HARAMAYA UNIVERSITY
OFFICE OF THE RESEARCH AFFAIRS

PROCEEDINGS OF THE 29TH ANNUAL RESEARCH AND EXTENSION REVIEW WORKSHOP 2011/2012

COMPILED AND EDITED BY STAFF OF THE OFFICE OF RESEARCH AFFAIRS

MARCH 2012
HARAMAYA UNIVERSITY

Haramaya University Office of the Research Affairs

Proceedings of the 29th Annual Research and Rxtension Review Workshop 2011/2012

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March 2012
Haramaya University

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Wassu Mohammed and Simeret Burga

1.1.1 Maintenance of Sweet Potato Genotypes at Haramaya University

Background and Justification

Sweet potato [*Ipomoea batatas* (L.) Lam.] produces storage roots rich in carbohydrates and β-carotene, and its leaves are rich in protein. The roots also contain vitamins C, B complex and E as well as potassium, calcium and iron. Purple-fleshed ones contain antioxidants such as anthocyanins. In world crop statistics, sweet potato ranked seventh, just after cassava, with an annual production of around 9 metric tons and a cultivated area of 110 million ha (FAO, 2009). In most developing countries, it is a smallholder crop tolerant to a wide range of edaphic and climatic conditions and grown with limited inputs. It is tolerant to cold and is cultivated at altitudes as high as 2,500 m.a.s.l. It has become the staple food of communities living in the highlands of Uganda, Rwanda and Burundi of Eastern Africa, and in Papua New Guinea where annual per capita fresh roots consumption is over 150 kg. Asia is the largest producing region and China alone accounts for almost 60% of the world sweet potato production. In the southern provinces of Sichuan and Shandong, sweet potato is a major source of raw material for food processing industries (Fuglie and Hermann, 2004).

Sweet potato is cultivated in Ethiopia mainly for human consumption and as animal feed. It ranks third after enset (*Ensete ventricosum* (Wele) Cheesman) and potato (*Solanum tuberosum* L.) as the most important root crops produced in the country. Although the crop is drought tolerant, it needs sufficient moisture at early stage especially during the first six weeks. The total area under production reached 33,070 ha and the annual production is estimated to be over 2,628,539 quintals (CSA, 2003). According to FAO (2000) and CSA data (CSA, 2005, 2006), the national average storage root yield of sweet potato of Ethiopian ranges between 8 to 10 t ha^{-1} with experimental storage root yields ranging between 30 to 73 t ha^{-1} (Hall and Harmon, 1989; Bhansari and Ashley, 1990).

Similar to other crops, sweet potato genetic resources show a wide spectrum of gene pool that can be categorized under the following groups; wild species, weed or feral species, native cultivar, improved cultivar and breeding line. Current knowledge of the distribution of sweet potato genetic resources indicates that the maximum diversity of *I. batatas* is in northwestern and southern America and Africa. Like other major crops, sweet potato genetic resources are facing a high risk of losing a significant amount of variation (Zosimo, 1987). Thus, Haramaya University emphasizes on the importance of intensive collection of sweet potato germplasm. The University maintains 116 sweet potato germplasm from international and national collections. The germplasm collection is not only used by the University, but also by the national research system. Therefore, it is necessary to maintain these valuable materials for future use. The objective of this project was therefore to maintain sweet potato collection at field at Haramaya University.

Materials and methods

The materials were maintained under a field condition. One hundred sixteen sweet potato genotypes were planted in a non-replicated trial at Haramaya University. Vine cuttings of each genotype were planted at the spacing of 50 cm by 80 cm on ridges. All the required cultural practices were applied according to the recommendation.

Results

One hundred and sixteen sweet potato genotypes were maintained. The list of the genotypes is given in Table 1.1.

Duration

The maintenance activity started decades ago and will continue for unlimited number of years to come.

Activities to be accomplished during the remaining period

The genotypes will be maintained and morph-physicochemical characterization activities will be accomplished to identify the characteristics and the purpose the accession will be used for and other information will be documented and made available for users.

Table 1.1. Sweet potato germplasms collection at Haramaya University

No.	Variety	No.	Variety	No.	Variety	No.	Variety
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	Guba-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

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1.1.2 Maintenance of Potato Genotypes at Haramaya University

Background and Justification

Potato is one of the most important staple food crops in East and Central Africa region. It helps in ensuring food security, especially in disaster situations. Potato production in these regions increased from 2.8 million metric tons in 1998 to about 4.2 million metric tons in 2002 implying a growth rate of nearly 8% per annum. Despite this remarkable growth, yields are low as compared to those obtained elsewhere in the World. The average yield of potato in Ethiopia ranges only between 8 to 10 t/ha, which is much lower than the yields obtained in the Sudan (17 t/ha) and Egypt (26 t/ha) (Haverkort et al., 2012). 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. Shortage of improved seeds or planting materials and inadequate provision of extension services also contributed greatly to the low potato yields in the country (George and Otim, 2007).

Source materials and germplasms are very crucial in variety development and release. In most cases, the richer the germplasms, the more and better varieties are developed and released. However, countries in East and Central Africa have different approaches to accelerate release of acceptable varieties. They also follow different approaches in building the source of materials and germplasms. Some countries depend entirely on CIP and/or PRAPACE for materials for breeding programs, while others generate own crosses using both local and exotic materials. In Ethiopian, the Ethiopian Agricultural Research Institution (EARI) has a national mandate to conduct and coordinate research, but higher education institutions (Universities and Colleges) are also engaged in research on potato and other crops. EIAR has a strong collaborative research with international agricultural research centers such as CIP on potato and sweet potato research. Variety development, evaluation, release, and registration procedures pass through several stages (George and Otim, 2007). However, EIAR along with Universities such as Haramaya University released considerable number of potato varieties for different regions and agro-ecologies mainly depending on CIP for potato germplasm source.

The presence of genetic variability is considered the prerequisite in any plant-breeding program. Therefore, maintaining the available potato germplasm is crucial for the success of potato improvement. Haramaya University is a pioneer institution in starting potato research in the country and is known for maintaining accessions obtained from International Research Centers. The collection that the University maintained also serve as deposit for the national potato research program. Therefore, the objective of this project was to maintain potato genotypes at Haramaya University and make available for regional and nation research system.

Materials and Methods

Three hundred fifty potato genotypes were planted in a non-replicated trial with three rows at Haramaya University. Medium size and well-sprouted potato tubers were planted at a spacing of 75 cm between rows and 30cm between plants. All agronomic practices were applied as per the recommendation for the crop.

Duration

The activity was started decades ago and it will continue for unlimited number of years.

Activities to be accomplished during the remaining period

The genotypes will be maintained and screened for disease resistance, yield, and other quality traits. The potato accessions, which will fulfill the objective of the breeding program, will be promoted to subsequent breeding stages to improve the crop. In addition, the accession will be available for other research activities.

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1.2 Lowland Oil Crops Research Program Activities (2011/12 Cropping Season)

Amare Kebede

Introduction

Haramaya University (HU) is conducting research on groundnut (*Arachis hypogaea* L.), sesame (*Sesamum indicum* L.) and linseed (*Linum usitatissimum* L.) under Oil Crops Research (OCR) Program. The research program includes highland and midland oil crops. In each commodity program (Table 1.2), there are breeding, crop management and socio-economic related activities. Under the national level, the OCR program is conducting research focusing on the following general objectives:

- To develop improved varieties of oil crops and production practices for different agro-ecologies of the country.
- To develop integrated and sustainable pest management options to increase production and productivity of oil crops.
- To assess production opportunities and constraints, analyze the adoption of technologies in oil crops in major production areas.
- To transfer the existing and upcoming improved technologies to end-users and assess their impacts on the livelihood of the society.

Table 1.2. Outline of Haramaya University lowland oil crops research activities during 2011/12 main cropping season

		Research activities				
No.	Commodity	Completed	On-going	Reinitiated	New	Total
1	Groundnut	1	2	1	2	6
2	Sesame	-	-	-	3	3
3	Linseed	-		-	2	2
4	Nationally coordinated	-	3	-	-	3
Total						14

Groundnut

Groundnut is the sixth most important oilseed crop in the world. It contains edible oil and protein, and is a rich source of dietary fiber, minerals and vitamins. In addition, it fetches high price. In Ethiopia, groundnut is grown mainly for food, including the extracted edible oil. The by-product from oil extraction of groundnut (groundnut cake) serves as animal feed. Thus, groundnut research is required to develop high yielding varieties with other desirable traits.

Completed Groundnut Research Activity

1.2.1 National Groundnut (*Arachis hypogaea* L.) Variety Trial

Abstract: *The performances of eleven groundnut (Arachis hypogaea L.) genotypes at 6 environments were evaluated in eastern Ethiopia. Among these genotypes,* BaHa-jidu *(NC-AC-2748 X Chico) and* BaHa-gudo *(ICGV-88357) were found best in dry pod and other agronomic traits.* BaHa-jidu *is runner type and medium seeded, whereas* BaHa-gudo *is erect type and large seeded. Both varieties are red in testa color, have 53% oil content and moderately resistant as standard check (*Werer-962*) to leaf spot and rust.* BaHa-jidu *gives 2.08 t/ha dry pod yield (DPY) and has 26% advantage over* Werer-962. BaHa-gudo *gives 1.97 t/ha DPY and has 20% advantage over* Werer-962. *This variety is preferred for roasted grain (kolo) due to its seed size. After official approval for release,* BaHa-jidu *and* BaHa-gudo *will be recommended for production in the coming years.*

Keywords: Environment; Genotype; ICGV-88357; NC-AC-2748 X Chico

Introduction

Among factors, contributing to low yield of groundnut is lack of high yielding varieties. To develop high yielding groundnut varieties, Haramaya University lowland OCR program conducted research on different groundnut genotypes in eastern Ethiopia.

Methodology

Genotypes were introduced from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). To select best genotypes in desirable traits, eleven groundnut genotypes were evaluated at Babile and Likale research sites of eastern Ethiopia for three years. The verification trial was conducted at Gursum, Likale, Babile and Gursum in 2011 main cropping season and evaluated by National Variety Release Committee (NVRC). Dry pod yield, days to flowering, days to maturity, number of pegs per plant, number of mature pods per plant and reaction to major diseases data were collected. The experiment was arranged in RCBD in 5 rows with inter and intra row spacing of 60cm and 10cm, respectively with 3 replications. Statistical Analysis System (SAS) software of General Linear Model (GLM) procedure was applied to analyze data. Mean separation was carried out using the Least Significant Difference (LSD) test.

Results and Discussion

BaHa-jidu (NC-AC-2748 X Chico) and BaHa-gudo (ICGV-88357) out-yielded the checks in dry pod yield. BaHa stands for Babile Research Station of Haramaya University and literally refers to the eastern part of Ethiopia. BaHa-jidu and BaHa-gudo are distinct in their agronomic characteristics **(Table 1.3)**. BaHa-jidu is the runner type whereas BaHa-gudo is erect type. Both varieties are red in testa color. BaHa- jidu and BaHa-gudo are medium and large-seeded, respectively.

Table 1.3. Agronomic descriptions and yield of *BaHa-jidu* and *BaHa-gudo*

	Mean dry pod yield t/ha							
	2007 G.C		2008 G.C		2009 G.C			Dry pod yield advantage over
Genotypes	Babile	Likale	Babile	Likale	Babile	Likale	Mean	*Werer-962* (%)
BaHa-jidu	2.08	2.72	2.49	2.08	2.52	0.59	2.08	26.83
BaHa-gudo	1.81	2.88	1.96	2.10	2.23	0.82	1.97	20.12
Werer-962	1.57	2.48	1.84	1.48	2.01	0.47	1.64	

Genotypes	Days to flowering	Days to maturity	Number of pegs/plant	Number of Mature pods/plant	Hundred seed weight (g)	Shelling percentage
BaHa-jidu	33.54	125.88	29.16	14.79	50.03	70.00
BaHa-gudo	33.25	126.88	23.91	11.32	73.97	65.90

The mean dry pod yield performance of *BaHa-jidu* and *BaHa-gudo* was superior to the standard check (Table 1.3). *BaHa-jidu and BaHa-gudo* were as moderately resistant as the standard check to leaf spot and rust in the tested environments. The oil content of *BaHa-jidu* and *BaHa-gudo* are 53.6% and 53.5%, respectively. *BaHa-gudo* is preferred for roasted grain (*kolo)* because of its large-sized seed. Thus, after an official approval by the National Variety Release Committee, these varieties will be recommended for production in Babile, Likale and other similar agro-ecologies with altitude ranging 1400 to 1650 meter above sea level.

Summary

BaHa-jidu gives 2.08 t/ha dry pod yield (DPY) and has 26% advantage over Werer-962. *BaHa-gudo* gives 1.97 t/ha DPY and has 20% advantage over Werer-962. The candidate varieties will be recommended for production in Babile, Likale and other similar agro-ecologies with altitude ranging 1400 to 1650 meter above sea level.

On-going Groundnut Research Activities

1.2.2 Identification of Causative Factor(s) of Groundnut Wilt in the Farmers' Field and Controlmeasure(s) Formulation

Amare Kebede, Amare A., Anteneh Argaw., Muluken Goftishu., Habtamu Bekele., Awol S.

Introduction

During farmers' field inspections, more than half of the plants of groundnut observed to be wilted and died. Upon examination, roots of some plants were found to be rotten, associated with termites and/or fungal molds. Some plants exhibited symptoms of one or more diseases and insect pest incidences. However, the actual causes of plant wilting and death were not identified clearly. Thus, this research activity was proposed to identify the causes of plant wilting and death, and design appropriate control/management measure(s) against wilting and death of the plants.

Methodology

Multidisciplinary approach was proposed to identify the cause of wilt and death of the crop. Plant and soil samples from the vicinity of plant roots were collected from Gursum, Likale, Babile, Fedis and Kile. The evidence of fungi, nematodes, termites, soil pH and nutrient status were examined. In greenhouse experiment, suspected young culture isolates of fungi will be inoculated on groundnut seedlings.

Highlights of results

From the overall farmers' groundnut field observation, higher numbers of diseased plants occurred in poorly managed fields compared to well-managed fields. From the individual diseased and healthy plant examination, diseased plants showed ineffective and lower number of nodulation than the healthy ones. In addition, *Aspergillus flavus, Aspergillus niger, Fusarium and Rhizoctonia* spp. were isolated from diseased plants. Plant parasitic nematodes: *Criconemoides, Helicotylencus, Hemicycliophora, Longidorus, Meloidogyne* (juveniels)*, Pratylenchus, Trichodorus,* spp. *and f*ree-living bio indicator nematodes were observed in association with diseased plants and soil samples from the vicinity of diseased plant roots. Termites were found in association with both diseased and healthy plants. For assesment of soil nutrient status, soil samples have been prepared for analysis in a laboratory.

1.3 Sorghum Research Program

Ketema Belete

Introduction

Sorghum (*Sorghum bicolor*) is a major cereal crop in eastern Ethiopia. Most of the sorghum cultivated in this region is tall and late maturing local landrace. The crop is used for food, feed, construction and firewood purposes. The early maturing short stature varieties released for production are not preferred by farmers because they have low biomass for use as animal feed, firewood and construction purposes. The early maturing and short varieties are used by some farmers in lowland areas whenever the local varieties fail due to moisture shortage and/or *Striga* problems. Therefore, the focus of the sorghum improvement program at Haramaya University is to identify high yielding local sorghum varieties. To this effect, the initial work of selecting the best sorghum varieties for highland and lowland areas was done at Haramaya and Babile research station of the University, respectively. The breeding approach used was more of pure line selection method.

In pure line selection method, the sorghum germplasm are collected from farmers' fields. The collection will be evaluated in observation nursery for one season or for two seasons. The evaluation is mainly visual. The best observation nursery material will be advanced to preliminary variety trial (PVT). In PVT, the genotypes under evaluation are compared with recently released and local sorghum varieties in replicated trials. The best PVT material will be grown in at least three sites including on station (Haramaya for highland and Babile for lowland) as a regional variety trial (RVT). The experimental varieties in RVT will be evaluated with the checks for a minimum of two years on farmers' fields and on station. The varieties that perform significantly better than the recently released variety in terms of yield and other important traits will be proposed to the National Variety Release Committee (NVRC) for release.

Developing varieties is not the only activity of the sorghum improvement program. Crop management, disease management and popularization of sorghum varieties have also been done. To this effect, agronomists, plant pathologists and agricultural extension experts are working as team members of the crop improvement program.

Realizing the importance of crop diversification, pearl millet research has been initiated for execution in the next cropping season (2012/13 croping season). The crop is more tolerant to drought than sorghum. However, its yield potential is less than sorghum. Nevertheless, there is a need to investigate its potential as an alternative crop owing to its superior drought tolerance.

In this report, breeding and agronomic research highlights (activities) of the 2011/12 croping season are presented as follows.

Completed Breeding Activities

1.3.1 Regional Varity Trial for Highland Areas of eastern Ethiopia

Objectives

- To identify high yielding and best performing sorghum varieties for the highland areas of eastern Ethiopia.

Background

Regional Varity Trial (RVT) is the third breeding activity in varietal development when pure line selection method is used. The first and the second are observation nursery and PVT, respectively. Usually, the activities prior to RVT are

conducted on station, but RVTs include minimum of two off station activities. The varieties that performed better than the checks (based on data of minimum two years on two sites) in RVT will be advanced to variety verification trial.

Methodology

Six experimental varieties and four check varieties (3 as standard check and 1 as local check) were grown for two years at three locations: Adele, Haramaya and Kersa. Randomized complete block design with three replications was used. Agronomic data were collected.

Highlight of the results

Three experimental varieties were found to be best based on the results of the two-year trials at the three locations (Table 1.4). The three varieties are Wegarie-3, Wegarie-5 and Fendisha-5. These varieties will be advanced to variety verification trial (VVT) as candidate varieties for release after being evaluated by the National Variety Release Committee (NVRC).

1.3.2 Preliminary Variety Trial for Highland and Intermediate Areas of Eastern Ethiopia

Objectives

- To identify high yielding and best performing sorghum varieties for the highland and intermediate elevation areas of eastern Ethiopia.

Background

Preliminary variety trial (PVT) is the second breeding activity in varietal development when pure line selection method is used. The first is observation nursery. It is conducted on station rather than on farmers' fields as done for RVT, because the varieties in PVT are large in number. The varieties that performed better than the checks (usually for one cropping season) will be advanced to RVT.

Table 1.4. Mean grain yield and days to flowering of sorghum varieties grown at Adele, Haramaya and Kersa as RVT during the 2010 and 2011 cropping season

No.	Variety	Yield (kg/ha)	Days to 50% flowering
1	Wegerie-3	7007	140
2	Wegerie-5	6531	143
3	Fendisha-5	6299	150
4	Muyra-3	5325	148
5	Muyra-4	5078	141
6	Fendisha-2	4790	150.
7	Muyra-1	5271	144
8	Muyra 2	4826	136
9	Chelenko	5263	145
10	Local	4498	143
11	LSD	692	2.5

Methodology

There were three sets of PVT, PVT-1, PVT-2 and PVT-3 consisting of 17, 21 and 25 varieties, respectively. The first two (PVT-1 and PVT-2) were conducted at Haramaya for highland and PVT-3 at Babile for intermediate/lowland altitude. At each location, appropriate check was used. At Haramaya 4 varieties (3 as standard check and 1 as local check) and at Babile 2 varieties (1 as standard check and 1 as local check) were among the 17, 21 and 25 varieties. Randomized complete block design with three replications was used. Agronomic data was collected. The varieties were evaluated for one croping season at Haramaya and Babile.

Highlight of the result

All the varieties in PVT-1 were as good as the check varieties in terms of overall plant aspect and were not significantly different among each other in yield (Table 1.5). Entries number 1 to 10 and 14 from PVT-2 (Table 1.6) and entries 1-3, 7, 9-11, 13 16-18 and 22 from PVT-3 (Table 1.7) were selected based on yield and overall plant aspect. The selected entries from PVT-1 and PVT-2 will be evaluated again as PVT at Haramaya and those selected from PVT-3 at Babile. The need of evaluating these varieties in PVT rather than RVT is because of two reasons. The selection from each is too

large to be evaluated on more locations and there is a need of grouping the selection of Haramaya into two different sorghum types, Sheferie and Muyra.

Table 1.5. Mean rain yield and overall plant aspect of sorghum Preliminary Varity Trial Set-1 (PVT-1) grown at Haramaya during 2011 cropping season

No	Entry Name	Yield (kg/ha)	Overall plant aspect*	Remark
1	Sheferie Red	4355	3	All of the 13
2	Sheferie Red	3822	3	have been
3	Sheferie Red	6713	1	selected
4	Sheferie Red	6046	1	
5	Sheferie Red	5387	2	
6	Sheferie Red	5174	2	
7	White Muyra	3776	3	
8	Yellow Muyra	5136	3	
9	White Muyra	6488	2	
10	White Muyra	5619	1	
11	Sheferie Red	4960	2	
12	White Muyra	5857	2	
13	Sheferie Red	4633	2	
14	Muyra 1	6302	2	
15	Muyra 2	4782	1	
16	Cnelenko	4446	2	
17	Long Muyra	4640	3	
	LSD	1027		

* Visual evaluation, where 1 = Excellent, 2 = Very good, 3 = Good, 4 = Fair, 5=Poor

Table 1.6. Mean grain yield and overall plant aspect of sorghum Preliminary Varity Trial Set-1 (PVT-2) grown at Haramaya during 2011 cropping season

No	Entry Name		Yield (kg/ha)	Overall plant aspect*		Remark
1	Wegerie Yellow	7422		1		Selected
2	Wegerie Yellow	5422		3		Selected
3	Wegerie Yellow	6644		3		Selected
4	Wegerie Red		4320		2	Selected
5	Wegerie Red	5287		1		Selected
6	Wegerie Yellow	4659		1		Selected
7	Wegerie Red		6187		3	Selected
8	Wegerie White	6454		3		Selected
9	Wegerie Red	6995		3		Selected
10	Wegerie Red	6400		2		Selected
11	Wegerie Yellow	7361		4		
12	Wegerie Yellow	6088		4		
13	Wegerie White	5467		4		
14	Wegerie Red		5600		1	Selected
15	Wegerie White	4862		5		
16	Wegerie Red		5955		4	
17	Wegerie Red		6134		4	
18	Muyra 1	4587		2		
19	Muyra 2		4610		1	
20	Chelenko	7886		2		
21	Long Muyra		6534		3	
	LSD		1516			

* Visual evaluation, where 1 = Excellent, 2 = Very good, 3 = Good, 4 = Fair, 5 = Poor

Table 1.7. Mean grain yield and overall plant aspect of sorghum Preliminary Varity Trial Set-1 (PVT-3) grown at Babile during 2011 cropping season

No	Entry Name	Yield (kg/ha)	Overall plant aspect*	Remark
1	2009 collection # 1	1920	1	Selected
2	2009 collection # 3	1992	2	Selected
3	2009 collection # 4	2773	1	Selected
4	2009 collection # 5	2018	4	
5	2009 collection # 7	1501	4	
6	2009 collection # 9	1672	4	
7	2009 collection # 11	1787	2	Selected
8	2009 collection # 12	1582	4	
9	2009 collection # 13	2240	3	Selected
10	2009 collection # 16	2126	2	Selected
11	2009 collection # 19	1982	2	Selected
12	2009 collection # 21	1547	4	
13	2009 collection # 24	1902	3	Selected
14	2009 collection # 25	1840	4	
15	2009 collection # 26	1688	4	
16	2009 collection # 27	2240	3	Selected
17	2009 collection # 30	1920	2	Selected
18	2009 collection # 32	1886	3	Selected
19	2009 collection # 33	1502	4	
20	2009 collection # 35	2336	4	
21	2009 collection # 37	1883	4	
23	2009 collection # 39	2294	3	Selected
23	IS 9302	2275	3	
25	Chame	1654	1	
	LSD	567		

** Visual evaluation, where 1=Excellent, 2=Very good, 3=Good, 4=Fair, 5=Poor*

1.4 Small Cereals Research Program

Ongoing Projects

1.4.1 Wheat Stem Rust Surveillance in Eastern Ethiopia

Temam Hussien

Introduction

It is to be recalled that Haramaya University is a team member of the National Wheat Rusts Surveillance Project. The University is mandated to make surveys in the major wheat growing regions of eastern Ethiopia and report to the coordinator at Ambo Plant Protection Research Centre. Climate change, in terms of rising temperatures, and the timing and increasing variability of rainfall, is contributing to the spread and severity of rust diseases. Emerging races of rust are showing adaptations to extreme temperatures not seen before. Scientists around the globe are working on monitoring and surveillance (close watch) of stem and stripe rusts to ensure rapid detection and reporting so farmers, policymakers, and agricultural research centers can respond more quickly to initial outbreaks.

