storage root yield, peel content. However, non-significant differences were observed between the check varieties for number of branches per plant, vine length, average number of storage root, marketable storage root number, unmarketable storage root number, average mass of storage root, total storage root yield, pH, moisture content and specific gravity.

Analysis of variance also exhibited highly significant ($P<0.01$) differences among tests for days to physiological maturity, total storage root yield, reducing sugar, total sugar, total starch content, pH and specific gravity. Likewise significant ($P<0.5$) differences were also exhibited among test entries for dry matter content, peel content and total soluble solid. However, number of branch per plant, vine length, above ground fresh biomass, above ground dry biomass, storage root fresh biomass, average number of storage root, marketable storage root number, unmarketable storage root number, average mass of storage root, marketable storage root yield, unmarketable storage root yield and moisture content found to be non significant.

The results of analysis of variance also revealed the presence of highly significant ($P<0.01$) differences among test versus control for days to physiological maturity, storage root fresh weight, total storage root yield, marketable storage root yield, total starch content, pH and moisture content while significant differences ($P<0.5$) was observed for average mass storage root and reducing sugar. However, non-significant differences among test versus control were observed for number of branch per plant, vine length, above ground fresh biomass, above ground dry biomass, average number of storage root, marketable storage root number, unmarketable storage root number, unmarketable storage root yield, dry matter content, peel content, total sugar, total soluble solid, and specific gravity.

3.2.2. Mean Performances of Accessions

The mean, minimum and maximum mean values in the experiment for each trait is presented in Table 3. Accessions were exhibited higher mean values than the mean values of the two checks (Adu and Berkome) with varying numbers ranged from 9 accessions for days to physiological maturity to 79 accessions for above ground fresh biomass yield. However, if early maturity is becoming a breeding objective, 92.11% accessions were exhibited early maturity than the two check varieties. Majority of the accessions were superior over released varieties for vine length, above ground fresh and dry biomass and specific gravity where 69.3, 62.28 and 62.28% of the accessions, respectively, had higher mean values than the mean values of the check varieties. For other traits such as number of branches and average mass of storage root, 41.23 and 47.37% accessions, respectively, had greater mean values than the mean of the check varieties. On the other hand, 49.12 and 38.84% of the accessions had higher moisture and peel content of storage roots, respectively, which was in undesirable direction. For yield and yield component, with varying number of accessions that ranged from 10.53% (marketable storage root yield t/ha) to 29.82% (unmarketable storage root yield t/ha) had mean values greater than the mean values of the check varieties. More importantly, 11.4, 17.54 and 28.07% accessions exhibited higher mean values for total storage root yield t/ha, dry matter content and total storage root number per plant, respectively, greater than the mean values of the check varieties.

Total storage root yield (t/ha) ranged from 2.261 to 28.461 with average yield of 12.025. Marketable storage root yield and unmarketable storage root yield (t/ha) ranged from 0.512 to 22.08 and 0.01 to 13.63, respectively. More interestingly, 15, 13, 12 and 20 accessions were performed for storage root fresh weight, total storage root yield, marketable storage root yield and dry matter content, respectively, better than the mean performance of check varieties Adu and Berkome.

Table 2. Mean squares for 22 traits of sweet potato [*Ipomoea batatas* (L.) Lam.] collections on the basis of adjusted means.

Trait	Replication (18)	Accession (115)	Error (18)	Among control (5)	Among tests (109)	Tests vs control (1)
Days to physiological maturity	2	380.71**	2.58	351.4**	261**	463.4**
Number of branches per plant	2.32	4.81 ns	2.85	4 ns	4.89 ns	7.12 ns
Vine length (cm)	336.38	436.66 ns	231.39	151.6 ns	436.23 ns	81.03 ns
Above ground fresh biomass yield (g/plant)	161301.68	106538.44 ns	56312.68	221885.81*	97485.46 ns	106516.65 ns
Root fresh weight (g/plant)	55646.28	66130.4*	26267.22	351318.6 **	44089.43 ns	2271536.94**
Above ground dry biomass yield (g/plant)	161301.68	106538.44 ns	56312.68	212975.84*	95178.10 ns	230199.24 ns
Average number of storage roots per plant	5.35	2.88 ns	3.96	7.5 ns	1.52 ns	6.87 ns
Average mass of storage roots (g)	0.006	0.002 ns	0.002	0.01 ns	0.02 ns	0.01 *
Marketable storage root number/plant	1.36	0.95 ns	0.8	1.8 ns	0.6 ns	0.29 ns
Unmarketable storage root number/plant	2.62	1.15 ns	2.07	3.2 ns	0.78 ns	5.31 ns
Total storage root yield (t/ha)	20.02	24.79*	9.59	53.8 ns	14.23**	234.46**
Marketable storage root yield (t/ha)	10.4	15.15*	5.79	30.7*	9.09 ns	141.93**
Unmarketable storage root yield (t/ha)	8.84	4.67 ns	3.67		4.71 ns	1.38 ns
Dry matter content (%)	13.01	21.61*	6.16	23.1*	16.83*	16.47 ns
Peel content (%)	61.77	95.2*	37.86	212**	80.84*	1.68 ns
Reducing sugar(mg/100 gm^{-1})	0.42	2.18**	0.23	2.6**	2.12**	2.22*
Total Sugar (mg/100 gm^{-1})	1.29	2.72**	0.55	5.7**	2.25**	0.94ns
Total starch content (mg/100g^{-1})	1.16	3.55**	0.49	11.9**	2.02**	5.8*
pH	0.04	2933.79**	0.04	0.05ns	3204.2**	117.35**
Total soluble solid (TSS)	0.75	2.85**	0.9	5.6**	2.27*	0.22ns
Moisture content (%)	2.72	4.71ns	2.78	7.1ns	4.27ns	48.39**
Specific gravity	0.73	15.26**	0.8	0.50 ns	18.63**	2.67 ns

**, ** and ns, significant at P<0.05, P<0.01 and non significant, respectively.*

Table 3. Mean, minimum, maximum values and standard deviation for phenological and growth traits of 116 sweet potato accessions on the basis of adjusted means.

Trait	Mean, minimum and maximum values for accessions			SD	Number accession above mean	Number accession below mean	Mean of check Varieties	Number accession above mean of check varieties	Number accession below mean of checks
	Mean	Min	Max						
Days to physiological maturity	173	111	199	18.03	54	60	189	9	105
Number of branches/plant	8.139	1.447	20.447	2.445	60	54	8.447	47	67
Vine length (cm)	67.729	3.62	138.862	26.213	67	47	58.487	76	38
Above ground fresh biomass yield	1875.877	265	5060	899.516	46	68	1365	79	35
Above ground dry biomass yield	952.3	210	2145	398.04	55	59	785.5	71	43
Storage root fresh weight	542.7807	103	1439	262.400	54	60	825	15	99
Average mass of storage root	0.149	0.018	0.318	0.053	54	60	0.189	54	60
Marketable storage root number	3.105	0.695	5.395	1.023	47	67	3.89	24	90
Unmarketable storage root number	3.712	0.816	6.316	1.284	49	65	4.316	24	90
Total storage root number	6.84	2	11	1.819	50	64	6.5	32	82
Marketable storage root yield	8.143	0.512	22.088	3.958	40	74	11.77	12	102
Unmarketable storage root yield	3.9	0.001	13.631	2.606	44	70	4.431	34	80
Total storage root yield	12.025	2.261	28.461	5.178	37	77	16.21	13	101
Dry matter	24.878	13.275	40.215	5.238	40	74	28.42	20	94
Specific gravity	1.194	1.046	1.334	4.043	37	77	1.75	71	43
Moisture content	80.5	70.03	86.69	2.848	54	60	8.8	56	58
Peel content	24.71	14.41	28.04	11.256	47	67	37.225	42	72

Min and Max = minimum and maximum mean values in the experiment, respectively. SD = standard deviation.

4. Discussion

The variation among accessions and check varieties were observed for the studied characteristics such as morphology, phenology, physical and chemical qualities of storage roots. Considerable number of accessions maintained at Haramaya University had desirable attributes better than the released varieties in many of the traits studied which can be exploited in sweet potato improvement program. Variation is the occurrence of difference among individuals due to difference in their genetic composition and/or the environment in which they are raised (Falconer., 1990; Allard, 1960; Welsh, 1990). If the character expression of two individuals could be measured in an environment exactly identical for both, difference in expression would result from genetic control and hence such variation is called genetic variation (Falconer, 1990). The results of the study indicated that the presence of genetic variability among accessions and the importance of maintaining accessions for long period to utilize the accessions for different breeding objectives in the process of improving the crop.

More importantly, 10 accessions had average marketable storage yield advantage of 32.49% over the mean of two check varieties which ranged from 6.78% to 87.66% yield advantages. These accessions also exhibited average marketable storage root yield advantage of 19.59% over the best performing check variety, Adu with the highest advantage of 69.39%. Similarly, 10 accessions exhibited 37.17%, 24.37%, and 52.91% average total storage root yield advantages over the mean of the two check varieties. Marketable as well as unmarketable storage root or total storage yield in general are inherited genetically or highly controlled by genetic constitution as well as environment (Huaman *et al*., 1999, Mukhtar *et al*., 2010). The observed differences among accessions in this study might be due to genetic differences since all accession as well as checks receive equal management and treatment. This indicated the highest yield advantages of accessions and the need to test accessions for yield and yield components.

Generally, it was observed significant differences among entries, among test versus control/check varieties, between check varieties of sweet potato for considerable number of traits which can be exploited in breeding program or that will allow breeders to select entries for desirable trait(s) that they wish to improve. Donald (1968) describes two basic principles for plant breeding, 'selection for yield' and 'defect elimination'. Therefore, the basic principles behind plant breeding programme are to develop cultivars with better yield potential and quality attributes as well as to develop cultivars that have genetic resistance against production hazards that can prevent a cultivar from expressing its yield potential (Acquaah , 2007). Based on these principles the sweet potato breeding programme may relies on improvement of storage roots yield and improved the quality of the storage roots as per the end use and the observed differences among entries may allow the breeders to use accessions for different objectives. Therefore, information generated in this study on variation of accessions justify to maintain accessions to be utilized by breeders since variability greatly helps in formulating sound crop breeding and improvement program (Welsh, 1990).

5. Summary and Conclusion

Sweet potato [*Ipomoea batatas* (L.) Lam] is cultivated in Ethiopia mostly for human consumption. Sweet poteto stands third after Enset [*Ensete ventricosum* (Wele) Cheesman] and Potato (*Solanum tuberosum* L.) as the most important root crops produced in the country. Sweet potato is the cash and home consumption crop for eastern region of Ethiopia. The world as well as the country needs to increase food production to feed the increasing population. Plant genetic resources constitute the foundation upon which agriculture and world food securities are based on. The genetic diversity in the germplasm collections is critical to the world's and the country's fight against hunger. They are the raw material for breeding new plant varieties and are a reservoir of genetic diversity. Haramaya University has released two sweet potato varieties namely; Berkume and Adu and made recommendation for cultivation in Eastern part of the country. Moreover, Haramaya University maintained 114 accessions and two released varieties for years. These collections are obtained from international and local sources. As our knowledge permits, we cannot found such large number of accessions maintained anywhere in the country. Therefore, maintaining these accessions is not only for the benefit of Haramaya University and thereby eastern Ethiopia in developing sweet potato varieties but it is also for the whole nation. This justifies the importance of maintaining accessions for long period though the associated higher cost is a major problem for the University.

Haramaya University has maintained 116 sweet potato accessions for decades for research and academic purpose. However, extensive agronomic and physicochemical attributes of collections has not been carried out to identify which accession(s) attributed what and potentially used for which purpose(s). Therefore, documenting the agronomic and physicochemical attributes of accessions was necessary. Based on this assumption, this research was conducted to evaluate, characterized and document agronomic, physical and chemical attributes of sweet potato collection obtained from international as well as local sources. The collections were tested in augmented block design with 19 replications or blocks. Each replication/block contained six entries/tests and two checks. Each check was appearing once in each block. The checks (Adu and Berkume) were replicated 19 times and 114 entries/tests were not replicated. Accessions showed significant differences for 12 out of 22 traits measured viz., days to physiological maturity, root fresh weight (g/plant), total storage root yield (t/ha), marketable storage root yield (t/ha), dry matter content (%), peel content (%), reducing sugar(mg/100 gm^{-1}), total sugar (mg/100 gm^{-1}), total starch content (mg/100g^{-1}), pH, total soluble solid (TSS) and specific gravity. Tests vs control also showed significant differences for many traits. The result showed the possibility to improve many of the characters through selection of accessions for traits which performed best. The observed significant differences among accessions, entries/tests and tests vs control for many of the traits including yield will allow testing accessions in replicated trial for which they exhibited significantly highest performance.

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11. Maintenance and Enhancement of Potato (*Solanum tuberosum* L.) Genotypes at Haramaya University

Wassu Mohammed Ali

Haramaya University, College of Agriculture and Environmental Sciences, School of Plant Sciences, Haramaya, Ethiopia
Author E-mail: wasmoha@yahoo.com

Abstract: Keeping in view the importance of maintaining germplasms for the improvement of crops Haramaya University maintained 329 potato genotypes which were introduced at the start of introducing the crop in Ethiopia. Three hundred genotypes were evaluated to late blight resistance where 42 accessions found as moderately resistant. Twenty accessions were evaluated for heat tolerance at Dire Dawa where 13 accessions were produced more than 10 t/ha total tuber yield. The observed variability among accessions for disease resistance and heat tolerance justified the importance of maintaining accessions and released varieties for long period though the cost related to maintaining is very high. Therefore, maintaining, characterization, evaluation and documentation of genotypes are necessary.

Keywords: Accession; Heat Tolerance; Late Blight

1. Introduction

Potato (*Solanum tuberosum* L.) is one of the most widely grown food crops after the three cereals, namely maize, rice and wheat (Vleeshouwers *et al*., 2011). In eastern Africa, potato is the best crop for food and nutrition where food security is a key priority for the over 200 million people that are envisaged to double by 2030 (Kyamanywa *et al.,* 2011). Potato is regarded as a high-potential food security and stable food crop because of its better ability to provide a high yield of high-quality product per unit input with a shorter crop cycle (mostly <120 days) compared to major cereal crops like maize (Hirpa *et al*., 2010). The crop is also appreciated for its high yield per unit area of land, and as a good source of nutritious food and cash by large number of food insecure smallholder farmers and pastoralists in Ethiopia (Haverkort, 2012). Approximately 1.3 million farmers (CSA, 2012) grow potato in mid and highlands of Ethiopia.

In the last 10 years, potato productivity in Ethiopia has progressed from 7 to 11 tons/ha. Nevertheless, the current area cropped with potato (about 0.16 million ha) is very small and the average yield is below 10 tons/ha far below the country‘s potential (Baye and Gebremedhin, 2013). It is also very low compared to the world's average of 16.4 tons ha $^{-1}$ and to other potato producing countries of the world, such as New Zealand (50 tons ha -1), Netherlands (44.7 tons ha -1), USA (44.6 tons ha-1), South Africa (34 tons ha-1), Egypt (24.8 tons ha-1), and Morocco (24.2 tons ha-1) (FAOSTAT, 2010). The major contributing factors to the low yields have been the use of inferior and/or poorly adapted varieties, high prevalence of diseases and insect pests, poor soils, and unfavorable weather conditions.

Germplasm source is a very crucial in variety development and release. In most cases, the richer the source materials and germplasms the more and the best varieties can be developed and released. However, countries in East and Central Africa have different approaches to accelerated release of acceptable varieties. They also follow different approaches on how they can build their source materials and germplasms. Some countries depend entirely on CIP for materials for their breeding programmes, while others generate own crosses using both local and exotic materials. When we consider Ethiopian condition, the Ethiopian Agricultural Research Institution (EARI) has a national mandate to conduct and coordinate research, but institutions of higher education (Universities and Colleges) are also engaged in research on potato and other crops. The organization has a strong collaborative research with international agricultural research centers such as CIP for potatoes. The variety development, which involves evaluation, selection, release and registration procedures pass through several stages (George and Otim, 2007). With this strength and mainly depending on CIP for potato germplasm source, the Institution along with Universities such as Haramaya University released considerable number of potato varieties for different regions.

The presence of genetic variability is considered to be the prerequisite in any plant breeding program. Therefore, maintaining the available potato germplasm is crucial for the success of the crop improvement. Haramaya University is pioneer in starting potato research in the country and it is also known in maintaining accessions obtained from International Research Centers and other sources. The collection that the University maintained could also served as deposit for the national potato research program. Therefore, maintaining the collections for long period is necessary for the success of potato improvement. This research activity was executed for a number of years by Haramaya University and reinitiated to continue in maintaining and evaluating the genotypes for different purpose.

2. Materials and Methods

The research consisted of two activities: 1) maintenance of the genotypes and 2) evaluating of the genotypes for some agronomic traits, particular for late blight resistance and yield potential at lowland conditions. Three hundred twenty nine potato genotypes including the released potato varieties by Haramaya University and other Research Centers were maintained at Haramaya University for last two years. The genotypes were planted in a non-replicated trial with three rows each has 12 meters length. Medium size and well sprouted potato tubers were planted at a spacing of 75 cm between rows and 30 cm between plants. All agronomic practices have been applied as per the recommendation made for the crop.

Three hundred potato accessions were evaluated to late blight resistance at Haramaya conditions as genotype enhancement activity which was superimposed on the maintenance activity for two years. The remaining 29 genotypes were the released varieties (22), heat tolerant (5) and other two genotypes were evaluated for yield and yield related traits. The released varieties evaluation report is separately prepared which is not the part of this project.

Evaluation of genotypes for heat tolerance was conducted using five heat tolerant potato varieties, which have been developed elsewhere in the world for low land agro- ecology and other 22 potato genotypes, which have been performed best at Dire Dawa in the past trial. The genotypes were evaluated for one season using randomized block design (RCBD) with three replications. The plot size of 3 × 3 m was used for each accession. A distance of 1m between blocks and 1m between plots was maintained. Each plot was consisted of 4 rows of 10 plants.

Land was prepared according to the recommendation made for the crop. Medium size and well sprouted potato tubers were planted at a spacing of 75 cm between rows and 30 cm between plants. Weeding, fertilizer application, cultivation, ridging were done to facilitate root, stolon and tuber growth.

Total tuber yield, marketable and unmarketable tuber yield, tuber number per plant and dry matter content were collected. Data were collected from the two central rows excluding the two plants grown at both ends of the rows.

3. Results

3.1. Maintenance of the Genotypes

A total of 329 genotypes were maintained of which 75 were with initial AL which are the old accessions. Others were with CIP, UK and K initials which accounted 215, 6 and 4, respectively. The released varieties, lowland and other clones were 22, 5 and 2, respectively (Fig. 1). The list of the genotypes is presented in Table 1.

Table 1. Potato genotypes under maintenance.

No.	Genotype	No.	Genotype	No.	
1	AL-1(moger)	43	AL-436-2	85	UK-94-10
2	AL-100	44	AL-436-3	86	UK-94-18B
3	AL-100-1	45	AL-436B	87	UK-96-1
4	AL-107	46	AL-441B	88	HU01
5	AL-118	47	AL-448-3	89	HU6
6	AL-119	48	AL-450	90	HU16
7	AL-148	49	AL-450-5	91	HU19
8	AL-148-1	50	AL-456	92	Vivilda
9	Al-148-12	51	AL-471	93	C1P-372146-27B
10	AL-148-4	52	AL-472	94	C1P-377046-20
11	AL-148-B-1	53	AL-501	95	C1P-377308-10
12	AL- 148-6	54	AL-503	96	C1P-377412-2
13	AL-200	55	AL-517	97	C1P-377838-1c
14	AL-204	56	AL-528	98	C1P-378313-18B
15	AL-207	57	AL-531	99	C1P-378326-6
16	AL-208	58	AL-536-2	100	C1P378328-6
17	AL-209	59	Al-553-1	101	C1P-378329-2
18	AL-212	60	AL-556	102	C1P-378361-5B
19	AL-214	61	Al-556-2	103	C1P-378371-19
20	AL-214B	62	AL-560	104	C1P-378371-3
21	AL-216	63	AL-562	105	C1P-378501-9A
22	AL-221	64	AL-567	106	C1P-382121-6
23	AL-250	65	AL-570	107	C1P-383032-15
24	AL-252	66	AL-601	108	C1P-386034-4f
25	AL-253	67	AL-624-2	109	C1P-386040-8
26	AL-254	68	AL-624-2	110	C1P387143-33A
27	AL-255	69	Al-624-3	111	C1P388452-4
28	AL-258	70	AL-624-3	112	C1P-389701-3
29	AL-259	71	AL-624-33	113	C1P391058-506
30	AL-259B	72	AL-624-35	114	C1P-391058-512
31	AL-268	73	AL-624-5	115	C1P391058-555
32	AL-269	74	AL-624-9	116	C1P-391058-557

33	AL-270	75	AL-635	117	C1P-391058-558
34	AL-280	76	CIP-K-59a(26)2b	118	C1P-392622524
35	AL-348	77	CIPUK-97-6	119	C1P-392640-540
36	AL-350	78	clone#77	120	C1P-396029-18C
37	AL-406	79	K-59a(26)2b2	121	C1P-399665-4
38	AL-406B	80	K-59a(26)2b2-1	122	C1P-90134-2
39	AL-406c	81	K-59A(26)2B2B	123	C1P-90162-3
40	AL-416	82	SIRO	124	C1P-90178-8
41	AL-416B	83	UK-90-3	125	CIP-377143-33
42	AL-436	84	UK-94-1	126	CIP-377164-20

Table 1. Continued.

No.	Genotype	No.	Genotype	No.	Genotype
127	CIP-377176-2	169	CIP-378501-16	211	CIP-387046-20
128	CIP-377808-10B	170	CIP-378501-16A	212	CIP-3870808-10H
129	CIP-377808-10B1	171	CIP-378501-5	213	CIP-387096-11A
130	CIP-377823-2	172	CIP-378501-5b3	214	CIP-387096-5
131	CIP-377838-1	173	CIP-378501-7A	215	CIP387096-5A
132	CIP-377838-1A	174	CIP-3785019-1	216	CIP387146-20
133	CIP-377852-2	175	CIP-378501-9A	217	CIP-387146-26A
134	CIP-378194-28	176	CIP-378551-7A	218	CIP-387146-6B
135	CIP-378194-6A	177	CIP-378554-8A	219	CIP387224-25
136	CIP-378313-22A	178	CIP-378554-8B	220	CIP-387292-27c
137	CIP-378313-27A	179	CIP378570-2	221	CIP-387308-10I
138	CIP-378321-7B	180	CIP-378570-4B	222	CIP387808-10
139	CIP-378323-2	181	CIP-378570-6	223	CIP-387808-10A
140	CIP378323-2A	182	CIP-378571-5A	224	CIP-388313-18
141	CIP-378323-2B	183	CIP-381058-516	225	CIP-388313-18A
142	CIP-378326-2	184	CIP381381-20	226	CIP-388370-12B
143	CIP-378328-6	185	CIP-381403-5	227	CIP-388443-3A
144	CIP-378329-2	186	CIP-382018-520	228	CIP-388452-10
145	CIP-37834333B	187	CIP-382121-5	229	CIP-388452-2
146	CIP-378348-8	188	CIP-382146-27B	230	CIP-388452-2A
147	CIP-378361-5B	189	CIP-382171-3B	231	CIP-388452-3b2
148	CIP-378366-2	190	CIP-382174-4	232	CIP-388453-3A
149	CIP-378370-14	191	CIP-382180-2	233	CIP-388453-3b2
150	CIP378370-3	192	CIP-382620-511	234	CIP-388453-3b5
151	CIP-378371	193	CIP-382640-508	235	CIP-388464-6
152	CIP-378371-12	194	CIP-382650-506	236	CIP-388764-26
153	CIP-378371-12A	195	CIP-383667-3D	237	CIP389658-5
154	CIP-378371-13A	196	CIP-384321-3	238	CIP-389668-4
155	CIP378371-16	197	CIP-384321-3B	239	CIP-389673-2
156	CIP-378371-19	198	CIP-385012-26	240	CIP-389673-2B
157	CIP-378371-21	199	CIP-385383-12	241	CIP-389701-1
158	CIP-378371-23	200	CIP-386029-10A	242	CIP-389701-3
159	CIP-378371-3A	201	CIP-386029-18A	243	CIP-390010-8A
160	CIP-378371-51	202	CIP-386029-18B	244	CIP-391058-504
161	CIP-378371-9B	203	CIP-386029-18C	245	CIP-391058-506
162	CIP-378371-9c	204	CIP-386031-4A	246	CIP-391058-507
163	CIP-378371-9G	205	CIP-386031-4A1	247	CIP391058-513
164	CIP-378376-2B	206	CIP-386034-4	248	CIP-391058-514
165	CIP-378453-3B	207	CIP-386034-4	249	CIP-391058-520
166	CIP-378454-3b	208	CIP-386034-4B	250	CIP-391058-522
167	CIP-378501-10A	209	CIP-386040-8	251	CIP-391058-523

168	CIP-378501-10B	210	CIP-386423-13	252	CIP-391058-538

Table 1. Continued.

No.	Genotype	No.	Genotype
253	CIP-391058-545	295	CIP-90134-5
254	CIP-391058-548	296	CIP90138-1
255	CIP-391058-554	297	CIP-90147-34
256	CIP-391058-558	298	CIP-90147-91
257	CIP-391058-563	299	CIP-90162-18
258	CIP-391240-2	300	CIP-90162-2
259	CIP-392140-516	301	CIP-90162-34
260	CIP-392140-526	302	CIP-90162-3B
261	CIP392618-517	303	CIP-90170-46
262	CIP-392622-514	304	CIP-90178-8
263	CIP-392622-516	305	CIP-90178-8A
264	CIP-392622-517	306	CIP-384321/3A
265	CIP-392622-519	307	CIP-384321/3B
266	CIP-392622-521	308	AL-624
267	CIP-392627-508	309	Ararsa
268	CIP-392627-517	310	Awassa
269	CIP-392637-500	311	Bedasa
270	CIP-392640-501	312	Belete
271	CIP-392640-502	313	Bete
272	CIP-392640-504	314	Bubu
273	CIP-392640-514	315	Bule
274	CIP-392640-516	316	Chiro
275	CIP-392640-517	317	Gabisa
276	CIP-392640-518	318	Gera
277	CIP-392640-520	319	Gorebella
278	CIP-392640-521	320	Guassa
279	CIP-392640-523	321	Gudenie
280	CIP-392640-525	322	Harchasa
281	CIP-392640-528	323	Jalenie
282	CIP-392640-531	324	Jarso
283	CIP-392640-539	325	Marachere
284	CIP-392640-540	326	Menagasha
285	CIP392640-540B	327	Moti
286	CIP-392640--541	328	Wechacha
287	CIP-392640-544	329	Zemen
288	CIP-392640-560	330	Jarso (Local cultivar)
289	CIP-392650-517	331	Bete (Local cultivar)
290	CIP-396029-18		
291	CIP-575049		
292	CIP-702867-51NA		
293	CIP-702867-51NB		
294	CIP-90134-2		

Note: AL, CIP, UK and K represented the old Alemaya accessions, CIP-Peru, England and Korea accessions, respectively.

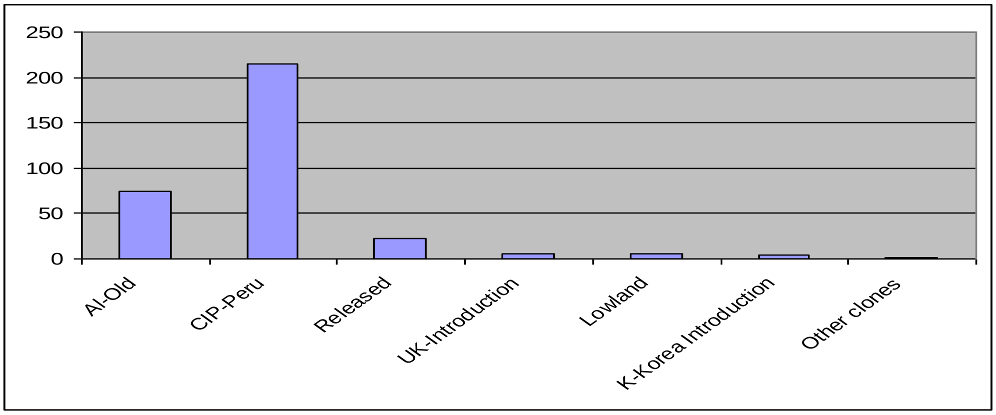

Figure 1. Potato genotypes maintained at Haramaya University.

3.2. Evaluation of Genotypes to *Phytophthora Infestans* (Mont.) de Bary Resistance

Disease assessment was conducted starting as soon as disease symptoms appeared on susceptible genotypes the onset of the disease in the most susceptible accessions near to 40 days after planting for two years. The activity was repeated every 20 days interval for subsequent two disease assessments which the final disease was recorded when majority of the genotypes attained physiological maturity. Disease severity was assessed following CIP (2006) and assessment of late blight severity under field conditions described by Henfing (1987). Three hundred potato accessions and released varieties along with two local cultivars and promising genotypes were evaluated to late blight resistance as separate trial and only the 300 accessions result is presented.

During 2004/05 cropping season, 216 accessions were evaluated as the most susceptible which recorded average *Phytophthora infestans* severity of more than 75%. The remaining 24, 17 and 28 accessions recorded 0 to <2.5, 2.5 to <10 and 10 to <25%, respectively, which are considered as resistant and moderately resistant. Other 10 and 5 accessions evaluated with 25 to <50 and 50 to <75% disease severity, respectively (Fig. 2).

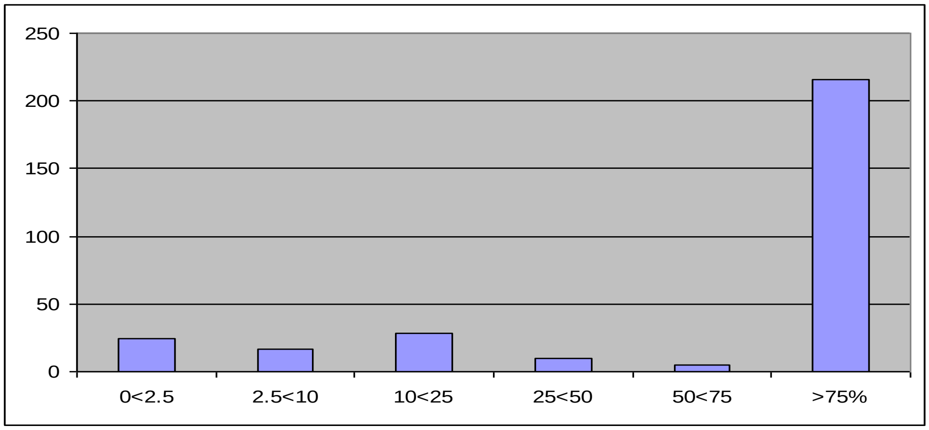

Figure 2. Potato accessions and *Phytophthora infestans* severity in percent (2004/05)

During 2005/06 cropping season, none of the accessions were evaluated as resistant with <10% disease severity. Only 5 and 37 accessions were evaluated with 10 to <25 and 25 to <50%, respectively. Most of the accessions (85%) were severely affected by the pathogen *Phytophthora infestans* with average severity >75% (Fig. 3.).

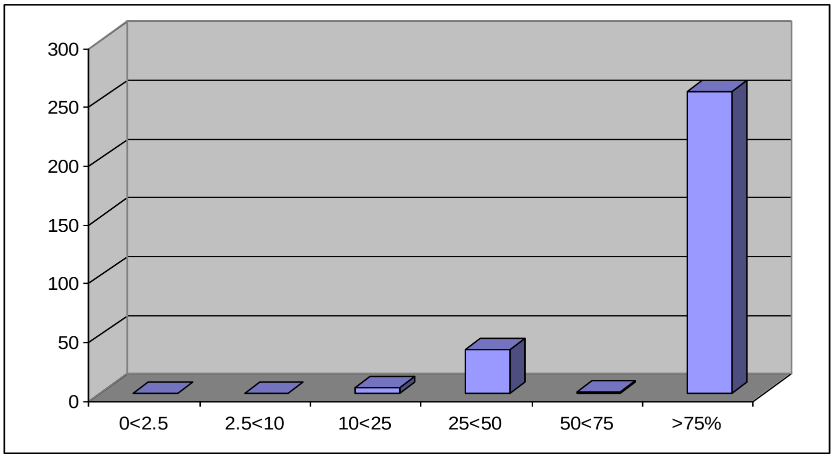

Figure 3. Potato accessions and *Phytophthora infestans* severity in percent (2005/06).

The two years disease assessment was averaged to identify accessions which are resistant and moderately resistant to *Phytophthora infestans*. Accessions recorded average severity of 25% and below can be used for further evaluation using replicated trial which include preliminary yield trial. Only 13.33% of the accessions recorded 10 to <25% severity and other two accessions recorded 25%. The list of accessions and average disease severity along with two consecutive year's assessment data are presented in Table 2. None of the accessions recorded less than 10% severity rather 72.33% of the accessions registered average disease severity >75% and 7.67 and 6.67% of the accessions recorded 50 to <75% and 25 to <50% severity, respectively. Number of accessions along with the calculated average disease severity in percent is presented in Figure 4.

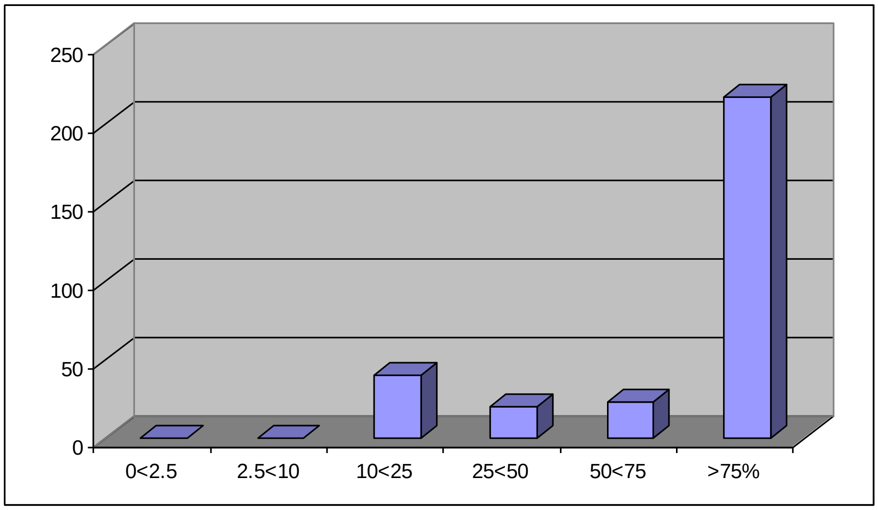

Figure 4. Average disease severity in percent corresponding number of accessions as evaluated for two cropping season (2004/05 and 2005/06).

Table 2. Potato accessions with less severity late blight (≤25%) under field conditions.

No.	Accession	2004/05 severity	2005/06 severity	Average severity
1	CIP-377046-20	25	25	25
2	CIP-377308-10	0	20	10
3	CIP-377412-2	5	25	15
4	CIP-377838-12	10	30	20
5	CIP-378194-6A	5	35	20
6	CIP-378326-2	15	25	20
7	CIP-378326-6	10	20	15
8	CIP-378328-6	3	35	19
9	CIP-378329-2	5	35	20
10	CIP-378321-13A	0	40	20
11	CIP-378454-3b1	3	35	19
12	CIP-378501-91	2	40	21
13	CIP-381403-5	20	20	20
14	CIP-383032-15	20	20	20
15	CIP-384321-13B	3	25	14
16	CIP-384321-3	10	35	23
17	CIP-386029-10A	0	25	13
18	CIP-386029-18B1	15	25	20
19	CIP-386029-18B	15	25	20
20	CIP-386034-4F	10	25	18
21	CIP-387096-5	10	25	18
22	CIP-387143-33A	10	25	18
23	CIP-388313-18A	0	30	15
24	CIP-388370-12B	5	25	15
25	CIP-388452-4	0	30	15
26	CIP-389701-03	0	25	13
27	CIP-390010-10	5	30	18
28	CIP-390010-8A	10	25	18
29	CIP-391058-506	15	25	20
30	CIP-391058-554	10	30	20
31	CIP-391058-555	0	25	13
32	CIP-392618-517	15	25	20
33	CIP-392622-516	15	25	20
34	CIP-392640-501	0	25	13
35	CIP-392640-525	15	20	18
36	CIP-392640-528	0	35	18
37	CIP-392640-540	5	40	23
38	CIP-587146-6B	10	25	18
39	CIP-90162-3	0	30	15
40	CIP-90162-3B	10	25	18
41	CIP-391058-558	20	30	25
42	CIP-378313-27A	0	35	18

Severity late blight in percent under field condition was assessed as per Henfing (1987).

3.3. Evaluation of Accessions for Heat Tolerance

Field trial was conducted during 2004/05 of cropping season to evaluate 22 accessions which were under maintenance and five heat tolerance genotypes along with the recently released potato variety Bubu at Dire Dawa during the hottest period of the area. The list of the accessions along with mean performance of yield and yield component is presented in Table 4. One of the planted 27 genotypes was failed to grow under heat stress and data were collected for 26 genotypes. The analyzed data are presented below.

3.3.1. Analysis of variance

The analysis of variance result revealed that the presence of significant differences among genotypes for total and marketable tuber yields tons/ha, unmarketable tuber number per plant and dry matter content (%). However, non-significant differences among genotypes were observed for unmarketable tuber yield t/ha, tuber number per plant and marketable tuber number per plant.

Table 3. Mean squares from ANOVA for seven yield and yield components of 26 potato genotypes grown at Dire Dawa, eastern Ethiopia.

Trait	Replication (2)	Variety (25)	Error (50)
Total tuber yield tons/ha	210.73	56.15**	23.65
Marketable tuber yield tons/ha	271.96	66.35**	21.20
Unmarketable tuber yield tons/ha	5.785	1.955	1.599
Tuber number per plant	0.681	2.864	3.546
Marketable tuber number per plant	14.865	3.819	2.447
Unmarketable tuber number per plant	17.394	2.608*	1.014
Dry matter content (%)	53.229	6.793**	2.307

** & **, significant at $P<0.01$ and $P<0.05$, respectively.*

3.3.2. Performances of potato genotypes

In this research, total tuber yield was recorded as high as 24.3 t/ha for introduced heat tolerant accession (Vivadial) and as low as 7.41 t/ha for the old introduction of potato genotypes. Therefore, it was evident the possibility of obtaining average total tuber yield of 12.89 t/ha (Table 4). Only seven genotypes were performing below 10 t/ha and six genotypes were performing above 15 t/ha. The remaining 13 genotypes including Bubu (recently released variety) produced between 10 and 15 t/ha which was more than the national average yield. Some of the accessions were performed better than one or more (even more than four) the introduced heat tolerant genotypes.

Regarding the economic importance parameter i.e. marketable tuber yield, genotypes produced 4.44 to 22.52 t/ha with average of 10.62 t/ha. Unmarketable tuber yield tons/ha was ranged from 0.62 to 3.85 with overall mean of 2.28.

Dry matter of potato tubers ranges from about 15.7% to 20.96% with mean dry matter content of 17.79%. Only three genotypes including Vivadial (heat tolerant genotype) recorded more than 20% dry matter content. The remaining genotypes including Bubu exhibited <20% dry matter content.

Table 4. Mean Performance of 26 Potato Genotypes for Yield and Yield Components Grown at Dire Dawa, eastern Ethiopia.

Genotype	TTYt/ha	MTYt/ha	UNMTYt/ha	TN/plant	MTN/plant	UNMTN/plant	DM (%)
CIP-392640-516	13.04	11.25	1.78	7.6	4.73	2.67	18.54
HU19	11.26	7.41	3.85	7.67	3.53	4.13	20.96
HU16	17.18	16	1.19	6.8	5.33	1.47	17.34
Al-100	7.41	4.44	2.97	6.13	2.53	3.6	17.36
CIP-392640-541	15.7	13.33	2.37	8.33	5.07	3.33	17.95
Al-348	13.33	10.96	2.37	5.87	2.87	3	17.26
AL-503	10.37	6.82	3.56	7.33	3	4.33	15.7
CIP-392640-528	15.14	14.52	0.62	5.8	4.4	1.4	17.55
CIP-386029-18c	7.4	4.74	2.67	5.6	2.4	3.2	17.24
AL-209	9.78	6.22	3.56	6.67	2.6	4.07	18.81
CIP-392140-526	21.63	19.85	1.78	7.4	5.27	2.13	17.25
CIP-392640-525	17.78	16	1.78	6.8	5.27	1.53	16.52
Al-269	13.63	10.07	3.55	6.33	3.67	2.67	16.3
CIP-378371-9c	7.4	5.04	2.37	7	2.13	4.87	20.81
Al-119	8.59	6.82	1.78	6.87	3.4	3.47	18.45
CIP-378323-2B	12.77	11.85	0.92	5.53	4.13	1.4	16.65
Al-270	9.33	6.67	2.67	5.6	2.9	2.7	14.89
Vivadial	24.3	22.52	1.78	8.73	6.33	2.4	20.08
CIP-378501-10A	14.52	12.44	2.08	7.47	4.6	2.87	17.8
CIP-391058-506	8	6.22	1.78	5	2.67	2.33	17.52
CIP-391058-520	15.73	13.33	2.4	6.07	4.33	1.73	18.66
CIP-392037-500	13.63	11.56	2.08	7.47	4.47	3	15.92
HU01	13.96	11.85	2.37	7	4.67	2.33	19.17
HU14	11.85	8.89	2.97	6.13	3.6	2.53	16.24
CIP-378371-19	7.7	5.33	2.37	5.07	2.4	3	19.02
Bubu	13.78	12	1.78	5.6	3.5	2.1	18.67
Mean	12.89	10.62	2.28	7	4	3	17.79
LSD (5%)	7.98	7.55	2.07	3	2.57	1.65	2.491
CV (%)	22.1	20.5	20.6	2.4	19.7	19.4	8

TTYt/ha = Total tuber yield tons/ha, MTYt/ha = Marketable tuber yield tons/ha, UNMTYt/ha = Unmarketable tuber yield tons/ha, TN/plant = Tuber number per plant/hill, MTN/plant = Marketable tuber number per plant, UNMTN/plant = Unmarketable tuber number per plant and DM (%) = Dry matter content (%).

3.3.3. Genetic gain and heritability

Genotypic and phenotypic coefficient of variation values ranged from 6.85 to 36.53 and 10.96 to 57.48%, respectively. The estimated phenotypic coefficient of variation was relatively greater than the genotypic coefficient of variation in magnitude and the differences between the two were high for all the traits.

Heritability in broad sense ranged from 6.09% to 41.52% where the lowest value was computed for tuber number per plant followed by unmarketable tuber yield t/ha (6.91%). Genetic gain (advance) at 5% selection intensity ranged from 3.48% (tuber number per plant) to 48.49% (marketable tuber yield t/ha) (Table 5). Unmarketable tuber yield t/ha and dry matter content also recorded less than 10% genetic advance.

Table 5. Genetic gain and heritability in 26 potato genotypes tested at Dire Dawa.

Trait	Range	Mean	σ^2 g	σ^2 p	GCV	PCV	H_2	GA
Total Tuber Yield tons/ha	7.4-24.3	12.89	10.83	34.48	25.53	45.56	31.42	29.48
Marketable Tuber Yield tons/ha	4.44-22.52	10.62	15.05	36.25	36.53	56.69	41.52	48.49
Unmarketable Tuber Yield tons/ha	0.92-3.85	2.28	0.12	1.72	15.11	57.48	6.91	8.18
Tuber Number per plant	5-9	7	0.23	3.78	6.85	27.76	6.09	3.48
Marketable Tuber Number per plant	2-6	4	0.46	2.90	16.91	42.61	15.75	13.82
Unmarketable Tuber Number per plant	1-4	3	0.53	1.55	24.30	41.44	34.38	29.35
Dry matter content (%)	14.89-20.96	17.79	1.50	3.80	6.87	10.96	39.33	8.88

σ^2 g = genotypic variance, σ^2 p = phenotypic variance, GCV = genotypic coefficient of variation, PCV = phenotypic coefficient of variation, H_2 = broad sense heritability and GA = genetic advance at 5% selection intensity.

4. Discussion

Genetic viability was observed among potato accessions for late blight resistance though small proportion of accessions was found to be moderately resistant. Late blight resistance and susceptibility of accessions ranged from <25% to 100%. Particularly, the old accessions which had AL initial were highly susceptible and none of the accessions from this group exhibited <75% disease severity. This might be due to that accessions carried a varying number of R-genes. The observed resistance to *Phytophthora infestans* (Mont) de Bary in accessions introduced at different time was in line with other authors who reported the history of Ethiopian potato varieties development. The National potato research programs in sub-Saharan Africa obtained the germplasm for selection from the International Potato Center (CIP) in Peru (Gebremedhin *et al*., 2008; E1-Bedewy *et al*., 2005). Most of the potato genotypes that have been introduced, developed and released in Eastern Africa before 2008 either have genes for vertical resistance to late blight or have been developed for horizontal resistance in the presence of unknown resistance (major R) genes which were named population A clones (Landeo *et al*.,1997). Similarly, in Ethiopia, varieties which were released up to 2008 were from population A (Gebremedhin, 2013). Therefore, many of the accessions introduced some decades back which showed differential reaction to *Phytophthora infestans* may be due to the R genes they carry and are from population A.

The analysis of variance computed for seven yield and yield components of potato accessions grown at Dire Dawa revealed that the presence of significant differences among accessions for total tuber yields t/ha, marketable tuber yield tons/ha, unmarketable tuber number per plant and dry matter content (%).The presence of significant difference among accessions for most of economic importance traits suggested the existence of variability among potato accessions which selection can be effected. In addition, the result also suggested including many potato accessions as much as possible, since variability to heat stress tolerance was evident from this single trial which only consisted of few potato accessions. In other words, the more the accessions tested under heat stress there will be the higher probability of obtaining high yielding heat tolerant genotypes.

The total area cropped with potato in Ethiopia was 59,508.67 ha (CSA, 2011/12) which was very low as compared to the existing potential that the crop can be grown on about 70% of the 10 million hectares of arable land in the country and the average yield (8 tones ha^{-1}) was far below the potential (FAO, 2008). The low acreage and yield are attributed to many factors, but lack of high quality seed potatoes and high yielding varieties are the major factors (Endale *et al*., 2008a; Gildemacher *et al*., 2009). Particularly high yielding varieties are lacking for lowland areas or there is no report regarding to heat tolerant varieties in the country. In this research, total tuber yield was recorded as high as 24.3 t/ha for introduced heat tolerant accession (Vivadial) and as low as 7.4 t/ha for the old introduction of potato accession. It was evident the possibility of obtaining average total tuber yield of 12.89 t/ha and few accessions produced yield <10 t/ha. This indicated that the accessions have a potential of producing more than the average national yield of potato under mid and high altitude agro-ecologies which suggested the inclusion of more accessions to obtain high yielding genotypes under lowland condition.

Dry matter is particularly significant when frying as the greater the Dry matter the less fat uptake because there is less water for it to replace (Lisika and Leszcy, 1989). In this study the average dry matter of potato was17.79 and with the range of 14.89 to 20.96% which indicated that i) genotypes had not dry matter content below the minimum range for the crop, ii) genotypes had an acceptable dry matter content under heat stress conditions and iii) it is possible to select genotypes that can be used for wide array of end use i.e. for table potato (boiled potato) to French fries.

In this experiment both GCV and PCV values were moderate to high as described by Siva Subramanian and Menon (1973). As the authors indicated genotypic and phenotypic coefficient of variation values can be categorized as low (0-10 %), moderate (10- 20%) and high (20 % and above). The estimated phenotypic coefficient of variation was relatively greater than the genotypic coefficient of variation in magnitude for all the traits and the differences between the two were high indicating the more sensitivity of these traits to environmental modifications.

As per the description given by Robinson *et al.* (1949) for heritability and Johnson *et al.*(1955) for genetic advance, heritability was moderate to total tuber yield t/ha, marketable tuber yield t/ha, unmarketable tuber number per plant and dry matter content. Similarly, the expected genetic advance values or genetic gain was high for total tuber yield and marketable tuber yield t/ha. The observed high genetic advance coupled with moderate heritability was an indication of more additive gene action (Panse, 1957). For these traits which had moderate heritability and high genetic advance, selection may be effective in improving the yield of potato at lowland condition since this indicated the masking effect of environment on the genotypic effect was minimal. Generally, by selecting 5% of the genotypes it was possible to have 29.48% and 48.49% genetic gain of total tuber and marketable yield, respectively, in the genotypes tested.

5. Summary and Conclusion

The richer the source materials and germplasms the more and the best varieties can be developed and released. Though, the potato accessions were introduced starting many decades back and might be considered as obsolete, it is necessary to maintain accessions to use as a source of genes or to select accessions to other desirable traits. The observed variability among accessions for disease resistance and heat tolerance justified the importance of maintaining accessions and released varieties for long period though the cost related to maintaining is very high.

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12. Camel Slaughtering Practices, Meat Production and Preservation in Eastern Ethiopia

Mitiku Eshetu Guya[1] and Getachew Neme[2]

[1]School of Animal and Range Sciences, Haramaya University, Ethiopia
[2]School of Food Science, Post Harvest Technology and Process Engineering, Haramaya University, Ethiopia

Abstract: This study was conducted in Jigjiga and Shinile Zones of Somali National Regional State and Afar region from April to June 2012 to assess camel slaughtering practices and camel meat processing and preservation technologies in the regions. The result of this study revealed that camels are slaughtered first immobilizing the camel by cutting the hind leg at the *Achilus tendon*. Then the animal becomes immobile and guided to slaughtering floor to cut its throat. Subsequently, flying, evisceration, and dressing are undertaken. Then, the meat was transported to butcher house. The butcher house could sell the meat either fresh or traditionally process and preserve it. Preservation of meat was conducted by boiling the meat to reduce the water content as well as to reduce the water activity of the meat. Butter was also added while boiling to enhance flavor and eating quality of the product. This preservation method was common in Ethiopian Somali region among Somali tribes and the preserved camel meat is called *Mukmud* or *Muremure*. This product is claimed to have up to six months shelf life. While slaughtering camel, the animal was suffering from an excruciating pain from broken cut hock as well as from the act of cutting the throat. Therefore, camel slaughtering practice in Somali region was not following the ethical animal slaughtering practice and it breaks the animal welfare protection law. Therefore, immediate interventions need to be taken to stop such cruel act of cutting the legs of live animal while the animal is conscious and feel the pain. There was no practice of cutting *Achilles tendon* in Afar region.

Keywords: Animal Welfare; Meat Preservation; *Muremure*

1. Introduction

Ethiopia possesses 2.4 million heads of camel and majority of these camels are found in the eastern part of Ethiopia mainly in Somali and Afar National Regional states. Camels are slaughtered to produce meat especially during holidays and festivals. Camels are mainly reared for production of milk and milk products. Meat production from camel was not common in the pastoral and agro-pastoral production system of Ethiopia. But the current national economic growth coupled with the increased demand for camel meat from neighboring Middle East countries awaken pastoralists to reconsider camel for meat production.

Camel slaughtering in local abattoirs was investigated and found to be substandard and special way of immobilizing camel was practiced in Jigjiga, Hartichek and Dire Dawa abattoirs. In this slaughter practice, the camel hind legs were first cut at *Achilus tendon* to immobilize the animal. Then the camels were guided to slaughtering floor where cutting of the throat takes place. In this slaughter method, the animal suffer from the broken hind leg and pre-slaughter mishandling. Therefore, slaughter camels need due attention to control and to prevent such needless suffering in almost all aspects of animal handling and husbandry.

Camel has a big role in earning foreign currency through export of live camel. In 2011, of the total exported live animals, camel accounted for 13% and 25% to the revenue generated (NBIIA, 2011). Future research efforts need to focus on exploring the potential of the camel as a source of meat through multi-disciplinary research into efficient production systems, and improved meat technology and marketing.

In addition, camel meat is becoming popular among consumers due to its medicinal and health enhancing properties. According to Kurtu (2004), camel meat is considered as a high quality food with medicinal value and a least cost source of meat in Jigjiga and Harar towns. Moreover, the price of camel meat is increasing from time to time as a result of increased urbanization, economic growth and consumers' awareness about the unique quality of camel meat compared to the common meat of cattle and small ruminants. But the slaughter practice of camel is not well documented and there is no sufficient information. Somali and Afar region are the main camel producing regions of the country and possess majority of the camel population. This research is therefore designed to evaluate camel meat production and to elucidate procedures followed to slaughter camel in the light of animal handling ethics and welfare issues.

2. Materials and Methods

2.1. Description of the Study Area

Jigjiga is the capital city of the Ethiopian Somali National Regional State and found 630 km East of Addis Ababa at a latitude of 9^0 21'N and longitude of 42^0 48' E. The area is characterized by unreliable and erratic rainfall with precipitation ranging from 300 to 600 mm per annum (Bekele, 2001). Altitude of Jigjiga Wereda ranges from 500-1500 m.a.s.l. and majority of the camel herders are Somali ethnic groups. Numerically, camels are the most abundant domestic animals in the area followed by goat. In Jigjiga city, there is one municipal slaughter house where all livestock species are slaughtered and then distributed to the different butcher houses. Slaughtering of animals was takes place starting from 2:00 AM and completed early in the morning.

Dire Dawa is one of commercial city in the Eastern part of Ethiopia. It is found in 515 km East of Addis Ababa at 9^0 27'N latitude and 42^0 89' E longitude. It is bounded in the north west and east by Somali National Regional State and in the north by Oromiya National Regional State.

The mean annual and temperature and precipitation were about 25.3 and 640 mm, respectively (IRDMP, 2004). Dire Dawa town has one municipal slaughter house where different livestock species are slaughtered and distributed to different butcher houses. Pastoralists and agro-pastoralis in Dire Dawa Administrative town and in Shinile Zone were the main supplier of camel for Dire Dawa municipal slaughterhouse.

2.2. Method of Data Collection

The objectives of this paper are to review camel meat production, assess camel slaughtering practices, and recommend possible interventions. To this effect, meat production data were collected from Dire Dawa Administrative and Ethiopian Somali and Afar regional states. Meat vendors and key informants were interviewed and focused group discussions were also undertaken to collect data on method of camel slaughtering, meat processing and preservation methods. Moreover, data on use of preserved meat, type of meat used for the preparation such products were collected. Data on slaughter practices were collected from Jigjiga and Dire Dawa municipal slaughterhouses through observation and interview using pre-tested questionnaire. Moreover, secondary data were collected and reviewed.

Body condition score of slaughter camels

Body condition score (BCS) of camels was assessed following six scale scoring method developed by Faye et al (2001) where zero is for very thin camel and five for fat camel.

2.3. Data Analysis

Data collected from slaughterhouses and meat preservation methods were analyzed using descriptive statistics.

3.Result and Discussion

3.1. Camel Meat Production

Camel takes longer time to reach slaughter weight and age, hence meat production from camel is costly and less common or less heads of camel slaughtered per day. In rural area, slaughtering of camel is also restricted to special occasions like holidays and wedding. Many authors indicated that camel meat, especially young camel meat, is similar in taste and texture to that of beef. The average birth weight is 35 kg, and adult male and female camels weigh 486 ± 81.3 kg and 427 ± 62.2 kg, in Jigjiga area and 384 ± 80.8 kg and 326 ± 62.9 kg in Shinile area, respectively (Tezera Getahun, 1998). The average dressing percentage found to be 50 - 55%.

Many authors indicated that camel meat, especially young camel meat, is similar in taste and texture to that of beef. The amino acid and mineral contents of camel meat are often higher than beef, probably due to lower intramuscular fat levels as most of the fat is deposited in the hump leaving minimal marbling of the red meat. Due to the low fat content, camel meat is therefore believed to be nutritionally healthier and is getting more acceptance than before.

In Somali region, there is a long tradition of processing camel meat into stable dried and oiled meat products. This processed meat product is highly regarded and present to honorable guests and wife presents to her husband as a symbol of respect.

3.2. Body condition of slaughtered camels

The result of this study indicated that out of the total 25 and 30 camels slaughtered in Jigjiga and Dire Dawa slaughterhouses during this study period, 90% and 85% were having two BCS (thin camels), respectively. The remaining slaughtered camels BSC score were three (good camel). Therefore, it is possible to conclude that majority of slaughtered camels were of poor body condition and unfit for production of good quality and quantity meat. Such meat will have poor palatability and short shelf life.

Type of camel slaughtered in Jigjiga and Dire slaughter house were found to be of poor body condition and aged camels. The number of camels slaughtered per day was significantly lower than other livestock species especially cattle, goat and sheep. The average camels slaughtered per day was three camels. The respondents indicated the reason for slaughtering of camels in poor body condition was that young and good body condition camels were used for legal as well as for illegal cross boarder export trade as the export market fetch more money to the producer. Hence there was fierce competition between the local and cross boarder export market.

3.3. Camel Meat Consumption

Camel is usually slaughtered during holidays, wedding and mourning. In Afar region, camels are slaughtered by a group of men who intended to build up themselves for defending their community. In this practice, a total of 10 youngsters make a group and depart to a forest area having a slaughter camel. In the forest they slaughter camel and consume the camel meat without mixing it with other food ingredients. While eating camel meat in the forest, drinking of water is strictly prohibited due to the perception that drinking water in such occasion will have bad impact on their performance. This practice is called Dasiga. There was such practice in Somali region, but preservation of camel meat in the form of dried meat is very common and widely practiced in Jigjiga and to some extent in Dire Dawa and Shinile. This processed camel meat is highly regarded and can be kept for a long period of time with extended shelf life where there is no refrigeration facilities coupled with high ambient temperature suitable for spoilage microorganisms.

Camel was slaughtered for the following reasons: when a camel gets broken due to accident or fighting; wedding; circumcision; mourning (prominent & celebrity personality); holidays; Sedqua/feeding poor sickness; and to injured and bone fractured person mainly due to conflict.

3.4. Camel Slaughtering Practice

Camel slaughter procedure followed at Jigjiga and Dire Dawa slaughterhouse was that first the animal leg was cut at Achilles tendon (hock) to immobilize it and then the animal became unable to walk and drag its hind legs. Then restraining was done by holding the neck and making the animal in squat position after which severing of the neck was undertaken. In this practice, it was observed that the animal was conscious and suffering from the excruciating pain. Such method was practiced in Jigjiga, Hartichk and Dire Dawa slaughterhouses. There was no practice of cutting Achilles tendon in Afar region. With regard to meat quality, it is possible to harvest wholesome and nutritious meat whenever slaughter animals are treated as per humane slaughter procedure as pre-mortem handling of animals has determinant effect on meat quality and subsequent meat processing.

Result of observation of Dire Dawa and Jigjiga Municipal slaughterhouse revealed that these slaughter houses were not fulfilling the requirement for standard slaughterhouse. Hence, it can negatively influence humane handling of slaughter animals. This leads to mishandling of slaughter animals which will have impact on the quality and quantity of meat harvested. This could raise issue of slaughter animal welfare, how slaughter animals are treated in slaughterhouses found in the country as whole.

There was no exception to slaughter camel even it was the worst if we consider what has been practiced in Jigjiga and Dire Dawa Municipal slaughterhouses. In this slaughterhouses camel slaughtering begin with cutting the Achilles tendon at hock to immobilize the animal. Then severing of the neck takes place with little effort to immobilize the camel. The British Humane Slaughter Act of 1933, make stunning compulsory, and permit use of modern methods, such as the captive bolt pistol and electric tongs. The wording of the 1933 act specifically outlaws the poleaxe. Hence, Ethiopia need also to develop such regulation to protect slaughter camels from such malpractices prevailing in Jigjiga and Dire Dawa slaughterhouses in particular and the whole animal slaughtering practices in the country in general.

In USA Humane Method of Livestock Slaughter Act (HMLSA), the first Human Slaughter Act (1902) stated that either all animals are rendered insensible to pain or by slaughtering in accordance with the ritual requirements of the Islamic and Jewish faith whereby the animal suffers loss of consciousness by anemia of the brain caused by the simultaneous and instantaneous severance of the carotid arteries with a sharp instrument and handling in connection with such slaughtering.

According to the law, animals should be stunned into unconsciousness prior to their slaughter to ensure a death with less suffering than in killing methods used earlier. The most common methods are electrocution and CO_2 stunning for swine and captive bolt stunning for cattle, sheep, and goats. An animal is considered properly stunned when there is no "righting reflex"; that is, the animal must not try to stand up and right itself. Only then can it be considered fully unconscious. It can then proceed down the line, where slaughterhouse workers commence in cutting up its body.

Ethical concern for animals is often based on assessment of their mental capacities, especially the capacity to feel pain consciously (Allen, 1998). Even though the methods used for slaughtering livestock species such as cattle, sheep and pigs have improved considerably (Gregory, 1998), there is no government policy that protect animal rights including slaughtering of meat animals in Ethiopia. Hence animal slaughtered practices differ from region to region.