To combat the problem of wheat rusts, farmers in rust prone regions need to adopt new varieties of wheat that have durable resistance to both stem and stripe rusts. New rust resistant varieties are in the pipeline at international and national agricultural research centers. Breeders are selecting for other important characteristics including improved yield performance, drought tolerance, and regional suitability. Country preparedness for outbreaks of wheat rusts involves such issues as the availability of resistant varieties that are known to and accepted by farmers, the availability of sufficient quality seeds of new varieties for farmers to use, and the availability, accessibility and affordability of effective fungicides and capacity of farmers to use them.

In most cases, the bottleneck to getting resistant varieties into the field in time to protect local harvests is local capacity and the ability of national programs to rapidly multiply seeds and deliver them to market. Improving country capacity requires long-term planning, funding, and getting farmers involved earlier in the variety selection process. There is a need for enhancing in-country capacity of the breeding, seed and extension systems to continuously ensure that new, highly productive and genetically diverse resistant varieties are available and accepted by farmers to meet the challenges

of changing rust virulence. Coordination and timely information sharing among all the stakeholders from surveillance and plant protection officers to wheat breeders, seed system, extension agents, and farmers are necessary.

Directed, optimized mitigation of the threat of stem and yellow rusts to resource poor farmers cannot be achieved without vigilant monitoring of the incidence and nature of stem rust in countries thought to be Ug99-free today, and in those where Ug99 is already established. The stark fact is that today, we do not know how far Ug99 or its derivates have migrated. Lack of this knowledge impedes resolution and adoption of appropriate national and international policies, investments, and strategies in plant protection, plant breeding, seed systems, and research on the stem rust pathogen. It is insufficient to predict the pathways by which the Ug99 lineage will migrate, since mutation and sexual recombination (especially in East Africa and Central Asia where the alternate host is endemic) will spawn new variants; variants whose characteristics may dictate changes in gene deployment strategies in both the choice of gene combinations used by breeders, and in the distribution and retirement of varieties by national seed sectors. Such variants can arise anywhere, not just East Africa.

Currently, however, no framework exists for acquiring and sharing data on incidence, severity, and genetic composition of stem rust infections in the developing world. Likewise, there is no singular source of information on the spatial and temporal distribution of wheat (or wheat varieties) in these regions through the course of a year. Combined, these deficiencies preclude directed, efficient action by scientists and policy makers tasked with mitigating the threat to cereal production posed by wheat stem rust.

Materials and Methods

Survey sites

Surveys of wheat fields were carried out in East and West Hararghe zones' major wheat growing areas from 7 to 15 November 2011 to check status of wheat rusts with emphasis on stem rust.

The field survey was carried out along the following survey routes:

Haramaya→Kersa→Lange→Kullubi→Chelenko→Kobo→Dedder→Karamekela→Harawacha→Mole→Masa→Mesela→Hirna

Hirna→Bedessa→Wachu→Harar

Harar→Kurfachelle→Gurawa→Harar

Harar→Kombolcha→Jarso

Harar→Jigjiga→Chinaksen→Haramaya

Survey Methodology

Surveys were carried out along the main roads and wheat fields were observed at intervals of approximately 15 to 20 km. Geographic locations, approximate sizes of fields and wheat growth stages were first recorded. Following this, plants were inspected for symptoms of wheat rusts (stem/black, leaf/brown and yellow/stripe rusts) by walking in a zigzag manner starting from one to the other side of each field. Disease incidence (proportion of plants infected expressed as percentage of the total plants assessed) was determined on 100 plants/field that were scored as either diseased or disease free. Disease severity (percentage of plant part infected) was recorded using the Modified Cobb Scale on 10 randomly selected plants per field.

Results and Discussion

The surveyed areas were situated between 09°02.223´ to 09°32.061´ N latitude and 040°54. 436´ to 042°44.457´ E longitude (Table 1.8). The altitude of the surveyed areas ranged from 1664 to 2739 m.a.s.l. In the majority of the surveyed fields, wheat plants were between growth stages 7 and 9 (grain dough to ripening stages) on the growth stage scale suggested by Zadoks and co-workers (Zadoks et al., 1974). The approximate sizes of the surveyed fields ranged from 0.1 to 0.5 hectares. A total of 57 fields were observed, but data was recorded from 43 fields only.

Stem and leaf rusts were not encountered in all the fields inspected except traces of leaf rust on three cultivars in the East African Disease Trap Nursery. Yellow rust was encountered in fields located at $\geq$2400 m.a.s.l. with severities ranging from trace to 40S particularly on the improved variety named Kubsa (HAR 1685). The absence of stem and leaf rusts and low severity of yellow rust could be attributed to unfavourable environmental conditions. Several reports have indicated that wheat rust diseases are severe only in years when conditions are unusually favourable, susceptible varieties are grown, cultural practices are altered, or when the above conditions occur in combination. The range of temperatures that favour the development of stem, leaf and yellow rusts are 15-30°C, 15-25°C, and 10-15°C, respectively. According to earlier reports, under Ethiopian conditions, the rusts infect wheat late in the season, but if favourable conditions prevail and susceptible varieties are grown, early infections are possible.

Recommendation

In general, during the 2011/2012 main crop season, the weather particularly the relatively dry condition that prevailed during the season seems to have been unfavourable and suppressed rust development. Due to this severity of stem, leaf

and yellow rusts was very low. In the future, the rust infections need to be correlated with the weather data particularly temperature, moisture and relative humidity.

Table 1.8. Wheat rusts distribution in the major wheat growing areas of Hararghe in 2011 main cropping season

District	Location Name	Altitude (m)	Latitude	Longitude	Stem rust		Leaf rust		Yellow rust	
					Incidence	Severity	Incidence	Severity	Incidence	Severity
Chinaksen	Almale	1980	09°29.441'	042°38.796'	0	0	0	0	0	0
Chinaksen	Yugyug	2008	09°32.061'	042°32.223'	0	0	0	0	0	0
Chiro	Arberekete	2264	09° 02.223'	040°54.436'	0	0	0	0	0	0
Deder	Obi	2406	09° 18.852'	041°25.963'	0	0	0	0	0	0
Deder	Chafégurmu	2425	09°17.400'	041°23.307'	0	0	0	0	0	0
Deder	Waltebudim	2554	09° 16.468'	041°21.161'	0	0	0	0	0	0
Deder	Lemenwattaha	2739	09° 12.525'	041°20.268'	0	0	0	0	0	0
Diretayara	Hasangey	2060	09 ° 20.863'	042 ° 06.620'	0	0	0	0	0	0
Gurawa	Aradayaya	2494	09°12.027'	041°47.298'	0	0	0	0	100	40S
Gurawa	Hulajeneta	2485	09°09.885'	041°47.459'	0	0	0	0	100	20S
Gurawa	Hulajeneta	2490	09°08.891'	041°48.827'	0	0	0	0	100	20S
Haramaya	Haramaya Univ.	2031	09 ° 25.178'	042 ° 02.199'	0	0	3	tr	0	0
Jarso	Ifajalala	2495	09°29.210'	042°12.878'	0	0	0	0	0	0
Jarso	Ararsa	2556	09°29.292'	042°14.878'	0	0	0	0	0	0
Jarso	Afugug	2538	09°29.731'	042°18.170'	0	0	0	0	0	0
Jarso	Afugug	2535	09°27.340'	042°14.502'	0	0	0	0	1	tr
Jarso	Afugug	2534	09°29.276'	042°14.094'	0	0	0	0	2	tr
Jarso	Galtakke	2491	09°29.196'	042°12.850'	0	0	0	0	1	tr
Jijiga	Umerjey	1736	09°24.237'	042°44.457'	0	0	0	0	0	0
Jijiga	Wataharta	1740	09°24.457'	042°44.138'	0	0	0	0	0	0
Jijiga	Sugdug	1664	09°07.015'	042° 04.865'	0	0	0	0	0	0
Kersa	Metekoma	2133	09°26.856'	041°50.320'	0	0	0	0	0	0
Kersa	Yabetaleucha	2133	09°26.858'	041°50.322'	0	0	0	0	0	0
Kersa	Lencha	2019	09°26.433'	041°46.507'	0	0	0	0	0	0
Kersa	Unidentified	2128	09°26.870'	041°50.022'	0	0	0	0	0	0
Kombolcha	Tula	2186	09°23.853'	042°06.439'	0	0	0	0	0	0
Kombolcha	Waramohammed	2447	09°29.004'	042°12.461'	0	0	0	0	0	0
Kombolcha	Waramohammed	2452	09°28.999'	042°12.458'	0	0	0	0	0	0
Kurfacele	Jirubalina	2405	09°14.055'	041°48.818'	0	0	0	0	0	0
Kurfacele	Odagudina	2519	09°12.495'	041°48.830'	0	0	0	0	0	0
Kurfacele	Jirubelina	2397	09°14.052'	041°48.802'	0	0	0	0	0	0
Kurfacele	Rasajenata	2491	09°12.402'	041°48.049'	0	0	0	0	0	0
Melkabelo	Burkanegaya	2630	09° 10.291'	041°18.387'	0	0	0	0	0	0
Melkabelo	Odabelina	2421	09° 13.879'	041°48.731'	0	0	0	0	0	0
Mesala	Bahabiftu	2436	09° 07.682'	041°13.388'	0	0	0	0	0	0
Mesala	Lubudekeb	2341	09° 04.520'	041°09.705'	0	0	0	0	0	0
Mesala	Burka	2169	09° 04.778'	041°08.856'	0	0	0	0	0	0
Meta	Hawibilisuma	2313	09°26.405'	041°42.609'	0	0	0	0	0	0
Meta	Chelenkolola	2142	09°24.954'	041°37.030'	0	0	0	0	0	0
Meta	Dursitubilisuma	2239	09°24.612'	041°35.862'	0	0	0	0	0	0
Tullo	Odabalena	1797	09°13.108'	041°06.483'	0	0	0	0	0	0
Tullo	Odanegaya	1818	09°13.151'	041°06.430'	0	0	0	0	0	0
Tullo	Tarkanfata	2207	09°10.955'	041°03.236'	0	0	0	0	0	0

1.4.2 East African Wheat Rusts Trap Nursery (EAWRTN)

Temam Hussien

Introduction

East Africa Wheat Rusts Trap Nursery (EAWRTN) was previously (2007-2010) known as Ethiopian Wheat Rusts Trap Nursery (EWRTN). But later it was changed to EAWRTN as three East African countries, i.e., Kenya, Tanzania and Uganda became participants in this program as of the 2011 cropping season. The main objective of the EAWRTN is to monitor prevailing virulences of the pathogens causing leaf, stem and yellow rusts and effectiveness resistance genes.

Materials and Methods

This nursery included 146 entries grouped into four sets (See Table 1.9, set II is not presented)
Set I: 45 commercial varieties,
Set II: 17 yellow rust differentials (to be grown in yellow rust hot spot areas),
Set III: 42 stem rust differentials (to be grown in stem rust hot spot areas), and
Set IV: 42 leaf rust differentials (to be grown in leaf rust hot spot areas).
Set II which consist of 17 yellow rust differentials was not grown at Haramaya University main campus site because this site is not considered hot spot for yellow rust. During the 2011 main crop season, EAWRTN was planted on Haramaya University Main Campus Research Site traditionally known as *Rare*. Each entry was planted in two rows of one meter long and 20 cm apart. Diseases were recorded using the Modified Cobb Scale which has two parameters: disease severity (percentage of rust infection of the plant) and plant response to infection (type of infection).
The disease severity was expressed as percent (ranging from 0 to 100) of rust infection of the plant. The numbers are always multiples of five, i.e., 0, Tr (trace level), 5, 10, 15….95, 100, N (when the plant is completely dead). The infection types were expressed as follows: 0 = Immune, R= Resistant, MR= Moderately Resistant, MR-MS = Both Moderately Resistant and Moderately Susceptible but the MR frequency is higher in the plant, MS = Moderately Susceptible and S= Susceptible. Disease records included both the severity and the type of infection (host response) as shown in the examples given below:
TrR: Trace level of % rust infection with resistant plant response,
10MR: 10% of rust coverage (severity) and moderately resistant host response,
40S: 40% of rust coverage (severity) and susceptible host response

Results and Discussion

Effectiveness of commercial varieties in controlling the three rusts

Seventeen (38%) of the commercial varieties were immune from leaf, stem and yellow rusts. However, when individual rust is considered, 56% of the commercial varieties were immune and 44% showed traces of infection to leaf rust. Eighty percent of these varieties were immune while 20% showed traces of stem rust infections. Similarly, 69% of these varieties were free and 31% indicated traces of yellow rust infections. The virulence of the three rusts on the commercial varieties was very low during the 2011 main cropping season. It seems that the commercial varieties were effective in controlling the three rusts. However, a one year's data cannot be conclusive. Therefore, the study must be repeated in the 2012 cropping season for proper conclusion.

Prevailing virulence of the pathogen causing leaf, stem and yellow rusts

When virulence of the pathogens causing leaf, stem and yellow rusts were considered, only trace infections of the three rusts were detected. However, the data was insufficient to draw conclusions.

Recommendation

The study must be repeated for at least one year.

Table 1.9. Varieties included in East Africa Wheat Rust Trap Nursery

Set I. Commercial Varieties

Entry No.	Variety	Yellow rust scoring	Stem rust scoring	Leaf rust scoring
	Thai	0	0	0
	Gassay	0	0	TrR
	Senkegna	TrR	0	0
	Dega Menz Bollo	0	0	0
	Menze	TrR	0	0
	Sulia	TrR	0	0
	Enseno	0	0	0
	Bako-1	0	0	TrR
	Bako-2	0	0	0
	PBw343	TrR	0	TrR
	Mada Wollabu	0	0	0
	Sofummer	0	0	0
	Ude	0	TrR	0
	Yerer	0	0	0
	Digelu	0	0	TrR
	Millennium	0	0	0
	KBG01	TrR	0	TrR
	Danphe	0	0	0
	Picaflor	0	0	0
	PBW343	0	TrR	0
	Morocco	TrMs	TrR	TrMs
	Flag-5	0	0	TrR
	Tusie	0	0	0
	Enkoy	TrR	0	TrR
	Pavon-76	0	0	TrMR
	Kubsa	0	0	0
	Galama	0	0	TrR
	KENYA KUDU	TrR	TrMs	TrR
	KENYA PLUME	TrR	0	TrR
	ET 13A2	0	0	0
	PBW343	TrR	TrMs	TrR
	K62954A	0	0	TrR
	Dashen	0	0	TrR
	HAR719	0	0	0
	HAR723	TrR	0	TrR
	HAR 934	TrMs	0	TrR
	HAR743	0	0	0
	HAR733	TrR	0	0
	HAR820	0	0	TrR
	Meraro	TrR	0	0
	PBW343	0	0	0
	Morocco	TrR	0	TrR
	Abola	TrR	0	0
	Shorima	0	0	TrMs
	ETBW 5496	0	0	0

Set III. Stem rust differentials

Entry No.	Stem Rust Differentials	Stem rust scoring
1.	ISR8ARA	0
2.	BARLETA BENVENUTO	0
3.	W2691SR9B	TrR
4.	VERNSTEIN	0
5.	ISR5SB	TrR
6.	CNS (TC2B)/LINE E	0
7.	W2691SR10	TrR
8.	ISR11RA	0
9.	CH.SP. (TC3B)	0
10.	PBW343	TrR
11.	W2691SR13	0
12.	LINE A SELN.	0
13.	W2691SR15NK	0
14.	COMBINATION VII	0
15.	Cham 8	0
16.	SWSR22T.B.	TrR
17.	SeRi 82	0
18	EAGLE	0
19.	W2691SR28KT	0
20.	PBW343	0
21.	Morocco	TrR
22.	PUSA/EDCH	TrR
23.	BTSR30WST	0
24.	LINE E/KVZ	0
25.	CNS SR32 AS	TrR
26.	TETRA CANTHTCH/Ag. SQUARROSA (RL5045)	0
27.	MQ (2)5*G2919	0
28.	W3763	0
29.	W2691 SRTT1	TrR
30.	W2691 SRTT2	0
31.	PBW343	TrR
32.	FED.*2/SRTT3	0
33.	MEDEA AP9D	0
34.	BTSRGAMUT	0
35.	PELISS	TrR
36.	BT/WLD	TrR
37.	H44 DERIV	TrR
38.	ENTRELARGO DE MONTIJO (W3560)	TrR
39.	TAF-2	TrR
40.	MARQUIS (W2)	0
41.	PBW343	TrR
42.	Morocco	TrR

Set IV. Leaf rust differentials

Entry No.	Leaf Rust Differentials	Leaf rust scoring
1.	THATCHER	TrR
2.	TC*6/CENTENARIO (RL6003)	0
3.	TC*6/WEBSTER (RL6016)	TrR
4.	TC*6/CARINA (RL6019)	TrR
5.	TC*6/DEMOCRAT (RL6002)	0
6.	TC* ANIVERSARIO (RL6007)	TrR
7.	TRANSFED/6*TC (RL6010)	0
8.	TC*6/EXCHANGE (RL6004)	TrR
9.	HUSSAR (W976)	0
10.	PBW343	TrR
11.	MANITUOU	0
12.	SELKIRK/6*TC (RL6013)	TrR
13.	TC*6/MARIA ESCOBAR (RL6006)	TrR
14.	TC*6/KENYA1483 (RL6052)	TrR
15.	TC*6/EXCHANGE (RL6005)	0
16.	KLEIN LUCERO/6*TC (RL6008)	TrR
17.	TC*7/AFRICA43 (RL6009)	0
18.	TC*7TR (RL6040)	0
19.	THEW (W203)	TrMR
20.	PBw343	0
21.	Morocco	TrMS
22.	TC*6/RL5406 (RL6043)	0
23.	TC*6/RL5404 (RL6044)	0
24.	LEE310/6*TC (RL6012)	TrMR
25.	TC*6/AGENT (RL6064)	0
26.	TC*?/TRANSEC	0
27.	TC*6/ST-1-25 (RL6078)	TrR
28.	GATCHER (W3201)	TrMS
29.	CS2D-2M	0
30.	TC*6/CS7AG#11 (RL6080)	0
31.	PBW343	TrR
32.	TCLR32 (RL5497)	TrR
33.	TC*6/PI58548 (RL6057)	0
34.	TC*6/PI58548 (RL6058)	0
35.	RL5711	0
36.	E84018(NEP/AE.SPELTOIDES 2-9-W//5*NEPT/3/3*MITU)	0
37.	TC*6/VPM (RL6081)	TrR
38.	TC*6/CARINA (RL6051)	0
39.	WL711	TrR
40.	GAZA (W277) (DuRuM)	0
41.	PBw343	0
42.	Morocco	TrR

1.5 Common Bean Research Programme

Bulti Tesso and Yonas Moges

Introduction

The lowland pulse research program of Haramaya University have the mandate of developing lowland pulse technologies (variety development, agronomic, crop protection and socioeconomic) for eastern Ethiopia. The program focuses on common bean as 95% of the national lowland pulse research program focuses on the same crop. However, research on cowpea has also been conducted at regional as well as national level. Despite the importance of common bean in this region, its productivity is constrained by different biotic and abiotic factors. Moisture stress in the lowlands such as Babile and Fedis, and high severity of different fungal and bacterial diseases in the high potential areas such as Haramaya, Hirna and similar environments, are the major factors that limit bean production in the region.

The bean research program of Haramaya University has been conducting regional variety trials on the major common bean market classes for the last two decades to develop high yielding, disease resistant, and moisture stress tolerant varieties that also meet the consumers' and market criteria. These variety trials are conducted at four research stations (Haramaya, Hirna, Babile, and Fedis) that represent the different bean production environments of east and west Hararghe zones. The major bean market classes preferred in the region are small reds, large seeded beans, red mottled beans, and white pea (navy) beans, where the latter is mainly produced for market.

In variety development efforts made hitherto, six common bean varieties that fulfil the aforementioned breeding objectives have been released between 1997 and 2008. As a continuation of this variety development process, six candidate varieties were verified on farmers' fields at several representative localities in 2011 main rainy season. The national variety release committee evaluated these candidate varieties on verification plots by October 2011 in accordance with the national variety release procedure. This report presents the results of the on farm and on station evaluated candidate varieties and the four sets of regional variety trials and brief descriptions of the new activities proposed for 2012 main rainy season.

Objectives

General

- Increasing common bean production and productivity and thereby contribute to enhanced food security and poverty reduction in Ethiopia in general and in eastern Ethiopia in particular.

Specific

- To develop and promote high yielding and multiple stress resistant common bean varieties with desirable agronomic practices, and acceptable quality for food and market.
- To demonstrate and promote common bean protection technologies for eastern Ethiopia.
- To develop improved common bean technologies for the mid and lowland areas.

Ongoing Activities

1.5.1 Regional Variety Trials

Four sets of replicated variety trials, representing four different market classes of bush beans, were planted and evaluated at four different locations in eastern Ethiopia. The trials were planted in mid to late July 2011 at all locations because of late onset of rainfall. Ten to 13 genotypes selected from the respective pre-regional variety trials in 2010 were included in each trial along with the standard checks. RCBD with three replications was used to conduct the trials at each location. The trials are described in Table 1.10.

Table 1.10. Description of common bean regional variety trials

Trial title	Market class represented	No. of genotypes	No. of replications	No. of locations*
Red Mottled Bean Variety Trial	Red mottled	10	3	4
Speckled Bean Variety Trial	Cream/speckled	10	3	4
Large Red Bean Variety Trial	Large red kidney + large round red	10	3	4
Small Red Seeded Bean Variety Trial	Small red	13	3	4

**The test locations are Haramaya, Hirna, Babile, and Fedis research stations*

The four test locations were selected to represent the major bean growing areas of eastern Ethiopia, and vary widely with regard to the biotic and abiotic factors constraining bean production in the region. Babile and Fedis stations are characterized by low amount and erratic distribution of rainfall **(**but this was not the problem this year**)** as well as low soil fertility, while Hirna and Haramaya stations are characterized by moderate to high rainfall and fertile soils. Hirna and Haramaya are hot spot areas for most bean diseases, mainly for CBB, anthracnose, ALS, rust and halo blight. This gave us the opportunity to screen genotypes for drought resistance/tolerance, tolerance to low soil fertility (N & P), and for resistance to common bean diseases. Compared to the past years, the 2011 planting season provided a unique opportunity for screening genotypes for resistance/tolerance to disease, bean stem maggot, and excessive rainfall. Despite its late onset, the rain continued without interruption from planting up to pod filling on daily basis. Due to this, there was problem of water logging (especially at Haramaya and Hirna), heavy stem maggot infestation, and high severity of CBB at all locations. Generally, except for rust, which did not occur during the season, the genotypes in all trials showed clear genotypic variations for disease resistance and overall performance under the excess rainfall condition of this year (see Figure 1.1).

Figure 1.1. Common Bacterial Blight (CBB) - a clear contrast between resistant and susceptible genotypes at Haramaya (*Haramaya University Campus*): *Photo taken on September 18, 2011*

Highlights of Results

Data collection was completed on disease reaction and pertinent agronomic traits including yield at all locations and for all trials. Potential genotypes were identified from each trial (market class) based on disease resistance, grain yield and overall performance at the four research stations. However, the trials will be repeated in the 2012/13 cropping season to fulfill the number of environments required to release varieties (a minimum of 3 locations for a minimum of two years).

1.5.2 Collaborative National Yield Trials (Ongoing activities)

Six national and two pre-national variety trials constituted from bush beans of different market classes were planted at Haramaya research center in July 2011. The pre-national variety trials consisted of 25 genotypes each, while 12 to 16 genotypes were included in the national variety trials. The trials represent the major market classes important in Ethiopia, including red mottled, medium and large reds, small reds, medium and large whites, navy, and cream-speckled types. The genotypes in each trial were critically evaluated for disease reaction and other agronomic traits. As the season was conducive for disease development, except rust, resistant and susceptible genotypes were clearly differentiated. Moreover, some genotypes in the National Variety Trials sent from Melkassa were completely killed by BCMV at Haramaya (Figures 1.2). In addition to critical evaluation for disease reaction and overall performance in the field, data were collected on pertinent agronomic traits including grain yield.

Figure 1.2. A genotype highly susceptible to BCMV in National Variety Trial at Haramaya (Photo taken on September 18, 2011)

Highlights of Results

High yielding and disease resistant genotypes that showed better overall performance under the prevailing edaphic and climatic condition of Haramaya were ranked and selected from each market class. These will be included in multi-location yield trials and will be tested at four research stations in eastern Ethiopia for the next two years (2012- 2014) to identify and release new varieties with better adaptation to environmental stresses.