Animals should move quietly at a walk through pens and races with a minimum of visible excitement or agitation. Most animals should walk calmly into a stunning pen or a restrainer without the use of an electric goad (Gregory, 1998).

The importance of reducing stress during slaughter is clear. In pigs, reducing excitement and agitation during handling in the stunning race will improve welfare and help to preserve meat quality (Barton-Gade, 1984; Grandin, 1994). A study by Warriss et al (1994) indicated that the sound level of vocalizing pigs in a slaughter plant was correlated with reduced pork quality. Furthermore, Voisinet et al (1997) found that cattle which become agitated during handling and restraint had tougher meat, and more borderline dark cutters. In many different pork slaughter plants, it was observed that reducing the use of electric goads and preventing pig pile-ups in the stunning race resulted in a reduction of PSE (pale soft exudative meat) by approximately 10%. Pork slaughter-plant managers have reported that when handling practices were improved, 10% more pork was accepted for export to Japan. Even though such information is lack in came meat quality in relation to mishandling of slaughter camel.

Camels were slaughtered on concert floor (Dire Dawa slaughterhouse) and even on dusty floor (Jigjiga slaughterhouse). Flying, dressing and cut up were done on concrete floor. Such practices adversely affect meat quality. Both slaughterhouses workers indicated that new slaughter houses were under construction.

Figure 1. Slaughter camel restrained after the *Achilles* tendon was cut.

Figure 2. The way camel drag its hind legs after cut at *Achilles*. tendon

1.1.3

But it is possible to harvest wholesome and nutritious meat from animals that are treated properly during pre-mortem handling as it has determinant effect on meat quality and subsequent meat processing.

Figure 3. Hanging of camel meat using robes at Jigjiga Market.

Afar

First the camel is guided to crouch/squat and then tightly tie the legs to immobilize. Then severing of the neck at atlas region and then at the bottom. Sometimes cutting of *Achilles* tendon practiced for aggressive slaughter cattle.

3.5. Meat Fabrication

The result of the study showed that there are 12 main cut up at Jigjiga and Dire Dawa Slaughter houses. These are four legs; two ribs; two loins; two sirloins; and two sternums. Digestive organs were mostly regarded as inedible and wasted away except some organs like liver which was consumed in raw state in Afar region.

Meat fabrication at Dire Dawa slaughter house was in the following order:

1. Cut *Achilles* tendon
2. Severing the neck
3. Totally separate the neck along with the head from the body

4. Cut the leg at hock & knee
5. Flying
6. Removal of forelegs with scapula
7. Removing ribs coverings (M. *Latissimus dorsi* and M. *External abdominal oblique*)
8. Cutting the ribs into two parts
9. Removal of spinal cords
10. Removal of internal organs
11. Separation of hind legs

In Somali region, preparation of dried processed preserved meat was common. For example, in Hartichek there were people involved in *muremure* production and marketing. In Dire Dawa, this dried preserved meat can be purchased from open market. It was claimed to have medicinal values to sick people especially for recovering from bone fracture, and from weakness and depressed immunity. Moreover, during wedding wife present this processed meat to her husband to express her regard and respect. This type of processed meat was also being exported to Somali and even to Europe as it was reported by some of respondents in the study area. Some respondents also indicated that *muremure* can prevent hypertension. But in Afar region there was no processed meat.

Figure 4. Ways of cutting meat for making

Figure 5. Processed *muremure.*

3.6. Camel Hide

Flaying of camel hide was conducted by cutting it into small pieces without giving due care in Jigjiga, Dire Dawa, and Afar region. The result of group discussion indicated that camel hide was not processed into leather as done for cattle hide and small ruminant skin, but only locally processed to manufacture some local containers, shoe and belts. This attribute for poor attention to harvest quality and quantity hide that could further processed to manufacture good quality leather products. Some literature indicated that camel hide is as strong as cattle hide and even stronger and thicker. There is also lack of information on the properties of camel meat which renders it to be less important in the face of lucrative market and increasing demand for leather products in the country.

According to Gitao (2006) camel hides are an important resource that could contribute a significant income to pastoralists if there is a reliable market and if they are properly cured. Foxwell (1999) observed that pastoralist use poor methods of curing camel hides leading to poor quality of hides as a result of this many tanneries have rejected camel hides. Camel hides have more fats than cow hides or goats skins and unless it is well removed, the hides rot (Foxwell 1999). For camel keepers to get maximum profit from camel hides proper curing methods, flaying and proper animal husbandry practices are paramount.

According to Kagunyu and Matiri (2012), in Kenya, camel hides are used to make the roofs for traditional pastoral houses, for making ropes, guards, drums, seats, sandals, praying mats used by Muslims, and water and milk containers. Moreover, vegetable tanned camel hides by pastoral communities are used to make hand crafts such as key holders, maps, belts, folders which are sold to tourists. According to the same author camel hides tanned in Kenyan tanneries into wet blues and large amount was exported to Middle East and to other African countries. A small percentage was used by domestic leather manufacturers, where they were used to make leather boots used by Kenyan army, shoes, saddles, bags and jackets among other products.

Figure 6. Flying of camel hide.

4. Summary and Conclusion

Camel is a good source of meat and has high potential as meat animal. It has also a big role in earning foreign currency through export of live camel, and processed meat. The current scenario of camel production and marketing indicated that there are lucrative market opportunities especially from Middle East and North African countries for slaughter camel. Moreover, processed camel meat can be improved in terms of quality and safety for wider distribution and marketing which would in turn improves the livelihood of pastoralists and peoples involved in this business.

There are animal ethics and welfare issues related with camel slaughtering and pre-slaughter handling. This is because slaughtering of camel was conducted in cruel manner than any other livestock species in the country. This was manifested by cutting a live camel at knee (*Acilles tendon*) and makes the animal to drag its hind leg with excruciating pain. Such practice will not only break animal welfare and slaughter animals handling ethics but also affects meat quality and safety that will be harvested. Therefore, attention should be given concerning proper handling during pre-slaughter and at slaughter to reduce animal suffering and to maintain quality of harvested meat. Proper feeding and slaughtering of camel in good body condition is another area that need due attention for production of good quality and quantity camel meat.

According to compassion in World Farming, all slaughter should be humane, which means that animals must be stunned prior to slaughter using a method that causes immediate unconsciousness or, in the case of gas stunning, does not cause distress during the period before loss of consciousness. Both EU and UK legislation on the welfare of animals at slaughter allow exemptions for religious communities. Whilst valuing religious freedom, this should not extend to practices which inflict suffering on animals.

Drafting regulation and getting approved on procedures to be followed in camel slaughtering will have a paramount importance to safeguard camel against unethical and cruel handling during slaughtering. Establishment of modern slaughter house could also serve the purpose and will enable production of quality and quantity camel meat. Training of individuals involved in camel slaughtering, and camel meat traders about humane handling and slaughtering of animal will contribute in averting the current inhumane and substandard slaughter practices.

Future research efforts need to focus on exploring the potential of the camel as a source of meat through multi-disciplinary research approach. Improved meat technology and marketing is equally important. Further research is also recommended for in depth study of camel meat preservation and its quality. Possibilities of hide and leather production and its quality could the other issues that need to be addressed in the future.

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13. Effect of Integrating Climate Change Resilience Strategies on Common Bacterial Blight of Common Bean in Semi-arid Agro-ecology of eastern Ethiopia

Negash Hailu*, **Chemeda Fininsa and Tamado Tana**

School of Plant Sciences, Haramaya University, P. O. Box 138, Dire Dawa, Ethiopia

Abstract: Common bacterial blight (CBB) caused by Xanthomonas axonopodis pv. phaseoli is the most important biotic production constraints to common bean in eastern Ethiopia. Climate change could have an impact on the disease epidemiology of CBB by influencing both common bean growth and the pathogen reproduction. The effects of climate change needs to be mitigated using climate change resilience strategies. Field experiments were conducted in the 2012 and 2013 cropping seasons at Haramaya and Babile research stations in eastern Ethiopia to assess the effects of integrating climate change resilience strategies on CBB of common bean. These strategies used alone and in integration were compost application, row intercropping and furrow planting. Sixteen treatment combinations including sole planting (SP) were arranged in a randomized complete block design with three replications. Disease severity data were recorded from 10 randomly tagged plants from four central rows per plot. Disease severity, area under disease progress curve (AUDPC) and disease progress rate were significantly different among treatments, between varieties, cropping seasons and locations. Disease severities, AUDPC and disease progress rate were consistently less on row intercropping + compost application + furrow planting and row intercropping + compost application than less integrated and SP plots in both locations and seasons. The disease epidemic was relatively higher on Mexican 142 than Gofta and during 2012 than 2013 at Babile than Haramaya. Integrated climate resilience strategies reduced CBB epidemics could be applied as a component in management of the disease in eastern Ethiopia and in areas with similar agro-ecological zones.

Keywords: Xanthomonas axonopodis pv. phaseoli; Climate Change Resilience; Phaseolus vulgaris

1. Introduction

There are several biotic and abiotic production constraints of common bean (*Phaseolus vulgaris* L.) in semi arid agro-ecologies of eastern Ethiopia. Diseases, insect pests, low soil fertility and periodic water stress are the major constraints (Tana *et al.*, 2007; Katungi *et al.*, 2009). The major diseases of common bean in the tropical regions, including Ethiopia that should be targeted for management are common bacterial blight (CBB) caused by *Xanthomonas axonopodis* pv. *phaseoli*, halo blight caused by *Pseudomonas syringae* pv. *phaseolicola,* bacterial brown spot caused by *Pseudomonas syringae* pv. *syringae,* rust caused by *Uromyces appendiculatus*, anthracnose caused by *Colletotrichum lindemuthianum* and other viral and root rot diseases (Fininsa and Tefera, 2002; Fininsa and Yuen, 2002; Lemessa *et al.*, 2011). These diseases are frequently occurring and widely distributed in Ethiopia and are destructive agents of common bean production causing heavy yield loss and seed quality (Fininsa and Yuen, 2001; Fininsa, 2003; Fininsa and Tefera, 2006; Lemessa *et al.*, 2011). Of the major diseases of common bean, CBB is the most important constraint to common bean production in eastern Ethiopia. CBB is one of the most destructive bean diseases when environmental conditions are favourable for the pathogen during long periods of warm and humid weather causing reductions in both yield and seed quality (Abo-Elyousr, 2006). CBB incidence (53%) and severity (63%) were recorded in sole cropping system of common bean in eastern Ethiopia (Fininsa, 2003). Relative yield loss of 22-40% was found in pure stand cropping system.

Change in rainfall pattern, soil moisture, soil temperature, and soil fertility has direct impact on the disease epidemiology by influencing host plant growth and susceptibility; pathogen reproduction, spread, survival, activity and host-pathogen interaction (Ghini *et al.*, 2008). According to International Panel for Climate Change (IPCC, 2007) the average global surface temperature increases by 2.8°C ranging from 1.8 to 4.0°C during 2050 assuming no emission control policies. Climate models suggest that Ethiopia will see further warming in all seasons of +1.2 (0.7°C - 2.3°C) by the 2020's and of +2.2 (1.4°C- 2.9°C) by the 2050s (EPA, 2010). It is likely that this warming will be associated with heat waves and higher evapotranspiration. Nowadays, the debate on climate change is not on its occurrence and effects, but rather on how to mitigate the ever-happening effects of climate change to manage crop production and protection to ensure food security of the ever-growing population and the proper functioning of the natural ecosystem. This needs to set resilience strategies that can mitigate the existing and ever happening effects of climate change.

As favorable environment of pathogen and diseases are closely related, climate change variables may create favourable conditions for pathogens and alter the spatial and temporal distribution of disease epidemics. The host plant agro-climate will be altered and pathogens and other microorganisms related to the disease will be affected negatively or positively. To this effect, new diseases may arise in certain regions, and other diseases may cease to be economically important, especially if the host plant is introduced into new areas (Coakley *et al.*, 1999; Chakraborty *et al.*, 2011). Pathogens tend to follow the host plant in their geographical distribution, but the rate at which pathogens become established in the new environment is a function of the mechanism of pathogen dispersal, suitability of the environment for dispersal, overseasoning, and physiological and ecological changes in the host plant (Chakraborty *et al.*, 2011). Climate variability has the potential to modify host physiology and disease resistance and to change the stages and rates of development of pathogens. The most likely impacts would be shifts in the spatial distribution of host and pathogen, changes in the physiology of host-pathogen interaction, alteration in crop loss and changes in the efficacy of management strategies (Doll and Baranski, 2011; Gautam *et al*., 2013). Climate variability itself may be an important factor of pathogen selection pressure (Garette *et al*., 2006).

Inspite of crop diseases reducing crop productivity and food supply, there has been limited field based empirical research to assess the potential effect of climate change on plant disease (Boland *et al*., 2004; Ghini *et al*., 2008; Newton, *et al*., 2011). Most research on how climate change influences plant disease has concentrated on the effects of one or two of the changing climatic factors on the host, pathogen, or the interaction of the two under controlled conditions that are very different from those in the real field. Other situational studies are based on modelling of data from controlled experiments (Doll and Baranski, 2011).

Research in climate change related issues could result in improved understanding and management of crop diseases in the face of current and future climate extremes (Garette *et al*., 2006; Doll and Baranski, 2011). Understanding the effect of climate change resilience strategies such as plant nutrients through compost application (Sullivan, 2004; Luske, 2010), soil and water conservation (Aydinalp and Cresser, 2008; Toulmin, 2011), and species mixture combination (Fininsa, 2003) management practices on disease intensities will assist identification of the most important variables and focus efforts in developing integrated management packages. The epidemics of CBB needs to be assessed under sole and integrated field based climate change resilience strategies such as intercropping, compost application and furrow planting. The objective of this study, therefore, was to assess the effects of climate change resilience strategies against CBB epidemiology of common bean.

2. Materials and Methods

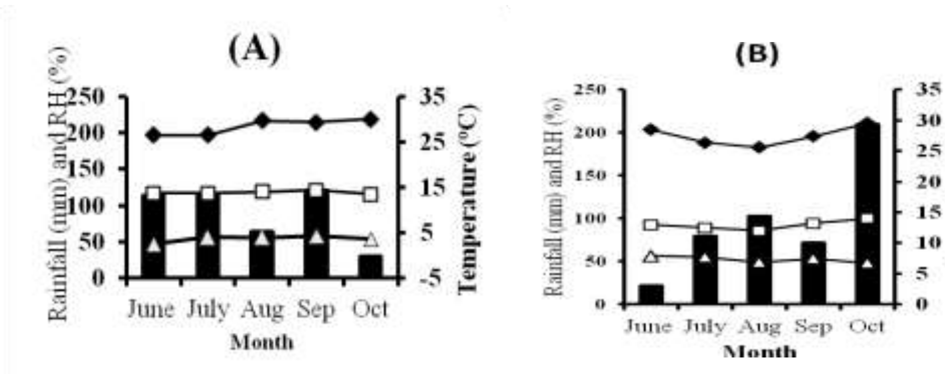
2.1. Experimental Location

Field experiments on CBB of common bean were conducted at Haramaya University experimental field stations at Babile and Haramaya, eastern Ethiopia during 2012 and 2013 main cropping seasons (June to November each year). Haramaya is located at 09° 26´ N and 42° 3´ E. The altitude of the area is 1980 meters above sea level with average annual rainfall of 786.8 mm, mean minimum temperature of 10.4°C, maximum temperature of 23.4°C and mean temperature of 16.8°C. The soil of Haramaya is alluvial type with organic matter content of 1%, total nitrogen of 0.17%, available phosphorus of 8.72 mg kg soil^{-1}, pH of 7.13 with percent sand, silt and clay content of 62.92, 19.64 and 17.44, respectively. Babile is situated at 09˚13´ N and 42˚19´ E, with altitude of 1655 meters above sea level with annual total rainfall of 719.2 mm. The mean minimum and maximum temperatures are 15.4 and 28.3˚C, respectively, with an average temperature of 21.8. The soil of Babile is characterized with organic matter content of 1.71%, total nitrogen of 0.01%, available phosphorus of 1.28 mg kg soil$^{-1,}$ pH of 6.6 with percent sand 45%, silt 24% and clay 31%.

Both locations represent important common bean growing areas and are conducive for CBB disease of common bean. Babile is a representative of semi-arid agro ecology whereas Haramaya is a representative of midland agro ecology, and both locations are highly affected by climate change events (increased temperature, variable rainfall pattern, and frequent drought). The weather variables (mean maximum and minimum monthly temperature, mean monthly total rainfall and mean monthly relative humidity) for 2012 and 2013 of both locations during experimental months are presented in Figure 1.

2.2. Experimental Design and Management

Three field based climate change resilience strategies and a control were used as treatments. The strategies consist of crop diversification (row intercropping), moisture conservation (furrow planting) and soil nutrient management (composting). The treatments were common bean-sorghum row intercropping, furrow planting, compost application, sole planting and their combination. The treatments were applied separately and in integration (minimum of two) using Gofta (G 2816) and Mexican 142 (G 11239) common bean varieties. Gofta is moderately resistant while Mexican 142 is susceptible to CBB. The varieties were obtained from Melkasaa Agricultural Research Center, Ethiopia. Sorghum variety, Teshale (3442-2 OP).



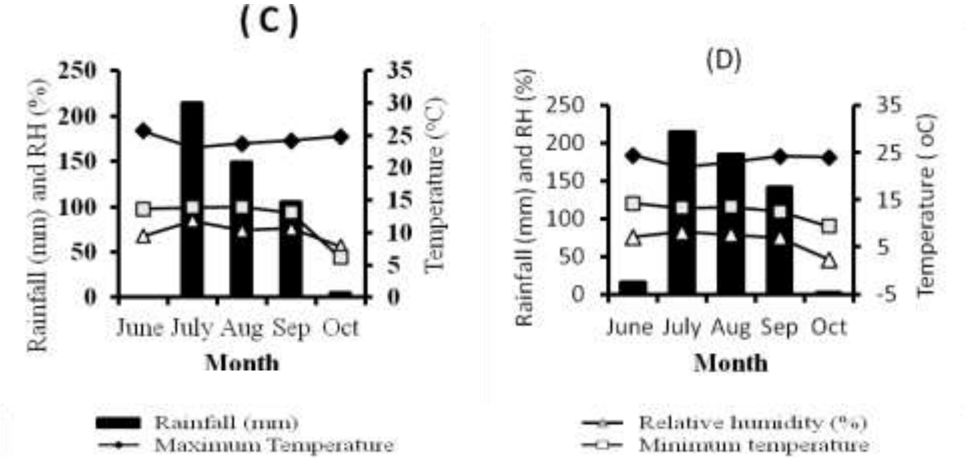


Figure 7. The weather variables (mean maximum and mean minimum temperature (°C), mean relative humidity (%) and total monthly rainfall (mm) at Babile in 2012 (A), in 2013 (B), at Haramaya in 2012 (C) and in 2013 (D).

Developed for the semi-arid environment as moisture stress and striga weed tolerant was used. Sixteen treatment combinations were arranged in a randomized complete block design in three replications on a plot size of 3.4 m x 3.6 m (12.24 m^2). Compost was applied two weeks before sowing at a rate of 8 tons per hectare, about half the rate recommended for cereals (Stutz *et al*., 2003) for both crops. Close-ended furrows were prepared by digging 20 centimeters deep rows two weeks before sowing in order to harvest the rainwater. Sorghum seeds were sown on 21 June 2012 and 28 June 2013 at Babile, 20 June 2012 and 02 July 2013 at Haramaya by drilling seeds at the seed rate of 5kg ha^{-1}. Common bean seeds were sown on 11 July 2012 and 05 July 2013 at Babile, 07 July 2012 and 09 July 2013 at Haramaya manually by planting two seeds per hill. A standard intra and inter-row spacing for both crops were used according to the recommended spacing. Sorghum was planted in 0.8 m inter-row and 0.25 m intra-plant spacing. In row intercropping, a row of common bean was planted in the center of sorghum rows at 0.1 m intra-plant and 0.4 m inter-row spacing. In row intercropping, simultaneous planting was used. Similarly, in sole planting of common bean 0.4 m inter-row and 0.1 m inter-plant spacing with nine rows per plot were used. Spacing between blocks was 1.2 m and between plots was 1 m.

After emergency and establishment of seedlings, the rows were thinned to one plant per hill. Recommended agronomic practices were used for sole common bean planting. Fertilizer application and artificial inoculation were not applied for common bean. Plants were hand weeded three times at Haramaya and two times at Babile and cultivated once during the growth periods at both locations. The treatment combinations for a susceptible variety are listed in Table 1 and the treatments were repeated for resistant variety constituting 16 treatments.

2.3. Disease Data

All disease data were collected from four central rows. Disease severity (leaf area showing characteristic CBB symptom) was assessed six times at an interval of seven days during the experimental periods beginning from 48-51 days after planting (DAP). Disease severity rating was performed on 10 randomly pre-tagged plants per treatment plot at both locations and seasons. Severity was rated using standard scales of 1 – 9 (CIAT, 1987; Buruchara *et al*., 2010) where 1 = no visible symptom and 9 = disease covering more than 25% of the foliar tissue and the severity grades were converted into percentage severity index (PSI) for analysis using:

$$\mathrm{PSI} = \frac{\text{Sum of numerical ratings X 100}}{\text{Number of plants scord X maximum score on scale}}$$

Disease progress rate (r) and area under disease progress curve (AUDPC) were calculated from the severity data. AUDPC was computed from PSI data calculated on each date of assessment as described by Madden (2006).

$$\mathrm{AUDPC} = \sum_{i=1}^{n-1} 0.5(\mathrm{xi} + 1 - \mathrm{xi})(\mathrm{ti} + 1 - \mathrm{ti})$$

Where n is the total number of assessments, t_i is the time of the ith assessment in days from the first assessment date, x_i is the percentage of disease severity at ith assessment. AUDPC was expressed in percent-days because the severity (x) was expressed in percent and time (t) in days. The rates of disease progress were obtained from regression of PSI data fit to Logistic Model ln [Y/1-Y))] with dates of assessments.

2.4. Weather Data

Weather data of each location were collected from the nearby meteorological station (as means of five years) for both experimental stations. Weather variables of minimum temperature at 09:00 h and maximum daily air temperature at 18:00 h (^oC), relative humidity (%) at 06:00 h, 09:00 h, 12:00 h, 15:00 h and 18:00 h, and daily rainfall (mm) were collected and the averages were of 2012 and 2013 cropping seasons were calculated and presented in Figure 1.

2.5. Data Analysis

Mean disease severity from each variety and treatment were examined and used for data analysis. Disease severity at different DAP and AUDPC were subjected to analysis of variance using the PROC GLM procedure of Statistical Analysis System or SAS version 9.1, (SAS Institute. 2003) to determine the treatment effects. Homogeneity of variances was tested using F-test as described by Gomez and Gomez (1984) and the F-test was significant. Thus, separated analysis of the two-year and two location data was performed. Differences among treatment means were compared using the Fisher's least significant difference (LSD) test at 5% level of significance. Regression analysis of PSI data was carried out to fit to Logistic Model ln [Y/1-Y))] with dates of assessments to determine the disease progress rate.

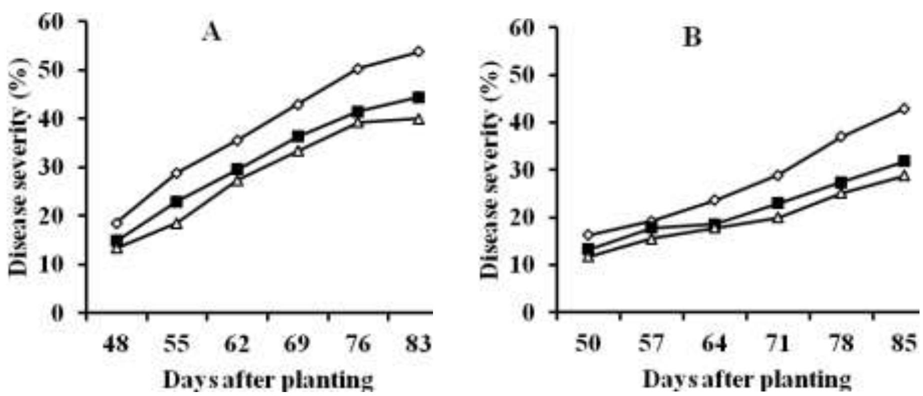
3. Results

3.1. Disease Severity

Common bacterial blight epidemics appeared on both varieties during both cropping seasons varied among the climate change resilience strategies significantly. Disease severity was consistently less on the most integrated plots than sole planted plots. Disease severity in the two cropping seasons was significantly different ($P<0.01$) among the climate change resilience strategies and between varieties. During both cropping seasons, the disease severity was significantly different ($P<0.01$) among climate change resilience strategies throughout the whole disease recording dates while significant difference ($P<0.01$) of disease severity between the two varieties were at late disease recording days.

In 2012, the highest initial disease severity (20%) at 50 days after planting (DAP) was recorded from sole planted plots of Gofta variety, while the lowest was recorded in row intercropping + compost application + furrow planting plots of Gofta and in row intercropping of Mexican 142 at Haramaya (Figure 3). Similarly, the highest final disease severity at 85 DAP was recorded from sole planning on Mexican 142 (56%) and on Gofta (48%) whereas lowest disease final disease severity was recorded from row intercropping + compost application on Gofta (40%) and from row intercropping + compost application + furrow planting on Mexican 142 (42.9%). During the 2013 cropping season, higher final disease severity at 86 DAP on Gofta (43%) and on Mexican 142 (54.8%) were obtained from sole planting followed by furrow planting while lower final disease severity on Gofta (28%) and on Mexican 142 (40%) were obtained from row intercropping + compost application + furrow planting at Haramaya (Figure 3).

With respect to mean initial and final disease severity of two varieties during 2012 cropping season, the highest mean initial disease severity was 18.2% at Babile and 19.8% at Haramaya in sole planting. The row intercropping + compost application had the lowest 13.3% at Babile and row intercropping + furrow planting had the lowest (14.08 %) mean initial disease severity at Haramaya (Figure 3). The highest mean final disease severity (53.9%) was recorded in sole planting at Babile and 52.4% at Haramaya. The lowest mean final disease severity was from row intercropping + compost application + furrow planting (40.7%) at Babile (Figure 2) and 41.8% at Haramaya during 2012 (Figure 3). The remaining climate change resilience strategies reduced CBB severity intermediately, showed similar pattern of disease progress curve from the first to last dates of disease recording, and were not presented in the figure for clarity.



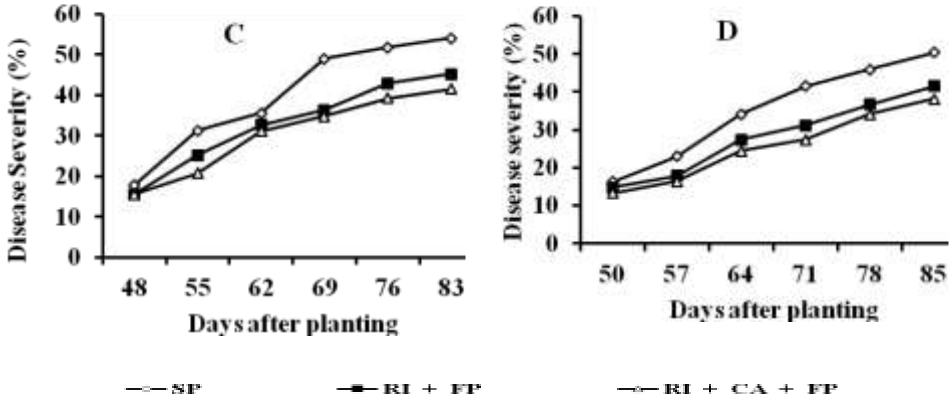


Figure 8. Disease progress curve of common bean common bacterial blight on (A) Gofta in 2012 (B) Gofta in 2013, (C) Mexican 142 in 2012 and (D) Mexican 142 in 2013 at Babile. RI + CA + FP, row intercropping + compost application + furrow planting; RI + FP, row intercropping + furrow planting; SP, sole planting.

During 2013 cropping season, the highest mean initial disease severity at 50 DAP was 16.3% in sole planting at Babile (Figure 2) and at 51 DAP was 17.8% in sole planting at Haramaya (Figure 3), while the row intercropping + compost application + furrow planting had the lowest mean initial disease severity 12.6% at Babile and 13% at Haramaya. The highest mean final disease severity at 85 DAP (46.7%) was recorded in sole planting at Babile and at 86 DAP was 48.9% at Haramaya while the lowest mean final disease severity was from row intercropping + compost application + furrow planting (33.5%) at Babile and 34.1% at Haramaya. The other climate change resilience strategies reduced CBB severity intermediately and showed similar trend of disease reduction form the first to last date of disease recording and the data were not presented in the figure for clarity.

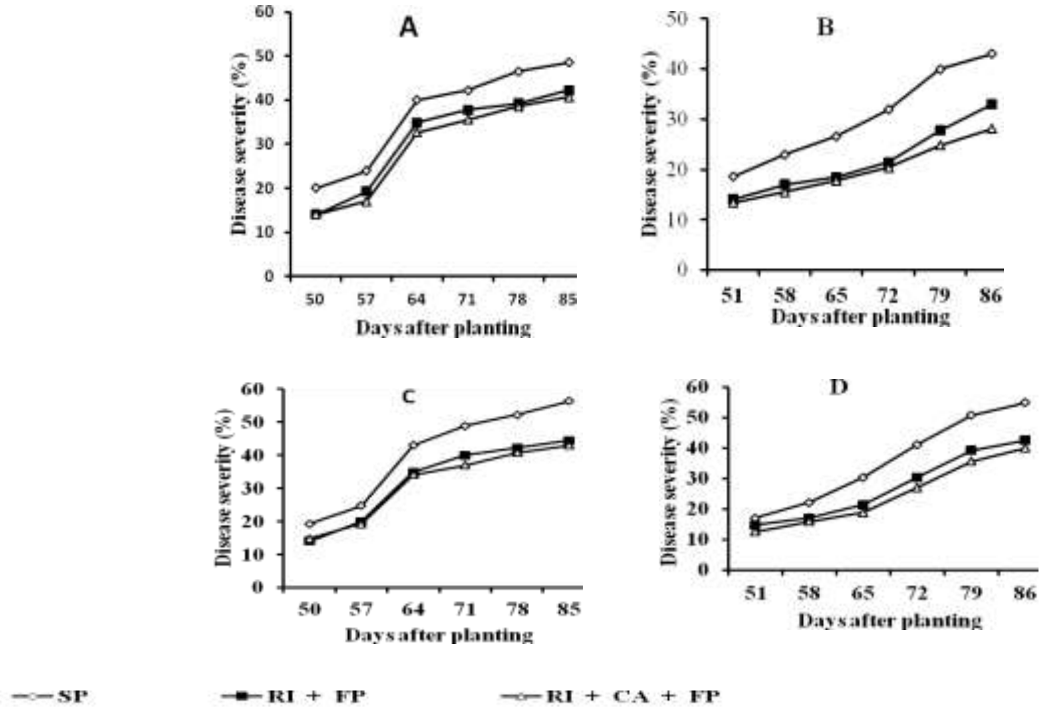


Figure 9. Disease progress curve of common bean common bacterial blight on (A) Gofta in 2012 (B) Gofta in 2013, (C) Mexican 142 in 2012 and (D) Mexican 142 in 2013 at Haramaya. RI + CA + FP, row intercropping + compost application + furrow planting; RI + FP, row intercropping + furrow planting; SP, sole planting.

In both 2012 and 2013, CBB appeared on both varieties were not varied during early disease recording dates. However, significant variations in the disease severity between varieties started from 55 to 69 DAP at Babile and from 64 to 83 DAP at Haramaya during 2012, whereas 50 to 85 DAP at Babile and 65 to 86 DAP at Haramaya during 2013 (Figure 3). At both locations and seasons, significantly higher disease severity was recorded from Mexican 142 than Gofta variety. Likewise, higher mean initial disease severity (15.8%, 15.3%) and final disease severity

(45.5% and 42.7%) were recorded on Mexican 142, during 2012 and 2013 respectively than on Gofta variety at Babile. A higher disease severity was observed in the year 2012 compared with the 2013 cropping season. The interaction between and among the climate change resilience strategies, varieties and location was not significant.

Considering the range of disease severity and percentage of disease severity reduction, the solely applied climate change resilience strategies had higher disease severity and lower reduction compared to most integrated and integrated ones. The most integrated climate change resilience strategy: row intercropping + compost application + furrow planting and row intercropping + compost application caused higher CBB severity reduction. The resilience strategies reduced final disease severity from 4.7-25.6% (mean 13%) during 2012 (Figure 2) and from 8.6-36.2% (mean 20.7%) during 2013 (Figure 2) on Gofta variety at Babile. Similarly, the resilience strategies reduced final disease severity from 12.1-34.5% (mean 20.3%) on Gofta and from 10.8-27% (mean 13.9%) on Mexican 142 (Figure 3) at Haramaya during 2013.

3.2. Disease Progress Rate

Comparisons of disease progress rates among treatments were made based on the Logistic model by fitting severity data with dates of assessment. The rates of disease progress were significantly different among treatments, between locations and seasons.

Table 1. Common bean common bacterial blight disease progress rate (r) logit per day and adjusted coefficient of determination (R^2) percentage on Gofta and Mexican 142 varieties at Babile and Haramaya during 2012 cropping season.

	Babile 2012				Haramaya 2012			
	Gofta		Mexican		Gofta		Mexican	
Treatment	Rate	R^2	Rate	R^2	Rate	R^2	Rate	R^2
SP	0.046	90.8	0.048	88.4	0.040	83.7	0.050	83.1
FP	0.046	89.7	0.046	87.0	0.040	79.0	0.044	82.1
CA	0.053	92.7	0.048	89.9	0.043	81.7	0.055	86.9
RI	0.046	89.3	0.042	86.9	0.042	82.0	0.049	84.2
CA + FP	0.050	93.9	0.050	84.6	0.042	79.5	0.052	85.1
RI + FP	0.043	87.6	0.041	86.5	0.043	79.0	0.046	84.2
RI + CA	0.048	87.8	0.044	84.1	0.040	81.2	0.045	83.8
RI + CA + FP	0.044	86.7	0.039	86.0	0.044	80.8	0.044	82.7

FP, furrow planting; CA, compost application; RI, row intercropping; CA + FP, compost application + furrow planting; RI + FP, row-intercropping + furrow planting; RI + CA + FP, row intercropping + compost application + furrow planting; RI + CA, row intercropping + compost apllication; SP, sole planting.

During 2012 cropping season, the highest disease progress rate (0.055-logit day^{-1}) was on Mexican 142 variety at Haramaya while the lowest epidemic rate (0.027 logit day^{-1}) was from Gofta variety during 2013 cropping season at Haramaya. The disease progress rates calculated for varieties, climate change resilience strategies, years and locations were different and presented in Table 1 for 2012 and Table 2 for 2013 seasons. The reduction of disease progress rate by climate change resilience strategies did not completely have similar trend to the disease severity and area under disease progress curve in varieties, locations and cropping seasons.

In the 2012 cropping season, the disease progress rate was higher on the Gofta (0.053 logit day^{-1}) treated with compost application, on Mexican 142 (0.050 logit day^{-1}) treated with compost application + furrow planting at Babile and on Mexican (0.055 logit day^{-1}) treated with compost application, at Haramaya (Table 1). Application of row intercropping + furrow planting reduced disease progress rate by 6.5% on Gofta and application of row intercropping + compost application + furrow planting reduced disease progress rate by 18.7% on Mexican 142 compared to sole planting at Babile during 2012 cropping season (Table 1).

Table 2. Common bean common bacterial blight disease progress rate (r) logit per day and adjusted coefficient of determination (R^2) percentage on Gofta and Mexican 142 varieties at Babile and Haramaya during 2013 cropping season.

	Babile 2013				Haramaya 2013			
	Gofta		Mexican		Gofta		Mexican	
Treatment	Rate	R^2	Rate	R^2	Rate	R^2	Rate	R^2
SP	0.040	90.3	0.048	90.1	0.035	91.0	0.054	93.3
FP	0.037	87.2	0.044	88.5	0.036	84.7	0.048	93.4
CA	0.034	83.5	0.041	86.2	0.033	80.1	0.055	95.3
RI	0.031	77.9	0.041	89.7	0.029	82.1	0.047	90.4
CA + FP	0.036	83.6	0.039	88.2	0.033	85.9	0.048	89.2
RI + FP	0.030	77.6	0.042	92.9	0.031	82.9	0.046	88.8
RI + CA	0.029	87.6	0.037	69.0	0.028	78.5	0.048	88.4
RI + CA + FP	0.031	86.1	0.041	90.7	0.027	82.9	0.046	91.1

FP, furrow planting; CA, compost application; RI, row intercropping; CA + FP, compost application + furrow planting; RI + FP, row-intercropping + furrow planting; RI + CA + FP, row intercropping + compost application + furrow planting; RI + CA, row intercropping + compost apllication; SP, sole planting.

Lower rate of disease progress was obtained from row intercropping + compost application on Gofta (0.040-logit day^{-1}) and from row intercropping + compost application + furrow planting on Mexican 142 (0.44 logit day^{-1}). Generally, application of row intercropping + compost application + furrow planting reduced the rate of disease progress by 12% on Mexican 142 variety at Haramaya during 2012.

In 2013 cropping season, a lower disease progress rate was observed on Gofta (0.029 logit day-^{1}) and on Mexican 142 (0.037 logit day^{-1}) treated with row intercropping + compost application at Babile and on Gofta (0.027 logit day^{-1}) and on Mexican 142 (0.046 logit day^{-1}) treated with row intercropping + compost application + furrow planting at Haramaya. In 2013 the disease progress rate on compost applied was faster (0.055 logit day^{-1}) than the remaining climate change resilience strategies on Mexican 142 (Table 2), and sole planting had faster disease progress rate (0.04 logit day^{-1}) on Gofta and (0.048 logit day$^{-1)}$ on Mexican 142 at Babile. The disease progress rate in compost application was highest in both cropping seasons on Mexican 142 at Haramaya. Application of the most integrated climate change resilience strategy: row intercropping + compost application + furrow planting reduced the rate of disease progress by 22.9% on Gofta variety and by 14.8% on Mexican variety during 2013 cropping season at Haramaya (Table 2).

4. Discussion

CBB epidemics significantly varied among and between climate change resilience strategies, between common bean varieties, locations and cropping seasons. Variety Mexican 142 had higher disease severity and higher area under disease progress curve than variety Gofta. Variety Mexican 142 is moderately susceptible for different bacterial and fungal diseases of common bean including CBB and variety Gofta is moderately resistant to CBB. Higher disease epidemic was found during 2012 cropping season than 2013 cropping season at both locations. In both location, higher relative humidity, higher minimum and maximum temperatures (Figure 1) recorded in August and September months during 2012 cropping season may be favourable for CBB disease progress than 2013 cropping season. Similarly, lower relative humidity, higher minimum and maximum temperatures were recorded at Babile than at Haramaya during both cropping seasons (Figure 1). At Haramaya, lower disease severity and lower area under disease progress curve were computed than at Babile during both cropping seasons. The result was similar with the findings of Fininsa (2003) as high temperature and low relative humidity favor higher common bacterial blight.

Climate change resilience strategies had lower final disease severity (8.6-36.2%) and lower area under disease progress curve than the sole planting on both varieties of common bean during 2012 and 2013 cropping seasons at both locations. The variation of final disease severity was based on the type of climate change resilience strategy, resistance level of common bean, suitability of location and weather variables of two cropping seasons. Intercropping common bean with sorghum has significantly lowered the severity level of CBB compared with sole planting control. Row intercropping + compost application + furrow planting and row intercropping + compost application showed significantly lower CBB severity than the sole plantings during both cropping seasons and locations.

All types of common bean–sorghum intercropping systems (row intercropping, row intercropping + furrow planting, row intercropping +compost application, row intercropping +compost application +furrow planting) significantly reduced the final disease severity (13-36.2%) and area under disease progress curve compared to sole planted plots at both locations and seasons. Similarly, Fininsa (2003) reported reduction of 17-40% common bacterial blight severity in bean-maize intercropping. In sorghum-common bean intercropping CBB disease epidemics were reduced because the sorghum may be used as physical barrier against *Xanthomonas axonopodis* pv. *phaseoli* inoculum from reaching to common bean and may cause common bean to be poorer hosts. Changes in microclimate such as temperature and wind velocity reduction may disfavor the pathogen and cause reduction in disease. Higher temperature and relative humidity are favorable conditions for CBB disease epidemics and a decrease in temperature in the intercropping system might have lowered the severity of CBB. A cool microclimate in row intercropping + compost application + furrow planting disfavours CBB pathogen infection that could be initiated from infected seeds, infested soil or infested debris in the soil. The microclimate may also retard proliferation and spread of the bacteria between plants as the result of non-host nature of component crop sorghum for *Xanthomonas axonopodis* pv. *phaseoli.* Intercropping common bean with sorghum therefore could have been reduced the CBB severity and area under disease progress curve compared to sole planting, during 2012 and 2013 cropping seasons at both location. Matusso *et al.* (2014) reported that the principal reasons for intercropping are soil conservation and improvement of soil fertility, diseases control and balanced nutrition.

Furrow planting reduced the final disease severity during both cropping seasons at both locations when applied singly (2.7-18.4%) or in combination (5.7-34.5%) with other resilience strategies such as compost application and intercropping. Furrow planting could conserve soil moisture and create sufficient water availability in the root system of common bean may enabled common bean to escape disease epidemics in agreement with the results of Aydinalp and Cresser, (2008), which states periodic low soil moisture make plant easily susceptible to diseases.

Compost application reduced the final CBB disease severity (3.9-17.3) when applied singly and (14.2-36%) of disease severity reduction when combined with other resilience strategies during 2013 cropping season. The result of this experiment is in agreement with the results of Vallad *et al.* (2003) and Abdasi *et al.* (2002). Vallad *et al* (2003) revealed that compost showed 34-65% of disease symptom reduction of bacterial speck of *Arabidopsis thaliana* caused by *Pseudomonas syringae pv. tomato* compared with non-amended soil. Abbasi *et al.* (2002) found that application of compost resulted in reduced bacterial spot incidence on fruit by 28-33%, compared with non-amended soil. Disease control with compost has been attributed to successful competition for nutrients by beneficial microorganisms, antibiotic production by beneficial microorganisms and activation of disease-resistant genes in plants. Using compost not only could supply plant nutrients, but also can increase tolerance and resistance to diseases, retains soil moisture (Barker and Bryson, 2006). Composts' contribution to nutrient fertility must also be taken into account because nutrient effects may influence the severity of pathogens and consequently reduce greenhouse gas emission (Luske, 2010).

When the climate change strategies are integrated their synergetic effect significantly reduced disease severity, area under disease progress curve and disease progress rate. Row intercropping + compost application and Row intercropping + compost application + furrow planting have shown significant difference in disease severity reduction compared to less integrated climate change resilience strategies and sole planted plots at Babile and Haramaya. Compost application aggravated the diseases severity on the susceptible variety of Mexican 142 when applied solely, at Haramaya during both cropping seasons. This was because compost application could have enhanced the growth of Mexican 142 variety at fast rate and created closed canopy earlier, consequently increased temperature, which in turn could create favorable condition for CBB development and spread. Generally, there were higher disease progress rates on Mexican 142 than on Gofta during both seasons and both locations. Intercropping and furrowing had smaller effect in reduction of disease epidemics when applied singly. When composting and furrowing are integrated to intercropping, they are highly effective in reducing disease severity, disease progress rate and the area under disease progress curve as the result of synergetic effect .In addition to reduce disease epidemics, they are responsible to reduce the greenhouse gas emission.

Comparisons of disease progress rates among climate change resilience strategies between verities, locations and cropping seasons have shown different trends when compared to disease severity and area under disease progress curve. The resilience strategies having lower disease severity exhibited higher disease progress rate. High disease rates were observed in some of resilience strategies that had lower disease severity. This could be due to high density of initial inoculum from the infected seeds, infested debris or infested soil. Experimental studies have shown that the rates of disease increase were considerably influenced by the number of initial inoculum (Jerger *et al.*, 2004). In an experiment with southern blight of processing carrot, the rate of disease increase generally increased as the number of initial foci increased (Smith *et al*, 1988). Furrow planting had promising potential of mitigating climate change and reducing disease severity when integrated with intercropping and compost application. It is more effective when the soil has good water holding capacity, like soil of Haramaya and less effective in sand soils with high drainage capacity like soil of Babile. These climate change resilience strategies of disease management are cheaper, sustainable and could be easily adopted by small-scale farmers in eastern Ethiopia. The results obtained from this study suggested the importance of climate change resilience strategies singly and in combination as management option of CBB and other common bean diseases in the eastern Ethiopia and in areas with similar agro-ecological conditions. The compost application rate of common bean should also need further investigation in the study area.

5. Acknowledgments

We would like to thank Masresha Lebie, Woinishet Feleke, Birhanu Asfaw, Azeb Tegenu and the late Cholamu Faltamo, field assistants in the School of Plant Sciences of Haramaya University, for their assistance in data collection and fieldwork. The project was financed by Haramaya University Research office (Government fund coded as common bean resilience).

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14. Evaluation of Improved Pepper (*Capsicum* spp.) Varieties for Yield and Yield Components in eastern Ethiopia

Wassu Mohammed Ali

Haramaya University, College of Agriculture and Environmental Sciences, School of Plant Sciences, Haramaya, Ethiopia
Author E-mail: wasmoha@yahoo.com

Abstract: Pepper (*Capsicum* spp.) is widely produced in eastern Ethiopia, however, the productivity of the crop is very low. This is may be due to absence of high yielding varieties. Therefore, this research was conducted to evaluate four improved pepper varieties (Marko Fana, Melka Dima, Melka Eshet and PBC-660 (Melka Awaze)) along with local cultivar as check for dry pod yields and yield components. The genotypes were tested at Hirna and Dire Dawa for two cropping seasons and at Haramaya for three cropping seasons, using randomized complete design (RCBD) with three replications. The combined analysis of variance over locations and seasons revealed the significant effect of genotype and environment on all the traits while genotype x environment interaction (G x E) significantly affected only number of dry pod per plant, total and marketable dry pod yield t ha^{-1}. On the basis of pooled mean values, only Marko Fana performed highest dry pod yields with higher men values than local cultivar for other dry pod traits. Additive Main effects and Multiplicative Interaction (AMMI) analysis of variance exhibited significant effect of genotype, environment and genotype x environment interaction on number of dry pod per plant, total and marketable dry pod yield, while the Eberhart and Russel's analysis of variance revealed the only significant effect of genotype on these traits. The AMMI model revealed that the contribution of G x E interaction sum squares to treatment sum squares were minimum for all traits ranged as compared to the sum of genotype and environment sum squares contribution. The two principal component axes (IPCA 1 and IPCA 2) contributed the largest proportion (>87%) to G x E interaction sum squares, moreover, the IPCA 1 explained more than 50% of G x E interaction sum squares. This indicated that the number of dry pod and yields of the genotypes can be more explained by the genetic potential of genotypes and the environment they were grown than the G x E interaction. Considering all stability parameters of the two models and performance of cultivars, Marko Fana can be recommend for production in eastern Ethiopia since it was high yielding (3.86 and 2.6 t ha^{-1} of total and marketable yield, respectively) and having all desirable pod traits. The other two varieties viz. PBC-660 (Melka Awaze) and Melka Eshet can be also considered for production of chilli (pungent pepper) and as sweet pepper for processing, respectively, since they produced dry pod yields greater than the local cultivar.

Keywords: AMMI (Additive Main effects and Multiplicative Interaction); Eberhart and Russell; Variety; Yield and Yield Components

1. Introduction

Hot pepper (*Capsicum annuum* L.) berries form an indispensable ingredient of the culinary throughout the world (Sanatombi and Jitendra, 2006). The available archaeological evidence showed that peppers are the first spices that have been used by human beings (Hill *et al.*, 2013). In contemporary world, the genus *Capsicum* is the second most important vegetable crop after tomato (Berhanu *et al.*, 2011). Besides vitamins A, C and E in high concentrations, the fruits contain mixtures of antioxidants notably carotenoids, ascorbic acid, flavanoids and polyphenols (Nadeem *et al.*, 2011). The vitamins and antioxidant compounds have a considerable contribution in protecting widespread noncommunicable human diseases and in some parts of the world it is also used for the treatment of fevers, colds, indigestion, constipation and pain killing (Dagnoko *et al.*, 2013, Howard *et al.*, 2000). Red pepper is also used in pharmaceutical industries (Sanatombi and Jitendra, 2006).

The history of pepper in Ethiopia is perhaps the most ancient (EEPA, 2003). The hot pepper was introduced in Ethiopia probably by the Portuguese in the 17 century (Hafnagel, 1961). It is cultivated in many parts of the country and the powder of hot pepper is a major spice of the traditional sauce called '*wot*'. In Ethiopia, vegetables account only for about 0.95% of the total area under cultivations. Of which the area under vegetables, 68.85% is under red pepper production. The average national yield per hectare of red and green pepper is 2.56 and 9.98 t ha^{-1}, respectively (CSA, 2011). However, it was also reported that the dry fruit yield was estimated about 0.4 t ha^{-1}in small holder farmers' and at experimental plot in the range between 2.5-3 t ha^{-1} (Fekadu *et al.*, 2008).

Hararghe is one of the main centers of cultivation (Alkamper, 1972 cited by Jansen, 1981). However, high yielding varieties were not developed and recommended for this part of the region to increase the productivity of the crop. Though considerable number of improved varieties for processing, vegetable and dry fruit yield were recommended for cultivation in the country (MoA, 2012; MoARD, 2009; EARO), these varieties have not been evaluated for dry pod yield and yield components in eastern Ethiopia. Therefore, it is necessary to identify superior varieties for dry pod yield performance. This requires testing of varieties at different locations over multiple years. The performance of a genotype is the result of its genetic potential and the interaction to the environment where it grows that hinders the achievable improvement (Yang *et.al.*, 2009; Zobel *et al.*, 1988). The field evaluation not only helps the breeders to identify superior genotypes but also to distinguish repeatable and non-repeatable genotype x environment interaction and to discern fixed (locations) and random (year) effects (Affleck *et al.*, 2008; Tai, 2007). Therefore, this research was conducted to evaluate four improved pepper varieties and one local cultivar at three locations in eastern Ethiopia with the objectives: i) to determine the influence of genotype x environment interaction on yield components and dry pod yield production of pepper varieties, and ii) to identify the high yielding and stable pepper varieties for dry pod yield production in eastern Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The field experiment was conducted at three locations viz. Haramaya, Hirna and Dire Dawa which represented middle altitude cool area, middle altitude and humid and lowland altitude (hot area), respectively. The varieties were evaluated for three consecutive cropping seasons at Haramaya (2012 to 2014), while at Hirna and Dire Dawa for two cropping seasons.

Haramaya is located at 9 °26' N latitude, 42 °3' E longitudes, and at an altitude of 2020 m.a.s.l. The mean annual rainfall is 760 mm (Belay *et al.*, 1998). The mean maximum temperature is 23.4^{0}C while the mean minimum annual temperature is 8.25^{0}C. The soil of the experimental site is a well-drained deep alluvial with a sub-soil stratified with loam and sandy loam. Dire Dawa is located between 09^0 28.1 N latitude and 41^0 38 .1 E longitude. The altitude of the experimental site is 1116 m.a.s.l. The temperature is generally high with monthly mean maximum of 28.1^{0}C (December) and 34.6^{0}C (June) with the mean annual temperatures in the range between 19^{0}C to 31.5^{0}C. The mean annual rainfall in the study area is 550 mm (Levoyageur Weather, 2012). Hirna is situated at a distance of about 134 km to the west of Haramaya. The site is located at 9 °12' North latitude, 41 °4'East longitude, and at an altitude of 1870 m.a.s.l. The area receives mean annual rainfall ranging from 990 to 1010 mm. The average temperature of the area is 24.0° C. The soil of Hirna is vertisols (HURC, 1996).

2.2. Experimental Material

Four improved varieties viz. Marko Fana, Melka Eshet, PBC-660 (Melka Awaze) and Melka Dima were obtained from National Vegetable Research Project and local cultivar from the region and evaluated for dry pod yield and yield components. Marko Fana was released in 1976 (Alemu and Ermias, 2000). and has large pod size and weight with dark red color, pungent with high oleoresin content (Lemma, 1998). Mareko Fana is the only cultivar being used for a long time by the local factories for the extraction of capsicum oleoresin for the export market (MARC, 2003). Melka Dima (Papri King) and Melka Eshet (Papri Queen) are released in 2004 by Melkassa Agriculture Center as improved sweet pepper. Melka Awaze (PBC 600) is released in 2006 by the same Ceneter as chili pepper (MoA, 2012).

2.3. Treatments and Experimental Design

Seeds of the five pepper cultivars were sown on seedbeds of 1 m wide and 5 m length. Seedlings were transplanted to the actual field when the seedlings attained 20 to 25 cm height or near to two months (64 to 70 days) after seeds sown. The seedlings were spaced at 60 cm between rows and 30 cm between plants as the recommendation made for the crop. The cultivars were planted in randomized complete block design (RCBD) with three replications. One replication consisted of five plots where each plot allocated for one variety/cultivar and each plot consisted of six rows with 12 plants. Data were collected from plants at four middle rows left the two extreme border rows and plants grown at the end of each row as border rows and plants, respectively. Fertilizer was applied as per the national recommendation for the crop, i.e., 92 kg P_2O_5 ha^{-1} or 200 kg ha^{-1} in the form of DAP as a side dressing during the transplanting operation and 84 kg N ha^{-1} in the form Urea (100 kg ha^{-1} UREA). Half of the recommended N applied during transplanting and half of it at 15 days after transplanting (EARO, 2004). Other agronomic managements were applied uniformly as per the recommendation made for the crop.

2.4. Data Collection and Analysis

2.4. 1. Data Collection

Data were collected for dry pod yield and yield components. Number of dry pods per plant were counted from experimental plants from the central rows of each plot at each harvest, summed up and divided by the number of plants after the final harvest. Red dry pod length and width were measured from randomly taken five fruits from each plot in each harvest and the mean values were computed. The length of pod was measured excluding the pedicel and width was measured at the base of the fruits. Surface area (cm^2) of the dry pod was obtained as product of pod length and width. Average weight of dry pod was recorded as the mean weight of all harvested pods in each plot. These fruits were dried under shade until the pods attained the constant weight. The seeds of five dry fruits at each harvest that were used to estimate fruit length and width were extracted, bulked and dried. From these bulked and dried seeds, thousand seeds were counted and weighted.

Total dry pod yield (t ha^{-1}) was estimated and recorded from the total fruits harvested from the four central rows after drying. The total weight of dry pods per plot was used to estimate dry pod yield t ha^{-1}. The total dry pods harvested from the net plot were sorted as marketable and unmarketable dry pods. Deformed shape, turned to white color and small size fruits were discarded as unmarketable dry pods and the remaining were weighted and recorded as marketable dry pod yield per plot and used to estimate dry marketable pod yield t ha^{-1}.

2.4.1. Data analysis

Data were subjected to analysis of variance considering each cropping season in each location as one environment which summed to seven environments. The pooled analysis of variance revealed non-significant mean squares of genotype x location for average dry pod weight, length, width and surface area as well as thousand seeds weight. For these traits, the pooled mean values of pepper varieties over locations and seasons were subjected to mean comparison using least significant difference (LSD) at 5 and 1% significance levels. However, the mean squares of genotype x location interaction were significant for number of dry pods per plant, total and marketable dry pod yield t ha^{-1} and further genotype x location interaction and stability analyses were conducted. These analyses were conducted using Additive Main effects and Multiplicative Interaction (AMMI) (Zobel *et al.*, 1988), and joint linear regression model as proposed by Eberhart and Russell (1966). In addition, AMMI stability value (ASV) was calculated as proposed by Purchase (1997) and as Purchase *et al.* (2000) as follows.

$$ASV = \sqrt{\left[\frac{IPCAISS}{IPCA\ 2SS}\ (IPCA1score)\right]^2 + [IPCA2score]^2}$$

Where, ASV=AMMI stability value; SS=sum of squares of IPCA1 and IPCA2 (the first and the second interaction principal component axes, respectively). The varieties with lower ASV were considered more stable than those with higher ASV values.

3. Results

3.1. Analysis of Variance and Yield Advantages of Improved Varieties

The mean squares of genotype and environment were significant for dry pod yield and yield components except non-significant environment mean square was computed for dry pod width. However, the mean squares of genotype x environment interaction were significant ($P<0.05$) only for number of dry pods per plant, total and marketable dry pod yield t ha^{-1}(Table 1). The nonsignificant influence of genotype x environment interaction on average dry pod weight, dry pod length, width and surface area, thousand seeds weight allowed to compare pepper genotypes based on pooled mean values over locations and seasons. But, further genotype x environment interaction and stability analyses were conducted to identify wide adaptable and high performing varieties for those traits which exhibited significant mean squares for genotype x environment interaction.

Marko Fana produced significantly highest total and marketable dry pod yield t ha^{-1} followed by PBC-660 (Melka Awaze) and Melka Eshet. However, Melka Dima produced dry pod yield lower than local cultivar (Table 5). However, the local cultivar had statistically non-significant and higher mean values as equal to high performing improved varieties for dry pod traits except Marko Fana showed superiority over local cultivar for dry pod width (Table 2 and Table 3). Marko Fana had 41.87 and 44.65% total and marketable dry pod yield advantages over local cultivar, respectively. Marko Fana variety also exhibited 30.43, 5.49 and 3.72% advantages of number of dry pod per plant, average dry pod weight and dry pod width over local cultivar, respectively. Melka Eshet showed 15.50, 20.93 and 13.04% superiority over local cultivar for total dry pod yield, marketable dry pod yield and number of dry pod per plant, respectively (Table 3). Regarding the environments, Haramaya site was better for the production of dry pod yields and yield components during 2012 cropping season, but it was not good during 2014 cropping season due to frost incidence (Table 2 and Table 3).

Table 1. Mean squares from combined analysis of variance for dry pod yield and dry pod characters of pepper varieties as tested at seven environments.

	Source of variation						CV (%)
Trait	Rep (2)	Geno (4)	Env (6)	G x E (24)	Error (68)	SE	
Total dry pod yield t ha^{-1}	6.49	7.69**	24.20**	1.38*	0.273	0.522	17.24
Marketable dry pod yield t ha^{-1}	3.1599	4.797**	15.10**	2.016*	0.263	0.513	20.67
Average dry pod weight (g)	1.252	1.931*	14.904**	0.829	0.258	0.508	19.7
Number of dry pod/plant	1030.3	1231.00**	3528.30**	315.10*	57	7.55	26.77
Dry pod length (cm)	1.848	7.687**	7.615**	1.325	1.391	0.681	7.75
Dry pod width (cm)	0.042	5.309**	0.257	0.125	0.118	0.198	8.64
Dry Pod Surface Area (cm^2)	17.29	489.74**	289.02**	39.53	31.88	3.26	17.06
Thousand seeds weight (g)	0.643	4.364**	3.657**	0.740	0.489	0.404	6.46

** and **, significant at P<0.05 and P<0.01, respectively. Numbers in parenthesis represents degree of freedom. Rep = replication, Geno = genotype, Env = environment, G x E = genotype by environment interaction, SE = standard error and CV (%) = coefficient variation in percent.*

Table 2. Mean performance of varieties over locations and years for dry fruit traits as tested in seven environments.

Environment	ADPW (g)	DPL (cm)	DPW (cm)	DPSA (cm²)	TSW (g)
Haramaya (2012)	2.41b	9.67a	2.375	23.16ab	7.14a
Haramaya (2013)	2.21b	9.18a	2.185	20.24bc	6.07cd
Haramaya (2014)	2.30b	8.96ab	2.327	20.88abc	6.34bc
Hirna (2012)	4.81a	7.99c	2.301	13.82d	5.96cd
Hirna (2013)	1.90b	7.99c	2.301	13.82d	5.96cd
Dire Dawa (2012)	2.20b	8.24bc	2.071	16.87cd	5.67d
Dire Dawa (2014)	2.21b	9.51a	2.477	24.93a	6.59b
Genotype					
Marko Fana	2.88a	8.94a	2.79a	23.76a	6.41a
Melka Eshet	2.59a	8.13b	2.47b	19.38b	6.52a
Marako Dima	2.62a	9.51a	1.78c	15.27c	5.87b
PBC-660	2.07b	8.21b	1.73c	13.25c	5.68b
Local Cultivar	2.73a	9.18a	2.69ab	23.86a	6.76a
Mean	2.58	8.79	2.29	19.11	6.25
LSD (5%)	1.25	1.92	0.559	9.19	1.139
CV (%)	19.8	13.4	15	19.6	11.21

Means in the same column with similar letter(s) are not significantly different each other at P<0.05. LSD (5%) = least significant difference at P<0.05 and CV (%) = coefficient variation in percent. ADPW (g) = average dry pod weight in grams, DPL (cm) = dry pod length in centimeter, DPW (cm) = dry pod width in centimeter, DPSA (cm²) = dry pod surface area in centimeter square and TSW (g) = thousand seeds weight in gram.