Completed Activities

1.5.3 On-farm and On-station Verification of Candidate Varieties

Six candidate varieties that have been recommended for release, based on their superior performances in three different regional variety trials at four locations over three years (2008-2010), were planted at nine on-farm and four on-station sites (*i.e.,* a total of 13 sites) for final verification. At each site, the candidate varieties were planted on plot sizes of 100 m^2 along with their respective standard checks. Farmers (women and men) have evaluated and ranked the candidate varieties based on their preference criteria. Moreover, a technical committee composed of breeders, pathologists, and experts from the Federal Ministry of Agriculture and Rural Development was sent from the national variety release committee to evaluate the performances of these candidate varieties in accordance with the variety release policy of Ethiopia. The candidate varieties proposed for release were the following:

Red mottled: ECAB 0023, ECAB 0060 & K-132

Large Red Kidney: ECAB 0247, ECAB 0203, & RXR- 10

The committee had critically evaluated the varieties in October 2012 and presented its comprehensive report on the national variety release standing committee annual meeting, which was held from 15 – 17 March 2012 in Addis Ababa. In its report, the committee has recommended five of the six proposed varieties for full release. The national variety Release Standing Committee has also accepted the technical committee's recommendation and approved the full release of the five varieties. From the proposed candidate varieties, ECAB 0023 was rejected due to its small seed size, though it is acceptable with regard to all other traits. The released five varieties are given below along with their descriptions (Table 1.11).

Table 1.11. Major characteristics of improved common bean varieties

Variety name				Days to			Yield (kg)	
Original designation	Assigned local name	Growth habit	Market class	50% flowering	Days to maturity	100 SW (g)	On research field	On farmers' field
RXR-10	Tinike	Type- IIa	Large Red Kidney	47	91	42.1	2000- 3000* 1000- 2100**	1500-2500
K-132	Hundane	Type- IIb	Red Mottled	46	91	40.7	2200-3000* 1200-2000**	1500-2000
ECAB-0060	Fedis	Type- IIa	Red Mottled	47	93	47.31	2300-3600* 1000-2500**	1000-2200
ECAB-0247	Babile	Type-IIa	Large Red Kidney	48	91	40.7	2400-3500	1500-3000
ECAB-0203	Hirna	Type- IIa	Large Red Kidney	48	92	45.69	2300-3400	1600-3000

**Yield at potential areas (Haramaya and Hirna) **Yield at moisture stress areas with low soil fertility (Babile and Hirna)*

Origin and pedigree
These varieties were originally introduced from CIAT/Tanzania through the East and Central African Bean Research Network (ECABREN) and had gone through multi location trials in the eastern parts of the country. The test results showed that they are best varieties for regional release.

Germplasm Maintenance
In addition to the activities described, about 200 germplasm lines have been planted for maintenance. Seed samples of past nurseries (germplasm/breeding lines) that may have potential future use have been kept in our seed store over the last many years. These were planted this year to produce fresh seed samples to avoid loss of viability.

Seed Multiplication
Six common bean varieties released by Haramaya University were planted at Haramaya research center for seed production (Table 1.12 and Fig 1.3).

Table 1.12. Amount of common bean breeder seed produced during 2011 main rainy season

Variety	Market class	Breeder seed produced (kg)
Gofta (G-2816)	Cream (Mulatinho)	300
Ayenew (GLP x 92)	Pinto	250
Chercher (STTT-165-96)	Navy	200
Haramaya (G-843)	Cream (Mulatinho)	230
Kufanzik (MX-8754-9M)	Pinto	250
Dursitu (G-811)	Small red	260

Figure 1.3. A partial view of breeder seed production field at Haramaya University campus: photo taken on September 18, 2011.

1.5.4 Collection, Characterization, Screening for Effectiveness of Native Rhizobia Strains and Field Testing of Effective Strains for Nitrogen Fixation on Common Bean Genotypes

Anteneh Argaw

Highlights

Native rhizobia strains collection and characterization
Native rhizobia strains were collected from bean fields in diverse agroecologies of Ethiopia and characterized in microbiology laboratory of Haramaya University in 2010.

Preliminary evaluation of rhizobia strains for effectiveness

The characterized rhizobia strains were inoculated to different bush bean genotypes in green house and in laboratory growth chambers to identify effective strains for biological nitrogen fixation potential. Based on the green house and laboratory results, ten best strains were selected for testing on common beans in the field.

Field experiment

The ten most effective rhizobia strains that were selected based on preliminary green house and laboratory inoculation tests were used for replicated multi-location field experiment. The rhizobia strains were inoculated to three bush bean varieties in factorial arrangement using randomized complete block design (RCBD) with three replications. Non-inoculated plots of the three genotypes were included as controls. The experiment was planted in July 2011 at two locations (Haramaya and Fedis research centers).

The bush bean varieties used for the field inoculation experiment are Mx 8754-9M, G-2816, and DOR 811, which represent early, medium, and late maturity groups, respectively. Mx 8754-9M (*Kufanziq*) represent pinto market class with Type IIIa growth habit; G-2816 (*Gofta)* represent cream-mulatinho market class with Type IIIb growth habit, while DOR 811 (*Dursitu*) is small red and represent Type IIa growth habit. Data on nodule count (total and effective nodules per plant) and other important agronomic traits including yield have been collected. Based on the obtained preliminary information, a new proposal has been drafted as "Integrated Soil Fertility Management" and submitted to the Pan African Bean Research Alliance (PABRA) for funding.

Constraints

The major constraints of the bean research program are the following.

1. Lack of seed storage: one small building is shared with the highland pulse research program. The germplasms introduced do not stay more than a year because of suffocation and over crowdedness.
2. Shortage of vehicle: this problem is evident at the pick periods, mainly at planting, data collection and harvesting times when all research programs compete for the limited number of vehicles.
3. Lack of office: the program does not have office for the technical and field assistants.

Acknowledgement

The successful completion of the reported completed trials was due to the hard work of Ms. Woinshet Feleke, a hardworking and experienced field assistant. These trials were conducted by the financial support we obtained from ECABREN/PABRA through the CIAT-Uganda administration. I would like to extend sincere thanks to the CIAT Uganda Office, to ECABREN and to PABRA for their generous support. I am also very grateful to the national bean program of Ethiopia (Melkassa) for the support provided to us, and for the germplasm that we have been getting. Finally, we would like to forward our sincere thank to the office of the Research and Extension of Haramaya University, for enabling us to accomplish our routine research activities as planned by providing vehicle and other facilities.

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1.6 Maize Improvement and Technology Generation Project

Habtamu Zeleke

Activity Report of the Period 2011/2012 Cropping Season

Introduction

Maize (*Zea mays* L.) is one of the world leading cereal crops. Maize being the highest yielding cereal crop in the world is of significant importance for countries like Ethiopia, where rapidly increasing population has already outstripped the available food supplies. In Ethiopia, during the year 2012, maize was grown on about 2.185 million hectares, resulting in total annual production of 6.5 million tons, with an average of 3.0 tons per hectare (CSA, 2012). It is a primary crop in majority of farming systems and staple food of the rural population in much of the mid-altitude sub-humid agro-ecology

of the country. Maize stands first in total production and productivity and, second in area coverage (22.2%) next to teff (28.4%) of all cereal crops cultivated in Ethiopia (CSA, 2012).

Given the potential the country, the total production and productivity of maize per unit area is very low compared with the yield levels per unit area attained in some major maize producing countries such as USA (10.3 tons ha^{-1}), Germany (9.7 tons ha^{-1}), and South Africa (4.96 tons ha^{-}) (FOASTAT, 2011). This calls for further improvement of maize management practices and also development of productive maize varieties with efficient nutrient use.

The maize research and extension program of the university has been working hand-in-hand with the National Maize Research and Extension for the past several years. As a result, it has been contributing in the development of improved maize technology for the Ethiopian farmers and that of the farmers of eastern Ethiopia.

In 2011/2012 cropping season, activities in areas of germplasm enhancement, variety development, variety verification, variety demonstration, and seed multiplication of two released varieties (Raare-1 and Gibe-1) have been conducted. The highlights of the results obtained are discussed as follows. The weather condition during the early stages of the 2011/2012 cropping season was conducive and the rainfall was good at planting, early seedling establishment period and at flowering with the exception of the scarce rainfall in the month of June.

Objectives

General

- Increasing maize productivity and production and thereby contribute to enhanced food security and poverty reduction in Ethiopia in general and in eastern Ethiopia in particular.

Specific

- To broaden the genetic base of maize germplasm for highland, mid-altitude and low altitude areas of eastern Ethiopia.
- To develop and promote high yielding, stress tolerant and widely/specifically adapted hybrids and open pollinated varieties with desirable agronomic practices and quality traits for food and feed.
- To develop improved maize protection technologies for mid and lowland areas.
- To renew and conserve breeding materials, to increase and maintain true to type breeder seeds.
- To demonstrate and promote improved maize technologies.

Breeding and Genetics

Germplasm enhancement

Success in maize improvement depends on the existence of genetic variability among the breeding materials for any trait of interest. Variability can be obtained from exotic and local sources as well as by the use of cross breeding and selection techniques. Experimental varieties (hybrids and OPVs) and inbred lines are generated in the breeding nurseries. Thus, availability of diverse germplasm is essential in a breeding program to guarantee the development of superior cultivars.

Objective

- To enhance the availability of elite germplasm for the development of improved varieties (both white and yellow hybrids and OPVs, non-QPM and QPM).

Germplasm maintenance

Activity 1: Maintenance of inbred lines
Activity 2: Maintenance of maize populations
Activity 3: Breeder seed multiplication

Methodology

One hundred twenty white seeded and 51 yellow seeded inbred lines were planted in two rows of 5.1 m length. The spacing between rows and between plants within the row was 0.75 m and 0.30 m, respectively. Off type plants from each line were strictly rouged out. Flowers of selected plants were isolated before pollen shed. Pollen was collected and dusted on the stigma and the pollinated plants were left covered until harvest.

Raare-1, Alemaya composite, Bukri, Alemaya popcorn and sweet corn were also planted in a plot of 20 m x 10 m. In each variety, flowers of about 200 plants were isolated by pollen and silk bags. Pollen was collected, bulked from the respective varieties separately and finally the isolated plants were pollinated by the bulk pollen. The pollinated plants were left isolated until harvest to secure genetic purity of the varieties.

1.6.1 Maintenance of inbred lines

Half to one kilogram of fresh and clean seed was obtained from the hundred 20 white seeded inbred lines and 51 yellow seeded lines. Part of the seeds will be used in the next season breeding nursery and part will be stored for maintenance.

1.6.2 Micro-seed Production for Maintenance of Maize Populations

Objective

- The objective was to increase the seeds of the genotypes for maintenance and for use in breeding programs.

Methodology

Nineteen early to late maturing maize varieties were grown during the season on a plot size of 10 m X 20 m in non-replicated trial. All recommended cultural practices were followed.

Highlights of Results

Ten to 15 kilograms of seed was obtained from each variety. These will be used in 2012/2013 cropping season.

1.6.3 Breeder Seed Multiplication

Objective

- The objective was to obtain fresh seeds of Raare-1, Al composite, Al popcorn-1976 and Al-sweetcorn.

Methodology

Raare-1, Alemaya composite, Al popcorn-1976 and Al-sweetcorn were planted in a non-replicated plot of size 20 m X 20 m. In each plot, about 200 plants were bagged by pollen (tassel) and shoot (ear) bags. Pollen collected from the respective varieties was bulked separately and used to pollinate that particular variety. All other cultural practices were followed as required.

Highlights of results

Ten to fifteen kilograms of Raare-1, Alemaya composite, Bukuri, Alemaya popcorn-1976 and Al-sweetcorn varieties were obtained.

1.6.4 Hybridization

Objective

- To produce SC yellow experimental hybrids.

Methodology

Yellow inbred lines were planted in a crossing block on a plot size of 3 mX 5.1 m with intra and inter row spacing of 25 cm and 75 cm, respectively. At flowering, selected lines were crossed using hand pollination technique.

Highlights of results

Sixty-three SC crosses of yellow experimental genotypes were obtained to be tested in 2012/13 cropping season (Table 1.13). From each cross, 0.25 to 0.5 ka clean seed was harvested.

Table 1.13. List of SC hybrids obtained during the season

No.	Cross	Type
1	CML-44 X CML-151	SC hybrid
2	CML-157 X AL99AL-79	SC hybrid
3	CML-44 X 157	SC hybrid
4	CML-157 X CML-151	SC hybrid
5	CML-157 X AL-195	SC hybrid
6	AL99CML-300 X CML-151	SC hybrid
7	AL99CML-300 X AL99AL-281	SC hybrid
8	AL99CML-300X TL-96A-1504-14	SC hybrid
9	AL99CML-39 X CML-44	SC hybrid
10	AL99CML-39 X AL99Al-281	SC hybrid
11	TL-96A-1503-31A X AL-162	SC hybrid
12	AL-149 X TL-96A-1503-31A	SC hybrid
13	CML-33 X TL-96A-1504-14	SC hybrid
14	AL99CML-300 X CML-272	SC hybrid
15	CML-272 X TL-96A-1504-14	SC hybrid
16	AL99CML-39 X CML-157	SC hybrid
17	AL-149 X TL-96A-1504-14	SC hybrid
18	CML-272 X AL99CML-39	SC hybrid
19	TL-96A-1503-31A X CML-28	SC hybrid
20	CML-28 X CML-151	SC hybrid
21	CML-44 X AL99CML-79	SC hybrid
22	AL99CML-39 X TL-96A-1504-14	SC hybrid
23	CML-28 X TL-96A-1503-31A	SC hybrid
24	TL-96A-1503-31A X CML-151	SC hybrid
25	AL-95 X TL-96A-1504-14	SC hybrid
26	CML-44 X AL99Al-281	SC hybrid
29	TL-96A-1504-14 X CML-151	SC hybrid
30	AL99Al-281 X CML-151	SC hybrid
31	CML-44 X TL-96A-1503-31A	SC hybrid
32	CML-149 X AL99AL-281	SC hybrid
33	AL99AL-281 X AL-162	SC hybrid
34	AL99CML-300 X CML-44	SC hybrid
35	All99CML-79 X AL99Al-281	SC hybrid
36	CML-44 X TL-96A-1503-31A	SC hybrid
37	CML-272 X AL-149	SC hybrid
8	AL99CML-39 XTL-96A-1504-14	SC hybrid
39	CML-151 X AL99Al-281	SC hybrid
40	CML-151 XCML-33	SC hybrid
41	AL99AL-281 X TL-96A-1504-14	SC hybrid
42	AL99CML-26 X TL-96A-1504-14	SC hybrid
43	TL-96A-1504-14 X AL-162	SC hybrid
44	AL99CML-79 X AL99AL-281	SC hybrid

45	CML-28 X AL-162	SC hybrid
46	CML-44 X CML-272	SC hybrid
47	AL99CML-79 X CML-151	SC hybrid
48	CML-151 X TL-96A-1503-31A	SC hybrid
49	AL99CML-79 X TL-96A-1503-31A	SC hybrid
50	AM99CML-300 X TL-96A-1503-31A	SC hybrid
51	AL-195 X TL-96A-1503-31A	SC hybrid
52	AL-162 X TL-96A-1503-31A	SC hybrid
53	AL99CML-26 X TL-96A-1504-14	SC hybrid
54	AL99AL-281 X TL-96A-1503-31A	SC hybrid
55	AL99AL-281 X CML-28	SC hybrid
56	CML-151 X TL-96A-1504-14	SC hybrid
57	TL-96A-1503-31A X TL-96A-1504-14	SC hybrid
58	CML-272 X TL-96A-1503-31A	SC hybrid
59	AL99CML-39 X CML-151	SC hybrid
60	CML-161 X AL99AL-281	SC hybrid
61	CML-161 X TL-96A-1503-31A	SC hybrid
62	CML-161 X CML-157	SC hybrid
63	CML-161 X TL-96A-1504-14	SC hybrid

Variety development

Experimental maize varieties which include OPVs and different types of hybrids (top cross, double top cross, single cross, three-way cross) are regularly formed in the breeding nurseries. These varieties will be organized into different sets of trials and tested for agronomic characteristics and their adaptation across locations within the mid and low altitude sub-humid agro-ecologies. Besides, the National Maize Research Project has a wealth of experience in hosting variety evaluation from different multinational private companies and local public seed companies. In the current project period too, the maize program will continue to evaluate these maize trials across locations, once they have gone through all the necessary steps to introduce and test the varieties. Thus, the objective is to evaluate and identify high yielding widely/specifically adapted maize varieties.

Experimental variety evaluation

1.6.5 Preliminary Variety Trials (PVTs) of Late and Intermediate Maturing Maize Hybrid Varieties (12).

Methodology

Twelve sets of trials have been conducted in this category. Each trial consisted of 18 - 72 entries that were planted in lattice design or RCBD depending on the number of entries included. The net plot size was 2 rows of 5.1m long with 30 cm and 75 cm intra and inter row spacing, respectively. During planting, two seeds were planted per hole, which was later thinned to one plant per hole. All the required agronomic management practices were done.

Highlights of Results

The main results obtained in each of the trials are discussed as follows.

PVT-2B (28 entries)

The analysis of variance indicated no significant difference between the entries for days to maturity and grain yield. However, highly significant difference among the entries was detected for plant height. The yield ranged from 5329.15-9852.90 kg/ha, with the lowest obtained from variety no. 13 and the highest from variety no. 8 (Table 1.14).

Table 1.14. Major findings of PVT-2B

	Pant height (cm)	Days to maturity	Yield (kg/ha)
Mean	190.00	176	7665.20
Range	170-210	171-179	5329.15-9852.90
Stat. sig.	**	-	-

PVT-2D (44 entries)

There was no significant difference among entries for days to maturity. However highly significant and significant difference among the entries was detected for plant height and yield, respectively. The yield ranged from 6516.81-10657.82 kg/ha, with the lowest obtained from variety number 13 and the highest from variety number 8 (Table 1.15).

Table 1.15. Major findings of PVT-2D

	Pant height (cm)	Days to maturity	Yield (kg/ha)
Mean	180	177	8440.50
Range	166-187	176-179	6516.81-10657.82
Stat. sig.	**	-	*

PVT-2E (42 entries)

There was no significant difference among entries for days to maturity, but there were highly significant differences for grain yield and plant height among enteries. The yield ranged from 8709 – 13963 kg/ha, with the lowest obtained from variety number 9 and the highest from variety 8 (Table 1.16).

Table 1.16. Major findings of PVT-2E

	Plant height (cm)	Days to maturity	Yield (kg/ha)
Mean	173	177	10750.00
Range	173-193.00	175-179	8709.90-13963.15
Stat. sig.	**	-	**

PVT-2F (18 entries)

Analysis of variance showed no significant difference among entries for days to maturity, grain yield as well as for plant height. The yield ranged from 6063 – 9582 kg/ha, with the lowest obtained from variety 12 and the highest from variety 6 (Table 1.17).

Table 1.17. Major findings of PVT-2F

	Pant height (cm)	Days to maturity	Yield (kg/ha)
Mean	160.20	177	7306.50
Range	143.30-183.30	176-178	6063.00-9581.90
Stat. sig.	-	-	-

PVT-2J (64 entries)

Analysis of variance indicated significant difference among entries for plant height and grain yield. The yield ranged from 5557.40 - 12671.40 kg/ha, which was produced by entry number 64 and entry number 13, respectively **(**Table 1.18**)**.

Table 1.18: Major findings of PVT-2J

	Pant height (cm)	Days to maturity	Yield (kg/ha)
Mean	175.60	177	5557.40
Range	155-210	175-179	5557.40-12671.40
Stat. sig.	*	-	**

PVT-2K (50 entries)

There was no significant difference among entries for days to maturity, however highly significant difference among the entries was detected for plant height and grain yield. The yield ranged from 5692 – 11536 kg/ha, with the lowest obtained from variety number 1 and the highest from variety number 31 (Table 1.19).

Table 1.19. Major findings of PVT-2K

	Pant height(cm)	Days to maturity	Yield (kg/ha)
Mean	176	176	9095.46
Range	140-195	174-177	9095.46-11535.54
Stat. sig.	**	-	**

PVT-2N (30 entries)

Analysis of variance indicated no significant difference among entries for days to maturity and grain yield, however highly significant difference among the entries was detected for plant height. The yield ranged from 5502-11399 kg/ha, with the lowest obtained from variety 10 and the highest from variety number 8 **(**Table 1.20**)**.

Table 1.20. Major findings of PVT-2N

	Pant height(cm)	Days to maturity	Yield (kg/ha)
Mean	176	176	9515.85
Range	150-193	174-182	5502.29-11397.86
Stat. sig.	**	-	-

PVT-2S (7 entries)

Analysis of variance indicated no significant difference among entries for days to maturity. However, highly significant difference among the entries was detected for plant height and grain yield. The yield ranged from 5502-11399 kg/ha, with the lowest obtained from variety number 10 and the highest from variety number 8 (Table 1.21).

Table 1.21. Major findings of PVT-2S

	Pant height (cm)	Days to maturity	Yield (kg/ha)
Mean	162	176	6918.00
Range	140-190	175-177	5620.35-8462.46
Stat. sig.	**	-	**

PVT-2V (72 entries)

There were significant differences among varieties for plant height and grain yield. The yield ranged from 2574-11340 kg/ha, with the lowest obtained from variety 20 and the highest from variety 18 (Table 1.22).

Table 1.22. Major findings of PVT-2V

	Pant height (cm)	Days to maturity	Yield (kg/ha)
Mean	158.80	177	7309.50
Range	110-210	176-178	2574.34-11340.01
Stat. sig.	*	-	**

PVT-2T (38 entries)

Varieties differed significantly in plant height and grain yield, indicating the existence of genetic difference for these traits. The yield ranged from 3138-10445 kg/ha, with the lowest obtained from variety number 20 and the highest from variety number 18 (Table 1.23).

Table 1.23. Major findings of PVT-2T

	Pant height (cm)	Days to maturity	Yield (kg/ha)
Mean	161.40	176	7328.90
Range	125-175	176-178	3137.50-10445.33
Stat. sig.	**	*	**

QPVT-2A (18 entries)
The analysis of variance showed significant difference among varieties for plant height and grain yield. The yield ranged from 4419-8595 kg/ha, with the lowest obtained for variety number 11 and the highest for variety number 18 (Table 1.24). In this set, none of the new entries out yielded the standard check, except entry number 10.

Table 1.24. Major findings of QPVT-2A

	Pant height(cm)	Days to maturity	Yield (kg/ha)
Mean	150.60	177	6149.59
Range	143.30-1667.70	176-178	4419.20-8594.60
Stat. sig.	*	-	**

1.6.6 NVTs-National Variety Trials (3) of White Late and Intermediate Maturing Non-QPM and QPM Hybrids

Objective
- To evaluate elite experimental varieties for yield and related traits.

Methodology
Ten to 30 entries selected from the non-QPM, and QPM preliminary variety trials were planted in RCB design replicated 3 times. Each genotype was planted on a plot size of two rows of 5.1m long with 30 cm within and 75 cm between rows. The trials were evaluated along with standard checks at Haramaya. All planned data were collected.

Highlight of Results
The results obtained in NVT-9A, NVT-8A and QNVT-8B is indicated as follows.

NVT-9A (13 entries)
Days to maturity and yield did not significantly differ among entries. However, significant difference among entries was detected for plant height. The yield range revealed that all the tested varieties have good yield potential. Eleven hybrids produced over 10 tons of grain yield per ha. The lowest yield was obtained from entry number 8 and the highest from entry number 3 (Table 1.25).

Table 1.25. Major findings of NVT-9A

	Plant height (cm)	Days to maturity	Yield (kg/ha)
Mean	234.4	178	11268.4
Range	220-253	177-179	9200.6-12872.5
Stat. sig.	**	-	-

NVT-8A (10 entries)
The analysis of variance indicated no significant difference among entries for grain yield. However, entries differed in plant height and days to maturity. Eight hybrids produced over 10 tons of grain yield per ha each indicating to be a potential candidate for future contemplated new hybrid(s). The lowest yield was obtained from entry number 7 and the highest from entry number 6 (Table 1.26).

Table 1.26. Major findings of NVT-8A

	Plant height (cm)	Days to maturity	Yield (kg/ha)
Mean	202.3	178.1	10786.3
Range	180-230	177-179	9715.8-11796.5
Stat. sig.	**	*	-

QNVT-8B (30 entries)
The analysis of variance revealed significant difference among entries for grain yield and plant height. Nine hybrids produced over 9 tons of grain yield per ha. This yield level for quality protein maize types is exceptional and one or two of these can be potential candidates for release. The lowest yield was obtained from entry number 23 and the highest from entry number one (Table 1.27).