Table 3. Percent advantage of improved varieties over local pepper cultivar for dry pod yield and yield components as tested in seven environments.

Trait	Marko Fana	Melka Eshet	Melka Dima	PBC-660	Mean advantage of varieties
Total dry pod yield t ha^{-1}	41.87	15.50	-18.07	16.97	14.07
Marketable dry pod yield t ha^{-1}	44.65	20.93	-12.56	24.19	19.30
Number of dry pod per plant	30.43	13.04	-4.35	78.26	29.35
Average dry pod weight (g)	5.49	-5.13	-4.03	-24.18	-6.96
Dry pod length (cm)	-2.61	-11.44	3.59	-10.57	-5.26
Dry pod width (cm)	3.72	-8.18	-33.83	-35.69	-18.49
Dry pod surface area (cm²)	-0.42	-18.78	-36.00	-44.47	-24.92
Thousand seeds weight in gram (g)	-5.18	-3.55	-13.17	-15.98	-9.47

3.2. Genotype x Environment Interaction Analysis

The AMMI model analysis of variance results showed significant mean squares for treatment, genotype, environment and genotype x environment interaction for number of pods per plant and marketable dry pod yield (Table 4). However, analysis of variance results from Eberhart and Russel's model revealed highly significant (P<0.01) mean squares only for genotype for all the three traits (Table 5).

The treatment sum squares (69.44 to 72.54%) accounted the largest proportion of the total sum of squares as compared to error sum squares (13.27 to15.3%). The environment sum squares (62.9 to 69.42%) had the largest share from treatment sum squares as compared to genotype (14.3 to 14.7%) and genotype x environment interaction (15.88 to 22.47%) for number of pods per plant, total and marketable dry pod yield. Both IPCA 1 and IPCA 2 (interaction principal component axes one and two, respectively) explained the G x E interaction sum of squares to the minimum 87.03% (marketable dry pod yield) and maximum of 96.83% (number of dry pods per plant) while residuals sum of squares accounted only 3.17 to 12.96% to G x E interaction sum of squares for all the three traits(Table 4).

3.3. Stability Analysis

Melka Dima had the largest IPCA 1 values and the highest ASV for total dry pod yield, while the local pepper cultivar had the lowest ASV. Melka Eshet followed by Marko Fana had second and third lowest ASV, respectively (Table 6). Melka Eshet, PBC-600 and Marko Fana were plotted at the right side of AMMI biplot for total dry pod yield where the former variety located nearest to the origin but the other two far from the origin. Melka Dima and the local cultivar were located at the left side (Figure 1). Melka Eshet followed by PBC-660 had lowest ASV while Marko Fana followed by Melka Dima had the highest ASV for marketable dry pod yield. Melka Eshet, PBC-660 and Marko Fana located above the origin at the right side on AMMI biplot, but Marko Fana plotted far from the origin (Figure 2). Regarding number of pods per plant, Marko

Fana followed by Marako Dima had lowest ASV values. In addition, the former variety was plotted at the right side but other two to the left above the origin of the biplot (Figure 3).

All cultivars had regression coefficient (bi) values significantly different from zero for both total and marketable dry pod yield, but all had sdi^2 (deviation from regression) values nonsignificant different from unity (Table 6). The bi and sdi^2 values for all cultivars were not significantly different from zero and unity, respectively, except the bi value of PBC-660 was significantly ($P<0.01$) different from zero. Regression analysis was computed taking environmental indices as independent variable and the three traits as dependent variable (response variable) to test the change in the magnitude of differences between cultivars performances and the changing environment. The correlation between cultivars performance and environmental indices was strong for total dry pod yield ($r >0.89$) (Figure 4) and number of dry pods per plant ($r>0.71$) (Figure 6) while none of cultivars had correlation coefficient $r>0.7$ for marketable dry pod yield(Figure 5). Coefficient of determination (R^2) values were higher ($R^2 \geq 0.51$) for total dry pod yield and number of dry pods per plant in all cultivars while except Marko Fana and local cultivar other varieties R^2 values for marketable dry pod yield were $R^2<0.40$. In general, Marko Fana followed by PBC-600 and Melk Eshet had higher mean values, coefficient of determination and strong correlation with environmental indices.

Table 4. AMMI analysis of variance for total and marketable dry pod yield, and number of dry pods per plant of four improved pepper varieties and one local cultivar used as a check in seven environments.

Sources of variation	DF	Total dry pod yield (t ha-1) Sum of squares	Mean squares	Sum of square Explained % Total	%G x E	Marketable pod yield (t ha-1) Sum of squares	Mean squares	Sum of square Explained % Total	%G x E	Number of dry pods per plant Sum of squares	Mean squares	Sum of square Explained % Total	% G x E
Treatment	34	209.17	6.152**	69.44		134.17	3.946**	72.03		33655	989.9**	72.54	
Genotype	4	30.75	7.688**	14.70		19.19	4.797**	14.30		4924	1231**	14.63	
Environment	6	145.21	24.202**	69.42		90.59	15.099**	67.52		21170	3528.3**	62.90	
Rep within E	14	50.57	3.612	24.18		27.37	1.955	20.40		5642	403	16.76	
G x E	24	33.21	1.384*	15.88		24.39	1.016**	18.18		7561	315.1**	22.47	
IPCA 1	9	16.62	1.847		50.05	13.76	1.529		56.42	6068	674.2		80.25
IPCA 2	7	13.27	1.896		39.96	7.47	1.067		30.63	1253	179		16.57
Residuals	8	3.32	0.415		10.00	3.16	0.395		12.96	240	30		3.17
Error	56	41.47	0.741	13.77		24.71	0.441	13.27		7098	126.7	15.30	
Total	104	301.21	2.896			186.26	1.791			46395	446.1		

** and **, significant at P<0.05 and P<0.01, respectively. DF= degree of freedom, Rep within E = replication within environments, G x E = genotype by environment interaction, IPCA 1 and IPCA 2 = interaction principal component axis one and two, respectively.*

Table 5. Analyses of variance from Eberhart and Russel's Model for number of dry pods per plant, total and marketable dry pod yield.

Source of variation	DF	TDPY t ha-1	MDPY t ha-1	NDPP
Genotypes	4	2.563**	1.599**	410.339**
Environment + (Geno x Env.)	30	1.982	1.278	319.233
Environment (linear)	1	48.404	30.198	7056.59
Genotypes x Env. (linear)	4	1.138	0.559	476.773
Pooled Deviation	25	0.261ns	0.236ns	24.533ns
Marko Fana	5	0.215 ns	0.148 ns	9.978 ns
Melka Eshet	5	0.130 ns	0.107 ns	21.111 ns
Melka Dima	5	0.083 ns	0.096 ns	67.895 ns
PBC-660	5	0.605 ns	0.501 ns	10.443
Local Cultivar	5	0.271 ns	0.328 ns	13.236 ns
Pooled Error	70	0.438	0.248	60.665

*** and ns, significant at P<0.01 and nonsignificant, respectively. DF= degree of freedom, Geno x Env = genotype by environment interaction, Genotypes x Env. (Linear) = genotypes by environment interaction linear, TDPY t ha^{-1} = total dry pod yield tons per hectare, MDPY t ha^{-1} = marketable dry pod yield tons per hectare and NDPP = number of dry pods per plant.*

Table 6. Stability parameters from AMMI and Eberhart and Russel's models for number of dry pods, total and marketable dry pod yield of four varieties and one local check tested at seven environments.

Trait	Genotype	Pooled mean	Mean based rank	AMMI model stability				ER's Model stability	
				IPCA 1	IPCA 2	ASV	ASV based rank	b_i	S^2di
	Marko Fana	3.863a	1	-0.64	-0.27	1.02	3	1.25**	-0.22ns
TDPY	Melka Eshet	3.145b	3	-0.46	0.14	0.81	2	1.13**	-0.31ns
(t ha^{-1})	Melka Dima	2.231c	5	1.07	0.73	1.48	5	0.40**	-0.36ns
	PBC-660	3.185b	2	0.56	-1.10	1.03	4	1.19**	0.17ns
	Local cultivar	2.723bc	4	-0.53	0.50	0.21	1	1.03**	-0.17ns
	Mean	3.03							
	LSD (5%)	1.76							
	CV (%)	20.56							
	Marko Fana	3.11a	1	0.97	0.14	2.56	5	1.06**	-0.01ns
MDPY	Melka Eshet	2.60bc	3	0.25	-0.27	0.11	1	1.09**	-0.14ns
(t ha^{-1})	Melka Dima	1.88d	5	-1.03	-0.22	2.25	4	0.50**	-0.15ns
	PBC-660	2.67ab	2	0.10	-0.51	0.51	2	1.33**	0.25ns
	Local cultivar	2.15cd	4	-0.29	0.86	0.84	3	1.03**	0.08ns
	Mean	2.48							
	LSD (5%)	1.33							
	CV (%)	19.11							
NDPP	Marko Fana	30b	2	-0.07	1.30	1.30	1	0.99ns	-50.69ns
	Melka Eshet	26bc	3	0.81	2.46	2.50	4	0.80ns	-39.55ns
	Melka Dima	22c	5	3.39	-3.18	1.46	2	0.48ns	7.23ns
	PBC-660	41a	1	-5.55	-1.39	11.17	5	1.99**	-50.22ns
	Local cultivar	23c	4	1.42	0.82	2.04	3	0.75ns	-47.43ns
	Mean	28							
	LSD (5%)	10.42							
	CV (%)	28.85							

*** & NS, significantly different (P<0.01) from unity and non-significant different from zero, respectively. Means with same letter(s) are not significantly different each other. ASV = AMMI stability value, ER's = Eberhart and Russel's, TDPY (t ha^{-1}) = total dry pod yield tons per hectare, MDPY (t ha^{-1}) = marketable dry pod yield tons per hectare.*

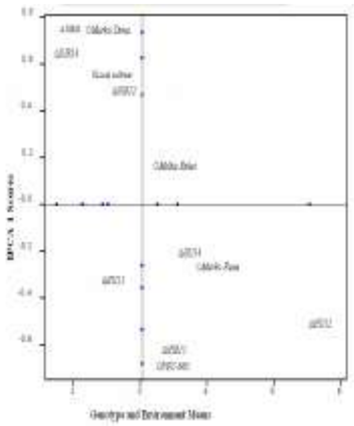

Figure 1. AMMI 1 biplot of five pepper genotypes evaluated for total dry pod yield t ha^{-1} at seven environments in eastern Ethiopia.

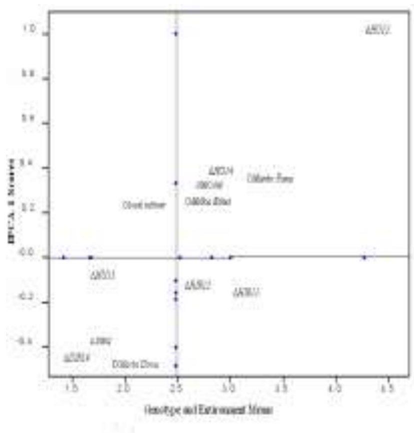

Figure 2. AMMI 1 biplot of five pepper genotypes evaluated for marketable dry pod yield t ha^{-1} at seven environments in eastern Ethiopia.

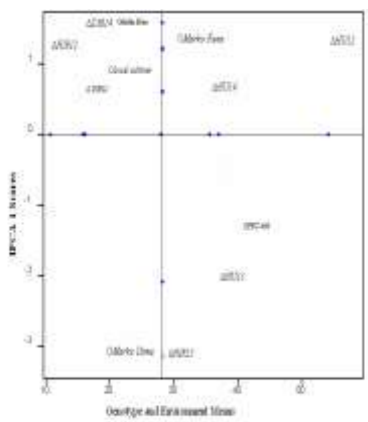

Figure 3. AMMI 1 biplot of five pepper genotypes evaluated for number of dry pods per plant at seven environments in eastern Ethiopia.

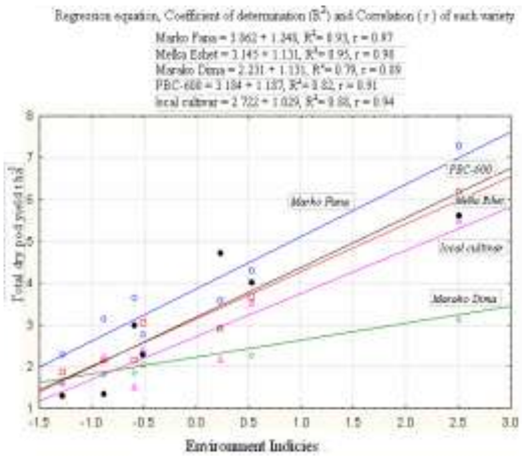

Figure 4. Regression of pepper total dry pod yield t ha^{-1} on environment indices with equation of best-fit line for combined average of seven environments.

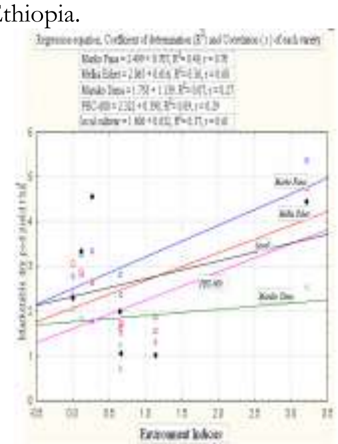

Figure 5. Regression of pepper marketable dry pod yield t ha^{-1} on environment indices with equation of best-fit line for combined average of seven environments.

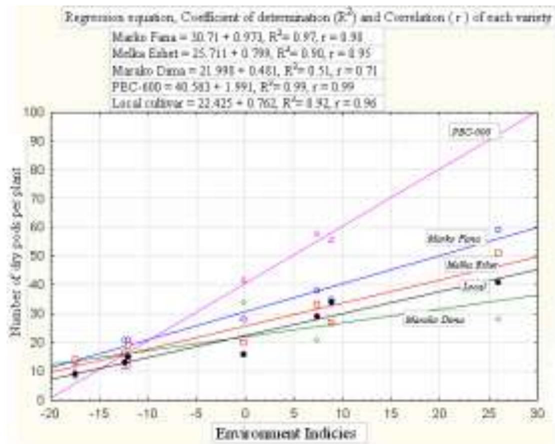

Figure 6. Regression of pepper number of pods per plant on environment indices with equation of best-fit line for combined average of seven environments.

4. Discussion

The observed significant differences among genotypes and environments with nonsignificant interaction of the two for dry pod traits (dry pod length, width and surface area, average dry pod weight and thousand seeds weight) indicated the importance of genetic differences and test environments for the expression of these traits. This suggested the possibility of selecting genotypes on the basis of their performance. In the absence of genotype x environment interaction, the superior genotype in one environment may be regarded as the superior genotype in all, whereas the presence of the interaction confirms particular genotypes being superior in particular environments (Samonte *et al*., 2005). Srividhya and Ponnuswami (2010) in paprika and Datta and Jana (2014) in chilli genotypes reported the significant influence of genotype and environment on pod characters.

Except Marko Fana for dry pod width, none of the varieties show superiority over local cultivar for pod traits. These suggested the higher possibility of obtaining local cultivars that perform better than the improved varieties. In the development of successful new genotypes stability is the key that the new genotypes must be performed consistently (Lin *et al*., 1986). The main effect of genotype concerns broad adaptation and for farmers, growing cultivars with stable performance (with large genotype effect and small genotype x environment interaction) results in a larger harvest (Gauch, 2006).

Besides the significant differences due to genotype and environment, it was evident that the significant differences in the number of dry pods per plant, total and dry pods yield t ha^{-1} was due to genotype x environment interaction. This suggested the importance of testing genotypes under different environments to identify the best genetic makeup that perform high in all environments and wide adaptable or adaptable in a particular environment. Other researchers (Datta and Jana, 2014; Abu *et al*., 2011; Srividhya and Ponnuswami, 2010; Reddy and Sadashiva, 2003) also reported the differential response of *Capsicum* genotypes for yield when it grew under different environments.

The AMMI model analysis of variance revealed that more than 77% of treatment variations for number of dry pods per plant, total and marketable dry pod yield t ha^{-1} were explained due to environment and genotype but more of by environment. In addition, more than 50% of genotype × environment interaction sum squares were explained by IPCA 1. The Eberhart and Russel's Model analysis of variance also revealed only genotype mean squares were highly significant for these traits. This indicated the observed variations were mainly due to the genetic potential differences of pepper cultivars and the environments as compared to varied response of genotypes due to the G x E interactions. The observed high proportion of variation due to environment effect on yield and number of pods per plant suggested the need of more testing sites or the importance of controlling environments at different locations (Gill *et al.,*1984). In general, the result suggested the importance of giving more attention for selection of high performing genotypes and growing them in most favourable environments to increase dry pod yields and number of dry pods per plant. Datta and Dey (2009) also reported the significant effect of genotype x environment interactions on pepper yield and yield components, but lesser importance as compared to genotype and environment.

The observed bi values significantly different from zero for all genotypes in total and marketable dry pod yield and non-significant Sdi^2 values from unity suggested the responsiveness of cultivars to the changed environments but not sensitive to the changing environments (Dabholkar, 1998). Though, the effect of genotype x environment interaction was less as compared to the effects of genotype and environment, some of the cultivars performance was inconsistencies for dry pod yields and number of pods. This suggested the importance of identifying superior and stable genotype, since all the genotypes may not be consistently superior in all environments (Yan and Kang, 2003). In the presence of genotype x environment interaction the targeting of cultivars to specific locations is difficult, since yield is less predictable and cannot be interpreted based only on genotype and environment means (Samonte *et al*., 2005; Akcura *et al*., 2005). This suggested that both predictable (locations) and unpredictable (year) environmental factors were important sources of variation. The potentiality of the genotype to express greater mean over the environment must be the most important stability parameter. Because, S^{2}di and bi values being nonsignificant have not practical utility as far as the genotype has low mean yield (Dabholkar, 1998). The stability statistics must be combined with performance to be informative and useful in selection. It is also difficult to identify single genotype that is stable for all measured characters (Yan and Kang, 2003). For instance, local cultivar and Melka Eshet identified as most stable for total and marketable dry pod yield, respectively, while PBC-660 for total and Marko Fana for marketable identified as most unstable. But, the former cultivars were not high yielding as compared the later varieties. Therefore, considering all stability parameters along with the performance of genotypes, the increase and decrease rates of performance both under favourable and unfavourable environments is necessary to recommend the genotype for production in the target region.

Marko Fana had highest mean values for most of the traits measured including total and marketable dry pod yield. Though it was identified less stable variety for some of the traits across locations and seasons, its response was proportional to the favorability and unfavorability of environments but more responsive to favorability environments. Therefore, Marko Fana can be recommended for production in eastern Ethiopia as spices and processing of oleoresin due to its large pod size and **weight** with dark red color, pungent with high oleoresin content (Lemma, 1998). PBC-660 and Melka Eshet also had second and third highest total and marketable dry pod yield t ha^{-1} but the former had small pod size but highest number of pods per plant. These varieties were identified as stable for most of the traits and less stable for some of the traits measured. Therefore, it is possible to recommend Melka Eshet (Papri Queen) as sweet pepper and industrial processing while Melka Awaze (PBC 600) as chili pepper (MoA, 2012). But it is not necessry to consider Melka Dima for production in the region since it performed lower than local cultivar.

5. Summary and Conclusion

The study showed the existence of significant variability among the pepper cultivars for dry pod yield and yields components. Dry pod traits were not significantly influenced due to genotype x environment interaction justify the selection of genotypes depending on their performances. But, significant effect of genotype x environment interaction on number of dry pods per plant, total and marketable dry pod t ha^{-1} indicated the performance of genotypes differed as the environments changed suggested selection of varieties is important considering their yield performance and stability across environments. Marko Fana and local cultivar had comparable performances for all dry pod traits while all other improved varieties were inferior to local cultivar. This suggested the higher chance of improvement of dry pod traits through selection of local cultivars and assembling with high yielding varieties in breeding programs. Marko Fana could be recommended for production in eastern Ethiopia due to its high yield and desirable dry pod traits across the environments. Though the variety was identified less stable for total and marketable dry pod yield t ha^{-1} on the basis of AMMI stability parameters, the correlations between the performance of the variety and environmental indices for number of dry pods per plant, total and marketable dry pod yield were strong with high coefficient of determination. This indicated the high performance and predictability of the variety across environments for all the traits. Melka Awaze (PBC-660) Melka Eshet also could be recommended for the production of chilli (pungent pepper) and processing as sweet pepper, respectively, since these varieties were producing higher yields than local cultivar. Generally, it could be concluded that the importance of selection of varieties on the basis of their performances for dry pod yield and its components through testing across multiple environments is necessary.

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15. Biodegradation of Locally Available Organic Wastes by Composting and Vermicomposting for Improvement of Soil Fertility and Crop Production

R. Hiranmai Yadav, Kibebew Kibret, Anteneh Argaw and Teferi Taddesse

Haramaya University, College of Agriculture and Environmental Sciences, School of Natural Resources Management and Environmental Sciences, Dire Dawa, Ethiopia.
Contact Email: mayahiranbt@gmail.com Mobile: 0919231748

Abstract: Low soil organic matter in Ethiopia soils is the major constraint for crop production. Integrated soil fertility management is the need of the present agriculture to improve the soil fertility and crop production. Therefore the present study was an attempt to produce the vermicompost of Parthenium, Lantana, Catha edulis and paper wastes admixed with farm wastes and different animal manures (Cow dung, Goat manure, Poultry manure and Swine manure) conducted in the research fields of Haramaya University, Ethiopia. The vermicompost was prepared using the earthworm variety Eisenia foetida, the red worm. The resultant product was analyzed for its nutrient content and suitability to be used as manure. The pH, Organic Carbon, Organic matter, Total Nitrogen, Phosphorus, Potassium, Sodium, Calcium, Magnesium, Copper, Iron, Zinc and Manganese contents were analyzed and found that these nutrient contents are improved after decomposition. The Parthenium and lantana vermicomposts were applied in different dosages along with fertilizer to potato crop and assessed for its performance. The different vermicomposts were found to be effective in improving different growth parameters of the crop. This could be a promising technology to improve the soil fertility in an economic way by the farmers of developing countries.

Keywords: Parthenium; Catha edulis and Paper Wastes; Lantana; Vermicompost; Nnutrients; Soil Fertility; Potato

1. Introduction

In Ethiopia, declining soil fertility presents a major challenge to bring about increased and sustainable productivity in order to feed the ever-increasing population of the country. As result, millions are suffering from poverty and malnutrition. Eyasu (2002) indicated that under increasing demographic pressure, cultivation becomes permanent. According to same author, the traditional farming systems in SSA lead to the mining of the natural soil fertility when cultivation becomes more permanent due to increasing population pressure. In many cases, removal of vegetation cover, depletion of soil nutrients and organic matter (OM), and accelerated soil erosion have all led to the drastic decline in soil productivity.

Biodegradable materials of microbial, plant or animal origin shall form the basis of the fertilization programme in organic farming. Composting is a controlled process of decomposition used to transform organic material such as kitchen scraps, yard wastes, weeds, paper products and other organic wastes into humus. Vermi-composting on the other hand, is a bio-oxidation and stabilization process of organic materials that involves joint action of earthworms and bacteria, but does not undergo a thermophilic stage.

The present project aimed for preparation of compost and vermicompost using *Parthenium hysterophorus* plant, *Lantana camara* plant, *Catha edulis* plant wastes and paper wastes from Haramaya university campus enriched by different combinations of crop residues and organic manures. The compost and vermicompost was applied to potato to assess its efficacy on growth, quality and yield of crops. Through this method aneco friendly manure could be developed that is useful for sustainable agriculture. The weed menace can be reduced and it may be utilized in a beneficial manner by the society in terms of compost and vermicompost units and entrepreneurship activities.

2. Materials and Methods

2.1. Description of the Site

Research field of RARE of Haramaya University campus is located in East Hararghe zone of western Oromiya National Regional state. The experimental field is located at 9^0 26'N latitude and 42^0 3'E longitude. The average altitude is about 1980 masl. It is located in the semi arid tropical belt of eastern Ethiopia and is characterized by a sub humid type of climate with mean annual rainfall of 777mm. The site receives bimodal rainfall March – April 25% rain and june to September 45%. The mean monthly temperature ranges from 9.2 to 23.2^0 C.

2.2. Experimental Procedure

Phase I

Collection of Materials for Vermicomposting

- Collection of farm wastes and organic manures (cow dung, goat manure, poultry manure and swine manure) Haramaya University farms and fields
- Collection of invasive weeds (*Parthenium hysterophorus* , *Lantana camara*)
- Collection of paper wastes from Haramaya University campus and *Catha edulis* from Awadey

Phase II

Preparation of Collected Materials for Degradation

The collected materials are processed according to the work plan designed for the study. The plants were collected and cut into small pieces. The paper wastes were made into small pieces and chat wastes were also reduced in its size. The farm wastes were collected from fields and they were also cut into smaller pieces. The animal manures were obtained from agricultural farm. Cement tanks measuring 1m x 1m X 1m were used for the vermicomposting. The mixtures were left with moisture for 21 days in order to semi compost the feed so that it becomes palatable for the worms. The moisture and temperature were maintained by sprinkling water and turning the mixture. Composting earthworm species *Eisenia fetida* commonly known as red worm were cultured in the compost unit and after 21 days the earthworm were introduced. The moisture content was maintained to 60-70 % and the tanks were covered with moist jute bags to protect the worms and prevent moisture loss. After 60 days the samples were collected and analyzed for quality.

The treatment combination prepared as follows :

1. *Parthenium hysterophorus* + crop residues + Cow dung
2. *Parthenium hysterophorus* + crop residues + Goat manure
3. *Parthenium hysterophorus* + crop residue + Poultry manure
4. *Parthenium hysterophorus* + crop residue + Swine manure
5. *Lantana camara* plants+ crop residue + Cow dung
6. *Lantana camara* plants + crop residue + Goat manure
7. *Lantana camara* plants + crop residue + Poultry manure
8. *Lantana camara* plants + crop residue + Swine manure
9. *Catha edulis* plant wastes+ crop residue + Cow dung
10. *Catha edulis* plant wastes+ crop residues + Goat manure
11. *Catha edulis* plant wastes+ crop residue + Poultry manure
12. *Catha edulis* plant wastes+ crop residue + Swine manure
13. Paper wastes + crop residue + Cow dung
14. Paper wastes + crop residue + Goat manure
15. Paper wastes + crop residue + Poultry manure
16. Paper wastes + crop residue + Swine manure

Phase III

Evaluation of the Vermicomposts for Nutrient Status

The vermicompost samples were tested in Soil Chemistry laboratory, Haramaya University. The samples were collected and shade dried. They were tested for selected physico-chemical parameters. The pH was measured with 1:10(w/v) using double distilled water. Total organic carbon content in the samples was measured by Walkley and Black (1936) method and the organic matter was calculated by multiplying the percent organic carbon by 1.724 assuming that organic matter is composed of 58% carbon and total nitrogen by microkjeldahl method (Humphries, 1956). The phosphorus was estimated by the method of Jackson (1973) and the Potassium by Piper (1966).The Calcium and Magnesium contents were estimated by the method of Hesse (1971). The micro nutrients namely Zinc, Copper, Iron and Manganese were assessed by Jackson (1973) method. C : N ratio was calculated by dividing the total carbon by total nitrogen.

Phase IV

Field experiments for assessment of the manurial value of decomposed products

Field experiments were conducted at Rare with potatoes

Treatments

T_0	Control- ½ RDF
T_1	Parthenium vermicompost + ½ RDF
T_2	*Lantana camara* plants+ Farm wastes + Cow dung + ½ RDF
T_3	*Lantana camara* plants + Farm wastes + Goat manure + ½ RDF
T_4	*Lantana camara* plants + Farm wastes + Poultry manure + ½ RDF
T_5	*Lantana camara* plants + Farm wastes + Swine manure + ½ RDF

Plot size- 3 X 4 m^2 (Each plot with three replications) Dosage – 4.2 kg/ plot (3.5 tonnes/ ha)

3. Results and Discussion

The physicochemical characters of the vermicomposts quantify their nutrient value. It depends on the factors like nature of substrate used and the vermicomposting process.

The vermicomposts obtained was brownish black in colour with an earthy smell that indicated the complete decomposition of the raw material. When different nutrients were analysed in the vermicomposts from different combinations they exhibited different values that indicated the quality of vermicomposts.

Table 1. Physico chemical parameters of composts prepared from Parthenium and Lantana vermicomposts.

Treat ments	PH	%OC	%Om	%TN	P (ppm)	K (ppm)	Na (ppm)	Ca (ppm)	Mg (ppm)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Mn (ppm)
	9.09	21.84	37.65	1.88	113.89	621.30	156.22	957.14	144.22	0.72	7.29	4.51	3.28
	8.77	24.96	43.03	2.15	111.94	557.20	145.06	1051.43	144.22	0.57	3.67	4.48	2.96
	8.7	25.935	44.71	2.24	112.69	581.85	133.90	1205.71	143.58	0.58	3.04	4.56	3.19
	8.54	24.96	43.03	2.15	112.87	522.68	137.62	1128.57	145.14	0.58	4.04	4.57	3.67
	9.81	24.57	42.36	2.12	116.57	616.37	111.59	622.86	123.12	0.65	3.44	4.41	3.68
	9.46	26.325	45.38	2.27	115.37	498.03	107.87	711.43	126.70	0.50	2.23	4.49	3.57
	8.46	25.545	44.04	2.20	120.00	611.44	152.50	957.14	143.21	0.32	1.27	4.63	3.75
	8.46	24.375	42.02	2.10	119.26	414.20	111.59	780.00	132.94	0.36	1.73	4.56	3.78

Table 2. Chemical properties of Lantana vermicompost.

S no	Parameters	T_1	T_2	T_3	T_4
1	OC(%)	2.507	2.421	2.786	2.614
32	Om(%)	4.322	4.175	4.803	4.507
33	TN(%)	0.28	0.322	0.224	0.238
4 4	P(ppm)	39.458	25.687	24.139	24.294
5 5	Cu(ppm)	4.37	4.25	2.41	3.33
6 6	Fe(ppm)	308	168	124	164
77	Zn(ppm)	5.13	3.96	3.79	5.07
88	Mn(ppm)	92.06	96.8	96.39	94.63

Table 3. Chemical parameters of paper waste vermicomposts.