Table 1.27. Major findings of QNVT-8B

	Plant height (cm)	Days to maturity	Yield (kg/ha)
Mean	162.0	178	8152.0
Range	136.7-193.3	?	5258.0-10669.5
Stat. sig.	**	-	**

1.6.7 Variety Verification Trial

Objective

- To present popcorn varieties to National Variety Release Committee for possible release.

Methodology

Standard methodology was followed as indicated in the National Variety Release guideline, i.e. the plot size was 10 m X 10 m = 100 m^2. Three were 13 rows per plot. The rows were spaced 0.75 m apart and the distance between plants within the row was 0.30 m. All other cultural practices were done as required. The locations were Haramaya University campus, Adele, and Tujigabissa peasant associations, the latter two being on-farm trials. Seeds were provided to 14 households to roast and evaluate the varieties and select their preferred variety using VERY GOOD, GOOD and FAIR to show the popping quality of the varieties.

Highlights of Results

Yield performance and popping quality performance of the verification have sown that the candidate varieties are acceptable. The yield of the two varieties is comparable (3813 and 4142 kg ha^{-1}, Table 1.28) which is a good yield level for popcorn. Moreover, on average both were evaluated by households as very good for their popping quality. The result is depicted in Tables 1.28, 1.29, and 1.30. The collected sample and user opinion are sent to the national coordinator so that the result can be compiled at national level and presented to variety release committee.

Table 1.28. Mean performance of candidate popcorn variety tested at Haramaya, eastern Ethiopia in 2011/2012 cropping season

	Traits						
Variety	PHT	EHT	Rust	Blight	PAS	EAS	GY/ha (kg)
Popcorn 2009	165	48	1.5	1	2	1.8	3812.93
Popcorn 2010	165	89	1.3	1	1.5	1.67	4141.73

PHT = Plant height (cm); EHT = Ear Height (cm); PAS = Plant aspect; EAS = Ear aspect and GY/ha = Grain yield/ha

Table 1.29. Results of popping ability evaluation of Var. Popcorn 2009 (HU 2012)

		Score		
Name	Evaluation by	Very good	Good	Fair
PPOCORN 2009	Family 1	√		
	Family 2		√	
	Family 3		√	
	Family 4	√		
	Family 5	√		
	Family 6	√		
	Family 7	√		
	Family 8	√		
	Family 9	√		
	Family 10	√		
	Family 11	√		
	Family 12	√		
	Family 13	Response not received		
	Family 14	Response not received		

Table 1.30. Results of popping ability evaluation of Var. Popcorn 2010 (HU 2012)

		Score		
Name	Evaluation by	Very good	Good	Fair
POPCORN 2010	Family 1	√		
(Improved)	Family 2	√		
	Family 3		√	
	Family 4		√	
	Family 5	√		
	Family 6	√		
	Family 7	√		
	Family 8	√		
	Family 9	√		
	Family 10	√		
	Family 11	√		
	Family 12	√		
	Family 13	√		
	Family 14	Response not received		

1.6.8 Highland Maize Variety Trials

Highland maize research project based at Ambo in collaboration with sister institutions in the country develop, evaluate, and release suitable varieties for highland agro-ecologies of the countries. With this aim, experimental varieties which include OPVs and different types of hybrids (top cross, double top cross, single cross, three-way cross) are regularly formed in the breeding nurseries and the formed varieties are organized into different sets of trials and tested for agronomic characteristics.

Objective

- The objective is to evaluate and identify high yielding widely/specifically adapted maize varieties for the highland agro-ecologies.

Methodology

During 2011/2012 cropping season, 13 sets of trials comprising of 22-36 entries were conducted. Each trial was planted in alpha lattice design replicated twice. Each plot consisted of one row with a row length of 5.1m. The distance between rows was 75 cm and between plants within the row was 30 cm. Planting was done when the soil moisture is optimum for germination and seedling emergence. Two seeds were planted per hole and later on seedlings were thinned to one plant per hole except the end holes where two plants were preserved until harvest. Other cultural practices were done as required.

Highlights of results

The highlights of results obtained in each set are discussed hereunder, except for AMB11PVT19-7 in which all the entries included produced significantly lower yield compared to the best check (Wonchi).

Highlights of results of AMB11, PVT1-7

Four varieties that are with similar yield potential as compared to the best standard check have been identified. These will be further tested in the coming season. These varieties produced 13044 to 14119 kilograms of yield per hectare (Table 1.31).

Table 1.31. Mean grain yield performance of four selected entries from AMB11PVT1-7

Entry No.	Yield kg/ha	% of the best check
7	14119.20	108.38
5	13246.51	101.68
9	13188.66	101.24
19	13044.05	100.13
22 (Best check)	13027.68	100.00

Highlights of results of AMB11PVT2-7

Four entries produced 11817 to 13108 kilograms of yield per hectare (Table 1.32). These yield level are not statistically different from that of the best check. These selected materials can be used in further breeding work.

Table 1.32. Mean grain yield performance of four selected entries from AMB11PVT2-7

Entry No.	Yield kg/ha	% of the best check
10	13108.35	103.79
13	12439.78	98.50
20	11952.78	94.64
2	11816.52	93.57
21 (Best check)	12629.09	100.00

Highlights of results of AMB11PVT3-7

Four entries that yielded similar grain amount as compared to the best standard check have been identified and these will be further tested in the coming season. These varieties produced 10805 to 11531 kilograms of yield per hectare (Table 1.33).

Table 1.33. Mean grain yield performance of four selected entries from AMB11PVT3-7

Entry No.	Yield kg/ha	% of the best check
14	11530.64	99.33
5	11421.04	98.38
12	11230.10	96.74
8	10804.71	93.07
22 (Best check)	11608.80	100.00

Highlights of results of AMB11PVT5-7

Four entries that gave statistically similar grain yield as compared to the best standard check have been identified. These varieties will be further tested in NVT trials. These varieties produced 13141 to 14544 kilograms of yield per hectare (Table 1.34).

Table 1.34. Mean grain yield performance of four selected entries from AMB11PVT5-7

Entry No.	Yield kg/ha	% of the best check
6	14544.31	110.96
18	14219.83	108.49
1	13412.51	102.33
7	13140.62	100.26
22 (Best check)	13107.15	100.00

Highlights of results of AMB11PVT8-7

Four entries that gave statistically similar grain yield as compared to the best standard check have been identified. These varieties will be further tested in NVT trials. These varieties produced 13059 to 13855 kilograms of yield per hectare (Table 1.35).

Table 1.35. Mean grain yield performance of four selected entries from AMB11PVT8-7

Entry No.	Yield kg/ha	% of the best check
3	13855.19	108.24
20	13543.38	105.81
13	13510.39	105.55
14	13058.75	102.02
22 (Best check)	12800.00	100.00

Highlights of results of AMB11PVT9-7

Four entries with yield potential similar or better than the best standard check have been identified for use in future breeding work or release as improved hybrid. These varieties produced 12050 to 13863 kilograms of grain yield per hectare (Table 1.36).

Table 1.36. Mean grain yield performance of four selected entries from AMB11PVT9-7

Entry No.	Yield kg/ha	% of the best check
13	13863.08	114.95
12	13024.09	108.00
20	12259.80	101.66
18	12049.69	99.92
22 (Best check)	12059.73	100.00

Highlights of results of AMB11PVT10-7

Four entries with yield potential similar or better than the best standard check have been identified for use in future breeding work or release as improved hybrid. These varieties produced 11209 to 12424 kilograms of grain yield per hectare (Table 1.37).

Table 1.37. Mean grain yield performance of four selected entries from AMB11PVT10-7

Entry No.	Yield kg/ha	% of the best check
4	12424.13	112.07
14	12361.82	111.51
7	11693.30	105.48
18	11209.08	101.11
22 (Best check)	11086.16	100.00

Highlights of results of AMB11PVT11-7

Four entries with yield potential similar or better than the best standard check have been identified for use in future breeding work or release as improved hybrid. These varieties produced 10342 to 12707 kilograms of yield per hectare (Table 1.38).

Table 1.38. Mean grain yield performance of four selected entries from AMB11PVT11-7

Entry No.	Yield kg/ha	% of the best check
10	12706.78	132.44
1	10998.32	114.63
12	10739.69	111.93
19	10341.83	107.79
21 (Best check)	9594.62	100.00

Highlights of results of AMB11PVT12-7

Four entries with yield potential similar or better than the best standard check have been identified for use in future breeding work or release as improved hybrid. These varieties produced 11498 to 12373 kilograms of grain yield per hectare (Table 1.39).

Table 1.39. Mean grain yield performance of four selected entries from AMB11PVT12-7

EntryNo.	Yield kg/ha	% of the best check
13	12373.33	104.61
20	11601.03	98.08
12	11598.40	98.05
1	11498.25	97.21
21 (Best check)	11828.59	100.00

Highlights of results of AMB11PVT13-7

Three entries with yield potential similar or better than the best standard check have been identified for use in future breeding work or release as improved hybrid. These varieties produced 10709 to 11700 kilograms of grain yield per hectare (Table 1.40).

Table 1.40. Mean grain yield performance of four selected entries from AMB11PVT13-7

EntryNo.	Yield kg/ha	% of the best check
19	11700.00	120.61
16	11089.15	114.31
6	10709.45	110.40
21 (Best check)	9700.75	100.00

Highlights of results of AMB11PVT17-7

Four entries with yield potential similar or better than the best standard check have been identified for use in future breeding work or release as improved hybrid. These varieties produced 7970 to 8348 kilograms of grain yield per hectare (Table 1.41).

Table 1.41. Mean grain yield performance of four selected entries from AMB11PVT17-7

Entry No.	Yield kg/ha	% of the best check
14	8348.33	102.9234
12	8184.11	100.8988
18	8150.89	100.4892
10	7970.21	98.26167
22 (Best check)	8111.21	100.00

Highlights of results of AMB11PVT23-7

Four entries with yield potential similar or better than the best standard check have been identified for use in future breeding work or release as improved hybrid. These varieties produced 10321 to 12941 kilograms of grain yield per hectare (Table 42).

Table 1.42. Mean grain yield performance of four selected entries from AMB11PVT23-7

Entry No.	Yield kg/ha	% of the best check
10	12940.95	130.81
13	12914.26	130.55
11	12416.00	125.51
14	10321.03	104.33
16 (Best check)	9892.57	100.00

Acknowledgement

I would like to thank all the technical and field assistants, particularly Mr. Degefa Gebissa and Mr. Elias Abrahim for their seriousness at work and quality data collection. Those who directly and indirectly contributed in the materialization of the project activities are also highly acknowledged.

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1.7 Highland Pulse Crops

Faba bean (*Vicia faba* L.)

Million Fikreselassie, Mekonen Dagne and Mekuanent Belay

Abstract: Six different sets of faba bean experiments were conducted at Haramaya University during the 2011 main cropping season with the objective of improving the productivity of faba bean through development of varieties tolerant/resistant to different constraints and suitable for cultivation in Eastern Ethiopia and to renew, increase and maintain true to type breeder seeds of released Gachena variety and make available for basic seed production. In the Preliminary Adaptation Trial, four materials which were superior to Gachena, (Moti, Gebelcho, Obse and Tumsa) were evaluated further and multiplied for utilization in East and West Hararghe. In the Regional Preliminary Variety Trial, there was significant difference among the tested genotypes regarding characters such as number of seeds per pod, thousand seed weight and seed yield. Six genotypes out yielded the standard check in terms of seed yield. In the National Variety Trial (Small seeded for wide adaptation), the trait thousand seed weight showed significant difference among the tested entries. Differences among the genotypes in terms of number of seeds per pod and per plant and thousand seed weight was significant in the National Variety Trial (Large seeded for wide Adaptation). The genetic purity of Gachena was maintained in Breeder Seed Multiplication and Maintenance experiment and the genetically purified seed will be delivered to the seed unit of the University for further pre-basic and/or basic seed production.

Keywords: Faba Bean; *Vicia faba* L; Pulse Crops; Eastern Ethiopia; Gachena

Introduction

Faba bean is one of the major pulse crops grown in the highlands (1800-3000 m.a.s.l.) of Ethiopia where the need of chilling temperature is satisfied. Faba bean is a crop of manifold merits for the farming communities in the highlands of Ethiopia. It serves as a source of food and feed with a valuable and cheap source of protein. It plays a significant role in soil fertility restoration as a suitable rotation crop that fixes atmospheric nitrogen. It is also good source of cash to the farmers, and generates foreign currency to the country. Despite the importance, the productivity of the crop is far below the potential due to several yield-limiting factors. The inherent low yielding potential of the indigenous cultivars is among the most important production constraint (Asfaw et al., 1994; Yohannes, 2000). Moreover, diseases and abiotic factors like water stress are important production constraints that deserve priority as breeding objectives (Gemechu et al., 2003).

It is obvious that the genetic modification of crops is preferred than the continual manipulation of environmental, particularly to the resource poor farmers who cannot afford the purchase of production inputs. The main objective of the faba bean research program was to improve the productivity of faba bean through the development of varieties tolerant/resistant to different constraints and suitable for cultivation under Eastern Ethiopia and to renew, increase and maintain true to type breeder seeds of released faba bean variety *'Gachena'* and make available for basic seed production. To meet the aforementioned objectives, different set of breeding experiments were conducted at Haramaya University during 2011/12 main cropping season. The brief account of the research methodology with the result of each experiment is discussed hereunder.

1.7.1 Faba Bean Preliminary Adaptation Trial

Materials and Methods

Seven recently released faba bean varieties collected from Ethiopian Institute of Agricultural Research with the check *Gachena*, were used. The treatments were laid in RCBD with two replications at Haramaya University research site. All pertinent agronomic data were collected as per the standard breeding procedure and the trial management was as per the recommendation.

Results

The mean performance of thirteen traits used for the eight commercial varieties is presented in Table 1.43. Analysis of variance showed significant difference ($P<0.05$) among the tested entries for the traits such as stand count, biomass yield and thousand seed weight indicating the existence of genetic variability among these commercial varieties. The highest thousand seed weight was recorded for *Gebelcho* (845.9g) and the lowest was for *Degaga* (517.9g) with the overall mean of 685g (Figure 1.4). Therefore, the materials can be used as a parent for crossing program to utilize the genotype efficiently.

Table 1.43. Mean performance of 8 commercial faba bean varieties during 2011 cropping season at Haramaya

Trt	*DF*	*DM*	*STD*	*Ch*	*Rust*	*Lodg*	*PH*	*PPPl*	*Spp*	*SPPl*	*BMY*	*TSW*	*SYLDH*
Moti	29.5	71	65	4.00	2.50	1.50	130.50	7.80	2.90	22.60	14.90	801.35	3200.00
Gebelcho	31.5	70	54	4.00	3.00	1.00	134.50	6.70	2.69	17.90	19.00	845.95	3000.00
Obse	30	72	65.5	4.00	4.00	1.00	136.00	6.80	2.75	18.80	18.10	705.15	2975.00
Tumsa	28.5	68.5	78	3.00	5.00	1.00	132.50	7.40	2.68	20.60	19.00	777.35	3150.00
Degaga	30	71	70.5	3.00	4.00	1.50	127.50	9.20	2.92	25.90	15.00	517.95	2500.00
Dosha	28.5	69	86	3.00	5.00	1.00	119.50	8.40	2.93	24.70	12.70	767.90	1950.00
Cs20DK	30	72.5	80	4.00	2.00	1.00	131.50	7.30	2.50	18.20	16.60	520.15	2750.00
Gachena	30.5	69	79.5	3.00	3.00	1.00	130.50	5.90	2.83	16.70	16.50	546.10	2950.00
Mean	29.81	70.38	72.31	3.50	3.56	1.13	130.31	7.44	2.77	20.68	16.48	685.24	2809.38
LSD	ns	ns	12.6	ns	ns	ns	ns	ns	ns	ns	3.45	181.7	ns
CV	6.93	3.07	7.64	28.57	26.92	33.59	3.36	22.09	10.7	24.49	10.44	11.59	29.23

Work plan

Four materials which were superior to *Gachena (Moti, Gebelcho, Obse and Tumsa)* will be evaluated further and multiplied for East and West Hararghe.

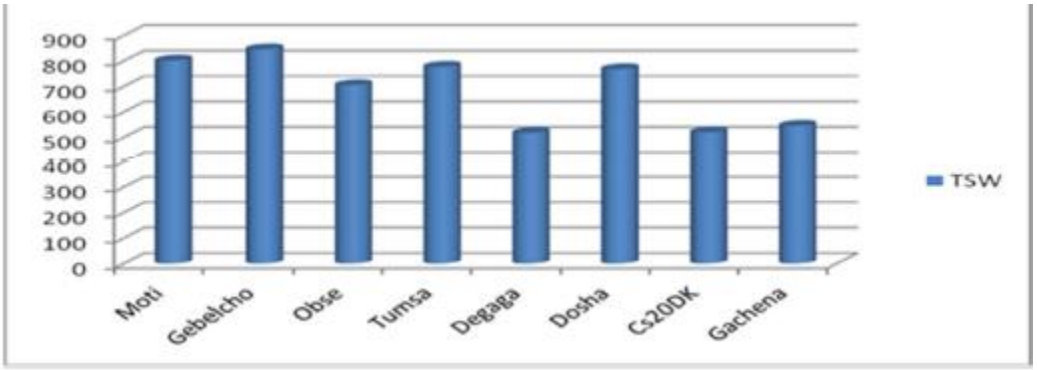

Figure 1.4. Variety over thousand seed weight

1.7.2 Faba Bean Regional Preliminary Variety Trial

Materials and Methods

Sixteen promising lines of faba bean along with the standard check *Gachena*, were used. The materials were laid in RCBD with four replications at Haramaya University research field. All cultural practices were used as per the recommendation of the location. Field and laboratory data were subjected to analysis of variance using the SAS software (SAS, 1996).

Results

Analysis of variance and mean agronomic performance of the genotypes is presented in Table 1.44. There was significant difference among the tested genotypes in number of seeds per pod, thousand seed weight and seed yield. Six genotypes out yielded the standard check in terms of seed yield. In this line, the highest yielders were Moti, EK01024-1-1, EK01024-1-2 and EK01021-4- in their decreasing order, whereas the lowest was the standard, *Gebelcho* with over all mean yields of 3552 g. With respect to thousand seed weight, the highest was recorded for the variety EK01024-1-2 (1021g) and EK01004-2-1(1019g), EK01002-1-1(1010g) in their decreasing order. Whereas, the lowest was recorded for the standard check, *Gebelcho,* (565g) with the overall mean of 912g. Based on the result, it can be suggested that there is sufficient variability among the tested genotypes for the intended traits implying that it is possible to improve the crop in this line.

Work plan

The six superior materials will be promoted for further breeding scheme in multi location trial to meet the national variety release standard (DUS principle)

1.7.3 Faba Bean National Variety Trial- Small Seeded for Wide Adaptation

Materials and Methods

Twenty small seeded genotypes of faba bean from Kulumsa Agricultural Research Center along with the standard check *Degaga*, were used. The materials were laid in RCBD with four replications at Haramaya University research station. All the cultural practices for the experiment were used as per the recommendation of the testing site. Field and laboratory data were collected and subjected to analysis of variance using SAS software (SAS, 1996).

Results

The mean performance of tested faba bean genotypes is given in Table 1.45. Significant difference was observed among the tested entries for the trait thousand seed weight. The highest thousand seed weight was recorded for accession EK01019-7-2 (862.58g) whereas the lowest for the standard, *Degaga*, (631.60g) with the overall mean of 762.98g indicating the probability of getting sound materials which can be used as a source of gene for thousand seed weight.

Work plan

Since the trial is an on-going experiment, the materials will be further evaluated for yield and traits that contribute to yield for one additional cropping season.

1.7.4 Faba Bean National Variety Trial- Large Seeded for Wide Adaptation-Set II

Material and Methods

Thirteen large seeded genotypes of faba bean from Kulumsa Agricultural Research Center along with the standard checks *Moti and Dosha*, were used. The materials were laid in RCBD with four replications at Haramaya University research station. All the cultural practices for the experiment were used as per the recommendation of the testing site. Field and laboratory data were collected and subjected to analysis of variance using SAS software (SAS, 1996).

Results

The mean performance of the tested faba bean genotypes is given in Table 1.46. Significant difference was observed among the tested entries for the traits thousand seed weight and seed yield. However, no accession was superior to the standard check, *Dosha*. The maximum seed yield was scored for *Dosha* (4614.31kg/ha) and the minimum for the genotype EK CSR 01009-2-2 (3294 kg/ha). Even if the standard gave highest seed yield, it was the lowest in thousand seed weight (771 g) whereas; accession EK 02005-1-1 gave the highest (982 g). The result indicated the existence of variability in the concerned traits. Thus, probability of getting sound materials that can be used as source of gene for thousand seed weight is high.

Work plan

Since it is on-going experiment, the materials will be further evaluated for yield and traits that contribute to yield for one additional cropping season.

1.7.5 Faba Bean National Variety Trial- Large Seeded for Wide Adaptation

Material and Methods

Sixteen large seeded faba bean genotypes collected from Kulumsa Agricultural Research Center along with the standard checks *Gebelcho* and *Moti*, were tested in this breeding experiment. The treatments were arranged in RCBD with four replications and conducted at Haramaya University research station. All the agronomic/cultural practices were used as per the recommendation of the testing location. Field and laboratory data were collected and subjected to analysis of variance using SAS software program.

Results

Table 1.47 presents the mean performance of the tested faba bean genotypes during the 2011 main cropping season. There was significant difference among the genotypes in terms of number of seeds per pod and per plant and thousand seed weight indicating the possibility of improving the crop in these traits of interest.

Work plan

The materials will be maintained and utilized for further breeding activity for specific traits.

1.7.6 Faba Bean Breeder Seed Multiplication and Maintenance (FBSM)

Materials and Methods

One regionally released faba bean variety, *Gachena*, from Haramaya University were purified and maintained in plot size of 10 m x 10 m in isolated field to avoid contamination, since the crop is *entimophilic* by its nature. The activity was carried out at Haramaya University research station during the 2011 main cropping season. All the necessary agronomic practice including rouging of the off-types was performed to maintain the genetic purity of the breeder seed.

Results

Some parameters was recorded and presented in Table 1.48. The genetic purity of the variety was maintained by distance isolation and discarding the off-type. About 193 kg of purified breeder seed was produced.

Work plan

Further purification and maintenance will continue and the produced seed will be delivered to the seed unit of the University for pre-basic and/or basic seed production.

Table 1.44. Mean performance of 16 faba bean accessions over 2011 cropping season at Haramaya

Trt	DF	DM	STD	Ch	Rust	Lodg	PPPl	spp	SPPl	BMY	TSW	SYLD
Moti	35.50	76.50	81.46	3.00	3.50	1.00	6.55	3.28	20.90	4.10	874	3968.06
EK-01001-5-1	35.75	77.00	61.75	3.00	4.00	1.00	6.50	2.84	18.75	3.43	856	3530.41
EK-01001-8-1	34.75	77.50	83.60	3.00	3.50	1.00	8.20	3.17	26.05	4.33	896	3659.47
EK-010001-9-2	35.00	77.00	69.83	3.00	3.50	1.00	6.05	3.26	19.85	4.15	960	3525.88
EK-01001-10-5	35.25	77.00	67.21	3.00	4.50	1.00	6.40	2.93	18.65	4.25	996	3405.00
EK-01004-2-1	35.25	76.75	74.81	3.00	3.50	1.50	7.60	3.05	23.00	4.70	1019	3764.94
EK-01006-7-1	35.25	77.50	63.89	3.00	4.00	1.25	5.80	3.20	18.70	4.25	940	3434.47
EK-01015-1-1	35.75	77.25	69.35	3.00	4.00	1.00	6.20	3.02	18.70	4.18	824	3094.38
EK-01019-2-1	35.50	77.00	71.96	3.00	5.00	1.00	5.60	3.36	19.15	3.70	916	3360.88
EK-01019-7-5	35.75	78.50	76.24	3.00	4.00	1.25	6.35	3.51	22.30	4.10	939	3552.19
EK-01024-1-1	36.00	78.25	74.81	3.00	3.50	1.00	6.35	2.97	18.20	3.68	948	3954.31
EK-01024-1-2	35.25	77.25	65.08	3.00	4.00	1.25	7.20	3.27	23.30	4.55	1021	3913.75
EK-01002-1-1	35.50	77.75	69.83	3.00	3.00	1.00	6.50	2.79	18.10	4.03	1010	3585.00
EK-01021-4-1	35.00	78.25	71.49	3.00	3.50	1.50	6.05	3.70	21.75	5.35	867	3782.28
EK-01004-2-1	34.75	77.50	69.83	3.00	3.50	1.25	6.60	3.05	20.20	4.40	973	3707.34
Gebelcho	36.00	78.50	70.06	3.00	3.00	1.00	7.15	2.97	21.50	5.08	565	2592.13
Mean	35.39	77.47	71.32	3.00	3.75	1.13	6.57	3.15	20.57	4.27	912.68	3551.91
LSD	ns	ns	ns	ns	ns	ns	ns	0.67	ns	ns	268.54	310.2
CV	2.61	2.43	13.63	0	28.25	28.11	20.63	10.67	22.03	18.28	14.96	16.3

Table 1.45. Mean performance of 20 faba bean accessions over 2011 cropping season at Haramaya

Trt	DF	DM	STD	Ch. Sp	Rust	Lodg	PPPl	SPP	SPPL	BMY	TSW	SYLD
EK 01023-1-2	36.25	80.00	60.80	1.00	2.50	1.25	11.65	2.82	31.90	3.48	812.73	3841.50
EK 01012-1-3	36.50	80.75	69.59	2.00	3.00	1.75	11.25	2.51	28.10	3.83	842.58	4689.94
EK 01019-7-1	37.00	79.75	77.43	1.00	3.00	1.75	10.75	2.83	29.70	3.63	799.00	4173.44
EK 01019-7-2	37.25	79.50	72.68	1.00	3.00	2.00	9.65	2.94	26.50	4.15	862.58	4378.28
EK 01019-7-3	37.00	78.75	81.23	1.00	3.50	1.50	11.85	2.65	30.55	3.78	825.03	4498.28
EK 01019-7-6	35.75	79.50	65.79	1.00	3.00	1.25	9.50	2.81	25.15	4.05	787.08	4765.88
EH 00128-3	35.75	80.75	74.10	1.50	3.50	1.50	10.35	2.63	25.00	3.83	840.00	4328.28
EH 00126-4	36.25	78.50	74.58	1.00	4.50	1.25	11.15	2.69	27.35	3.95	833.53	4926.66
EK CSR 02002-3	36.75	81.50	83.13	1.00	2.50	1.25	10.70	2.93	30.80	4.33	786.85	4427.59
EK LSS 02009-2	36.50	80.50	79.56	1.50	3.50	1.75	12.00	2.81	32.85	4.18	719.40	5059.00
EK LSS 02022-1	36.25	79.75	72.68	1.00	4.50	1.50	11.55	2.48	26.00	4.35	783.78	4704.47
EH00005-6-1	37.25	80.25	76.00	1.00	4.00	1.50	11.60	2.61	30.05	4.13	725.13	4616.88
EH00014-1	37.00	80.25	81.94	1.00	3.50	1.25	11.95	2.59	30.50	4.08	719.48	4529.06
EH00014-3-1	37.00	80.00	82.65	1.00	3.50	1.25	11.90	2.89	30.80	4.25	755.73	4102.03
EH00053-1	36.00	79.25	79.09	1.00	2.50	1.50	9.86	2.71	26.30	4.00	723.38	3846.66
EH00105-2	36.50	81.25	81.46	1.50	4.00	1.50	11.45	2.40	25.70	3.78	739.60	4243.75
EH 00016-2	36.50	80.50	86.21	1.50	3.00	1.50	10.00	2.66	25.75	4.00	667.75	3340.63
EH 00012-4	36.75	80.25	82.18	1.50	3.00	1.25	9.40	2.24	20.55	3.58	678.93	3773.06
EKLSS01009-2-1	36.25	80.50	75.53	2.00	2.50	2.00	8.90	2.77	24.30	3.68	725.55	3999.94
DEGAGA	36.50	80.50	77.19	2.00	3.50	1.25	11.20	2.49	27.70	4.00	631.60	4332.28
Mean	36.55	80.10	76.69	1.28	3.30	1.49	10.83	2.67	27.78	3.95	762.98	4328.88
LSD	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	139.1	ns
CV	2.08	2.1	14.45	52.2	30.35	30.86	25.14	13.59	21.13	15.67	9.47	21.25

Table 1.46. Mean performance of 13 faba bean accessions over 2011 cropping season at Haramaya

Trt	DF	DM	STD	Ch. Sp	Rust	Lodg	PPPl	spp	SPPl	BMY	TSW	SYLD
1	35.75	78.25	73.86	2.00	5.00	1.50	6.80	3.18	21.30	4.25	852.40	3937.34
2	36.50	77.50	76.48	1.50	3.50	1.00	5.95	2.99	17.30	3.88	898.65	3637.13
3	35.75	77.75	71.73	2.00	3.00	1.00	7.30	3.21	23.40	3.90	924.68	4021.56
4	35.50	78.00	66.98	1.50	4.00	1.25	8.05	2.98	23.15	3.90	777.35	3492.03
5	35.25	77.25	61.75	2.00	4.00	1.75	5.00	3.00	15.05	3.28	880.45	3472.97
6	36.25	78.25	74.58	1.50	3.50	1.50	7.70	3.22	24.75	4.08	982.63	4430.78
7	35.75	78.25	77.90	1.50	3.50	1.75	6.35	3.31	20.90	4.00	939.50	3705.09
8	36.50	79.50	81.94	1.50	3.50	1.00	5.75	3.01	17.25	4.23	943.45	4215.56
9	36.75	79.75	73.39	1.00	4.50	1.00	7.35	3.01	21.80	4.00	862.15	4033.59
10	35.50	78.75	77.19	1.50	4.00	1.25	7.25	3.44	24.35	3.80	905.98	4008.44
11	36.75	78.75	74.58	1.50	3.50	1.00	7.40	3.30	24.40	4.33	799.03	3294.00
12	35.25	77.50	71.01	1.00	3.00	1.25	8.55	3.18	24.95	3.75	872.20	3458.59
13	35.00	79.50	66.26	1.50	4.00	1.25	7.60	2.98	23.30	3.78	771.25	4614.31
Mean	35.88	78.38	72.89	1.54	3.77	1.27	7.00	3.14	21.68	3.93	877.67	3870.88
LSD	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	168.2	335.1
CV	3.16	2.19	16.88	59.49	30.68	32.87	23.96	18.74	22.8	11.73	9.32	15.22

Table 1.47. Mean performance of 16 faba bean accessions during the 2011 cropping season at Haramaya

Trt	DF	DM	STD	Ch.sp	Rust	Lodg	PPPl	Spp	SPPl	BMS	TSW	SYLD
Moti	39.00	80.00	67.45	1.00	2.75	1.75	8.10	3.01	24.40	3.70	807.25	4337.91
EK 01001-5-1	40.25	79.25	78.14	1.25	3.75	1.75	6.40	4.04	25.10	3.83	572.43	2573.13
EK 01001-8-1	39.00	82.00	73.63	1.00	3.00	1.50	6.10	2.47	15.15	4.03	967.63	4791.81
EK 01001-9-2	39.36	94.26	81.84	1.01	3.13	1.36	4.16	2.98	12.37	4.00	923.75	4005.16
EK 01001-10-5	39.50	255.00	74.34	1.00	2.50	2.00	6.45	3.36	21.20	3.95	1023.15	4595.25
EK 01004-2-1	40.25	82.25	85.26	1.00	3.00	2.00	6.30	3.01	18.50	4.10	990.78	4339.63
EK 01006-7-1	38.75	83.75	75.29	1.50	3.50	1.75	5.85	3.23	18.65	3.80	738.15	3503.59
EK 01015-1-1	40.25	81.25	83.13	1.50	3.50	2.00	6.25	3.62	22.65	3.98	933.00	4022.34
EK 01019-2-1	39.50	81.75	77.90	0.75	3.25	1.50	5.90	2.69	15.75	3.73	789.53	3601.03
EK 01019-7-5	39.75	82.00	86.45	1.00	3.00	1.75	5.75	2.78	15.80	4.10	856.63	4240.25
EK 01024-1-1	40.00	79.75	82.41	0.75	3.25	1.75	6.95	3.28	22.30	3.98	844.40	3314.63
EK 01024-1-2	39.75	80.75	76.48	1.25	2.75	1.75	7.05	3.20	22.50	4.23	880.30	4280.56
EK 01002-1-1	40.00	80.25	76.95	1.50	3.00	1.75	5.75	3.82	21.45	4.05	937.65	3942.91
EK 01021-4-1	38.78	75.64	74.59	0.99	2.92	1.58	6.02	4.20	24.06	4.16	885.09	4875.47
EK 01004-2-1	40.25	82.25	79.33	1.00	3.50	1.75	5.10	4.61	24.00	3.98	852.13	3969.22
Gebelcho	39.75	82.75	77.66	1.00	3.00	1.50	6.25	3.74	22.55	4.45	746.78	4573.44
Mean	39.63	92.68	78.18	1.09	3.11	1.72	6.15	3.38	20.40	4.00	859.29	4060.38
LSD	ns	ns	ns	ns	ns	ns	ns	1.61	8.1	ns	298	ns
CV	2.81		16.24	59.89	38.24	26.16	23.21	24.95	27.45	10.54	17.55	28.26

Table 1.48. Mean performance of released faba bean variety (*Gachena*) during 2011 cropping season at Haramaya

Range	DF	DM	Ch.spot	Rust	PH	PPPl	Spp	SPPl	TSW	SYLD
Mean	36.0	94.2	3.60	4.00	126.30	12.60	2.79	35.30	569.10	193.00
Max	39.0	105.0	5.00	5.00	145.00	17.00	3.75	60.00		
Min	33.0	68.0	3.00	3.00	110.00	7.00	1.92	16.00		

Acknowledgment

The financial assistance from Ethiopian Institute of Agricultural Research and Haramaya University for the research work is highly acknowledged. The authors also wish to thank the Office of Vice President for Research Affairs of the University for its invaluable support.

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Field pea (*Pisum sativum* L.)

Million Fikreselassie, Mekuanent Belay and Mekonen Dagne

Abstract: A total of three field pea experiments were conducted at Haramaya University research field during 2011 main cropping seasons to achieve the objective of developing and promoting high yielding, stress tolerant and widely/specifically adapted field pea varieties with desirable agronomic and quality traits in Eastern Ethiopia and to renew, increase and maintain true to type breeder seeds of released variety of Meti and make available for basic seed production. In the field pea Preliminary Variety Trial, the mean squares of the genotypes were highly significant for all characters studied. In the experiment field pea Preliminary Adaptation, two superior varieties (Milky and Gume) as compared to Meti in terms of various traits will be further tested, multiplied, and distributed to farmers in Eastern and Western Hararghe. In the field pea Breeder seed Maintenance and Multiplication experiment, the purity of the variety Meti was maintained by discarding the off-type and 100 kg of breeder seed was produced and the produced seed will be delivered to the seed unit of the University for further production of pre-basic or basic seed.

Keywords: Field pea; *Pisum sativum* L.; Genetic Improvement; Meti; Breeder Seed

Introduction

The pulse crops as a group in Ethiopia constitute a considerable number and diversity of crop species (Vavilov, 1926) one of which is the field pea (*Pisum sativum* L.). It is an annual grain legume of the papillonaceae family and has high protein level (23-33%) (Cousin et al., 1985). According to FAO (1998) center of origin/diversity of field pea are East Africa and West Asia with secondary center in South Asia and South and east Mediterranean sub-regions. The species *P. sativum* is dominant in Ethiopia even though wild and primitive forms are also known to exist in the high elevation of the country (Hagedorn, 1984, Amare and Adamu, 1994, Mussa *et al.,* 2003). According to CSA (2010), field pea covers about 226,532.57 ha of the total arable lands with a total production of 235,872.1 tons. This constitutes about15.21 percentage of the total area covered by pulses and12.43 percentage of the total annual production of pulses in the country.

The crop plays an important role in the economic lives of the farming communities in Ethiopia. It serves as a source of food and feed with a valuable and cheap source of protein. It plays a significant role in soil fertility restoration as suitable rotation crop that fixes atmospheric nitrogen. The crop is a good source of cash to farmers and foreign currency to the country (Girma, 2003). Despite its importance, however, the productivity of the crop is only 1.04 t/ha (CSA, 2010), which fluctuates and is far below the potential as compared to the research station yields of 2.5-3.5 t/ha (Mussa *et al*., 2003). The production has been constrained by several yield-limiting factors. Among them, the important once are the inherent low yielding potential of the indigenous cultivars (Asfaw et al., 1994), diseases like Ascochyta blight (*Mycospharella pinodes*) and Powdery mildew (*Erysiphe polygoni*) (Dereje and Tesfaye, 1994), poor soil fertility, unimproved cultural practice such as poor seed bed preparation and lack of fertilizer use (Amare and Adamu, 1994).

In order to best exploit the available genetic wealth, unraveling the information on the extent and nature of genetic diversity of the population is important. In line with this, the objective of the study was to develop and promote high yielding, stress tolerant and widely/specifically adapted field pea varieties with desirable agronomic and quality traits for Eastern Ethiopia and to renew, increase and maintain true to type breeder seeds of released field pea variety *'Meti'* and make available for basic seed production.

For all experiments, the field experiment was conducted at Haramaya University main campus research field during 2011/12 main cropping season. Haramaya has an altitude of 1980 meter above sea level. It is in semi-arid sub-tropical belt of Eastern Ethiopia. The area receives an average annual rainfall of 870 mm. The soil is characterized as a fluvisol with pH of 7.4 (Solomon, 2006). Highlights of the methodology and summary of results for each experiment are indicated hereunder.

1.7.7 Field Pea Preliminary Variety Trial

Materials and Methods

Twenty-seven genotypes of elite field pea materials along with two commercial varieties, *Burkitu and Latu,* were considered in this study. The materials were advanced from preliminary observation nursery received from Kulumsa Agricultural Research Center. Treatments were arranged in RCBD with three replications. All the agronomic/ cultural practices were used as per the recommendations of the testing site. Field and laboratory data were collected and subjected to analysis of variance using SAS software.

Result

From the analysis of variance results, the mean squares due to block/replication were non-significant for all traits, except stand count, number of seeds per pod and per plant, which were highly significant (Table 1.49). Mean squares due to genotypes were highly significant for all the traits studied and revealed the presence of variability for these traits in field pea genotypes investigated. The field pea genotypes evaluated in this study showed significant phenotypic variability in terms of plant morphology, phenology and yield attributes. These results are similar with the findings of other scholars like Tesfaye (1999) and Tezera (2000). In this study, efficiency of randomized complete block design was generally trait specific.

From the mean performance (Table 1.50), the commercial variety, *Burkitu*, along with two tested genotypes, EH-04049-1 and EH-05033-3, required longer days to mature and statistically different from the population mean (97.30). Generally, all accession required 34 to 44.67 days for grain filling and 55.33 to 60.33 days for vegetative growth. The result from this investigation is in agreement with the previous reports of Musa *et al. (*2003).

In general, the genotypes showed shorter days to maturity and grain filling periods. Thus, may be suitable for lower rainfall regions whereas the late types can be adapted to the highland areas with dependable rainfall. Thus, the variability that has been exhibited by these genotypes can offer great flexibility for the development of suitable varieties for the various agro-ecological zones in Ethiopia. The genotypes that possess shorter grain filling period character can be suitable for areas where terminal drought frequently occurs. From the results, the broad spectrum of variability observed among these genotypes of field pea for different characters generally indicates possibilities for genetic improvement of the crop through selection and cross breeding.

Table 1.49. Analysis of variance for 14 traits of elite field pea genotypes tested in 2011croping season at Haramaya University research field.

Variables	MSR(2) β	MSG(26)	MSE	CV (%)
DF	3.60^{ns}	168.06**	6.40	11.52
GFP	91.31*	91.42**	5.06	12.80
DM	241.98 ^{ns}	473.41**	10.85	11.41
STD	5594.87**	390.12**	11.97	1642
AB	0.12 ^{ns}	2.23*	0.97	25.69
Mldw	0.02 ^{ns}	2.31**	0.88	24.27
PH	2055.11 ^{ns}	2438.44**	30.66	16.61
Ppp	3.24 ^{ns}	8.62**	1.91	22.60
Spp	3.85**	1.48**	0.65	22.80
Sppl	603.52**	163.01**	6.51	26.42
Biom	0.80 ^{ns}	1.78**	0.78	19.54
TSW	21.88 ^{ns}	2966.38**	37.15	19.93
HI	39.55 ^{ns}	78.31**	5.25	28.26
SYLD	72.63 ^{ns}	126403.10**	228.26	30.21

*** Significant at 0.05 and 0.01 probability level respectively and ^{ns} non significant MSR= Mean Square due to replication, MSG= Mean Square due to genotypes, MSE= Mean Square due to error, CV%= Coefficient of variation in percentage. β Figures in parenthesis indicate degrees of freedom. DF= Days to 50% flowering, GFP= grain filling period, DM = Days to 90% maturity, STD = stand count, AB = Aschochyta blight, mldw = Powdery mildew, PH = Plant height in cm, PPP = Number of pods per plant, SPP = Number of seeds per pod, SPPL = Number of seeds per plant, Biom = Biomass yield, TSW = Thousand seeds weight in gram, HI = Harvest index in percentage SYLD = Seed yield in g per plant

Work plan

The superior materials will be promoted for further breeding scheme in multi location trial to meet the national variety release criteria (DUS).

Table 1.50. Mean performance of 27 field pea accessions during 2011 cropping season at Haramaya

Trt	DF	DM	STD	AB	Mldw	PH	ppp	spp	SPPl	BMY	TSW	SYLD
Burkitu	56.50	99.00	72.70	4.00	4.00	174.50	7.60	2.24	17.0	4.15	190.20	2705.56
EH 04049-1	55.50	100.00	68.68	4.00	3.00	163.00	8.70	2.64	23.1	3.45	159.65	3053.06
EH 04028-2	56.50	98.00	65.66	3.00	3.00	183.50	9.10	2.47	22.2	3.95	178.25	4308.89
EH 04057-2	55.50	97.00	81.41	4.00	3.00	162.50	11.30	2.79	31.0	3.85	168.80	4133.61
EH 04045-2	56.00	96.50	64.66	4.00	4.00	185.50	11.10	2.55	28.5	3.60	193.95	4238.61
EH 04057-1	56.00	96.50	73.70	5.00	4.00	209.00	7.70	2.47	18.7	4.40	203.15	4440.83
EH 04044-1	28.00	49.00	49.92	1.50	1.50	102.50	4.10	0.88	7.2	2.05	197.50	1536.11
EH 04029-2	57.00	97.50	58.96	5.00	3.00	201.50	9.10	3.00	25.6	4.65	225.15	4639.17
EH 04051-1	57.00	97.00	82.50	4.00	3.00	176.50	8.30	2.68	20.7	5.50	194.80	4890.28
EH 04053-1	56.50	99.50	68.34	4.00	4.00	185.00	6.60	2.77	19.1	4.00	200.70	4129.17
EH 04047-1	56.00	99.00	78.81	4.00	4.00	197.00	8.80	2.88	25.9	4.50	112.40	5967.78
EH 05028-2	58.50	97.50	76.72	4.00	4.00	181.00	7.00	2.54	18.0	3.85	209.35	4257.22
EH 05030-3	58.00	96.50	88.44	4.00	5.00	197.00	8.30	2.17	18.2	4.45	169.75	4524.44
EH 05002-3	57.50	96.50	80.40	4.00	4.00	182.50	8.80	2.91	24.2	4.00	188.35	3535.00
EH 05016-1	56.50	98.00	76.05	3.00	3.00	204.50	9.10	2.39	21.2	3.95	192.60	4535.83
EH 05014-6	56.00	97.50	84.42	4.00	3.00	197.00	10.10	2.55	24.9	4.50	182.70	4871.39
EH 05029-6	57.50	96.50	66.00	5.00	5.00	214.50	7.00	3.27	22.9	4.05	199.40	5668.06
EH 05024-2	59.50	99.50	84.76	3.00	5.00	190.50	6.30	2.84	18.3	3.95	176.70	2603.33
EH 05026-3	58.50	96.00	81.41	4.00	3.00	195.00	7.90	3.08	24.6	3.50	214.55	3297.50
EH 05043-4	59.00	97.00	75.04	3.00	4.00	188.00	8.00	2.78	22.4	4.05	216.10	4354.17
EH 05027-4	57.00	96.50	81.41	4.00	3.00	201.50	8.70	2.62	21.3	3.95	223.30	5159.72
EH 05024-4-1	59.00	97.00	85.09	3.00	4.00	222.50	7.20	3.03	22.2	4.45	188.20	3253.06
EH 05011-2	56.00	97.50	87.77	4.00	3.00	191.50	7.80	3.37	27.2	3.50	205.15	4468.89
EH 05024-3-1	57.50	97.50	81.07	4.00	4.00	177.00	9.10	3.05	27.7	3.00	175.45	4573.61
EH 05033-3	56.00	100.00	74.71	3.00	4.00	181.50	9.20	4.31	41.3	3.55	177.55	3928.61
EH 05032-1	55.50	98.50	82.75	3.00	4.00	189.00	8.80	2.91	26.2	4.08	191.00	5753.06
Latu	57.5	100	76.465	4	4	198.5	9.40	3.02	29.2	3.9	210.45	4567.78
Mean	55.93	95.96	75.84	3.76	3.65	187.11	8.34	2.75	23.29	3.96	186.86	4199.78
LSD	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	2553.3
CV	14.02	13.85	19.33	31.51	29.67	20.07	28	29.04	34.25	24.24	24.37	36.37

1.7.8 Field Pea Preliminary Adaptation Trial

Material and Methods

Seven recently released field pea varieties from Holetta Agricultural Research Center along with a regionally released *Meti* by the University were used in the experiment conducted at Haramaya University research station during 2011 main cropping season. The materials were conducted in RCBD design with two replications. All the necessary agronomic practices were maintained as per the recommendation.

Results

The mean performance of thirteen traits is given in Table 1.51. The analysis of variance revealed significant difference ($P<0.05$) among the tested varieties for the traits reaction to powdery mildew, thousand seed weight, biomass and seed yield. This indicates that the tested varieties are genetically different in these traits. The highest seed yield was recorded for *Milky* (3225) whereas the lowest for *Burqitu* (1725) (Figure 1.5), with the overall mean seed yield of 2625. The variety *Markos* recorded highest thousand seed weight (234g) and the lowest (134g) was recorded for the variety *Megeri* indicating the existence of genetic difference between the varieties, which can be utilized for further breeding, experiments.

Work plan

Two superior varieties (*Milky and Gume*) will be further tested, multiplied, and distributed to farmers in the East and West Hararghe Zones.

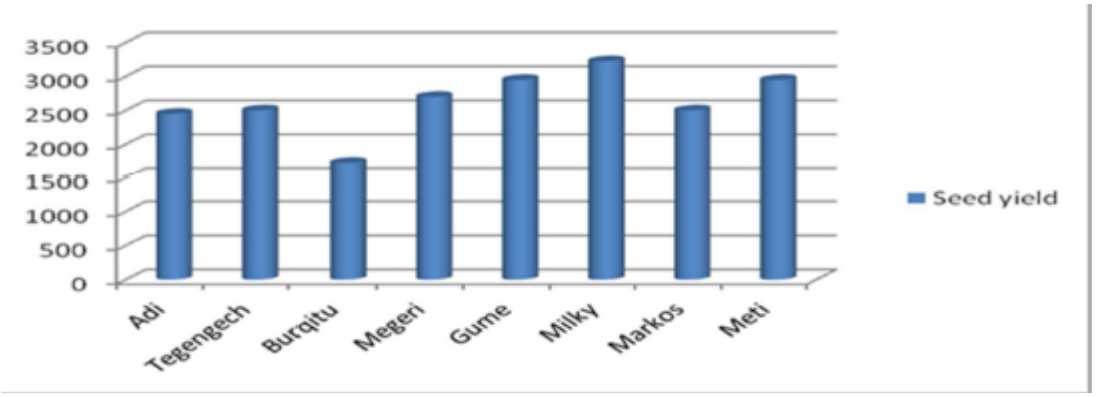

Figure 1.5. Variety over seed yield

Table 1.51. Mean performance of eight released field pea varieties (Fp-PADPT) during 2011 cropping season at Haramaya

Trt	DF	DM	STD	AB	mldw	PH	ppp	spp	sppl	BMY	TSW	SYLDP	SYLDH
Adi	45.0	63.0	736.0	3.0	5.0	157.0	10.8	3.2	35.2	18.5	217.2	4.9	2450.0
Tegengech	43.5	61.5	593.0	4.0	5.0	152.0	8.7	4.0	34.7	17.1	220.3	5.0	2500.0
Burqitu	44.0	64.5	543.5	4.0	5.0	147.0	8.3	4.0	33.4	13.5	217.4	3.5	1725.0
Megeri	43.0	63.0	649.0	5.0	3.0	145.5	9.3	3.8	35.6	15.1	134.2	5.4	2700.0
Gume	43.5	62.5	576.0	4.0	4.0	163.5	10.0	3.7	37.3	17.4	222.6	5.9	2950.0
Milky	44.5	63.5	629.5	4.0	3.0	161.0	8.9	3.7	32.9	18.5	191.4	6.5	3225.0
Markos	45.0	64.0	556.0	4.0	5.0	162.5	8.5	3.9	33.5	17.7	234.2	5.0	2500.0
Meti	45.0	62.0	642.0	3.0	3.0	162.0	8.9	4.2	37.8	18.0	215.0	5.9	2950.0
Mean	44.19	63.00	615.63	3.88	4.13	156.31	9.18	3.83	35.05	16.95	206.51	5.25	2625.00
LSD	ns	ns	ns	ns	1.15	ns	ns	ns	ns	2.76	16.3	1.4	72
CV	2.63	3.65	14.64	30.46	12.12	7.15	13.09	12.68	20.89	8.34	3.67	12.59	12.59

1.7.9 Field Pea Breeder Seed Maintenance and Multiplication

Materials and Methods

One regionally released field pea variety, *Meti*, were maintained in a plot size of 10 m x 10 m at Haramaya University research station during the 2011 main cropping season. All the necessary agronomic practice including close supervision of the experimental plot and rouging the off-type was performed. All management practices were accomplished as per the recommendations to maintain the genetic purity of the variety *Meti*.