S no	Parameters	T_5	T_6	T_7	T_8
1.	OC(%)	1.886	2.529	1.993	2.55
2.	OM(%)	3.251	4.359	3.436	4.396
3.	TN(%)	0.462	0.518	0.546	0.476
4.	P(ppm)	59.729	60.426	59.729	59.729
5.	Cu(ppm)	4.14	2.07	20.7	4.37
6.	Fe(ppm)	308	106	450	236
7.	Zn(ppm)	5.91	6.81	42.3	10.8
8.	Mn(ppm)	102.5	100.2	97.73	108.2

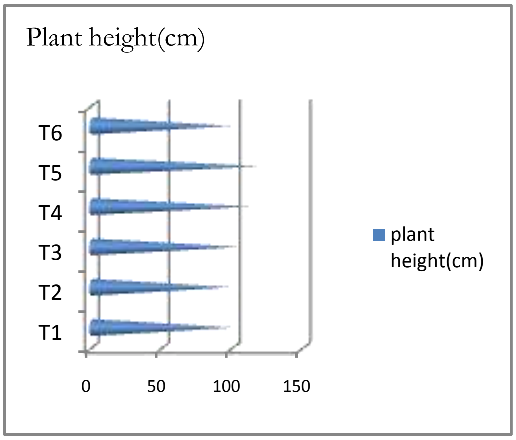

Figure 1. Plant height at flowering stage.

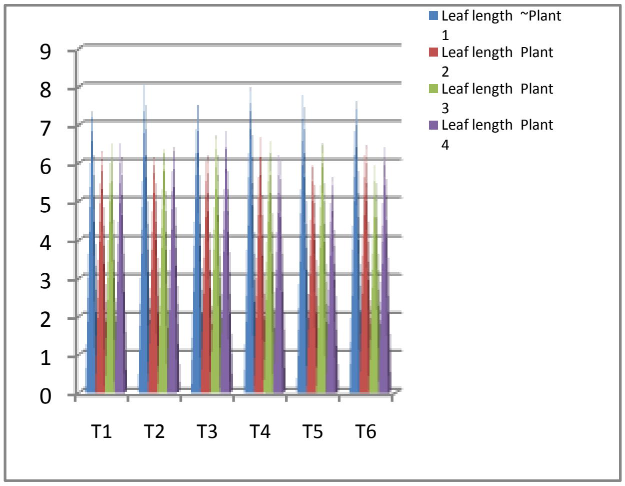

Figure 2. Leaf length at flowering stage .

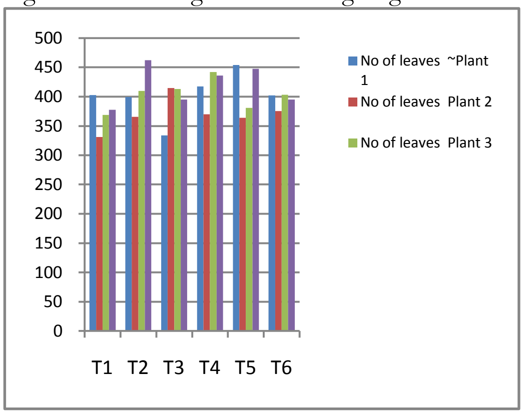

Figure 3. Number of leaves during flowering stage.

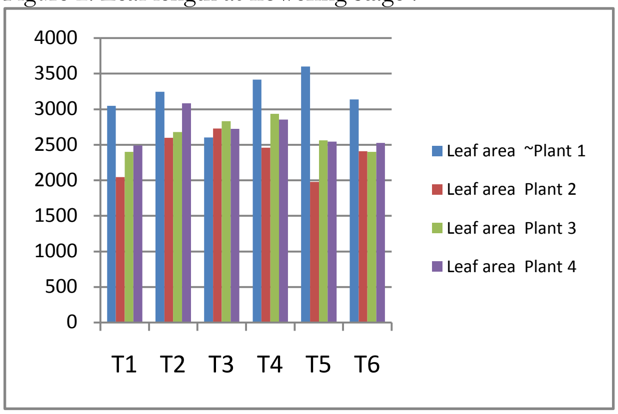

Figure 4. Leaf area during flowering stage.

4. Discussion

"Eradication by Utilization" is phrase first coined by Tessema (2012) to explain the economic exploitation of invasive species as a means of harnessing their economic potentials for meeting basic human needs and at the same time control its spread and possibly eradicate them. Proper utilization of Lantana biomass through appropriate technologies like composting and mulch etc. may help in supplementing chemical fertilizer besides adding organic matter to the soil. It proved highly useful raw material for compost production, particularly in combination with cattle dung and rock phosphate (Singh and Angiras, 2011).

Vermicompost is a controlled degradation or composting of organic waste, by earthworms, resulting in a stable nontoxic material with good structure which has a potentially high economic value as soil conditioner for plant growth. Agricultural waste (stem, leaves, husk peels orchard leaf litter, processed food wastes), forestry food wastes (wood shavings, peels, sawdust, and pulp), city leaf litter (mango, guava, grasses and certain seeds), waste paper and cotton cloths, city refuge, kitchen waste, biogas slurry industrial wastes can be used to produce biological fertilizer through vermicomposting. The production and use of vermicomposts in agriculture is economical and eco-friendly. The unique advantage of using vermicomposting is that it helps to build and sustain soil condition and fertility, which is necessary for, sustained agricultural activities. Vermicomposting reduces bad odors and prevents pollution of soil, air, and water. Vermicompost has been shown to have higher level of organic matter, organic carbon, total and available NPK, micronutrients, microbial and enzyme activities and growth regulators (Gupta, 2003).

Ansari and Ismail(2008) have reported that the application of vermicomposts improves the soil organic matter , organic carbon, available nitrogen carbonate ions, calcium ions , sodium ions and exchangeable sodium percentage. The pH and electrical conductivity are also influenced by the addition of vermicomposts. These changes in the soil indicate the improvement of soil quality by addition of vermicomposts as an organic source.

To increase the per capita income of the agriculture, there is a need to reduce the soil fertility depletion which can be achieved through the use of integrated organic and inorganic inputs (Sharma and Singh, 2011). Ghadge and Jadhav (2013) have reported that instead of eradicating Lantana camara with physical, mechanical and biological methods or burning it can be converted into manure by decomposition. It will be rich organic manure to improve soil fertility and increase the yield. Suthar and Sharma(2013) have vermicomposted Lantana with cowdung using *Eisenia foetida* and recorded a decrease in pH, total organic carbon and C/N ratio while there was an increase in ash content, total nitrogen, available phosphorus, exchangeable potassium and calcium and nitrate nitrogen. The microbial population was also increased and the population of actinomycetes indicated the maturity of composts. And from these results it could be stated that Lantana can be a potential source for vermicomposts production for sustainable agriculture.

Reddy *et al.*(2012) observed that the vermicomposts extracts preparation from weeds like Lantana can be a method for weed control and litter management. Yadav *et al.*(2013) have indicated that cow dung and biogas plant slurry could be decomposed by vermicomposting. The vermicomposting leads to the reduction of pH, total organic carbon, organic matter and C/N ratio and higher electrical conductivity, nitrogen, phosphorus and potassium content than the substrate. During decomposition the substrates get converted into homogeneous, odourless and stabilized humus like material. This can be an effective method to utilize the animal excreta to produce value added products. Bhat and Limaye (2012) has also reported that the vermicomposting improves the physic chemical properties of the product that in turn improves the soil nutrient content and soil fertility.

The physical and biochemical properties of substrates can be modified by vermicomposting, a bio oxidative process where the earthworms interact with micro organisms and other fauna within decomposer community. The physical process of degradation of organic substrates involves substrate fragmentation, thereby increasing the surface area of work, turn over and aeration. The biochemical changes during degradation are enhanced by micro organisms through enzymatic digestion, enrichment by nitrogen excrement and transport of inorganic and organic materials(Edwards *et al.*, 1998; Aira *et al.*,2002; Loh *et al.*, 2005; Molina *et al.*, 2013).The vermicomposting is also beneficial in recycling of animal wastes, crop residues and industrial wastes(Bansal and kapoor, 2000; Kaushik and Garg,2003; Yadav and Garg, 2010; Garg *et al.*, 2012). The earthworm of suitable species also has significance in the degradation process. The epigeic earthworms are widely used and *Eisenia foetida* is most widely used for vermicomposting of organic materials such as agricultural wastes and animal manures.

Animal manures have been effectively used as manures due to their high nitrogen content and they provided the nutrients required by the plants (Sloan *et al.*, 2003; Burton and Turner, 2003). Inappropriate disposal of wastes causes environmental pollution and the utilization of nutrients available in the animal manures can be utilized effectively for agriculture (Roeper *et al.,* 2005; Williams et al., 1999; Mattson, 1998). Co-composting is a preferred method to turn organic wastes to high nutrient content products that can be soil conditioners and amendments (Butler *et al.,* 2001). It is an integrated waste management system by biological stabilization of wastes that complement each other in decomposition and nutrient addition under thermophilic condition with elimination of pathogens and plant seeds (Ahring *et al.*, 1992; Angelidake and Ahring, 1997; Gopinathan and Thirumurthy, 2012).The co-composting also allows a humification process that mineralizes the organic matter(Campitelli *et al.*, 2006; Smidt *et al.*,2007). The organic substances are the greatest carbon reservoirs on the earth that adds organic matter to the soil (Pena- Mendez *et al.*,2005).

The earthworms and vermicomposts are helpful in maintaining the nutrient balance in soil cycling of organic waste. The African species *Eudrillus eugeniae* used to decompose the waste paper and found to be effective with paper waste and cowdung in 1:1 ratio (Basheer *et al.*, 2013). According to Arancon *et al.* (2008) vermicomposts produced from cattle manure, food wastes and paper wastes was found to be beneficial for the growth of Petunia plants. This might be due to improvement of physical structure of the potting medium, increased microbes, availability of plant growth promoting substances like hormones and humates probably contribute to the increased germination, growth and flowering of Petunia. The decomposition of *Parthenium hysterophorus, Eichornia crassipes* and *Cannabis sativa* using *Eisenia foetida* was found to increase nitrogen,phosphorus and potassium and decreased the organic carbon, C/N ratio and C/P ratio considerably(Chauhan and Joshi,2006). *Eisenia foetida* help to increase the microbial acivity and release nitrogen, potassium and calcium (Edwards, 1995). Before vermicomposting, thermocomposting is beneficial for waste stabilization as well as for mass reduction and effective in reducing the pathogens (Jaya Nair *et al.*, 2006).

The important factor influences the stability of the final product of decomposition (Hu *et al.*, 2008). Compost maturity is the level of decomposition that can be defined by the microbial biomass and decomposition of phytotoxic compounds in compost (Wu *et al.*, 2000; Wu and Ma, 2001). Reduction of wastes by co-composting using chicken slurry and pineapple wastes by Angelidake and Ahring(1997) have been found to be a digestibility of solid waste and improved nutrient balance. The co-composting by improved nutrient release reduces the cost and use of fertilizers.The cattle manure, food waste and paper vermicomposts was found to be rich in nutrients and vermicomposts contains plant growth regulating materials like plant growth hormones and humic acids that can increase the germination, growth and yield of plants (Atiyeh et al., 2002; Arancon et al., 2006b; Arancon and Edwards, 2006b).

5. Summary and Conclusion

The present study was conducted to utilize the biological wastes for crop production and improving soil fertility. These wastes could be effectively utilized by the decomposition using the earthworms and produce a valuable vermicomposts. The vermicomposts can be prepared by the farmers and utilized in integrated soil nutrient management. The experiment reveals that the obnoxious weeds, paper wastes, and chat wastes along with farm wastes and available animal manures can be convered into a organic manure within short duration by the farmers. This benefits the farmers, cleans the environment, and reduces the utility of fertilizer.

6. Recommendation

This study needs further research that could be carried out by Agricultural offices for famers.The result obtained indicates the positive effects for use of biodegradable wastes for vermicompost production and use as organic manure.

7. Acknowledgement

The authors are grateful to Haramaya University for funding the project and facilitating the research activities. They are also thankful to the technical staffs and field assistants in the School of Natural Resources Management and Environmental Sciences, College of Agriculture and Environmental Sciences, Haramaya University.

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16. Influence of Combined Use of Orga and Nitrogen Fertilizer on Soil Water Content, Yield and Yield Components of Maize (*Zea mays* L.) in Water Stressed Babile Area, Eastern Hararghe, Ethiopia

Solomon Tamiru and AyeleAkuma

Haramaya University, College of Agriculture and Environmental Science, Department of Natural Resource Management, P. O. Box 20, Dire Dawa, Ethiopia
Solomon Tamiru, tamirusolomon@yahoo.com, and AyeleAkuma, ayelea@gmail.com

Abstract: A field experiment was conducted during the 2014/15 growing season to evaluate the influence of combined use of orga and nitrogen fertilizer on soil water content, yield and yield components of a maize variety. The experiment was conducted at Babile area which is located in eastern Ethiopia. The site is is known for the presence of water stress in the soil for crops. Three levels of orga (0, 1.5 and 3 tons/ha) were arranged with three levels of nitrogen fertilizer (0, 100 and 200 kg/ha) in a two factor randomized complete block design with nine orga-nitrogen fertilizer combinations involving three replications. It can be seen from the results that seed yield and plant height (5%) and ear length (1%) were significantly affected by the main effect of nitrogen fertilizer application while the other parameters yield with cob, number of cobs per plant, above ground biomass yield excluding the seed yield and number of ears per plant remain unaffected by nitrogen application. The main effect of orga application significantly affected maize yield with cob, seed yield, plant height (1%) and number of ear per plant but not number of cobs per plant, above ground biomass yield without the seed and ear length per plant.The maximum yield was obtained with the O2 rate (3ton/ha) of orga application. Interaction effect was observed on maize yield with cob, seed yield, plant height, and ear length per plant. However, no interaction effect was seen on number of cobs per plant, above ground biomass yield and number of ears per plant. Day 2, day 4 and day 5 moisture contents were affected significantly by the main effect of nitrogen application; however, except day 6 moisture content, all other soil moisture contents were significantly affected by orga application. Interaction effect was detected between nitrogen and orga applications on all moisture content measurements except day 6 moisture content (at 1% and 5% on day 5).

1. Introduction

Ethiopia is a country that is endowed with a wide variety of climatic regimes and soil types. The agro-climatic zonation classifies the nation in to three major climatic areas, Dega (to mean highland), Kolla (arid and semi-arid) and Weynadega (between Dega and Kolla). While there is sufficient or more rainfall in the highland areas for crop production, there is severe shortage of soil water for crops throughout their growth period in the dry lands that cover quiet a large area. This has caused severe food shortage among the communities and continues to undermine the efforts of the government and other organizations working on food security in drought prone areas. Agricultural systems that give less attention to the use of organic fertilizers are partly responsible for reduced agricultural production in many areas of the country. This is because organic fertilizers not only improve the nutrient supplying power of the soil but also make the soil physically fit for cropping.

Climate change and variability is a considerable threat to agricultural communities, particularly in lower altitudes. This threat includes the likely increase of extreme weather conditions, increased water stress and drought, and desertification. Use of organic fertilizers (organic farming) together with inorganic ones is found to have potential for climate change and variability adaptation in terms of soil water content improvement (Mbagwu and Ekwealor, 1990). Organic farming emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. However, organic fertilizers alone do not often fulfill all the nutrient needs of crops as they contain small amount of nutrients per given quantity compared to synthetic fertilizers. Therefore, use of organic and inorganic fertilizers together is considered essential and allows recycling of nutrients; thus, contributing to sustainability of agriculture. Combined use of organic and inorganic plant nutrient sources in improving soil properties for improved crop performance and yield had been reported (Palm *et al*., 1997; Celik*et al*., 2004). Past experiences in organic and inorganic fertilizer application studies have indicated that the organic fertilizer in addition to releasing nutrients slowly is important to improve soil structure (Avnimelech and Cohen, 1988), improved infiltration rate and soil water content (Ebaid and El-Refaee, 2007) and reduction in bulk density (Hagan *et al*., 2010).

Orga is an organic fertilizer which is locally manufactured by National Fertilizer Manufacturing Pvt. Ltd. Co. (NAFMAC) and contains 1% N + 23% P2O5 which provides prominent level of phosphorus. Basically orga fertilizer is made up of bones, stomach paunch, horns and hooves by the action of phosphate solubilizing and nitrogen fixing bacteria (NAFMAC, 2002). Usually, organic fertilizers do not have phosphorus content more than 10%. However, orga contains a minimum of 23% Phosphorus (P2O5) and 21% Calcium oxide (CaO). In addition, application of most organic fertilizers is much bulky since they have low P content. But the application rate of orga is much more reduced since it has relatively high nutrient content compared to other organic fertilizers.

Although the effect of combined organic and inorganic fertilizer use on soil conditions and yield of crops was examined by many researchers, there has not been any attempt to evaluate Orga in combination with nitrogen fertilizer on maize in relation to yield and soil water content at water deficit Babile area. Therefore, this research was proposed with the objectives, i) to determine the performance of a maize variety supplied with both orga and N fertilizers in the water deficit area of Babile, and ii) to identify the contribution of orga towards soil water conservation.

2. Materials and Methods

2.1. Description of Experimental Site

The experiment was conducted at Babile area in the 2014/15 growing season. Babille is a small town located 36km east of Harar town. It is located at N09013.234" and E042019.407" and has an altitude of 1669 M.a.s.l.

2.2. Experimental Treatments and Design

Three levels of Orga (0, 1.5 and 3 ton/ha) were arranged with 3 levels of N fertilizer (0, 100 and 200kg urea/ha) in a two factor RCBD experiment with three replications. There would be a total of 27 experimental units. Spacing of 70cm x 30 cm was used between plants and a plot size of 2.1m x 4.9m which is 10.29m^2 was used which has 8 rows and 7 plants in a row. A Spacing of 1m was used between plots and 2m between blocks. No other source of phosphorous fertilizer was used.Treatment combinations were:

N0O0- no (zero) nitrogen + no Orga
N0O1- no nitrogen + 1.5ton/ha Orga
N0O2- no nitrogen + 3ton/ha Orga
N1O0- 100kg urea/ha + no (zero) Orga
N1O1- 100kg urea/ha + 1.5ton/ha Orga
N1O2- 100kg urea/ha + 3ton/ha Orga
N2O0- 200kg urea/ha + no (zero) orga
N2O1- 200kg urea/ha + 1.5 ton/ha Orga
N2O2- 200kg urea/ha + 3ton/ha Orga

2.3. Soil Water Content Measurement

Soil samples were taken throughout the growing season at an interval of time to determine the soil moisture content using gravimetric method. It was determined gravimetrically six times in the growing season at a constant time interval (every 2 weeks).

2.4. Data Collection

Agronomic data was collected on maize yield with the cob attached, number of cobs per plot, above ground biomass yield excluding seed yield, seed yield, plant height, number of ear per plant, and ear length per plant.

Five plants were randomly sampled from each plot at maturity and ears were counted for each plant and the average was treated as ear number per plant. From the same five plants, plant height was measured from the base of the stalk to the tip and averaged to give plant height values. The number of cobs per plot was obtained after counting the cobs harvested from each plot at maturity. Ear length was determined from the ears set on the five plants and the average of the five was computed to be used for the analysis. Maize plants were harvested from each plot at physiological maturity leaving the boarder rows on every end. The yield with the cob intact was determined from the central rows and treated as yield with the cob attached after dividing the total yield to the number of plants considered. Grain yield was obtained by adjusting the moisture level to appropriate level. After recording the seed yield, for each plot, five plants were taken randomly from the central rows and oven dried at 70^{0}C to constant weight and above ground dry matter yield without seed yield was determined.

2.5. Data Analysis

The collected data was analyzed using SAS software.

3. Results and Discussion

As it can be seen from Table 1, seed yield was significantly (at 5%) affected by the main effect of nitrogen. The maximum seed yield was registered with a nitrogen level of N2 (200kg urea/ha). The other parameters yield with cob, number of cobs per plot, above ground biomass yield excluding seed yield were not found to be significantly affected by the main effect of nitrogen. Yield of maize with cob and seed yield were significantly (at 5%) affected by the main effect of orga application. However, the main effect of orga application did not affect number of cobs per plant and above ground biomass yield excluding the seed yield. The maximum yield was obtained with the O2 rate (3ton/ha) of orga application (Table.1).

Plant height (5%) and ear length per plant (at 1%) were found to be significantly and highly significantly affected by the main effect of nitrogen application. Both 100kg and 200kg urea application rates were significantly different from the control where nitrogen is not applied even though they are statistically at par with each other. The number of ear per plant has not shown significant difference from the control due to nitrogen application. Application of orga affected plant height highly significantly (1%) and number of ear per plant significantly although it did not have any effect on ear length per plant (Table 2).

Table 1. Main effect of nitrogen and Orga application on yield of maize with the cob attached, no of cobs per plot, above ground biomass yield without seed yield and seed yield.

Treatment	YLCB Kg/plant	NCP No/plot	AGBY Kg/ha	SYLD Kg/ha
Nitrogen				
N0	4.13[a]	34.33[a]	387[a]	3870[b]
N1	4.57[a]	39[a]	527.59[a]	4958.4[a]
N2	5.02[a]	37.44[a]	479.21[a]	5230.5[a]
Orga				
O0	3.98[b]	37.11[a]	412.7[a]	4232.8[b]
O1	4.5[ab]	37.33[a]	452[a]	4489.8[ab]
O2	5.24[a]	36.33[a]	529.1[a]	5336.4[a]
CR	0.856	5.17	199.1	943.6
CV (%)	18.9	14.14	43.27	20.33
EMS	0.75	27.26	40415.73	907714

YLCB= yield with the cob attached, NCP= number of cons per plant, AGBY= above ground biomass yield excluding the seed yield, SYLD= seed yield. Means within a column followed by the same letter (s) are not significantly different.

Table 2. Main effects of nitrogen and Orga application on plant height, number of ears per plant and ear length per plant.

Treatment	PLHT cm	NERPP No/plant	ERLGPP cm
Nitrogen			
N0	158.76[a]	1.07[a]	13.11[a]
N1	173.58[b]	1.09[a]	15.41[b]
N2	175.84[b]	1.2[a]	15.44[b]
Orga			
O0	156.47[b]	1.02[b]	13.9[a]
O1	174.38[a]	1.09[ab]	14.98[a]
O2	177.33[a]	1.24[a]	15.08[a]
CR	12.21	0.209	1.207
CV (%)	7.28	18.85	8.32
EMS	151.95	0.044	1.49

PLHT= plant height, NERPP = number of ear per plant, ERLGPP = ear length per plant. Means within a column followed by the same letter (s) are not significantly different.

Table 3. Interaction effect of nitrogen and orga application on yield of maize with the cob attached, no of cobs per plot, above ground biomass yield without seed yield, seed yield, plant height, number of ears per plant and ear length per plant.

Treatment combinations	YLCB Kg/plant	NCP No/plot	AGBY Kg/ha	SYLD Kg/ha	PLHT cm	NERPP No/plant	ERLGPP cm
N0O1	3.93[b]	33[a]	276.6[a]	3537.4[c]	164.07[ab]	1[a]	13.93[a]
N1O2	5.13[ab]	39[a]	557.8[a]	5623.6[a]	182.73[a]	1.2[a]	15.6[a]
N2O0	4.17[ab]	34.67[a]	312.9[a]	4263[abc]	161.53[ab]	1.07[a]	15.57[a]
N1O0	4.18[ab]	40[a]	585[a]	4716.6[abc]	162.33[ab]	1[a]	14.93[a]
N0O0	3.58[b]	36.67[a]	340.1[a]	3718.8[bc]	145.53[b]	1[a]	11.2[b]
N0O2	4.87[ab]	33.33[a]	544.2[a]	4353.7[abc]	166.67[ab]	1.2[a]	14.2[a]
N2O2	5.72[a]	36.67[a]	485.3[a]	6031.7[a]	182.6[a]	1.33[a]	15.43[a]
N2O1	5.17[ab]	41[a]	639.5[a]	5396.8[ab]	183.4[a]	1.2[a]	15.31[a]
N1O1	4.4[ab]	38[a]	439.9[a]	4535.1[abc]	175.67[a]	1.07[a]	15.7[a]
CR	1.48	8.96	344.9	1634	21.15	0.36	2.09
CV (%)	18.9	14.14	43.27	20.33	7.28	18.85	8.32
EMS	0.75	27.26	40415.73	907714	151.95	0.044	1.49

YLCB= yield with the cob attached, NCP= number of cons per plant, AGBY= above ground biomass yield excluding the seed yield, SYLD= seed yield.PLHT= plant height, NERPP= number of ear per plant, ERLGPP= ear length per plant. Means within a column followed by the same letter (s) are not significantly different.

Interaction effect was observed in maize yield with cob, seed yield, plant height, and ear length per plant. The lowest values were recorded for the control treatment where nitrogen and orga were not applied. There was no interaction effect of nitrogen and orga application on number of cobs per plot, above ground biomass yield and number of ears per plant (Table 3). The maximum yield recorded with 200kg urea and 3 ton/ha orga was not found to be different from all combinations where nitrogen fertilizer was added at any level in terms of seed yield. However, it is significantly superior to the control treatment.

In general, the moisture contents of the soil samples from the experimental site can be considered as small due to the sandy texture of the soil. It was found that the moisture content of the soil on day 2, day 4 and 5 were significantly affected by the main effect of nitrogen. In this case, the lower value of moisture with no nitrogen application was may be due to the less cover provided by the maize plants to the soil and the sparse canopy resulting from low nitrogen in the soil. Significant effect was not detected on day 1, day 3 and day 6 moisture contents due to nitrogen application. However, all moisture content values were highly significantly (1%) affected by the main effect of orga application except day 6 moisture content (Table 4).

Table 4. Main effect of nitrogen and orga application on soil moisture content.

Treatment	Day 1 MC (%)	Day 2 MC (%)	Day 3 MC (%)	Day 4 MC (%)	Day 5 MC (%)	Day 6 MC (%)
Nitrogen						
N0	16.77^{a}	17.55^{b}	15.87^{a}	16.21^{b}	10.09^{c}	14.2^{a}
N1	20.12^{a}	18.68^{ab}	17.21^{a}	17.33^{ab}	13.04^{b}	9.8^{a}
N2	17.88^{a}	19.3^{a}	17.05^{a}	18.21^{a}	15.87^{a}	8.9^{a}
Orga						
O0	12.03^{c}	13.34^{c}	12.34^{c}	12.28^{c}	8.54^{b}	11.13^{a}
O1	17.49^{b}	18.46^{b}	17.45^{b}	18.65^{b}	14.19^{a}	11.63^{a}
O2	25.25^{a}	23.73^{a}	20.35^{a}	20.83^{a}	16.27^{a}	10.08^{a}
CR	3.32	1.41	1.77	1.84	2.43	6.44
CV (%)	18.37	7.7	10.68	10.74	18.88	59.41
EMS	11.25	2.03	3.18	3.43	6.02	42.31

MC= moisture content,Means within a column followed by the same letter (s) are not significantly different.

Interaction effect was detected between nitrogen and orga applications on all moisture content measurements except day 6 moisture content (at 1% and 5% on day 5). The moisture content values are consistently lower for those treatment combinations where orga was not applied in comparison to those with orga application. This indicates the significance of orga in improving the water holding capacity of soils. Orga application at a rate of 3ton/ha resulted in the highest values of moisture in the soil compared to the other treatments (Table 5).

Table5. Interaction effect of nitrogen and orga application on soil moisture content.

Treatment combinations	Day 1 MC (%)	Day 2 MC (%)	Day 3 MC (%)	Day 4 MC (%)	Day 5 MC (%)	Day 6 MC (%)
N0O1	20.71^{bc}	21.07^{b}	17.74^{b}	21.37^{a}	10.74^{cd}	19.42^{a}
N1O2	30.97^{a}	26.6^{a}	21.82^{a}	22.67^{a}	14.38^{bc}	10.76^{a}
N2O0	11.4^{e}	13.92^{de}	11.93^{c}	12.93^{cd}	8.64^{d}	10.3^{a}
N1O0	13.98^{de}	13.26^{e}	12.63^{c}	12.49^{d}	9.15^{d}	10.71^{a}
N0O0	10.71^{e}	12.85^{e}	12.47^{c}	11.41^{d}	7.82^{d}	12.39^{a}
N0O2	18.9^{dc}	18.74^{bc}	17.41^{b}	15.85^{cb}	11.69^{bcd}	10.79^{a}
N2O2	25.89^{ab}	25.85^{a}	21.82^{a}	23.97^{a}	22.74^{a}	8.7^{a}
N2O1	16.34^{cde}	18.11^{c}	17.41^{b}	17.74^{b}	16.23^{b}	7.55^{a}
N1O1	15.41^{cde}	16.19^{cd}	17.19^{b}	16.85^{b}	15.59^{b}	7.92^{a}
CR	5.75	2.45	3.06	3.18	4.21	11.16
CV (%)	18.37	7.7	10.68	10.74	18.88	59.41
EMS	11.25	2.03	3.18	3.43	6.02	42.31

MC = moisture content,Means within a column followed by the same letter (s) are not significantly different.

4. Summary and Conclusion

The use of integrated nutrient management which involves use of commercial as well as organic fertilizers is advertised by many professionals because it is believed that it has advantage on the physical structure of the soil in addition to provision of nutrients. Therefore, the use of this approach to increase productivity of soils extends the purpose of integrated nutrient management beyond the sole yield improvement.

The present study was conducted to examine the effect of combined use of orga and nitrogen fertilizer on soil water content, yield and yield components of maize. The experiment which was conducted at Babile in the 2014/15 growing season involved three levels of orga and three levels of nitrogen fertilizer laid out in a two-factor RCBD experiment with three replications.

Seed yield, plant height and ear length per plant were found to be significantly affected by the main effect of nitrogen fertilizer application. Whereas, yield with cob, seed yield, plant height and number of ears per plant were significantly affected by the main effect of orga application. Interaction effect was observed in maize yield with cob, seed yield, plant height, and ear length per plant. All treatment combinations where nitrogen fertilizer was added were not statistically different from each other with respect to seed yield although they are numerically different.Day 2, day 4 and day 5 moisture contents were found to be significantly affected by nitrogen application and all moisture content measurements except day 6 were significantly affected by the main effect of orga application.

Therefore, in the current study it can be concluded that neither of these treatment combinations can be recommended for a significantly superior seed yield production. However, the use of the integrated approach has many other advantages beside the sole seed yield production. This is because reduced dependence on chemical fertilizer source and attention to farming practices that favour the more economically viable and environmentally prudent system will benefit both agriculture and the environment and contributes to sustainability. The study indicated that the combined use of orga and nitrogen can improve the soil water status and help to better supply plants with water. The 3 ton/ha rate of orga is the one with the highest values of moisture level.