Results

Some parameter for the crop was recorded and presented in Table 1.52. The purity of the variety was maintained by discarding the off-type and 100 kg of breeder seed was produced from the plot with its thousand seed weight of 202g.

Work plan

Further purification and maintenance will continue and the produced seed will be delivered to the seed unit of the University for pre-basic or basic seed production.

Table 1.52: Mean performance of released field pea variety (*Meti*) during 2011 cropping season at Haramaya

Range	DF	DM	Blight	Mldw	PH	PPPl	Spp	SPPl	TSW	SYLD
Mean	51.5	83.8	3.96	3.88	156.88	7.12	5.07	35.56	202.60	100.00
Max	54.0	89.0	5.00	5.00	190.00	15.00	7.80	69.00		
Min	47.0	75.0	3.00	3.00	120.00	3.00	2.75	11.00		

Acknowledgment

The financial assistance from Ethiopian Institute of Agricultural Research and Haramaya University for the research work is highly acknowledged. The authors also wish to thank the Office of the Vice President for Research Affairs of the University for the invaluable support.

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Chickpea (*Cicer arietinum* L.)

Million Fikreselassie, Mekonen Dagne and Mekuanent Belay

Abstract: The field experiment was conducted at Haramaya University research field during 2011 main cropping season to develop and promote high yielding, stress tolerant, and widely/specifically adapted chickpea varieties with desirable agronomic and quality traits for Eastern Ethiopia. To achieve the objective, three distinct experiments were conducted. In the Chickpea Preliminary Adaptation Trial, significant difference (P<0.05) were observed among the tested varieties for date of flowering and maturity, stand count, hundred seed weight, biomass and seed yield. The most out-yielded varieties with yield and related traits such as Natoli will be multiplied and distributed to the user/farmers through the University. From the second and third experiment which were National Variety trial for Dessi and Kabuli type respectively, significant difference (P<0.05) were observed among the tested varieties for different traits of interest. This variability indicated the possibility of improving the chickpea for the concerned traits.

Keywords: Chickpea; Highland Pulse; Eastern Ethiopia; *Cicer arietinum* L.

Introduction

Chickpea is self-pollinated diploid (2n = 2x = 16) with a relatively small genome size of 740Mbp (Arumuganathan and Earrle, 1991). It is one of the food legume crops grown in the tropics, sub-tropics and temperate regions of the world. However, its production is concentrated in South, Central and West Asia, North and East Africa and Latin America. Among the two types (*Desi* and *Kabuli*), *Desi* accounts for about 85% of the world's chickpea production and is mainly grown in South Asia, Iran, Ethiopia and Mexico (ICRISAT, 2000). Ethiopia is considered as a center of diversity for chickpea and the wild relative of cultivated chickpea, *Cicer cuneatum,* is found in *Tigrai* region of Ethiopia (Kanouni *et al*., 2011).

The principal uses of chickpea in Ethiopia is its use as food grain and it is a good source of protein (20% to 30%) as compared with cereals (8% - 10 %). It contains about 40% of carbohydrates and 3-6% oil (Gil *et al*., 1996). It is also a good source of calcium, magnesium, potassium, phosphorous, iron, zinc and manganese (Ibrikci *et al*., 2003). It requires low input for production, maintain, and restore soil fertility. It can fix up to 60 kg N /ha/year, and can be used as a rotation crop which improve both the soil structure and fertility. In addition, it is a high potential crop for domestic and export market which fetches high revenue for farmers and producers. Despite its importance, the average national seed yield of chickpea is generally low (1.3 ton/ha), unstable and less than its potential (>4 tons/ha), which is mainly due to disease and poor management practices. On a global basis, annual yield losses in chickpea were estimated to be 4.8 million tons due to biotic stresses (Ryan, 1997). In line with these stresses, nowadays, influence of climate change aggravates and favors the emergence of new diseases races which significantly threatening chickpea production than before and becoming a major challenge to food security. Therefore, the objective of the chickpea research program was to develop and promote high yielding, stress tolerant, and widely/specifically adapted chickpea varieties with desirable agronomic and quality traits for Eastern Ethiopia.

For all experiments of chickpea, the field experiment was conducted at Haramaya University main campus research field during 2011/12 main cropping season. Haramaya has an altitude of 1980 meter above sea level. It is in semi-arid sub-tropical belt of Eastern Ethiopia. The area receives an average annual rainfall of 870 mm. The soil is characterized as a fluvisol with a pH of 7.4 (Solomon, 2006). Highlight of the methodology and results for each experiment is given hereunder.

1.7.10 Chickpea Preliminary Adaptation Trial

Materials and Methods

Fourteen released chickpea varieties from Debre Zeit Agricultural Research Center were involved in the experiment conducted at Haramaya University research station during 2011/12 main cropping season. The materials were laid on RCBD with three replications. All the necessary agronomic practices were maintained as per the recommendation.

Results

The mean performance of eleven traits is given in Table 1.53. The analysis of variance showed significant difference (P<0.05) among the tested varieties for date of flowering and maturity, stand count, hundred seed weight, biomass and seed yield. Variety *Mariyie* requires 106 days for physiological maturity whereas *Ejere* matures earlier in 101 days. In terms of seed yield, variety *Natoli* was the most out yielding variety (2665 kg/ha) and *Acos-Dube* the least (296 kg/ha) among

the tested varieties with over all mean of 1864 kg/ha (Figure 1.6). The low yield of the variety *Acos-Dube* was due to the high susceptibility of the variety to moisture, which might be due to large seed type (hundred seed weight of 52.35g).

Work plan

The most out-yielded varieties like *Natoli* will be multiplied and distributed to farmers.

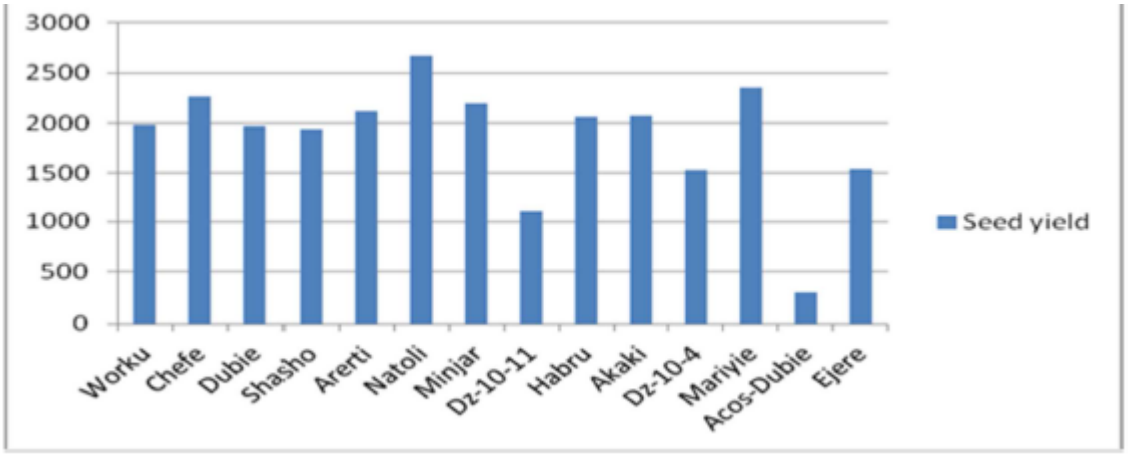

Figure 1.6. Chickpea variety versus seed yield

Table 1.53. Mean performance of 14 commercial chickpea varieties over 2011 cropping season at Haramaya

Trt	DF	DM	STD	PPL	SPP	SPPL	PH	BMY	HSW	SYLDP	SYLDH
Worku	44.50	105.00	78.21	35.60	1.31	45.70	40.00	4.00	21.40	1428.35	1983.80
Chefe	41.00	102.00	56.07	38.00	1.23	46.10	39.00	4.50	32.25	1631.55	2266.05
Dubie	41.50	102.50	75.71	42.50	1.23	53.10	39.00	4.15	20.45	1418.30	1969.85
Shasho	45.50	106.00	79.64	28.50	1.22	34.80	38.50	3.40	24.55	1395.95	1938.80
Arerti	45.00	105.00	80.36	31.90	1.26	40.50	38.50	3.25	22.90	1524.85	2117.85
Natoli	45.00	105.50	76.43	25.00	1.43	35.70	34.50	4.10	28.90	1918.85	2665.05
Minjar	41.50	102.00	75.00	42.30	1.37	57.00	40.50	3.65	18.95	1578.75	2192.70
Dz-10-11	44.50	105.00	72.86	40.30	1.30	52.10	35.50	3.00	11.45	792.25	1100.35
Habru	42.00	102.00	53.57	33.00	1.18	38.80	39.50	4.00	32.00	1484.30	2061.55
Akaki	45.00	103.50	76.07	33.70	1.36	46.10	39.50	3.20	18.35	1490.40	2070.00
Dz-10-4	44.00	104.50	77.86	30.50	1.18	36.70	37.00	3.40	10.10	1105.70	1535.70
Mariyie	45.50	106.00	67.50	41.30	1.55	63.80	38.00	3.95	24.80	1698.60	2359.15
Acos-Dubie	44.00	104.00	18.57	39.20	0.95	36.90	43.50	1.35	52.35	213.35	296.30
Ejere	41.00	101.50	78.57	31.60	1.10	34.70	36.50	2.95	34.80	1110.95	1543.00
Mean	43.57	103.89	69.03	35.24	1.26	44.43	38.54	3.49	25.23	1342.30	1864.30
LSD	3.03	2.9	31.03	ns	ns	ns	ns	0.79	3.7	491	686.1
CV	3.27	1.42	22.24	20.74	13.48	24.16	12.92	10.67	6.87	17.24	17.24

1.7.11 Chickpea National Variety Trial- *Dessi Type*

Materials and Methods

Eighteen chickpea genotypes were conducted along with two standards, *Minjar* and *Natoli*, and a local check at Haramaya University research station during 2011/12 main cropping season. The materials were laid in RCBD with four replications and all the necessary agronomic practice was maintained as per the recommendation.

Results

The mean performance of the eighteen genotypes for the ten traits is given in Table 1.54. The analysis of variance revealed significant difference (P<0.05) among the tested varieties for stand count and hundred seed weight. Accession *ICCV-07108* gave the highest score for the trait stand count (87%) while the *local* gave the lowest among tested material (49%). Regarding the trait hundred seed weight, accession *ICCX-940002-F5-242p-1-1-1* gave the highest (38.3g) whereas the local scored the lowest (10.38g) with the overall mean of 24.34g indicating the opportunity to improve the crop for these traits of interest.

Work plan

Since the experiment will be repeated for one more season, further evaluation on yield and traits that contribute for yield will be made.

Table 1.54**.** Mean performance of 18 chickpea (Dessi Type) accessions over 2011 cropping season at Haramaya

Trt	DF	DM	STD	PPl	SPP	Sppl	Ph	BMY	HSW	SYLD
ICCV-07108	41.50	79.75	86.75	54.50	92.40	1.83	35.75	1.23	27.38	2325.13
ICCV-04103	42.75	81.00	72.00	53.95	72.10	1.38	43.00	1.15	22.00	1969.58
ICCV-00104	42.75	81.00	66.75	49.45	68.55	1.35	35.25	1.38	24.83	2472.00
ICCV-04101	43.50	81.00	70.25	45.90	71.55	1.55	42.75	1.08	28.05	1820.13
BG-1101	44.00	82.25	76.75	47.15	73.30	1.55	36.75	1.28	25.48	2384.29
ICCV-97105	43.75	82.75	86.50	39.60	64.85	1.63	34.50	1.25	25.08	2176.58
ICCV-05110	42.50	83.50	74.00	54.70	88.20	1.58	35.25	1.03	25.93	2255.13
ICCX-940002-F5-88P-1-1-1	42.50	82.25	64.25	47.70	81.95	1.68	34.75	1.23	27.03	2102.00
ICCX-940002-F5-6P-1-1-1	44.00	84.25	64.00	57.75	77.50	1.38	35.00	1.23	24.20	2223.04
ICCV-00202	43.25	84.25	75.00	49.50	76.60	1.53	38.00	1.30	20.93	2556.79
ICCX-940002-F5-242P-1-1-1	44.25	85.25	83.50	54.50	99.10	1.90	37.50	1.40	38.30	2316.58
ICCX-940002-F5-335P-1-1-1	43.50	84.50	73.00	58.15	80.10	1.38	35.50	1.28	22.70	2362.83
ICCV-03203	43.50	84.50	76.25	54.95	82.20	1.50	34.75	1.13	22.45	1824.71
ICC-3195	42.25	83.50	60.00	52.85	73.55	1.43	37.75	1.43	21.25	1955.42
ICCX-910121-5	44.00	84.50	71.25	66.70	93.45	1.45	35.25	1.50	25.23	2510.21
Minjar	43.00	84.50	82.75	52.85	79.35	1.48	36.00	1.05	22.08	1892.63
Natoli	43.75	84.00	58.75	59.90	104.75	1.75	35.50	1.23	24.83	2021.79
Local check	42.00	82.50	49.50	66.80	102.10	1.58	36.75	1.10	10.38	1443.33
Mean	43.15	83.07	71.74	53.72	82.31	1.55	84.44	1.23	24.34	2145.13
LSD	ns	ns	28.1	ns	ns	ns	ns	ns	12.26	ns
CV	4.95	3.75	20.71	26.01	27.47	19.89	5,41	23.24	25.21	21.59

1.7.12 Chickpea National Variety Trial- *Kabuli Type*

Material and Methods

Eighteen chickpea genotypes were planted along with three standards, *Arerti, Habru,* and *Dz-10-4*, and checks, which were planted at Haramaya University research station during 2011/12 main cropping season. The materials were laid in RCBD with four replications and all the necessary agronomic practice was maintained as per the recommendation.

Results

The mean performance of the eighteen genotypes for the ten traits is given in Table 1.55. The analysis of variance showed significant difference (P<0.05 among the tested varieties for the traits days to flower and maturity, stand count, plant height, hundred seed weight, and seed yield indicating existence of sufficient variability among the tested genotypes. Among the tested materials, the standard check, *Habru,* was earliest to mature (77 days) with the highest hundred seed weight (27.45g) while *FLIP 01-58C* was late mature type (82 days). The material *FLIP 01-37C* gave the highest seed yield (467.6g/p) where as accession *FLIP 03-127C* gave the lowest (184) yield with the overall mean seed yield of 332g/pod.

Work plan

Since the experiment will be repeated for one more season, further evaluation on yield and traits that contribute for yield will be made.

Table 1.55**.** Mean performance of 18 chickpea (*Kabuli* Type) accessions during 2011 cropping season at Haramaya University

Trt	DF	DM	STD	PPl	SPP	Sppl	Ph	BMY	TSW	SYLD
FLIP02-24C	49.00	79.75	55.00	37.50	55.70	1.49	39.50	1.05	22.88	1489.17
FLIP03-127C	51.00	81.75	38.00	44.45	60.80	3.23	37.25	0.90	23.73	768.46
FLIP00-20C	49.25	80.00	46.50	45.50	53.35	1.18	34.50	1.15	26.43	1366.17
FLIP01-37C	49.75	80.25	55.25	36.55	46.95	1.28	45.00	1.20	24.30	1948.25
FLIP01-77C	51.50	81.25	52.25	56.15	73.50	1.29	43.00	1.38	24.83	1772.08
FLIP01-24C	50.75	81.25	46.25	44.85	59.30	1.31	35.25	1.18	24.75	1263.46
FLIP03-114C	48.25	81.75	37.25	46.15	62.00	1.35	36.75	0.98	24.88	816.88
FLIP03-125C	51.25	81.75	42.50	43.65	51.05	1.18	40.00	1.00	25.55	970.21
FLIP01-57C	48.50	80.00	64.50	40.85	50.45	1.24	40.50	1.08	22.40	1488.13
FLIP01-52C	50.50	80.50	61.00	32.40	41.65	1.29	42.25	1.43	24.63	1838.75
FLIP01-40C	48.50	79.50	67.50	38.95	49.50	1.28	43.00	1.03	24.63	1414.92
FLIP01-7C	49.25	80.00	50.25	43.30	58.65	1.34	41.00	1.03	24.20	1364.38
FLIP01-46C	48.00	79.50	54.25	50.60	66.50	1.29	39.00	1.23	22.80	1489.17
FLIP01-12C	49.50	80.50	57.25	37.30	49.45	1.31	39.75	1.05	20.20	1667.63
FLIP01-58C	51.25	82.25	59.25	42.40	45.80	1.09	42.25	1.33	26.20	1771.17
Arerti	47.75	79.50	54.50	45.05	57.05	1.26	33.75	1.03	20.28	1520.83
Habru	45.75	77.25	55.00	32.55	42.40	1.31	36.75	0.98	27.45	1192.29
DZ-10-4	50.25	81.00	52.75	37.15	47.70	1.30	38.00	0.93	7.45	791.38
Mean	49.44	80.43	52.74	41.96	53.99	1.39	39.31	1.11	23.20	1385.17
LSD	3.9	3.1	21	ns	ns	ns	8.6	ns	3.81	191
CV	4.06	2.03	20.86	32.47	33.53	66.77	11.92	21.51	8.62	29.59

Acknowledgment

The financial assistance from Ethiopian Institute of Agricultural Research and Haramaya University for the research work is highly acknowledged. The authors also wish to thank the Office of the Vice President for Research Affairs of the University for the invaluable support.

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Lentil (*Lens culinaris* Medic)

Million Fikreselassie, Mekuanent Belay and Mekonen Dagne

Abstract: An experiment was conducted in 2011 at Haramaya University research station, Ethiopia, to develop and promote high yielding, stress tolerant, and widely/specifically adapted lentil varieties with desirable agronomic and quality traits for Eastern Ethiopia. Two distinct experiments were conducted at Haramya University main campus research station. In the experiment Lentil National Variety Trial, significant difference (P<0.05) was observed among the tested varieties for the trait reaction to the Wilt dieses. The genotype EXOTIC# DZ/2008 AK was more susceptible to wilt whereas accession FILP 97-16L was more tolerant among the tested entries. In the experiment lentil Preliminary adaptation trial, nine released lentil varieties were used and significant difference (P<0.05) were observed among the tested varieties for days to physiological maturity and seed yield. The variety Derash will be multiplied and distributed to the user/farmers through the University.

Keywords: Lentil; Pulse Crops; Eastern Ethiopia; *Lens culinaris* Medic

Introduction

The age of domestication of Lentil crop (*Lens culinaris* Medik) dates back to 6000-8000 B.C. (Dawit et al., 1994). The Lidia-Kurdistana region (in southern Turky-north Iraq) is perhaps the place of domestication and center of origin of the crop (Cubero, 1981). It is an important cool season food legume in Ethiopia. It is one of the grain legume listed by Harlan (1968) that moved to Ethiopia from Asia, although the exact date of introduction is unknown. It is mainly grown in the central, northwest, south and eastern highlands of the country (Asfaw et al., 1994). Lentil is cultivated mostly for domestic consumption, which is an important source of protein accounting for 22.6% in the human diet (Agren and Gipson, 1968). Moreover, the demand and request for both whole and split red cotyledon lentil is very high particularly in Lebanon (EEPA, 2003a), India (EEPA, 2002a, b, c, and 2003b), Sri Lanka (EEPA, 2003c) and Bangladesh (EEPA, 2002a). It is almost a cash crop because it fetches very high prices compared with all other feed legumes and main cereal crops in the country.

Despite the above facts, the national average seed yield of these crops is very low which is 1.0 ton/ha (CSA, 2010) as compared to the crops potential yield which is 2.5 ton/ha for lentil in large-scale production. The formal and informal baseline surveys, backup research results, national reports and stakeholders' feedback, reveal several constraints that limit production and productivity of the crop. Among these, the low genetic potential and poor market quality of farmers' varieties, biotic (diseases, insects and weeds) and abiotic (high and low moisture stresses, low soil fertility and other soil related problems such as acidity and salinity, high and low temperature and inappropriate crop management practices) are the major ones. To mitigate these problems, numerous improved varieties were released, but only few of them are under production. Currently, improved varieties occupy less than 10% of the total cultivated area allotted to this crop (CSA, 2010).

Generation and promotion of lentil technologies are essential to improve agricultural productivity and thereby the livelihood of farmers living in potential and moisture stress growing environments. Thus, further development of improved technologies and their popularization in a concerted effort is necessary to ensure sustainable production with greatly increased productivity and export market. In line with this, the objective of the study was to develop and promote high yielding, stress tolerant and widely/specifically adapted lentil varieties with desirable agronomic and quality traits for Eastern Ethiopia. The field experiments were conducted at Haramaya University main campus research field during 2011/12 main cropping season. The area receives an average annual rainfall of 870 mm. The soil is characterized as a fluvisol with a pH of 7.4 (Solomon, 2006). Highlights of specific methodologies and results for each experiment are indicated hereunder.

1.7.13 Lentil Preliminary Adaptation Trial

Materials and Methods

Nine released lentil varieties collected from Debre Zeit Agricultural Research Center were planted at Haramaya University research station during 2011/12 main cropping season. The materials were arranged in RCBD with three replications. All the necessary agronomic practices were maintained as per the recommendation.

Results

The mean performance of the commercial varieties for the twelve traits is given in Table 1.56. Analysis of variance indicated significant difference (P<0.05) among the tested varieties for days to physiological maturity and seed yield. The

variety *Chalew* matures earlier (65 days) than the entire varieties and *Alemtena* became the late maturing type (76 days). Among the tested varieties, *Derash* gave the highest yield whereas the variety *El-142* gave the lowest (Figure 1.7) indicating the possibility of differential adaptability of the crop to the particular environment.

Table 1.56**.** Mean performance of 9 released lentil varieties (Ln=PADPT) over 2011 cropping season at Haramaya

Trt	DF	DM	STD	ROT	WILT	RUST	MLDW	VIGOR	PH	BMY	TSW	SYLD
Alemtena	44.33	76.67	414.33	1.00	3.00	2.00	1.00	1.00	52.67	2.84	2.97	1628.22
Chalew	43.67	66.00	320.00	1.00	2.00	2.00	0.00	1.67	41.67	3.99	3.53	1978.34
Ada'a	46.00	68.00	319.00	1.00	3.00	0.00	1.00	2.00	45.00	3.09	2.97	1609.47
Derash	45.33	70.33	342.67	0.00	3.00	1.00	2.00	1.67	45.33	3.90	3.13	1848.22
Chekol	46.33	66.67	354.33	2.00	1.00	3.00	0.00	2.00	45.00	3.12	3.07	1939.06
El-142	45.67	66.00	320.00	0.00	1.00	2.00	1.00	1.67	44.00	2.27	3.33	2080.63
R-186	47.33	66.67	301.67	1.00	1.00	2.00	2.00	1.33	40.33	2.53	3.53	2083.97
Alemaya	44.67	66.67	348.33	2.00	0.00	1.00	3.00	2.00	41.67	3.00	3.07	1668.53
Teshale	41.33	70.00	342.33	2.00	2.00	3.00	1.00	1.67	44.00	2.66	4.17	1751.03
Mean	44.96	69.89	340.30	1.11	1.78	1.78	1.22	1.67	44.41	3.04	3.31	1843.06
LSD	2.65	4.24	ns	ns	ns	ns	ns	ns	ns	ns	ns	56.4
CV	2.78	4.01	12.39	141.11	73.52	81.19	114.49	34.64	10.1	23.59	20.69	29.84

Work plan
The most out-yielding variety like *Derash* will be multiplied and distributed to the farmers.

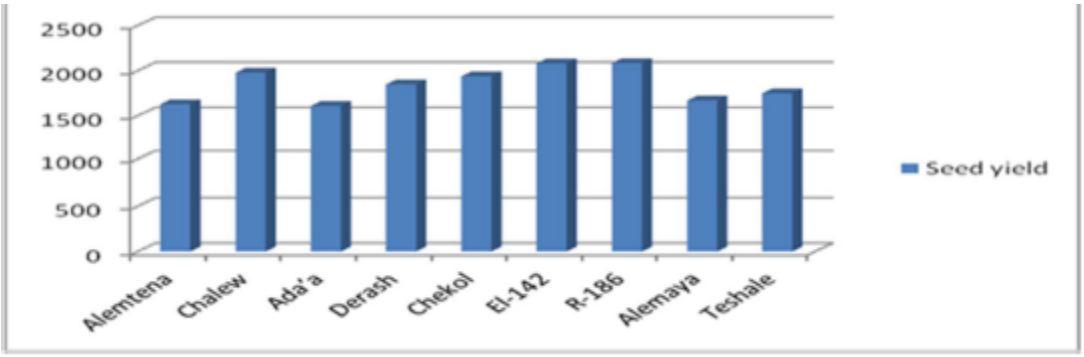

Figure 1.7. Lentil varieties versus seed yield

1.7.14 Lentil National Variety Trial

Material and Methods

Sixteen lentil genotypes were planted along with two standards, *Alemaya* and *Derash*, and local checks at Haramaya University research station during 2011/12 main cropping season. The materials were laid in RCBD with four replications and all the necessary agronomic practice was maintained as per the recommendation.

Results

The mean performance of the sixteen genotypes for the twelve traits is given in Table 1.57. From the analysis of variance, significant difference ($P<0.05$) was observed among the tested varieties for the trait reaction to the Wilt diseases. In line with this, accession EXOTIC #2 DZ /2008, AK was more susceptible to wilt where as accession FILP 97-16L was more tolerant among the tested accessions. This variability opens the opportunity for researcher to develop the resistant variety to the concerned disease.

Work plan
Since the experiment will be repeated for one more season, further evaluation on yield and traits that contribute for yield will be made.

Acknowledgment

The financial assistance from Ethiopian Institute of Agricultural Research and Haramaya University for the research work is highly acknowledged. The authors also wish to thank the Office of the Vice President for Research Affairs of the University for their invaluable support.

Table 1.57. Mean performance of 16 lentil accessions during 2011 cropping season at Haramaya

Trt	DF	DM	STD	ROT	WILT	RUST	MLDW	VIGOR	PH	BMY	TSW	SYLD
X2002S-161-20	46.75	99.00	335.75	0.75	1.50	1.50	0.00	1.50	40.50	2.44	3.80	3153.13
ILL-8008 X ILL-6025-5	45.75	100.0	323.75	0.75	1.50	1.50	2.25	1.50	39.25	2.79	3.80	1833.38
FLIP 2006-20L	46.50	100.5	318.75	0.75	2.25	2.25	0.75	1.50	39.00	2.61	4.48	2150.78
FLIP 2004-50L	47.75	99.25	303.25	0.00	0.75	1.50	0.75	1.25	39.50	2.26	3.55	2032.44
Exotic#2 DZ/2008 AK	47.75	99.25	317.50	0.75	3.00	0.75	1.50	1.75	36.00	2.06	3.48	1621.03
FLIP 97-16L	46.75	99.25	316.25	0.00	0.00	0.75	1.50	1.25	39.50	2.30	3.60	1876.88
Chekol X R-186-2	47.00	98.50	333.75	0.75	1.50	1.50	2.25	1.25	40.75	2.19	3.65	1487.34
R-186 X FLIP 86-38L-10	46.75	99.00	334.00	0.00	2.25	1.50	0.75	1.75	39.50	2.01	3.20	2476.41
R-186X FLIP 86-38L-24	46.75	99.00	316.25	0.75	3.00	1.50	0.75	1.50	39.75	2.79	3.70	1670.47
ILL-358XILL-2573-/2000	47.25	99.75	321.25	1.50	3.00	0.75	0.75	2.00	40.50	2.24	3.40	1866.72
Cechol X R-186-8-1	47.00	98.25	331.00	1.50	0.75	1.50	1.50	1.75	38.25	2.16	3.55	1490.41
R-186 X FLIP 86-38L-4	47.25	98.75	277.00	0.00	0.75	0.75	1.50	1.50	39.00	2.25	3.73	1745.47
EL-142 X R-186-3	46.00	99.00	359.00	0.75	1.50	0.00	0.00	1.75	37.75	1.95	3.15	1825.78
Alemaya	46.25	100.25	298.75	1.50	3.00	0.00	0.75	1.75	37.25	2.16	3.90	1476.09
Derash	46.75	98.75	295.75	0.00	1.50	1.50	0.00	1.25	42.50	2.09	3.53	1856.41
Local check	46.25	99.00	351.50	0.00	1.50	0.00	0.00	1.50	37.75	2.33	3.95	1950.72
Mean	46.78	99.22	320.84	0.61	1.73	1.08	0.94	1.55	39.17	2.29	3.65	1808.56
LSD	ns	ns	ns	ns	2.60	ns	ns	ns	ns	ns	ns	ns
CV	2.57	1.02	16.38	167.40	79.28	137.28	147.99	31.53	9.89	19.39	21.51	34.87

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1.7.15 Fenugreek (*Trigonella foenum*-graecum L.)

Million Fikreselassie, Mekonen Dagne and Mekuanent Belay

Abstract: The necessity of improving fenugreek landraces for Eastern Ethiopia is unquestionable. One hundred forty four accessions including the commercial variety challa were used in this study with the objectives of developing and promoting high yielding, stress tolerant and widely/specifically adapted fenugreek varieties with desirable agronomic and quality traits for western and eastern Ethiopia. The field experiment was conducted at Haramaya University research station during 2011 main cropping season. Treatments were arranged in a 12 x 12 simple lattice design. Significant difference ($P<0.05$) was observed among the tested accessions for the traits such as days to physiological maturity, reaction to the dieses powdery mildew, hundred seed weight and seed yield. High seed yield bearing accessions were those collected from northwest and central part of Ethiopia than accessions collected from eastern and northwestern Ethiopia. This variability would provide a basis for improving the crop in breeding program. From the experiment, twenty-five fenugreek accessions, which were superior in seed yield, and traits that contribute to yield are promoted to Regional Variety Trial for further multi-location evaluation.

Keywords: Improvement; Pulse Crops; Eastern Ethiopia; *Trigonella foenum-graecum* L.

Introduction

Grain legumes not only provide variety to human diet but also supply dietary proteins for vegetarians that abstain animal and fish proteins in their diet. Furthermore, considering the rapidly growing human population and associated demand for more food especially in Sub-Saharan Africa, use of legume species as a source of high-protein food is an amicable option. Moreover, legumes are also capable of symbiotic nitrogen fixation and thereby enriching the soil conditions that become suitable for crops following it (Bromfeild *et al.*, 2001).

Fenugreek is a chemurgic cash crop, usually cultivated as a break crop for cereal, and it is considered as a good soil renovator (McCormick, 2004). The whole plant is used as forage and vegetable, while the seeds (whole, powdered into flour, or roasted) are used as human food and animal feed (Mir and Smith, 1993), spice, dyeing, flavoring, as well as for medical (Westphal, 1974; Sharma, 1990) and industrial purposes (Sharma et al., 1991). The aim of plant breeder is to develop improved varieties with increased yield and an acceptable grain quality and stability. This is the major breeding objective for fenugreek, as reported by Edison (1995) in countries such as India.

Systematic breeding efforts on this crop have so far been neglected and the presence of variability in this crop offers much scope for its improvement. Only little of such vital information on fenugreek landraces is present under Ethiopian conditions. In view of filling up such knowldge gap, this research work was conceived to address the objective of developing and promote high yielding, stress tolerant and widely/specifically adapted fenugreek varieties with desirable agronomic and quality traits for western and eastern Ethiopia.

Materials and Methods

One hundred forty-three random samples of fenugreek accessions along with a commercial variety, *Challa,* were considered in this study. The accessions were collected from the most important production complexes of Ethiopia representing different agro-ecologies of varying altitude, rainfall, temperature, and soil type (Figure 1.8).

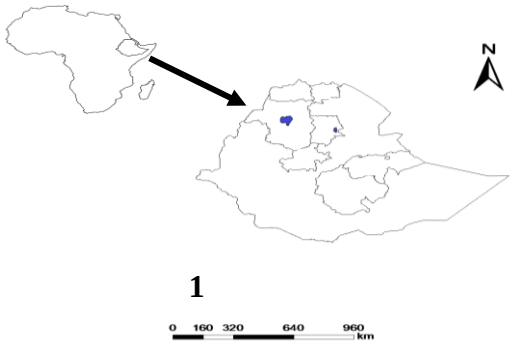

Figure 1.**8** Map of Ethiopia showing geographical locations from where accessions of fenugreek were collected.

The field experiment was conducted at Haramaya University research station which is located at 9°24'N latitude and 42°03'E longitude, during 2011 main cropping season. Haramaya has an altitude of 1980 meter above sea level. It is located in semi-arid sub-tropical belt of eastern Ethiopia. The area receives an average annual rainfall of 870 mm. The soil is characterized as a fluvisol with a pH of 7.4 (Solomon, 2006). Treatments were arranged in a 12 x 12 simple lattice design. Seeding was done in a plot of four rows with 2 m length and regular spacing of 10 cm between plants and 25 cm between rows. The layout and randomization were as per the standard procedure set by Cochran and Cox (1957). Two seeds per hole were placed carefully to ensure the first germination. Thinning was made at the true leaf stage. Weeding and other cultural practices were done as per the recommendations.

Results

The mean performance of hundred forty-four fenugreek accessions for the eleven traits is given in Table 1.58. Analysis of variance showed significant difference ($P<0.05$) among the tested accessions for traits such as days to physiological maturity, reaction to the diseases powdery mildew, hundred seed weight and seed yield. In line with this, the commercial variety, *Challa* , ranked 59th for thousand seed weight (18.29g), 72nd for earliness in days to flowering (47.96 days), 122nd for biomass yield and 61st for seed yield (1503.2 kg/ha) indicating the opportunity to improve the crop from diverse genetic resource with these traits of interest.

Work plan

Twenty-five fenugreek accessions with superior seed yield and traits contributing to yield will be promoted to Regional Variety Trial for further multi-location evaluation in Regional Variety trial to fulfill the DUS criteria.

Table 1.58**.** Mean performance of 144 fenugreek accessions during 2011 cropping season at Haramaya

Trt	DF	ML	ppp	sppl	SPP	PB	SB	PH	BM	TSW	SYLDH
FgColl53007	46.67	4.00	25.95	248.55	9.90	4.02	2.35	60.50	0.33	16.97	2241.25
FgColl53010	46.33	2.00	25.67	242.15	9.53	4.29	2.03	56.33	0.51	15.12	2677.07
FgColl215261	45.88	2.50	16.36	200.25	11.69	2.92	2.18	54.42	0.45	16.15	2263.46
FgColl213109	46.79	3.00	19.26	194.58	8.95	4.06	1.60	53.46	0.38	16.02	2240.22
FgColl213110	47.04	3.00	21.96	204.29	9.47	3.48	1.81	51.71	0.33	14.56	2081.23
FgColl213111	46.83	4.00	21.30	210.46	9.23	3.19	1.82	53.46	0.33	12.47	2102.01
FgColl213112	47.58	4.00	25.87	281.24	10.83	3.58	2.40	58.54	0.46	16.50	2339.45
FgColl213114	46.04	3.00	18.57	229.74	12.20	3.53	1.24	58.25	0.35	15.78	2235.66
FgColl213115	46.54	3.00	28.36	349.61	12.44	3.75	1.88	60.21	0.50	20.15	1878.58
FgColl53014	45.50	2.50	18.80	212.43	10.80	3.02	0.65	57.00	0.02	8.28	1192.27
FgColl53102	47.21	3.00	14.54	183.93	12.75	3.67	0.93	54.50	0.24	22.18	2107.29
FgColl53104	45.04	3.00	17.44	201.40	10.10	3.21	1.02	47.83	0.43	16.35	1069.70
FgColl53105	46.88	4.00	32.95	205.61	8.73	3.43	1.73	64.29	0.60	19.02	1955.04
FgColl212658	47.04	3.00	23.96	236.41	10.15	6.51	2.11	56.63	0.48	18.07	2700.00
FgColl212656	47.08	4.00	23.85	284.97	12.37	3.63	2.26	59.71	0.42	16.05	2259.75
FgColl212657	47.00	4.00	25.26	240.74	9.68	3.68	1.89	57.25	0.45	16.32	2075.61
FgColl213117	47.75	4.00	21.91	177.85	8.00	2.30	2.50	64.00	0.50	18.26	1738.37
FgColl215729	47.04	4.00	25.30	243.82	9.15	3.71	3.16	54.75	0.35	17.02	1959.90
FgColl215731	45.79	3.00	14.56	168.80	6.16	2.10	0.89	26.83	0.28	9.35	944.04
FgColl226090	46.75	3.00	20.16	239.00	11.73	3.45	2.43	63.54	0.28	19.18	1882.70
FgColl53012	46.75	4.00	21.96	208.77	9.22	2.87	1.86	59.50	0.62	24.95	1689.07
FgColl53013	47.21	3.00	19.40	205.60	10.83	3.53	1.04	66.79	0.44	18.13	1991.06
FgColl53019	45.42	4.00	20.84	208.29	9.13	3.38	1.72	60.29	0.51	23.33	2115.23
FgColl53103	43.75	5.00	7.64	128.66	7.03	1.33	0.80	21.63	0.30	7.85	912.63
FgColl234027	46.21	3.00	18.97	163.53	8.95	5.28	1.60	52.33	0.53	19.10	1345.18
FgColl234028	46.88	4.00	16.88	172.43	10.33	3.65	1.18	55.17	0.46	16.80	1391.89
FgColl234030	45.92	2.00	18.58	223.34	11.79	3.08	1.73	57.25	0.35	17.33	1534.09
FgColl234031	45.83	4.00	18.38	227.16	12.05	2.72	1.05	46.79	0.53	17.65	1695.80

Trt	DF	ML	ppp	sppl	SPP	PB	SB	PH	BM	TSW	SYLDH
FgColl234032	46.58	3.00	14.78	144.27	9.12	2.94	1.36	42.54	0.38	19.84	1509.36
FgColl234033	45.88	4.00	16.82	243.24	13.38	3.85	1.37	63.79	0.38	16.15	1671.84
FgColl235133	46.63	4.00	30.38	259.13	8.43	4.14	1.75	63.38	0.41	15.48	2190.08
FgColl234034	46.58	3.00	18.48	253.33	12.95	2.89	2.09	59.08	0.60	16.21	2022.94
FgColl237511	46.58	2.00	17.88	188.09	9.79	2.71	1.43	56.54	0.45	21.68	1856.70
FgColl207359	47.54	4.00	16.42	162.02	9.25	3.38	1.40	57.33	0.47	16.06	1869.60
FgColl207360	46.25	2.50	11.76	137.31	10.85	2.13	1.68	54.83	0.69	21.61	1441.22
FgColl207599	45.58	3.00	15.16	210.18	12.50	2.37	1.47	48.17	0.38	15.53	1069.52
FgColl215585	47.00	3.00	15.47	162.27	10.81	3.53	1.60	53.33	0.53	20.07	1284.17
FgColl234023	46.67	2.00	17.58	173.17	9.34	3.10	2.38	52.67	0.56	17.52	1231.68
FgColl234024	46.71	3.00	26.08	263.67	9.80	3.53	2.33	56.25	0.35	17.00	1533.03
FgColl234025	46.13	2.00	22.08	195.39	8.16	3.97	1.66	54.29	0.43	16.17	1341.49
FgColl234026	46.88	2.00	18.78	162.20	8.83	3.59	2.07	53.04	0.34	16.66	1798.30
FgColl234029		1.00	17.32	187.58	9.59	3.50	2.48	48.79	0.33	16.22	1654.93
FgColl235134		1.50	18.78	175.36	8.70	2.99	2.16	53.38	0.42	16.80	1337.32
FgColl53008	46.88	3.00	19.98	193.56	9.16	2.64	1.00	53.08	0.61	14.48	1535.18
FgColl53009	46.88	3.00	20.08	194.03	9.95	3.16	2.73	48.04	0.45	20.55	1219.00
FgColl53062	47.83	3.00	19.12	188.45	9.61	3.43	1.91	43.33	0.37	19.28	1993.54
FgColl53061	47.54	1.00	23.16	212.34	8.26	3.48	2.59	49.33	0.39	19.53	1351.06
FgColl53071	45.38	3.00	25.06	231.82	8.06	3.22	1.58	48.67	0.54	14.05	1633.51
FgColl236621	46.92	2.00	18.76	168.23	9.16	3.59	0.96	48.50	0.52	17.14	2006.85
FgColl53080	46.58	3.00	14.77	156.23	9.94	3.17	1.24	53.83	0.35	12.89	1887.71
FgColl53096	46.63	2.00	15.56	170.63	10.35	2.89	1.09	68.42	0.34	14.33	2162.41
FgColl5309746.	2.00	23.4	237.55	9.81	2.73	1.02	46.4	0.72	16.8	1707.5	
FgColl53107	47.29	2.00	14.77	148.26	10.18	3.16	0.63	52.21	0.38	18.98	2080.23
FgColl53108	46.58	3.00	20.30	200.83	8.84	3.37	1.44	56.46	0.37	14.49	1935.96
FgColl53109	46.83	5.00	15.47	193.42	12.10	3.96	1.32	55.04	0.25	16.17	1860.90
FgColl212775	46.29	2.00	19.87	247.62	11.86	2.81	1.46	55.25	0.25	14.55	2110.46
FgColl212776	46.29	3.00	24.82	203.38	7.75	3.13	2.79	54.71	0.14	19.67	1599.28
FgColl212779	48.25	2.00	16.40	184.41	10.86	5.09	1.27	50.50	0.41	18.10	1878.72
FgColl226091	46.96	0.50	25.65	232.80	8.76	3.54	2.15	57.50	0.28	20.80	1402.09
FgColl236622	46.29	3.00	21.85	246.28	9.76	3.28	1.93	53.33	0.33	14.52	1741.19
FgColl239065	47.13	3.00	25.51	214.49	9.03	4.19	2.42	60.25	0.43	17.73	2296.70
FgColl239066	46.79	3.00	19.83	180.59	8.75	3.67	1.20	59.58	0.56	16.23	2879.22
FgColl239068	47.83	3.00	22.82	270.09	11.31	2.49	1.95	57.17	0.35	16.37	2373.11
FgColl53005	47.25	1.00	24.48	251.11	9.67	3.13	1.88	52.71	0.48	14.08	1899.02
FgColl 53021	46.50	4.00	25.73	237.48	8.75	2.96	1.78	54.46	0.54	15.67	2302.53
FgColl53026	46.79	5.00	11.56	145.30	9.85	3.07	1.90	51.71	0.33	14.88	2223.31
FgColl53050	47.04	4.00	25.23	270.68	11.16	3.06	1.48	58.29	0.47	14.76	2109.95
FgColl53063	47.00	5.00	17.03	183.08	10.37	4.01	0.92	57.50	0.46	14.84	2126.11
FgColl53078	46.50	3.00	17.33	163.25	9.22	2.73	1.35	56.46	0.40	18.36	1623.28
FgColl53079	46.46	2.00	22.76	215.07	8.62	3.29	3.23	61.25	0.52	15.74	2136.92
FgColl53098	46.67	5.00	28.00	287.06	9.77	3.64	1.11	56.25	0.34	18.70	1950.29
FgColl53099	46.50	2.50	18.70	178.84	8.27	3.08	1.49	53.58	0.24	15.66	2191.05
FgColl205176	47.67	4.00	20.71	197.88	10.13	3.38	1.52	55.79	0.58	16.52	2777.43

Trt	DF	ML	ppp	sppl	SPP	PB	SB	PH	BM	TSW	SYLDH
FgColl207356	46.33	5.00	18.23	251.18	13.36	4.46	1.00	46.13	0.51	15.32	2195.74
FgColl207365	45.38	5.00	6.82	96.29	6.42	1.58	0.85	28.71	0.20	8.30	1178.84
FgColl207367	46.29	4.00	19.22	197.11	10.13	3.33	1.18	48.75	0.58	14.12	1909.75
FgColl207376	47.54	3.00	22.22	284.02	13.35	3.25	1.88	56.50	0.54	16.61	2514.11
FgColl207370	47.33	4.00	17.76	220.99	11.41	3.36	0.80	58.25	0.53	16.62	1956.54
FgColl207391	47.08	2.00	27.33	260.78	9.82	3.75	2.28	43.33	0.52	16.45	2756.48
FgColl212777	47.04	3.00	19.83	247.98	12.23	3.60	1.12	49.54	0.56	13.98	1978.49
FgColl215334	47.04	3.00	16.42	183.64	11.03	3.82	1.05	56.00	0.30	20.40	2249.80
FgColl215335	47.50	1.50	16.86	208.97	12.38	3.88	2.13	57.29	0.42	16.53	2194.30
FgColl239061	46.21	4.00	20.00	243.86	11.98	4.23	1.41	55.79	0.59	22.43	2480.17
FgColl239064	47.04	3.00	25.50	308.53	10.83	3.08	1.69	55.13	0.49	17.55	1951.77
FgColl239062	46.67	4.00	22.79	222.01	10.84	3.73	2.23	55.96	0.53	9.18	2293.64
FgColl237982	46.83	2.50	15.51	141.41	8.92	3.30	1.21	54.79	0.45	5.48	2234.45
FgColl229245	46.88	3.00	16.80	186.31	10.73	3.43	1.16	58.38	0.70	5.96	2170.85
FgColl229246	47.79	3.00	24.90	224.43	8.54	3.07	1.18	54.92	0.67	5.63	1775.91
FgColl229247	48.04	4.00	12.60	133.65	10.51	3.29	1.39	52.17	0.38	10.77	1014.42
FgColl53003	46.83	5.00	15.54	136.02	8.22	3.10	0.50	51.42	0.52	3.38	1580.20
FgColl53002	47.08	2.00	16.51	195.20	12.93	3.49	1.18	52.50	0.46	3.96	1933.49
FgColl53023	47.54	3.00	17.91	210.10	11.14	3.74	2.23	58.71	0.70	3.64	1913.00
FgColl53086	47.04	3.00	22.10	217.67	9.53	3.66	1.36	56.17	0.34	68.90	1490.12
FgColl53087	46.50	4.00	15.84	173.99	10.64	3.23	1.63	55.46	0.51	7.19	1618.81
FgColl53088	47.21	5.00	19.58	240.38	12.04	3.38	2.02	55.46	0.58	67.89	1217.18
FgColl53106	47.04	1.50	14.58	172.06	9.94	3.12	1.00	49.29	0.38	6.35	2061.23
FgColl212549	46.96	2.00	19.93	183.03	10.73	3.75	2.30	49.33	0.46	19.30	1736.13
FgColl212550	46.63	3.00	18.55	221.23	11.80	4.03	0.78	58.17	0.49	18.30	2176.09
FgColl212552	46.67	3.00	21.84	241.94	11.22	2.95	1.03	56.75	0.73	17.93	1058.34
FgColl214942	48.58	3.00	19.45	193.66	10.18	3.59	0.66	51.79	0.61	17.49	1860.90
FgColl215096	47.33	4.00	21.25	237.37	12.30	3.52	0.97	56.54	0.47	17.33	1313.61
FgColl239073	46.63	3.00	15.88	157.74	9.80	2.93	0.78	59.79	0.51	17.54	1577.69
FgColl230072	47.88	3.00	23.75	290.53	12.36	4.02	1.66	59.88	0.60	17.53	2329.28
FgColl53064	47.33	5.00	19.45	252.33	12.83	3.87	1.90	55.58	0.34	17.30	1382.14
FgColl53091	47.33	4.00	23.35	249.29	11.22	3.78	1.03	52.54	0.38	19.72	1381.80
FgColl53100	46.79	2.00	13.18	118.82	9.28	3.85	1.11	52.83	0.45	18.30	1982.15
FgColl212876	47.00	4.00	16.53	175.51	11.03	3.70	0.99	55.83	0.57	20.61	1605.52
FgColl212877	46.33	4.00	6.93	77.38	4.63	0.74	-	25.17	0.32	8.77	354.57
FgColl212878	46.92	5.00	21.60	217.46	10.74	3.65	0.75	58.71	0.65	17.94	2479.29
FgColl215405	46.08	2.00	14.02	153.26	10.91	3.53	1.23	48.04	0.43	17.24	1982.66
FgColl215406	46.13	3.00	18.01	219.06	11.23	3.25	1.68	52.13	0.48	15.83	1863.20
FgColl53072	47.04	3.00	26.21	233.58	9.13	2.99	2.00	53.67	0.55	17.29	1914.06
FgColl53074	46.79	3.00	20.21	218.90	11.21	3.22	0.81	63.92	0.36	18.63	1620.18
FgColl53075	45.08	3.00	2.55	29.07	5.26	1.33	-	26.17	0.20	7.49	740.90
FgColl216897	46.33	2.00	15.02	154.05	10.67	3.22	0.90	56.75	0.59	17.02	2639.15
FgColl216898	46.29	1.00	17.92	186.35	10.48	3.67	1.84	56.46	0.53	15.90	1857.00
FgColl216899	46.79	2.00	16.01	134.42	9.33	2.78	1.18	53.42	0.57	23.82	1515.02
FgColl230073	47.25	2.00	16.35	134.84	8.58	3.25	1.05	54.21	0.49	18.05	2103.71
FgColl232194	47.46	0.50	14.99	143.13	10.23	3.00	2.03	53.21	0.56	23.35	2666.18