The results of the present study have indicated that it is important to promote the combined use of orga and nitrogen fertilizer through national research programs. Efforts should be made, wherever possible, to conduct more research with different levels in different areas based on standard research methods. For alternative use 3 ton/ha orga application can be recommended.

5. Acknowledgements

We thank all those who gave us constructive ideas in shaping this manuscript and those who supported us financially to complete this research. However, only the authors did participate in the conduction of the study, data collection and interpretation and manuscript preparation.

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17. Assessment of Commercial Feedlot Finishing Practices at Eastern Shoa, Ethiopia

Tsegay Teklebrhan[1*], Mengistu urge[1]

[1]College of Agriculture, School of Animal and Range Sciences, Haramaya University Dire Dawa, Ethiopia;
Corresponding Author Email: ttmamy06@gmail.com

Abstract: This study was conducted to characterize and identify husbandry practice and major constraints of commercial feedlot industries in the study area. Forty eight commercial feedlot farms were used to collect data. Data were analyzed using Statistical Package for the Social Sciences (SPSS). The results showed that livestock species such as cattle, shoat and camels were used in commercial fattening though significant variation in demand among species. Cattle had got highest acceptance in feedlot industries followed by shoat however; camel and swine had least preference. All cattle breeds had equal requirement by domestic market. However, there is variation in demand among cattle breeds for export market. Boran was the most preferred cattle breed compared to the rest of cattle by the importers. Uncast rated bull demanded for export market however, castrated and female cattle were not used for export markets. Pastoralists were the potential supplier of feeder livestock followed by small holders to feedlot industries. *Tef* straw was predominantly used roughage feed in most of commercial feedlot farms and agro-industrial by products as a source of concentrate. However, sorghum and maize grains were utilized by very few farms. Vitamin and mineral supplementation were not often available except, common salt in all feedlot rations. Market was noted as the most potential constraints followed by feed and type of livestock coming to the markets in the commercial feedlot industries. The study suggested that, government and other development partners should provided and improve all services to pastoralists or producers in an organized way at their locality that would ensure sustainable supply of livestock to the market.

Keywords: Constraints; Feedlot; Livestock

1. Introduction

Ethiopia owned a large livestock population (CSA, 2010). It is home to Africa's largest livestock population, and is Africa's top livestock producer and exporter (principally to the Middle East). Ethiopia is the world's tenth largest producer of livestock, and the livestock sector represents about one-fifth of its gross domestic product (GDP). The government has indicated a strong interest in increased foreign investment in the agriculture sector, among others, commercial breeding and production of meat, milk, and eggs. Although domestic demand for animal products in Ethiopia is increasing driven by the urban middle and upper class export potential is a key force encouraging expansion and intensification of livestock production. In 2008, Ethiopia exported nearly 300,000 live animals primarily cattle as well as 6,000 metric tons of meat products, earning about U.S.$56 million.7 In 2009, the government sought to double the previous year's income from live animal exports ($40 million8) and raise the number of animals exported to 400,000.9 The government is keen to foster an upward trend. For 2009–10, it set targets for export of meat products of nearly 16,000 metric tons, a nearly four-fold increase over the 2007 level. While the contribution of the livestock industry to the country's total exports is currently low compared to its potential, this is due to the fact that livestock production has mostly been subsistence oriented and characterized by very low reproductive and production performance which is not even enough to meet the domestic requirement of community for animal protein. This is because of major limiting factors on farm conditions, among others, feed shortage, low genetic potential and diseases.

However, market oriented livestock production has been gradually emerging in very recent years. The government of Ethiopia is trying to expand sector by motivating investors to meet projected increase in demand from both export and domestic markets. Export of meat and live animals that can contribute to market-led economic growth and poverty reduction in the country. Accordingly, live animal export accounts 4.5%, meat and meat products 1.7%, from the total export potential of the country (CSA, 2010). The goal is to increase annual export of live animal and meat from Ethiopian cattle, sheep and goats by about three fold though; the markets are sophisticated and extremely competitive for high quality product. Feedlot provides the means to maximize the opportunities offered by these markets for a consistent supply of high quality product for the particular needs of the market. The continuing growth of the feedlot sector is necessary to meet projected increase in demand from both export and domestic markets. However, such growth must progress according to community expectations and requirements to develop and maximize the profit from the livestock business.

Information about commercial fattening or feedlot practices and its constraints is important for researchers, policy makers to take serious measures and suggest possible technologies to improve the productivity of the sector and hence maximize its contribution to the total Gross Domestic Product (GDP) or economy of the country. However, there is no documented information on fattening practices of commercial feedlot and their challenges in Ethiopia. Therefore, the paper is designed to characterize and identify husbandry practice and major constraints of commercial feedlot industries in the study area.

2. Materials and Methods

2.1. Description of Study Area

The study was conducted in Adama, Methara and Mojo towns found in east Shoa Zone, Oromiya Regional State, Ethiopia. It is located at about an altitude of 1650 meters above sea level and its annual temperature ranges from 13.9^{o}C – 29^{o}C. The mean annual rainfall of the area is 1024 mm. The livestock population of the area was estimated to be 70,622 cattle, 36,142 sheep, 42,968 goats and 2,193 equines (CSA, 2004).

2.2. Sampling and Data Collection

Three towns Adama, Methara and Mojo were purposely selected based on their potential for feedlot industry. From which a total of 48 feedlot farms were randomly selected and used for the study. Primary data were collected using pre tested semi-structured questionnaire through interview and discussion with the feedlot operators. In addition, secondary information was gathered from literature and Central Statistical Agency (CSA) reports. Physical observation of commercial farms was also used as an instrument to collect data during the study.
Data on the types of livestock species used for feedlot, pattern of livestock preferences, breeds of cattle and market demand, value chain of marketing, fattening cycle and duration, feed resources feeding procedure and constraints and housing of commercial fattening were collected from the commercial fatteners.

2.3. Statistical Analysis

Data were subjected to Statistical Package for the Social Sciences (SPSS, 2003) and analyzed using simple descriptive statistics such as frequency and percentage.

3. Results and Discussion

3.1. Commercial Fattening and Livestock Species

Commercial feedlot is a confined yard area with watering and feeding facilities where livestock are completely handled or mechanically fed for the purpose of production. Number of heads that would fatten at a cycle was variable across the farms depending on the capacity of the farms. From that reason, commercial feedlots finished relatively large number of animals at a time than small scale fattening. Accordingly, most of commercial farms had 100-500 heads followed by 1000-1500 heads at a time as shown in Table 1.

Table 1. Livestock species and type of cattle breed used for commercial feedlot

No of livestock head	N	Percentage
100-500	42	87.5
1000-1500	6	12.5
Livestock species		
Boran	39	81.25
Boran, Bale and Arsi	5	10.42
Hararghe Highland and Ogaden Cattle	1	2.08
Shoat and camel	3	6.25
Total	48	100
Age of animal purchased		
4-6 years	45	93.75
Not known	3	6.25
Total	48	100

N = number of respondents

Livestock species such as cattle, shoat, and camels are used in commercial fattening and then exported as live animal and meat; however; cattle breeds were usually used for fattening in the study areas as listed in table 1. Among the cattle breeds, feed lot operators showed highest preference on Boran followed by Bale and Arsi cattle. In consistent to this study, Asfaw (2011) reported that the main live animal species exported include cattle, sheep, goats, and camels. In addition, discussants revealed that Boran cattle are docile temperament, short horn and efficient as well as better in carcass conformation this would attributed to be breed of demand for export. This result is consistent to the reports of Aynalem (2011). However, Hararghe Highland and Ogaden cattle breeds had least acceptance for commercial fattening in the study area. This variation on the cattle breed requirement might be associated with available export market demands and fattening performance of the breeds. For example, discussants argued that Hararghe Highland shrunk its body weight when came from its original place (highland) to the fattening unit (lowland). Likewise, most of feedlot fatteners during discussion also noted that they knew nothing about the performance of Ogaden cattle. All fatteners agreed that uncast rated bull was required for export market as compared to castrated cattle (steer and stag). In this regard fatteners explained that the export market demand is lean meat than that of castrated from which fatty meat with high fat coverage is actually produced. In all commercial fattening areas, male livestock was preferred than female. This is because of male having better carcass conformation compared to female cattle. In addition, discussants also strongly argued that export of female is impossible. This study also showed that 93.75% respondents noted that bulls were purchased at about age of 4-6 years.

3.2. Pattern of Preferences of Livestock species in Commercial Feedlot Industries

All livestock species were preferred for fattening industry though there was significant variation among farms on degree of choices as shown in Table 2. For that reason, 89.58 % feed lot farms consider cattle as their 1st choice for commercial fattening. Physical observation also confirmed that except the three farms in Methhara all farms of the study areas were only engaged in cattle fattening enterprises. All discussants, agreed that fattening of cattle was advantageous because of low mortality, better tolerance for some diseases, frequent availability at the market place, best suitable and manageable and, required small space particularly as compared to camel. Shoat was found as the 2nd important livestock species for commercial fattening by most of the feedlot farms in the study area. For that reason, the discussants elaborated that, shoat required low amount of feed and space as compared to cattle and camel. However, shoats had higher mortality and rapid lost or shrink of live weight particularly during long distance travel for long time from the country to export destination because of in appropriate transport systems.

This study also showed that camel was preferred as third important livestock used for fattening and highest requirement in the export market. However, most of feedlots retained camel for short period of time until it is exported. This could be due the fact that camel requires large area of land and because of feeding habits needs browses rather than stall feeding. This study confirmed that pig was least required for commercial fattening by most of the farms, though it is considered as the first choice of most of the Asian and European countries involved in fattening enterprises. This is may be due to lack of knowledge on the importance of this livestock and mainly because of socio-cultural and religious barratries. In addition some discussants believed that swine is a livestock species required large amount of feed per unit of gain and never satisfied and domestic market demand problems. However, it is known that swine is rapid growing, efficient feed converter and even fed on most of least cost feeds and organic wastes.

Table 2. Ranking of livestock species for commercial fattening.

Livestock	N	1st	P	2nd	P	3rd	P	4th	P
Cattle	45	43	89.5	2	4.1	0	0	0	0
Shoat	37	2	4.1	24	50.0	11	22.9	0	0
Cmel	25	3	6.2	12	25.0	10	20.8	0	0
Pig	11	0	0	0	0	0	0	11	22.9

N = *number of respondents;* P = *percentage*

3.3. Fattening Cycles and Duration of cattle in Commercial Feedlot

Almost all fattening farms finish the bull for about an average of 3-4 months in table 3. In agreement to this study, previous result reported a range of 80 to 145 days to finish steers (Leupp *et al.*, 2009). However, few farms finished the bull at 6 months and very few at 1 month.

Table 3. Fattening cycles and duration of cattle.

Fattening duration	N	P	Fattening cycle	N	P
3-4 moths	42	87.5	Two	9	18.8
6 months	5	10.4	Three	30	62.5
1 months	1	2.0	Four	9	18.8
Total	48	100	Total	48	100

N = *number of respondents;* P = *percentage*

Generally, feedloters agreed on the strong relation between age of bull at purchase and for how long the bull will be retained on fattening. Accordingly, bull entered as feeder at relatively younger age will retain for long time and the reverse is true for relatively older bull. Fattening cycles of beef cattle is important to secure continued supply of meat for consumption as well as local and export markets. Most of the respondents engaged in the fattening venture agreed on three cycles of fattening per year but very few feedlot fatteners fattened two and four time per year as reported in table 3. Discussants declared that, the reason of variation in fattening cycles among feedlots were fattening duration, types of feed, market situation and weight of cattle.

3.4. Effect of Breed, Sex and Gender of Cattle on Market Demand

All cattle breeds are preferred for export market; however, there is variation in demand among breeds as shown in Table 4. Accordingly, most of the feedlot operators exported Boran cattle than the rest of cattle breeds. This is the reflection of the inherent quality of the specified breed in that it possessed docile temperament, heavier live weight, better feed conversion efficiency and lean carcass compared to the rest of the cattle breeds. However, all cattle breeds had equal benefit for the domestic markets as shown in Table 4.

Table 4. Effect of Breed, sex and gender of cattle on market demand.

Export market	N	Percentage	Sex class	N	percentage
Boran	29	60.4	Castrated	0	0
Boran, Bale, Arsi and Hararghe Highland	16	33.3	uncast rated	48	100
All breeds	3	6.2	Gender		
Domestic market			Male	48	100
All breeds	48	100	Female	0	0
Value addition					
Yes	0	0			
No	48	100			

N= number of respondents.

Feedloters mentioned that cattles which were not fit for export markets were dumped to domestic market. Generally, the export volume of the country is limited to very few destination countries principally to Middle East. This may be associated with international standard quality of the product and demand of importers. In addition, some of the trade and zoonotic diseases; foot and mouth disease, contagious bovine pleuropheumonia (CBPP), Peste des petits ruminants (PPR), lumpy skin disease (LSD), contagious caprine pleuropneumonia (CCPP), sheep and goat pox and brucellosis are not controlled in the country (MoARD, 2007). Moreover, discussants argued that long horned cattle breed like Afar were not required by the Arab importers.

With regard to value addition and diversification of products, none of the feedlot farms were engaged in value addition, though government is showing commitment to support and encourage the business. However, all feedloters have an interest to add value and diversify the export commodities from the fattened livestock for the future rather than exporting of only live cattle.

3.5. Value Chain of Livestock Marketing in Commercial Feedlot

As shown in Figure 1, pastoralists were the potential supplier of livestock followed by smallholders to feedlot industries in study area. Respondents noted that usually marketing of livestock in commercial feedlot followed the trend as indicated by the block arrows staring from producers up to destinations. Accordingly, small local trades bought small number of livestock at the farm gate and in turn sold to the other intermediate actors in the chain and continued in such away. Similarly, Negassa and Jabbar (2008) reported same role of pastoralists and small holder farmers at livestock marketing.

However, in rare cases, livestock marketing followed a different and short path that is a direct purchase of livestock from producer by the commissions or larger traders and feedlot operators. Similarly, the marketing root was also organized from the producers to the farmer union/ other cooperatives and this in turn to fattening farms as indicated in the direct line arrows of Figure 1. This seems to be best alternative to minimize and avoid unprofitable transactions in the chain to assured fair and legitimate market systems.

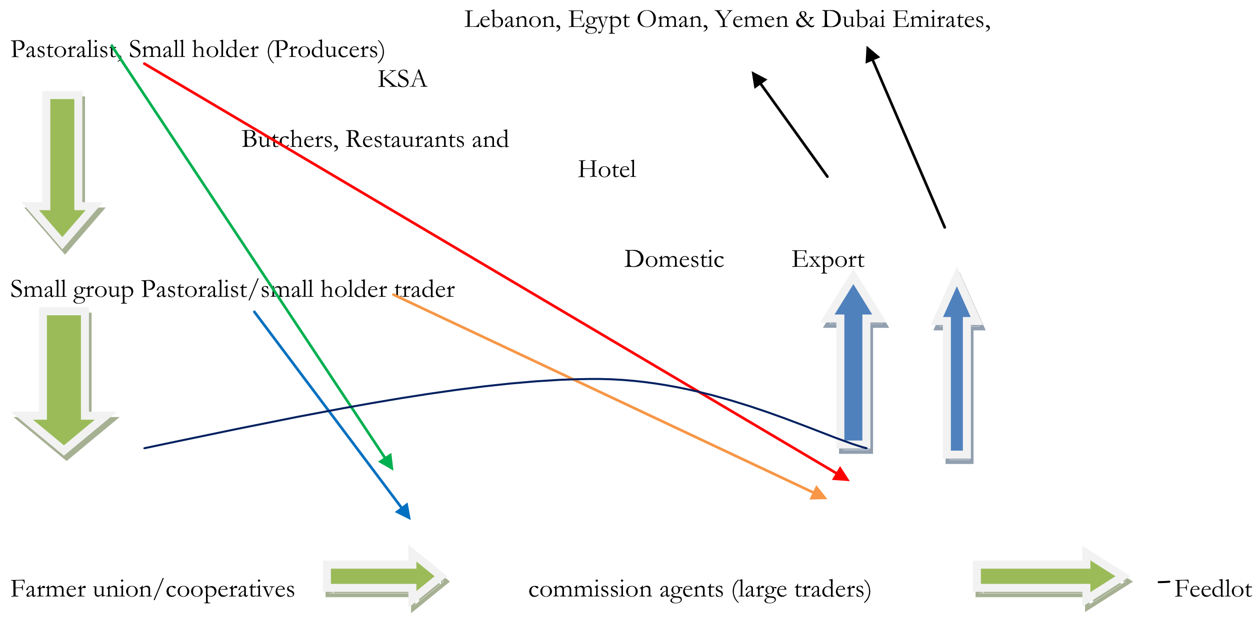

Figure 1. Flow chart of value chain of commercial feedlot marketing (interview, 2013).

3.6. Feed Resources for Commercial Feedlots

As shown in Table 5, all commercial feedlots were depending on purchased feed sources for fattening because of shortage of land for feed production. Accordingly, native grass hay was purchased from Sululta, and straws from Welenchiti. Agro-industrial byproducts were also bought from the factories in and around East Shewa. This could be mainly because almost all commercial farms were found around this areas and this gives them easy access to agro-industrial byproducts which in turn forms a major portion of the concentrate mix fed to feeder livestock.

3.6.1. Roughage

Roughage feeds are characterized by relatively higher fiber content and lower energy and protein contents than concentrates. The source of roughage used for commercial feedlot includes crop reside (tef straw, wheat straw) and native grass hay. In consistent to this result, Solomon (2008) and Yayneshet (2010) reported that crop residues from cereals used as source of roughages for livestock feeding. In this study, *tef* straw was usually utilized by most of feedlot operators whereas the other roughages were rarely utilized in the study areas (Table 5). According to the information obtained from the fatteners the type of roughage used was directly related with cost effectiveness and availability of the roughage nears to fattening units. Discussants noted that the availability of crop residues is closely related to the farming system, type of crops produced and intensity of cultivation.

3.6.2. Agro industrial byproducts

Agro-industrial byproducts are widely used as source of livestock feed include those resulting from flour mills, oil processing factories, and sugar factory. The agro-industrial byproducts (concentrate) feeds are used as energy and/or protein. Accordingly, they classified as energy or protein sources. The source of concentrate feeds commonly used by almost all farms in the study area includes weat bran, wheat middling, whole cotton seed, cotton seed cake, noug seed cake, Soybean, lentil bran, haricot bean bran, haricot bean shorts, and lentil shorts. However, sorghum and maize grains were utilized by few farms as shown in table 6. Similarly, the grains and agro-industrial byproducts were utilized as concentrate feed sources in feedlot industries (Leupp *et al.*, 2009; Yayneshet, 2010; USDA, 1985; Roy, 1994). Most feedlot farms used wheat bran, wheat shorts, whole cotton seed and its cake Noug-seedcake, Soy bean and wheat middling; however, sorghum and maize grains were utilized as an ingredient to the compound concentrate feed by few farms (Table 5).

Table 5. Feed stuffs used for commercial fattening.

Feed resources	N	Percentage	Non-conventional feeds	N	percentage
Purchased	48	100	Poultry feces	3	6.25
Own	0	0	Not used	47	93.75
Roughage sources			Growth promoters		
Tef straw	24	50.0	Yes	0	0
Grass hay	6	12.5	no	48	100
Tef and wheat straw	5	10.4	pre-mixes (vitamin and mineral mix) use		
Tef straw and hay	6	12.5	yes	0	0
All	7	14.6	no	48	100
Total	48	100	Water		
Source of concentrate feeds			*Ad libitum*	48	100
Agro industrial by-products[1]	41	85.4	Restricted	0	0
Sorghum and maize grain	7	14.6			

Agro-industrial by-products = Wheat bran, wheat middlings, whole cotton seed, cotton seed cake, noug seed cake, Soybean, lentil bran, haricot bean bran, haricot bean shorts, lentil shorts; N= number of commercial feedlot

3.6.3. Non conventional feeds and other feed stuffs

These are assumed to be off value and wastes by most of the producers. Accordingly, 93.75% of feedlot enterprises did not use the non-conventional feed stuffs though 6.25 % feed lot farms included as one of feed resources for fattening. As shown in table five, poultry feces were used as protein source in some farms. Minerals such as major minerals (Ca and P) as well as trace mineral (cobalt, copper, iodine, iron, manganese and zinc) are also used as the important component of the feed in growing and finishing steers (Leupp *et al.*, 2009; Secrist, 1997). In the study areas, only salt was mixed in feeder ration in all farms as a mineral supplement. However, components of other mineral supplements were not included to the ration. Vitamins were not also used in all feedlot farms in the study area.Vitamins like, A, D and E are widely utilized in commercial farms for better performance (Leupp *et al.*, 2009).

Water is one of the indispensable nutrients in feedlot industries. It is available as free choice every day throughout fattening in all farms in the study area. Synthetic steroid hormones are known for better efficiency and faster growth of livestock. In all feedlot farms synthetic hormones were not used. This could be due to lack of familiarities of fatteners with the implants and their application, notion of producing organic product and the risks in wellbeing of the consumers that is the issue of wholesomeness of the product.

3.7. Feeding Procedure in Commercial Feedlots

With regards to feeding procedure, initially, animals were not weighed and feed was provided by common sense. Moreover, the ratio of concentrate to roughage was not known in all commercial farms as show in Table 6. The daily feeding frequency followed by almost all commercial farms was twice except few farms were followed three times of feeding. In addition, almost all farms followed the classical daily feeding procedure that is initially gave the roughage and then concentrate on the top of roughage whereas; the reverse procedure was noted by only one farm. Generally, all farms provided roughage and concentrate at mix which is uncommon in the trials usually conducted in stations.

The 70.8% of feedlot owners provide roughage as an *ad libtum*. However, in 29.2% of farms roughage offered was restricted. As a common procedure, in 72.9 % of commercial farms roughage was provided twice a day at the morning and evening before provision of concentrate in both cases. This result also noted that by all feedlot farms no attempt had been done to improve the nutritional value of the roughage feeds.

All feed lot farms provided concentrate twice a day. Usually all farms offered concentrate mix, though the ratio of mixing of ingredients was so variable or not uniform across the farms. Concentrate was offered every day throughout the fattening period. The amount of concentrate mix provided was different from farm to farm as shown in table 6. From that reason, most feed lot farms offered 9-10 kg of concentrate mix per head/day followed by 7-8 kg. Whereas, few feedlot farms reported that least amount of daily concentrate was offered (3-4kg/head/day) as reveled in Table 6.

Feed was given by common sense in all feedlot farms without considering whether the traditional ration meets the nutritional requirement of feeder or not. Therefore, generally livestock were provided feed without knowing the age and body weight of by conventional agreement. This could be resulted because of lack skilled personnel or particularly nutritionist in the farm to improve the profitability and sustainability of the business, involvement of skilled personnel has to be planned for the future as one of the requirement.

Table 6. Feeding procedures in commercial feedlot

Is roughage provided every day/throughout fattening	N	Percent	Roughage treatment	N	percent
Yes	48	100	yes	0	0
No	0	0	no	48	100
Daily feeding frequency			Ration formulation		
Twice	35	72.9	yes	0	0
Three	13	27.1	no	48	100
Is feed given based on body weight			Ratio of concentrate to roughage known		
Yes	0	0	Yes	0	0
No	48	100	no	48	100
Is concentrate every day/throughout fattening			Amount of concentrate (kg)		
Yes	46	95.8	3kg	3	6.2
No	2	4.2	5-7kg	5	10.4
Roughage provision			8-10kg	31	
Ad libtum	34	70.8	11-12kg	9	18.8
Restricted	14	29.2	total	48	100
Total	48				
Daily feeding procedure					
Concentrate-roughage mix	1	2.1			
Roughage-concentrate mix	47	97.9			

N = *number of respondents.*

3.8. Housing Facilities of Commercial Feedlots

In all commercial farms, fattening animals were fed and drunk in group because there had no compartment with a specific dimension in both feeding and watering troughs during physical observation of the farms. Most feeding troughs were made up of woody materials but few from cement concrete.

Furthermore, most of shelters were exposed to sun, rain and wind without over head shed, but there were sheds for watering and feeding troughs. In few farms isolated house had not available for patient livestock. Moreover, in all feedlot farms there were no drainage systems and the out late for the waste materials produced.

3.9. Constraints of Commercial Feedlots

Challenges of commercial fattening are listed based on their order of importance as shown in Table 7. Most of feedlot farms noted that market was considered as the most challenging in failure or success of the enterprise. This is could be due to unorganized market systems in both local and export markets. In addition, most of the existed markets as a whole and export market in particular lacked consistency and continuity. Usually, feedlot owners or investors were considered as the only role player in identification and searching of market for the finished livestock. Feedloters also noted conflicts in the region and informal or smuggling trade of livestock throughout the border of the country had significant effect on marketing of the fattened animals. Similar to this study, Negassa and Jabbar (2008), Aklilu (2002), Hurissa and Eshetu (2003) and Hurissa and Legesse (2008) reported several constraints violating the smooth flow livestock market from the producer to the feedlots, processing, and consumption points in Ethiopia.

As shown in Table 7, feed was the 2nd limiting factor followed by type or quality of livestock coming to feedlot and water shortage. All discussants argued that feed availability was season dependent and lead to variation in cost between seasons. From that reason, ample amount of hey is produced starting from end of October to beginning of March and within which the price of hay is reasonable. Whereas, the availability of hay decreased and cost of hay/bale is very high in the period starting from April to September.

Similarly, the availability of concentrate decreased starting from March to the end of June because at that time there is shortage of pasture and crop resides and leads to high competition between farmers and feedlot operators in purchasing of concentrate to their livestock. Whereas, almost all feedlot farms noted that diseases and skilled manpower had least effect on commercial fattening.

Table 7. Ranking of constraints for commercial fattening

List of constraints	Total	1st	2nd	3rd	4th	5th	6th
Market	48	32	15	0	1	0	0
Feed	41	5	11	12	2	11	13
Type of livestock	35	7	2	13	5	0	8
Water shortage	27	0	2	5	10	0	15
Disease	20	1	2	0	8	9	0
Skilled personnel	19	0	0	11	0	1	7

Hence, to overcome the challenges, almost all fatteners declared that Ethiopian Commodity Exchange (ECX) should be developed for livestock marketing like that of other commodities in the country. A link has to be created starting from producer to the end of consumer. Furthermore, feedloters suggested that pastoralists or producers should be supplied all the necessary services and improvement strategies in an organized way at their locality so as to ensure sustainable supply of livestock to the industries. In addition, development of quarantine has to be available in all livestock source areas.

4. Conclusion and Recommendation

This study revealed that Borona cattle were the most preferred cattle breed compared to the rest of cattle to the export;however, all cattle breeds had equal acceptance by domestic market. Pastoralist was the potential suppliers of feeder animal followed by small holders to feed lot industries in the study area and the market system was unorganized and dominated by informal and unprofitable transactions. The major feed resources used in commercial feedlot includes, roughage feeds, agro-industrial by products and grains in few farms. Non-conventional feed stuffs were also used by few farms as feed for fattening. Vitamins and mineral supplementations were not often available except, common salt in all feedlot rations. This study also confirmed that almost all fattening farms finish the bull for about an average of 3-4 months and followed three times of finishing per year.

The present study recommended that to develop the sector and bring change, Ethiopian Commodity Exchange (ECX) should be incorporated to develop the livestock marketing sector like that of other commodities in the country to create a link staring from producer to the end of consumer. Finally, the study recommended that the government should be hand-in-hand with the investors to organize market in a very short run to eradicate the informal market and ensure successful development of the sector and secure food security in the country.

5. Acknowledgement

The authors duly acknowledged Ethiopian Ministry of Education for sponsoring the study. The authors further like to thank Dr. Kimia quarantine head of animal section for her assistance and facilitation during survey work.

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18. Value Chain Analysis of Tomato in Erer Valley, Eastern Ethiopia

Wesagn Berhane, Ranjan S.Karippai, Debebe Tolossa, Chanyalew Seyoum, Hailu Kassaye, Tibebu Bezabih

College of Agriculture, Department of Rural Development and Agricalture Extension, Haramaya University Dire Dawa, Ethiopia

Abstract: Ethiopia is endowed with diverse climatic condition that supports the production of horticultural crops. Among these crops, tomato production is among the lucrative ones. Though tomato is one of the most important crops in a household consumption and contributes in generating foreign currency, there are no enough multi-location studies made in its value chain. The study was intended to analyze the value chain of tomato with its attributes of actors' linkage, benefit distribution and constraints and opportunities in Eastern Haraghe, Erer Valley. It generated and used data from producers, wholesalers, retailers, and consumers in the analysis. The results showed that actors are linked in a multidirectional manner with actors. A gap exists between producers and wholesalers in the link. The chain is confronted with some constraints which include problems of disease/pest in production, lack of producers' price satisfaction, rotting, shortage of place in the market etc. On the contrary, there are some opportunities that could help in commercializing the sector. Consumers' desire for quality, shortage during low supply season, and irrigation facilities are some of the opportunities. The alleviation of the problems created by the constraints and the utilization of the opportunities would help in commercializing the chain. Areas for further research have been identified. Finally, organizing producers under cooperatives, establishment of mini market within the community, introduction of production technology to improve quality and product are some of the recommendations made.

1. Introduction

Fruits and vegetables production is usually lucrative compared to staple cereal crops. Horticultural produce has high value addition and income generation potential. The production of fruits and vegetables has a comparative advantage particularly under conditions where arable land is scarce, labor is abundant and markets are accessible (Weinberger and Lumpkin, 2005: 19).

Diversification into horticultural crops is becoming attractive for many poor farmers around the world. Worldwide production of fruit and vegetable crops has grown faster than that of cereal crops, albeit from a much lower base. Review of worldwide trends in horticultural production shows that the production of horticultural crops has grown faster than that of cereal crops regardless of the vast resources channeled to improvement of cereal grains. Between 1960 and 2000, the area under horticultural crops worldwide has grown more than double. While in 1970 only 3.9% of world arable land was under fruit and vegetable production, by the year 2000 this share had risen to 6.7% (Weinberger and Lumpkin, 2005:6-12).

Ethiopia has an immense potential to develop intensive horticulture on small as well as commercial scale. The diverse climatic condition of the country is suitable for the production of various horticultural crops. Regarding the production status of horticultural crops, CSA (2010) reported the area coverage of 90,584.55 ha of vegetables, 36,780.09 ha of fruits and 265,754.27 ha of root and tuber crops, all the three together, constituting about 4% and 18.3% of total crop area and production respectively by 2001/02 production year. The report only addressed the private holding and did not include non-private holdings such as state farms.

Ethiopia has a variety of vegetable crops grown in different agro ecological zones produced through commercial as well as small farmers both as a source of income as well as food. However, the type is limited to few crops and production is concentrated to some pocket areas. In spite of this, the production of vegetables varies from cultivating a few plants in the backyards for home consumption up to a large-scale production for domestic and export markets (Dawit *et al.*, 2004).

Banks of Erer valley which is part of Babile woreda of Oromia and Harari region is one of the potential tomato growing areas. The high irrigation potential (more than 2000 ha) has given better opportunity to farmers to produce different vegetable crops of which tomato is the major one. In an effort to improve the production and productivity of the crop, different improved tomato cultivars were introduced to the area by the research system. However, so far, there is no empirical study conducted in the area and hence there is no information about the value chain of vegetable and fruit crops in general, and tomato in particular. As a result, this study is designed to fill the gap with regard to what has been stated above.

Objectives of the Study

The general objective of this study was to undertake value chain analysis of tomato crop in Erer Vally. The specific objectives were to:

- conduct in-depth value chain analysis of tomato in the study area;
- make comparative assessment of the profit margins of farmers and other actors in the value chain of tomato;
- identify linkages among different actors and benefit distribution, and
- analyze the constraints and opportunities for market oriented tomato production in the study area.

2. Research Methodology

2.1. Research Design

Descriptive research design preceded by an exploratory survey research with the help of a check list, has been initially conducted with flexible sampling design representing different actors in the value chain, from producers up to final consumers. The necessary information has been gathered to frame the descriptive research design.

Erer valley covering parts of Babile woreda of Oromia and of Harari region is selected purposively for two reasons. First, the site belongs to the mandate area of Haramaya University and second, it produces a lot of tomatoes using irrigation from Erer river. Four PAs having tomato cultivation have been selected for the study. The sampling frame for farmers' related inquiry has been farmers growing tomato in Erer valley. From this sampling frame, 120 farmers were selected randomly as sample respondents for the primary survey on production aspects. Since this is a value-chain analysis, other categories of respondents have also formed the sample of the study. Hence, wholesaler, retailer and consumers were added to the sample. Except for wholesalers category, 25 sample respondents were taken for data collection. In the case of wholesalers, all the available were taken since they were 17 in number. Hence, the total sample respondents for primary data of this study were about 187 belonging to different categories of actors. In addition, qualitative data on market linkages, and constraints and opportunities for commercialization of this horticultural crop were analyzed.

Primary data were collected from producers, intermediaries, and consumers and analyzed using appropriate statistical tools like chi-square test and independent sample t-test with the help of SPSS software. Qualitative data was analyzed using descriptions, narrations and interpretations.

3. Results and Discussion

This section provides the research results along with their discussion. In the first place, the nature of the link of the value chain of tomato in the study area will be presented. Then, profit distribution among actors of the value chain will be discussed. Thirdly, constraints and opportunities to commercialize tomato production in the study area will be illustrated.

3.1. Production/Business Facilities and Actors' Decision

In this section factors that, at face value, have relation with the efficiency of the value chain of tomato and the response of actors with respect to these factors will be presented.

3.1.1. Farmland allocation by producers

At the production level, producer make decisions which may affect the nature of the value chain of a product. Among these, farmland allocation is one. Producers divide their farmland among alternative crops on the basis of their evaluative framework in making production decision. It has been tried to determine the amount of farmland allocated by producer for the production of tomato and a comparison is made between the total farmland size producers have and the proportion of it that has been allocated for tomato production, Table 1.

Table 2. Farmland allocation for tomato production

Type of farmland	Observed	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the	
					Lower	Upper
total land	120	1.6115	1.68024	0.15338		
tomato land	120	.5064	0.62759	0.05729	0.78161	1.42860

Source: Own Survey result (2012)
*Note: - *** statistically significant at 1% level.*

One possible reason that could justify the lesser amount of farmland allocated to tomato crop could be the permanently occupied fragment of farmland that might be allotted to the "khat" crop which could be more preferred than tomato.

3.1.2. Access to and ownership of water pump

Producers' ability to efficiently utilize farmland contributes in improving profitability. To efficiently utilize farmland farmers who are engaged in the production of annual crops like tomato should be able to produce the maximum number of times possible in a year. Access to irrigation facilities play important role in this regard. The result obtained in relation to producers status to access and own water pump for irrigation is illustrated in Table 2 below.

Table 3. Producers access and ownership to water pump.

	Facility			
	Access to Water Pump***		Ownership of water pump**	
Status	Observed	Percent	Observed	Percent
Yes	80	66.67	49	40.86
No	40	33.33	71	59.17
Total	120	100.0	120	100.0

Source: Own Survey result (2012)
*Note: ***statistically significant a 1% level, **statistically significant a 5% level*

3.1.3. Production season

Given the condition of producers with regard to ownership and access to irrigation facilities like water pump, they tend to behave in some manner in relation to producing more than once in a year depending on the nature of the crop. Tomato is a crop which can be cultivated at least three times a year. Table 3 illustrates the result found in this regard.

Table 4. Number of times tomato is produce in a year.

Season of production***	Observed	Percentage
One	52	43.3
Two	47	39.2
Three and above	21	17.5
Total	120	100.0

Source: Own Survey result (2012)
*Note: ***statistically significant a 1% level.*

Even though almost half of the producers owned water pump; it is less than 20% of them who crop tomato three times a year. These contradictory results might reflect the priority that the "*Khat*" crop has in the study area. The mere ownership of water pump may not mean that it is as profitable to use pumps for tomato production as that for "*khat*".

3.1.4. Post harvest management issues

Among the factors that either encourage or discourage the commercialization of tomato production are the ways by which producers deal with the produce after the harvest. Since tomato is among the perishable crops it needs careful post harvest management. Besides, the proportion of the produce that is marketed out can be an indicator for the tendency that the sector has for commercialization. In relation to these, sample producers have been asked to crudely estimate the proportions of their produce that is consumed at household level, marketed out and wasted. These results are summarized in Table 4 below.

Table 5. Proportion of product marketed out by producers

Category	Proportion	Observed(N=120)	Percentage
marketed out***	<25%	5	4.17
	25 - 75%	6	5.0
	>75%	109	90.8
Consumed***	<25%	112	93.3
	25 - 75%	5	4.2
	>75%	3	2.5
Wasted***	<25%	112	93.3
	25 - 75%	5	4.2
	>75%	3	2.5

Source: Own Survey result (2012)
*Note: ***statistically significant at 1% level, N = Total number of observations in each category.*

3.1.5. Storage facility

In commercial agriculture, storage plays significant role for producers and other businessmen in the chain. In a market where the demand and price of a product vary, frequent access to storage facilities are basic requirements. The status of sample actors with regard to this important issue has been assessed. The result found is shown in Table 5 below.

Table 6. Actors' access to adequate storage facility.

Presence of access to storage facility	Actors					
	Produces*** (N=120)		wholesalers** (N=17)		Retailers*** (N=25)	
	Observed	Percent	Observed	Percent	Observed	Percent
yes and it is enough	5	4.2	5	29.4	0	0
yes but not enough	11	9.2	1	5.9	0	0
no but I would need to	104	86.6	11	64.7	25	100

Source: Own Survey result (2012)

*Note: *** statistically significant at 1% level, ** statistically significant at 5% level, **** variable is constant,*

3.1.6. Value addition

Actors in a given value chain are assumed to perform something to add value on the product they handle in the chain. Variety selection, separation and grading and packaging, are some of the value addition processes that have been considered in this study. Table 6 provides the response of sample actors on these activities of value addition.

Table 7. Value added by actors.

value addition	Actors								
	Produces (N=120)			wholesalers (N=17)			Retailers (N=25)		
	Response	Observed	Percentage	Response	Observed	Percentage	Response	Observed	Percentage
variety selection	Yes***	114	95.0	Yes***	16	94.1	Yes*	16	94.1
	No	6	5.0	No	1	5.9	No	9	5.9
cleaning produce	Yes***	77	64.2	Yes****	17	100.0	Yes****	25	100.0
	No	43	35.8	No	0	0.0	No	0	0.0
separation and grading	Yes***	107	89.2	Yes****	17	100.0	Yes****	25	100.0
	No	13	10.8	No	0	0.0	No	0	0.0

Source: Own Survey result (2012)

*Note: * not statistically significant, *** statistically significant at 1% level, ****variable is constant, chi-square test cannot be performed.*

The above result shows that almost greater proportion of actors from all categories involved the indicated value addition activities. This might be an indicative of the notion that the actors have difference in the value with in the market.

3.1.6.1. Variety selection

Value addition in the value chain of a given crop starts from the decision made on the variety of the crop to be cultivated. Producers add value on the crop through their decision of variety choice. The survey result in relation with this activity is given below in Table 7.

Table 8 Producers' preference ranking to first rank tomato variety.

Variety***	Observed	Percent
Kukurfa	39	32.5
Metehara	26	21.7
Roma vf	24	20.0
Areb	22	18.3
Others (Freng, Dedelo, Shashemene, Deilo, t-1) each contribute < 3%.	9	7.5
Total	120	100.0

Source: Own Survey result (2012)

*Note: *** statistically significant at 1% level*

3.1.6.1.1. Reason for variety choice

Among the activities agricultural producers do in a value chain in the production of a crop is variety selection. A given variety is selected based on either some physical factors such as its availability or some other perceptual factors. Table 8 provides the reasons that producers have given for their preference of one variety over another.

The two most cited reasons in variety selection might be considered as indicative of the primary market orientation goal of producers in the production of tomato. This result seems to coincide with the tendency of producers to market out greater proportion of the produce as indicated above in Table 4.

Table 9. Reason given by tomato producer for tomato variety preference

Reasons for variety of choice***	Observed N	Percent
high demand	45	37.5
cheap production	18	15.0
easy seed availability	10	8.3
high seed quality availability	8	6.7
high yield	39	32.5
Total	120	100.0

Source: Own Survey result (2012)
*Note: *** statistically significant at 1% level*

3.1.7. Motivational factors and actors behavior

Any of the conscious activities done by actor of the value chain of tomato is supposed to be motivated by some factors. Leaving alone the factors for which the actors might be unconscious, it deemed to be important to identify the other factors. On this basis, the survey has tried to get respondents' views on this regard.

3.1.8. Importance attached with tomato value chain

One of the issue that might affect the behavior of actors in a given value chain is the degree of importance they attach with the product compared with other competing alternatives. The importance that tomato value chain actors attach to tomato business has been considered and presented in Table 9. In addition, Table 10 illustrated the rank that sampled tomato consumers give to the consumption of tomato in their diet.

Table 10. Importance of tomato business as perceived by actors

	Actors					
	Produces* (N=120)		wholesalers*** (N=17)		Retailers* (N=25)	
Level	Observed	Percent	Observed	Percent	Observed	Percent
most important	59	49.2	12	70.6	9	36.0
among the most important ones	61	50.8	4	23.5	16	64.0
not that important	0	3.3	1	5.9	0	0

Source: Own Survey result (2012)
*Note: *** statistically Significant at 1% level, ** statistically Significant at 5% level, * not statistically significant.*

The result shown above (Table 9) could not say conclusively that producers and retailers considered the chain of tomato as the most important one. The likely reason for this could be that producers may be compelled by the popularity and profitability of "*Khat*" whereas retailers as they are involved in the retailing of diversified items may have other comparable alternative like onion, for instance.

Table 11. Rank of tomato consumption compared with other vegetables as ranked by consumers.

Rank given****	Observed	Percent
First	24	96.0
Second	1	4.0
Total	25	100.0

Source: Own survey result (2012).
*Note: *** statistically significant at 1% level.*

3.1.8. Price satisfaction

It is believed that price plays an important role in determining the amount of product that producers are willing to bring to the market. Hence, the satisfaction that different actors get from the price of the produce they provide to customers at different level is among the motivational factors that influence the behavior of actors in the value chain of the product. The survey result of this motivational factor is illustrated in Table 11 below.

Table 12. Price satisfaction in selling as perceived by actors.

Price satisfaction	Actors					
	Produces*** (N=120)		wholesalers*** (N=17)		Retailers* (N=25)	
	Observed	Percent	Observed	Percent	Observed	Percent
Satisfied	32	26.7	15	88.2	13	52.0
Unsatisfied	88	73.3	2	11.8	12	48.0

Source: own survey result (2012).
*Note: *** statistically significant at 1% level, * not statistically significant.*

As it is evidenced by the result shown in the above table, the majority of producers are unsatisfied by the market price with which they trade tomato. One probable reason for this may be the inability of these producers to find a place in the market where they can store the produce. In this condition, unless they are willing to sell with the price they are offered, it may be difficult to take home back what they bring to market place since bringing it back home may result another worse decision because they have to pay for transportation again.

3.2. Transportation

Among the backup services that support a value chain of tomato in the study area is transportation. Producers opt to use among the available transportation means to the chain. In this study, respondents have been inquired regarding the transportation means they use. The survey result of this is summarized in Table 12 below.

Table 13. Usage of transportation means by producers.

	Transportation means					
	Animals***		Human labor***		Vehicle***	
Use	Observed	Percent	Observed	Percent	Observed	Percent
Yes	2	1.7	29	24.2	110	91.7
No	118	98.3	91	75.8	10	8.3
Total	120	100	120	100.0	120	100.0

Source: own survey result (2012).
*Note: *** statistically significant at 1% level.*

What the result tells is that more than 90% of producers are able to access vehicle transport facilities. This situation is very conducive to strengthen the value chain if other drawbacks of can be tackled properly.

3.3. Actors' Linkage

One of the characteristic features of a value chain is the kind and nature of the link that exists between actors. In this study, producers, wholesalers, retailer, broker and consumers were found to be the main actors for examining the link. The kind and nature of the link have been treated from the perspective of each actor's preference of actors for business interaction, presence of multidirectional link among actors, and actor's location preference.

3.3.1. Linkage Pattern among Actors

In a given chain, actors may have their own preference with which actor to be linked. The actor may prefer to get linked with one, two or more actors in the chain for some personal or interpersonal reasons. Here in this study, the survey result indicated the presence of multiple ways of linkage between actors as shown in Table 13 below.

Table 14. Actors business contact linkage matrix.

Actors	Producers	Wholesalers	retailers	Consumers	brokers
Producers	-	*	*	*	*
Wholesalers	*	*	*	*	*
Retailers	*	*	*	*	*
Consumers	*	*	*	-	-
Brokers	*	*	*	-	No information

Source: own survey result (2012).
** indicates presence of business interaction among actors.*

Even though actors seem to be linked with every other actor in the chain, it does not mean that the strength of those links are the same as measured by the ranking made by the respective actor to their most preferred actor in the chain. Linkages among actors of the value chain are characterized by different forms of business interactions they make with other actors. As has been shown in Table 13 above, the linkage matrix tells that there exists multidirectional linkage among actors. This means that a given actor is interacting with remaining other and/or actors of same category with or without the need for other actors' mediation. Hence, producers can directly sell their products either to consumers, retailer, and/or wholesalers independently. Though that is truly visible from the result of the survey, the same also tells that there is difference in the weights of preference actors attach with other actors. This is clearly shown in the ranking made by each actor to the most important actors for them in the chain.

The information presented in Table 14 and Table 15 illustrate the ranking made by producers and wholesalers to their customers and wholesalers and retailers' preferred tomato providers respectively. Table 16 shows location preferences of wholesalers for collecting tomato. Lastly, consumers' preference ranking of market fragment, wholesale or retail, and criteria of choice in selecting tomato sellers are depicted in Table 17 and Table 18.

Table 15. Preference ranking made by actors to their respective customers in selling tomato.

	Actors			
	Producers***(N=120)		Wholesaler ***(N=17)	
Preferred customer	Observed	Percent	Observed	Percent
Consumer	30	25.0	4	23.5
Retailers	55	45.8	6	35.3
Brokers	9	7.5	7	41.2
Large suppliers	26	21.7	-	-

Source: own survey result (2012).
*Note: *not statistically significant, *** statistically significant at 1% level..*

Producer put retailers as their first choice customers in the business interaction. Out of the total number of sample producers around 46% of them indicated that choice while putting consumers and wholesaler in the second and third place leaving brokers as the least preferred actors in the chain. One plausible reason for producer to take brokers as the least preferred customer might be the low price offer brokers they make to producers as brokers are added in the supply chain and they should get their compensation by optionally reducing the price that producers get. Besides, the low operating cost that retailers may face which in turn enable them to make better price offer to producers could also be one likely reason for retailers to be most preferred by producers.

Table 16. Preference ranking made by actors to tomato providers in buying tomato.

	Actors			
	Wholesaler***		Retailers***	
Tomato Providers	Observed	Percent	Observed	Percent
Brokers	16	94.1	23	92.0
Large suppliers	1	5.9	1	4.0
Retailers	-	-	1	4.0

Source: own survey result (2012).
*Note: *** statistically significant at 1% level.*

The other dimension with which linkage among actors have been considered is with regard to the preference of actors to tomato providers. The result on this issue indicated that wholesalers depend on brokers to greater extent in procuring tomato. This is implied from that 94.1% of them preferred brokers as their first rank tomato provider preferably from regions outside the study area which includes Adama, Bole, Meki and Ziway areas as has been indicated by 88.2% of sample wholesalers. One likely reason for brokers' domination might be that of producers dependence on brokers as they may lack bargaining skill and power with customers.

Table 17. wholesalers' preference ranking of tomato buying location.

Buying location ***	Observed N	Percentage
within region	2	11.8
out of region	15	88.2
Total	17	

Source: own survey result (2012).
*Note: *** statistically significant at 1% level.*

The result found in the preference of wholesalers to tomato providers demonstrated one big problem reflecting the presence of a weak linkage between producers and wholesalers found within the study area. But for the value chain under consideration, strengthening and improving the linkage between these two actors is mandatory. Among the indicated reasons by wholesalers for this weak linkage is the inability of producers within the study area to provide the commodity with the required quality and quantity. One likely reason for producers' failure to do so might be the importance they attach with tomato production since they probably have "*khat*" production as a better and lucrative optional crop. One finding of this survey that goes in line with this likely assumption is that the proportion of farmland size that producers allocate for the production of tomato. It is only around one third of the total farmland holding that is allocated for tomato production.

On the part of retailers, sample respondents preferred brokers as their first rank tomato providers with 92% of sample retailers showing their preference to brokers as their first rank tomato providers. Wholesalers and other retailers are all ranked second.

Table 18. Consumers ranking of fragment of market in buying tomato.

Market fragment*	Observed N	Percentage
wholesale market	11	12.5
retail market	14	12.5
Total	25	

Source: own survey result (2012).
*Notice: * not statistically significant.*

Actor preference of customers in buying tomato has been treated differently for some technical reason. Instead of mentioning actors specifically the choice has been provided as wholesale and retail market. This is because of the technical reason that consumers may not have the exact information to recognize produces from other retailers acting in the market. On the basis of this, sample consumers are found to be indifferent in getting the produce whether it is from the wholesale or retail market. Nevertheless, the reason they mention to go to either of the markets seem to be statistically different with 76% of the respondents saying quality as the main driving factor to the choice they make and the remaining 24% of them mentioned cheap price as the driving factor.

Table 19. Criteria used by consumers to select tomato sellers.

Criteria***	Observed N	Percentage
quality of product provided	19	76.0
cheap price	6	24.0
Total	25	100.0

Source: own survey result (2012).
*Notice: *** result is statistically significant at 1% level.*

3.3.2. Price setting

Price setting can be considered as one of the ways by which the linkage among actors of the value chain can be characterized. Along with price setting actors may have different feeling towards the price set. The following tables, Table 19, and 20, display the response of actors on price setting when selling and buying tomato respectively.

Table 20. Price setting when selling as perceived by actors

	Actors					
	Producers***(N=120)		Wholesalers***(N=17)		Retailers***(N=25)	
who set price	Observed	Percent	Observed	Percent	Observed	Percent
Me	22	18.3	14	82.4	20	80.0
Buyer	35	29.2	-	-	-	-
Bargaining	58	48.3	3	17.6	20	80.0
market condition	5	4.2	-	-	-	-

Source: own survey result (2012).
*Note: *** statistically significant at 1% level.*

Price setting is one of the most important factors which determine the nature of a given market. The results found in this survey shows that the majority (48.3%) of producers mentioned bargaining as the main role playing factor in price setting when selling the commodity. Lesser proportions of wholesalers (17.6%) and retailers (20.0%) mentioned it as a main factor in price setting. Greater proportions of the later two actors said that they set price without the influence of other parties in the deal. The likely reason for most producers in the study area to have the option of bargaining rather than simply delivering their produce to customers at a specified price might be that they have the choice of selling to wholesalers, retailers, brokers and consumers as well in the same market place.

Table 21. Price setting when buying as perceived by actors.

	Actors			
	Wholesaler**		Retailers**	
who set price	Observed	Percent	Observed	Percent
Seller	13	76.5	18	72.0
Bargaining	4	23.5	7	28.0

Source: own survey result (2012).
*Note: ** statistically significant at 5% level.*

On the contrary, the opposite happens when both parties, retailers and wholesalers, buy the commodity. In that case greater proportion of wholesalers (76.5%) and retailers (72.0%) indicated that the power to set price is of the providers. In this case this may happen as brokers have the tendency of hiding information from other parties for the sake of manipulating prices as they want.

3.4. Benefit Distribution and Marketing Margins

There might be different ways to be employed to understand the nature of benefit distribution taking place among actors of value chain. Among them are profit distribution and marketing margin. This part, therefore, make use of these two mechanism for presenting and discussing the result.

3.4.1. Profit distribution

The Profit that sampled actors gained in the production and/or marketing of tomato has been compared in such a way that it is possible to weigh it against the cost incurred by each actor. To create a clear picture of this, the mean profit earned by each actor as percentage of the mean total cost incurred by the respective actor has been calculated as shown in Table 23 below. This helps the comparison of the proportionate benefits earned by the actors.

Table 22. Comparison of the mean profit as percentage of total cost between actors.

Compared Category	N	Mean Profit	Std. Deviation	Std. Error Mean
Producer**	120	82.6807	234.37416	21.39534
Wholesaler	17	35.2200	26.65108	6.46384
wholesaler**	17	35.2200	26.65108	6.46384
Retailer	25	44.2556	24.83129	4.96626
Producer**	120	82.6807	234.37416	21.39534
Retailer	25	44.2556	24.83129	4.96626

Source: own survey result (2012).
*Note: ** statistically significant at 5% level.*

Producers seem to gain profit which is greater in percentage (82.68%) of the cost they incur. On the other hand wholesalers and retailers gain 35.22% and 44.26 % respectively. But this may not mean the money gains exactly corresponds the percentages indicated here since the percentage also depends on the amount of cost incurred. (Refer Table 27).

3.4.2. Marketing margins

In addition to the above information given on the profit distribution among the actor of tomato value chain, Table 24 provides the nature of marketing margin in the chain.

Table 23. Marketing Margins.

Actors	Mean selling price	Marketing margin			
		When the link is "A" type	When the link is "B" type	When the link is "C" type	When the link is "D" type
Producer	7.09	0	35.37	48.40	48.40
whole seller	10.97	-	-	-	20.16
retailer	13.74	-	-	-	-
consumers	10.95	-	-	-	-

Source: Own survey (2012)

Note: "A" type link: Producer →Consumer
"B" type link: Producer → Wholesaler→Consumer
"C" type link: Producer → Retailer → Consumer
"D" type link: Producer → Wholesaler → Retailer → Consumer

The marketing margins of producers and wholesaler have been calculated using data of the survey. The marketing margins are calculated considering all the possible ways by which the product can reach the final consumers. The results tell that there is money spent for marketing function which could possibly be earned by producer. But the decision to be made out of this result requires further research and careful analysis since marketing function has its own cost and there are efficiency issues that might be achieved through division of labor.

3.5. Constraints and Opportunities for Commercializing the Chain

Actors from different category ranked the constraints they have been experiencing in undertaking tomato business. Producers mentioned disease/pest problems, poor access to irrigation and poor storage facility as the first with 45.0% vote, second with 19.2% vote, and third with 10.0% vote respectively, among other, to be the most important constraints for the business. Retailers on the other hand cited rotting, lack of area in the market, pressure from authority and lack of access to credit to be the top prioritized business constraints on equal basis. On the third place wholesalers put rotting and quality related problems, lack of space and access to credit and running cost to be the equally ranked business constraints they confront.

Table 24. First rank constraints in the value chain as perceived by Actors.

Actors	Production constraints	Observed N	Percent
Producers***	Disease/pest	54	45.0
	Poor access to irrigation	23	19.2
	Poor storage	12	10.0
	Others (Absence of market place, Poor access to high quality seeds, Poor access to credit, Poor access to transportation, Poor labor availability, Shortage of technical knowledge and skill, Shortage of labor, Shortage of land, Poor access to information) each contribute less than 8% to this category.	11	25.8
	Total	120	100.0
Retailers*	Rotting	2	8.0
	Lack of space	8	32.0
	Access to credit	7	28.0
	Pressure from authority	8	32.0
	Total	25	100.0
Wholesalers*	Rotting and quality related	7	41.2
	Lack of space	7	41.2
	Running cost and access to credit	3	17.6
	Total	17	100.0

Source: own survey result (2012).
*Note: *** statistically significant at 1% level.*. * not statistically significant

Price satisfaction of sellers is also a concern in sustaining a given chain. Here in this study the result indicated, 73.3% of the producers being unsatisfied with the price of tomato they transact. On the other side, 88.2% of wholesalers said they are in general satisfied with the price in the marketing of tomato while the satisfaction level of retailers remained indeterminate. It should be noted that the starting point of the chain are producers. Therefore, the existence of the chain will be in question if this segment of the chain cannot be benefited. Hence, this situation should be taken as one of the challenges of an effort directed at commercializing the value chain of tomato in the study area.

The chain under consideration is not characterized only by the constraints rather there are also opportunities for commercialization. Concerning the weight consumers put on price and quality of tomato, the result shows, 96.0% of them prefer quality to be the most important attribute which is indicative of the presence of market environment conducive to commercialize the sector since quality improvement is one of the ways by which we add value on a product.

Table 25. Weight consumers give to price and quality of tomato.

Most important of Product***	Observed N	Percentage	cumulative percentage
Price	1	4.0	4.0
Quality	24	96.0	100.0
Total	25		

Source: own survey result (2012).
*Note: *** statistically significant at 1% level.*

Consumers' preference in any of the features of a given product might be taken as starting point for the value addition function of entrepreneurs. Hence, the identification of those features can play a role in the efforts made to commercialize the production of tomato. The weights consumers attach with what they perceived as quality, the preference they give to quality and price and the extent to which they are able to manage purchasing the amount of tomato they need during low supply season have been examined and presented in Table 27, Table 28 and Table 29 below.

Table 26. Consumers reaction to cheaper price of tomato.

Buy more if cheaper	Observed N	Percentage
yes, if good in quality	14	56.0
yes, regardless of quality	2	8.0
no, what I buy now is enough	9	36.0
Total	25	100.0

Source: Own survey (2012).
*Note: ** statistically significant at 5% level.*

If it is somehow possible to implement a production technology that decreases production cost which increases production and improves quality then the market may have absorptive capacity to the increased product with cheaper price. This is because 56.0% of the sample consumers are willing to increase purchase of tomato if they are cheaper and good in quality as well. Moreover, the commercialization of the sector could be backed up by the inability of the current market condition to satisfy the demand of consumers during low supply seasons since 92.0% of the sample consumers are not able to either partially or completely manage to get what they demanded during the season.

Table 27. Consumers ability to purchase the amount they need during low supply season.

manage to purchase during off-season	Observed N	Percentage
Yes	2	8.0
yes, but less than in the season	20	80.0
No	3	12.0
Total	25	100.0

Source: Own survey (2012).
*Note: * statistically significant at 1% level.*

4. Conclusion

In the value chain of tomato, actors are found to be linked in multiple manners. A given actors can be linked with any other actors in the chain. Linkages among actors do not have the same strength as the strength of the linkage producers' form with wholesalers and consumers might be different as measured by the percentage of producers who preferred any one of the two actors as the most important for them. The most important actors found in the value chain of tomato under consideration are Producers, wholesalers, retailers and brokers. The linkage between producers and wholesalers in the study area is found to be weak since wholesalers prefer to get the commodity from areas outside of the region. In general, the three actors involved in the production or marketing of tomato seem to benefit from the chain as the benefit they get is measured in terms of the profit as percentage of the total cost they incur in the production or marketing of tomato. Producers get the greatest percentage followed by retailer while wholesalers earning the lowest percentage. But this may not be indicative of the amount of the real amount of money the actors earned since the percentage depends on the cost they incur.

In addition, there is money spent by consumers as marketing margins. The marketing margins depend on the kind of link established in delivering tomato to consumers. The value chain has both constraints and opportunities to commercialize it. Among the constraints some are faced by producers while wholesalers and retailers confronted the other. Disease/pest, lack of area in the market and rotting and quality related problems are among the constraints mentioned by the actors. Despite the multidimensional constraints the chain faces there are also many opportunities which could be utilized to commercialize the chain. These opportunities emanate from different corners. Some come from the behavior of consumers. For instance consumers want to increase the quantity they purchase if quality improves and price decreases. Most producers cultivate tomato more than once in a year. Besides, the market has additional absorptive capacity since it cannot satisfy consumers demand during low supply season.

5. Recommendation

Although it is possible to speculate probable reasons for the presence of linkage gap among producers and wholesalers, speculation is not enough. Therefore it will be necessary to conduct additional researches which deal with examining the proper reasons for this gap.

Concerned bodies in the area should find a way by which produces can improve the quality of tomato they produce since quality is found to be a drive factor in choosing market segment by consumers.

If there is an interest in improving the living condition of farmer producers, it will be necessary to improve their market power. Hence, necessary arrangement should be made to provide tomato producers with convenient selling location in Harar city in the absence of which they are forced to give their produce to either wholesalers or retailer or even consumers at a lesser price. One of the manageable ways to carry out this task could be through organizing tomato producer under producers cooperative and arrange a place in the central market where this producer can do their business.

Concerned agricultural offices and research institution in the area should help producers through proposing workable solution for the problems of tomato disease/pest.

The establishment of multi-location mini market in different places within the vicinity of dweller and provision of selling area to retailer could alleviate the pressure retailers have from the lack of area in the central market and the pressure they face from authority as a consequence of lack of area.

Among the results found some urge the agricultural office in the area to find a technology that improves quality, reduce cost of production and increase production since an increased production with good quality and cheaper price can be taken up by consumers

6. Acknowledgment

The research team would like to express its warmest gratitude to Haramaya University Office of Research and Extension for its facilitation through the provision of necessary financial requirements and other services. We also want to thank all the research participant involved in this study for willingly providing information required from them. All the data collectors also deserve to be appreciated.

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