Trt	DF	ML	ppp	sppl	SPP	PB	SB	PH	BM	TSW	SYLDH
FgColl236992	47.29	4.00	12.79	137.71	9.98	2.64	0.82	48.54	0.41	17.57	2011.94
FgColl237984	46.96	3.00	22.50	191.23	11.24	4.25	2.80	65.79	0.63	18.59	1736.29
FgColl239727	45.63	3.00	13.32	106.23	5.86	2.63	0.73	39.13	0.26	11.89	1836.30
FgColl53006	47.17	4.00	26.31	205.24	9.23	4.95	1.88	63.71	0.70	19.97	2436.85
FgColl53085	46.08	4.00	13.91	128.06	6.63	2.09	1.20	33.25	0.43	11.13	996.96
FgColl230070	48.33	3.00	27.91	268.57	11.46	5.12	3.21	66.00	0.39	20.03	2362.97
FgColl232195	47.13	5.00	21.55	290.84	15.36	4.43	1.53	58.25	0.48	16.63	2277.10
FgColl219250	46.88	3.00	22.32	245.93	12.87	4.42	2.00	73.33	0.67	20.82	2706.99
FgColl223349	46.83	4.00	25.42	292.13	13.38	4.87	2.65	69.54	0.66	19.35	1790.70
FgColl53016	46.33	2.00	14.41	108.09	5.23	1.88	1.28	35.50	0.35	15.41	1201.17
FgColl53017	46.29	3.00	12.85	140.02	7.53	2.15	1.05	37.79	0.27	11.05	1498.21
FgColl53018	45.50	0.50	13.69	91.61	5.08	2.60	0.54	40.29	0.44	15.15	888.18
FgColl208679	46.33	3.00	9.49	72.48	5.18	1.54	0.12	33.63	0.34	9.81	1346.48
FgColl208680	47.58	6.00	20.60	195.88	10.48	4.49	1.45	66.00	0.68	19.12	3139.76
FgColl53016	46.75	3.00	32.01	332.48	10.85	4.37	1.63	55.33	0.50	15.52	2298.88
FgColl223350	47.29	3.00	19.10	263.19	14.02	3.19	1.78	61.92	0.70	16.65	1757.77
FgColl223351	46.21	4.00	28.50	308.81	10.93	3.73	1.80	51.46	0.47	17.51	1869.48
FgColl223352	47.46	4.00	22.40	271.82	12.05	3.86	1.51	55.71	0.38	19.05	1766.39
FgColl223353	45.75	5.00	5.44	86.49	6.65	2.07	0.32	23.96	0.27	8.21	846.32
FgColl230536	46.50	2.00	20.31	218.08	10.71	2.96	0.90	57.54	0.56	16.05	2259.56
FgColl230540	45.96	2.00	8.71	103.58	5.93	1.81	1.04	24.25	0.35	7.58	944.12
FgColl230880	47.46	3.00	35.30	328.54	9.22	4.03	2.18	62.71	0.59	24.19	1187.89
FgColl230883	47.42	3.00	18.54	142.97	8.18	3.19	1.25	57.00	0.51	17.98	2132.43
FgColl241140	47.13	1.50	33.18	218.36	7.18	3.54	2.13	63.50	0.48	22.98	2355.80
Challa	47.96	4.00	23.18	259.43	10.28	3.08	1.72	56.83	0.53	18.29	1503.20
Mean	46.75	3.11	19.53	202.80	10.01	3.35	1.53	53.49	0.45	16.79	1842.96
LSD	ns	0.72	ns	ns	ns	ns	ns	ns	ns	11.14	876.91
CV	1.89	46.4	35	36.88	30.22	29.94	53.7	23.22	40.4	7.33	13.08

Acknowledgment

The financial assistance from Haramaya University for the research work is highly acknowledged. The authors also wish to thank the Office of the Vice President for Research Affairs of the University for its invaluable support.

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1.8 Natural Resources Management and Environmental Sciences

1.8.1 Production of Vermicompost from Khat (*Catha edulis)* Wastes Using *Eisenia foetida* Earthworms

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Abstract: Khat (Catha edulis) is a flowering evergreen plant used since ancient times as a recreational and religious stimulant in different parts of eastern Africa. It is a cash crop harvested everyday for the use of young fresh leaves with small twigs. The young leaves are chewed and the older leaves and twigs are dumped as a waste material. The city of Awaday is known for its Khat market and it produces enormous waste everyday, which is either dumped as a waste or used as firewood. Organic farming using compost is an eco- friendly technology that can be used to improve the soil conditions and crop production. The wastes can be composted and used as an organic fertilizer. The present work was an attempt to vermicompost khat waste collected from Awaday and analyzing its nutrient content and observing its suitability to be used as manure. The earthworm used was Eisenia foetida, the red worm. The results of the compost analysis reported to be improving the quality of the product by increasing the macro and micronutrients.

Keywords: *Catha edulis*; Waste Material; Vermicomposting; Eisenia foetida; Macro and Micro Nutrients

Introduction

Catha edulis commonly called as *khat* is a commonly grown plant around Oromiya, Hararghe region of East Ethiopia. The plant serves the economy as an export material. It is part of the social and cultural life of people. The processing and packaging of the leaves and export marketing is a yearround business that occurs in this region. The chewing of khat is commonly observed in this region. The processing of the plants and the chewing of the leaves produces a large quantity of waste material that is dumped into the environment. The solid waste material that is dumped can be collected and utilized for the production of manure. This will benefit farmers and improve soil fertility as well as environmental sanitation. Awaday market produces approximately 15-20 tons of waste each day. The production is more in the summer as compared to the winter times. Kobo and Awaday towns form the main market place for khat. Though Awaday is also market for vegetables and fruits, it is more renowned for the khat marketing due to more accessible to the international air port at Dire Dawa, asphalt road connection to Harari region, Addis Ababa city and Jigjiga (Somali National Regional state), and some towns of Somali Land.

The attention given to the processing or proper disposal of waste from khat is currently much less as compared to the level of use of khat. The packaging material for khat to maintain its freshness also adds to the solid waste. The packaging material and processing for export even adds more waste leaves. Often thick and older part of the plant is cut while exporting it. The utilization of khat twigs as firewood is practiced but the quantity of that generated and the utilization are not matching. Thus, the solid waste is accumulated in the environment in enormous quantity. Therefore, simple and efficient method of processing of these waste substances into useful product is necessary.

Vermicomposting is the process by which worms are used to convert organic materials (usually wastes) into a humus-like material. The goal is to process the material as quickly and efficiently as possible. It is a low cost technology used to convert different solid waste materials of biodegradable nature to valuable farm manure. The resultant product is a very good source of nutrients to the crops as well as the soil. The positive effects of the biofertilizer add to its importance for using it in agriculture to improve soil fertility and thus enhance crop production (Cristina and Jorge, 2011). The vermicompost is a nutrient rich amendment with microbiological activity that conditions the soil. The activity of earthworms and microorganisms during the biodecomposition process is important in improving the organic matter of the soil. The vermicompost is a stable peat like material with low C:N ratio, high porosity, high water holding capacity and readily available form of nutrients (Dominguez, 2004). The action of earthworms in soil makes them mechanical blenders fragmenting the organic matter and increasing the surface area for microbial activity. They improve the physical and chemical status of the soil. The activity of earthworms results in earthy appearance of the substrate with good organic matter and heterogeneous appearance of the product of decomposition (Dominguez et al., 2010, Ndegwa and Thompson, 2001, Tognetti et al., 2005). The present study was carriedout with an objective of decomposing the solid waste generated from khat market and converting it into useful manure using *Eisenia foetida* earthworms.

Materials and methods

Description of the Study Area

East Hararghe zone is located in eastern part of the regional state of Oromia. In East Hararghe zone, there are twelve urban centers having their own municipal authorities. Awaday is one of urban centers. The town is located in the Eastern Hararghe zone of Oromia region at 419 km from Adama, and about 510 kilometers from Addis Ababa. Awaday town was established in 1946 E.C. According to informants, the name of the town was "Didimtu" which means red and sandy top soil. The main and important factors that contribute to the town's establishment were the geographical location of the town between Harar city and Haramaya town. Awaday town is the center of trade. Moreover, it has strategic location for khat trade and good climate condition for the preservation of khat. Awaday is bordered with Harar city to the southeast, Haramaya town to the north-west, Fadis and Gara Mulata Woredas to the south-west and Kombolcvha Woireda to the northeast. The location of this town is in the center of the above Waradas, which have high potential of khat production, and the town developed domestic and international market.

Research field of Haramaya University campus is located in East Hararghe zone of Oromiya National Regional state. The experimental field is located at 9° 26'N latitude and 42° 3'E longitude. The average altitude is about 1980 m.a.s.l. 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 777 mm. The site receives bimodal rainfall that occurs between March – April and June to September. The mean monthly temperature ranges from 9.2 to 23.2 °C.

Process of Vermicomposting

Khat waste was collected from Awaday and composted using earthworms at Rare research site, Haramaya University. The vermicomposting process was carriedout in pits of 1 m x 1 m x 0.3 m, and all were arranged in triplicates. Each pit was stocked with 28 kg of two different forms of feedstock: Treatment 1 (Tr.1): Feedstock exclusively composed of khat residue (100%), Treatment 2 (Tr.2): Feedstock composed of khat residue (70%) and leafy twigs of Eucalyptus species (30%). The vermipits were thinly bedded with 6 kg of fresh cow dung together with each form of the feed stocks, chopped into smaller pieces to enhance rate of the composting process (Borah et. al., 2006), and then uniformly stacked to 15 cm depth. After four weeks of thermophilic stage, 350 matured earthworms (*E. foetida*) were released into the pits with some humic materials. The worms were abundantly multiplied. Throughout the process, pits were aerated and the residues were thoroughly mixed up once a week. In addition, moisture content was closely checked so that water is added whenever required. Then, all pits were covered with gunny cloth to avoid excessive moisture loss. After 17 weeks of the process, the ending product was harvested, air-dried, passed through 2 mm sieve, and weighted. Throughout the process, the daily range of temperature was 5 – 25 ºC.

Analysis of Physical and Chemical Properties of the Vermicompost

Some physical parameters such as moisture content, particle size (texture), bulk density, and water-holding capacity were determined following the standard procedures. The water holding capacity (WHC) (% volume) was calculated as [(wet weight - dry weight)/volume] x 100 (Inbar et al., 1993). The moisture content was determined after drying at 70°C for 24 hours. Sieved samples were packed in paper bags and stored at 5 ºC. The vermicompost produced was tested at Haramaya University soil laboratory. Chemical parameter such as pH was determined using compost:water ratio (w/v) 1:15 (Inbar et al., 1993) and the same suspension were used for measuring electrical conductivity using a conductance meter after being standardized with 0.1M KC1. Total nitrogen (%) was measured by Kjeldhal method (Jackson, 1973). Available phosphorous was measured using the method described by Olsen et al. (1954). Basic cat ions (Ca, Mg, K and Na) were analyzed using a flame photometer, micronutrients (Fe, Zn, Mn and Cu) by DTPA method (Lindsay and Norvell, 1978). Organic carbon (%) was determined by wet oxidation method.

Data were analyzed by descriptive statistics using the coefficient of variation (CV), linear regression analysis, and mean values. CV (%) is the best measure of comparing the variability or consistency of two or more samples or varieties of distributions. The smaller the coefficient of variation, the greater is its consistency. SAS ver. 9 (SAS Institute, Inc.) was used for statistical analysis.

Results and Discussion

The main physical and chemical properties of the khat residue based vermicompost are summarized in Table 1.59. Statistical analysis shows no significant difference between the treatments ($P > 0.05$) in the different parameters maesured, may be due to the relatively low composting khat residues in both treatment materials (100% and 70% in Tr.1 and Tr.2, respectively). Since it is realized that certain elements are needed by plants in trace amounts (Fe, Zn, Mn and Cu), the processed products may be valuable in this regards.

Based on the analytical results, pH values of both treatments are within the optimum range of 6.5-7.5. Within this range, most of the micronutrients exhibit maximum availability though metallic ions are generally less available above pH 7. It has been shown by repeated research that when compost is added to the soil, it acts as a chemical buffer, increasing the plant's tolerance to pH; and adding compost to a slightly alkaline soil will bring it towards neutral. In this regard, the

khat residue based vermicompost may be used as bio-manure under such limitation (www.ranchomondo.com). The EC level was very low in both treatments. For example, the tolerable salt level for fruits and vegetables equals to 6 dS/m, and 1dS/m for salt sensitive species (Leslie, 2004). Therefore, the result revealed that there is no risk of salinity when vermicompost is used as organic fertilizer.

Micronutrients are moderately available in the khat residue based vermicompost when their mean values are compared with the standard compost quality (TMECC, 2001; Nagavallemma, 2004). Several field experiments have proven that plant available nitrogen increases with time after harvesting vermicompost (Vermicompost Research Update, 2009). The C:N ratio (= 11) also shows that *khat* residue made vermicompost can be stabilized and become matured within the specified time (17 weeks). The C:N of stable humus in fertile soils is generally in the range of 10-15 (Nagavallemma, 2004). Regarding water holding capacity of the compost, it is very high (198 % and 210 % for Tr.1 and Tr.2, respectively). This might be due to spongy nature of the vermicompost, which implies that *khat* residue based vermicompost may be effective to potential reductions in irrigation amount and frequency. Gezahegn et al. (2012) has reported that the vermicomposting of *khat* wastes with *Eisenia andrei* was found to increase the macro and micro nutrient contents making it suitable manure.

Table 1.59. Nutrient value of Khat residue based vermicompost

S.no	Parameters	Mean values		CV (%)
		Treatment-1 (Tr.1)	Treatment-2 (Tr.2)	
1	pH (H_2O)	7.4	7.3	1.69
2	EC (ds/m)	0.65	0.68	6.4
3	Mg (cmol(+)/kg)	4.29	4.18	2.64
4	Ca (cmol(+)/kg)	20.2	20.7	3.54
5	K (cmol(+)/kg)	0.89	0.96	14.3
6	Na (cmol(+)/kg)	0.48	0.53	15.05
7	Zn (ppm)	39.5	39.6	2.09
8	Mn (ppm)	34.1	39.6	13.04
9	Fe (ppm)	27.9	28.9	5.49
10	Cu (ppm)	13.1	12.5	12.2
11	Total nitrogen (%)	1.1	1.4	19.1
12	Available phosphorus (%)	0.56	0.57	21.43
13	Organic Matter (%)	21.7	28.0	-
14	Organic Carbon (%)	12.6	16.2	-
15	Ash content (%)	38	43	-
16	C:N ratio	11.4	11.5	-
17	Particle size	2mm	2mm	-
18	Bulk density(g/cm^3)	0.60	0.63	-
19	Water holding capacity (%)	198	210	-

During the process of composting, the volume of *khat* waste has reduced significantly. The volume reduction is attributed to the decomposition of organic substances and compaction. Thus, simple and traditional way of composting is considered cost effective and environmentally friendly method of waste reduction and removal unlike the technology based factory level composting which requires maintaining the C: N ratio feed stocks. The temperature of the piles was found to pick up to a maximum of 64°C. Subsequently the temperature starts declining to a daily average temperature of 25°C as the compost in the center of pile is cooled or reaches its maturity. The analytical results of the nutrients contents of eight samples of composts were 0.9-1.40% for nitrogen, 532-803 ppm available phosphorus, and 6775.72-12445.24 ppm for available potassium. The volume of waste piles have been reduced from $1m^3$ to 0.40 m^3 (Mahabub, 2008).

Decomposing of strawboard manufacturing waste was found to reduce the volume of waste and the nutrient contents were improved significantly in the composted material (Chapman and McCartney, 2005).Vermicompost is a nutritive 'organic fertilizer' rich in NKP (nitrogen 2-3%, potassium 1.85-2.25% and phosphorus 1.55-2.25%), micronutrients, beneficial soil microbes like 'nitrogen-fixing bacteria' and 'mycorrhizal fungi' and are scientifically proving as 'miracle growth promoters & protectors'(Sinha et al., 2009). Annual applications of adequate amount of vermicompost also result in significant increase in soil enzyme activities such as 'urease', 'phosphomonoesterase', 'phosphodiesterase' and arylsulphatase'. The soil treated with vermicompost has significantly more electrical conductivity (EC) and near neutral pH (Tiwari et al., 1989).

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1.8.2 Assessment and Evaluation of Need of Inoculation of Effective Rhizobia Isolates on Common Bean (*Phaseolus vulgaris L.)* in Ethiopia Soils

Anteneh Argaw, Bulti Tesso, Ayele Akuma

Background and Justification

Common bean is widely cultivated in areas with altitude range of 1400-2000, as a sole crop or inter cropped with sorghum, maize and other crops. The Rift valley contributes 48% out of the total land of 163,688ha covered with common bean in the country. It also produces 55% of the total yield of 1,384,216 quintals of the country (Teshale Assefa *et al.,* 2006). The Hararghe highland is also one of the major common bean producing areas in the country (Wortmann and Allen, 1994). It is estimated to cover 267,069 ha of land with a production of 1 ton per ha (CSA, 2009). It is becoming important as short duration crop because of the recurrent late onset and early termination of rainfall in these areas.

The yield is extremely low due to low soil fertility, smallholder farming and limited access to external inputs (Amare Abebe 1987; EARO, 2000). One of the most important factors of soil fertility is nitrogen (N) deficiency of most Ethiopian soils (Desta Beyene and Angaw Tsigie, 1986). Most farmers in the developing countries such as Ethiopia are resource poor and cannot afford the required inputs, mainly in the form of chemical N fertilizers. Legume-*Rhizobium* has been exploited elsewhere as a substitute for the N fertilizers (Aynabeba Adamu *et al.,* 2001). Inoculation with highly effective rhizobia, a common practice in agricultural production (Catroux et al., 2001), requires survival and establishment of inoculated rhizobia in the soil environment (Da and Deng, 2003). Therefore, biological nitrogen fixation should be more exploited to increase nitrogen for common bean cultivation in Ethiopia. To our knowledge, two preliminary studies have reported the presence of rhizobia nodulating common bean in Ethiopian soils (Anteneh, 2007; Belaineh, 2009). Moreover, Anteneh (2007) indicated the presence of highly effective rhizobia nodulating common bean in Eastern Ethiopia soils. Identification of effective locally adapted strains could be useful in the development of inoculant strains, which can survive longer in agricultural soil and hence reduce the need for inoculant application each growing season.

General objective

- To assess and evaluate symbiotic effectiveness of effective rhizobia isolates on yield and yield components of common bean cultivated in eastern Ethiopian soils

Specific Objectives

- To isolate and characterized effective strain of rhizobia nodulating Common bean.
- To evaluate the symbiotic effectiveness of selected strain of rhizobia at Haramaya, Fedis, Babille and Hirna experimental sites.

Materials and Methods

Source of bacterial isolates

Well characterized rhizobia nodulating common bean under greenhouse condition on sand and soil cultures was obtained from Haramaya University, Biofertilizer Research and production centre. The isolates have been verified under laboratory and greenhouse condition at Haramaya University.

Experimental sites

The study of the effect of inoculation on common bean growth was conducted at Fedis and Haramaya experimental fields. These are located in eastern Ethiopia, Hararghe Highland.

Soil Sampling and Analysis

Soil samples from a depth of 0-30cm were collected at random from each experimental site before and after planting. A subsample of the composite was air-died, sieved through a 2 mm sieve and analysed for important soil physico-chemical properties such as soil pH, EC, available P, Total N, exchangeable bases (Na, Ca, Mg ,K), B, Mo, Total P (inorganic and organic P), CEC, and soil texture following the procedure indicated in Sahlemedhin and Taye (2000). The native rhizobial population nodulating common bean was estimated using a fresh soil subsample according to the most probable number (MPN) method (Vincent, 1970).

Seed sources and Biofertilizer preparation

Seeds of improved common bean cultivars were obtained from Melkasa Agricultural Research Centre and Haramaya University lowland pulses improvement project. Whereas, the local varieties currently cultivated by local farmer's was

used as local cultivars. Biofertilizer from highly effective rhizobia were prepared one month prior to seeding by adding 30ml rhizobial culture (grown to lag phase in yeast extract Manitol broth containing 10^8 of bacterial ml^{-1} of culture) to 200g sterile vermicompost prepared from parthinium weeds. These were well mixed and incubated for 14 days at 27°C (pryor *et a*l., 1970). Then seeds were planted manually to a depth of 1 cm.

Field experiment

In each experimental field, trials were carried out using selected highly effective eight rhizobia nodulating common bean isolates. The experiments were laid out in RCBD fashion. All treatments were replicated three times. There are ten (10) treatments, and the treatments consisted of T1- Rhizobium inoculums 1, T2 Rhizobium inoculums 2, T3- Rhizobium inoculums 3, T4- Rhizobium inoculums 4, T5- Rhizobium inoculums 5, T6- Rhizobium inoculums 6, T7- Rhizobium inoculums 7, T8- Rhizobium inoculums 8, T9- positive control (with starter nitrogen i.e. 20kgN/ha); T10-Negative control (with no chemical and biofertilizer application). All seeds were surface sterilized with alcohol followed by 5% H_2O_2 to avoid contamination and then washed five times using sterilized water as indicate in Vincent (1970). Seed inoculation was performed before sowing using 10gm/kg of seed (to make approximately $1x10^6$bacterial cells/seed). For inoculated treatment, biofertilizers were separately mixed with the seeds with sucrose solution to increase adherence. All plots were fertilized with phosphorus fertilizer at rate of 46kg P_2O_5/ha as TSP whereas 20 KgN/ha as Urea was applied for positive control plots.

Results

Eight isolates of rhizobia were selected based on their symbiotic effectiveness under control environment (Tables 1.60, 1.61, and 1.62). The data indicated that isolates showed significant effect on grain and biomass yield of three tested cultivars of common bean at Haramaya experimental site. These isolates are being evaluated under field condition at Haramaya, Fedis, Babile and Hirna experimental sites**.** So far, nodulation data and plant tissue samples for tissue analysis were collected from each experiment.

Table 1.60. The effect of rhizobia spp. on yield of Common bean (*Phaseolus vulgaris* L.) var. Kufanzik at Fedis and Haramaya experimental sites

	Biomass yield (ton/ha)		Grain yield (kg/ha)	
Treatment	Haramaya	Fedis	Haramaya	Fedis
Isolate 1	4.8898^{d}	5.543^{abc}	3131.4^{bc}	2938.8
Isolate 2	5.9758^{bcd}	5.414^{abc}	3832.6^{abc}	3714.0^{ab}
Isolate 3	4.9506^{d}	5.520^{abc}	2969.9^{bc}	4178.3^{a}
Isolate 4	5.3447^{cd}	3.966^{c}	2979.9^{bc}	2197.6^{d}
Isolate 5	7.4945^{a}	4.437^{abc}	3984.1^{ab}	2719.3^{bcd}
Isolate 6	6.7087^{abc}	4.710^{abc}	2990.5^{bc}	2199.9^{d}
Isolate 7	4.6341^{d}	6.539^{a}	2769.1^{c}	3380.0^{abc}
Isolate 8	5.5837^{bcd}	6.153^{ab}	3654.7^{abc}	3714.0^{ab}
Positive control (46kg N/ha)	6.8880^{ab}	4.143^{bc}	4400.2^{a}	2312.9^{d}
Negative control	4.8486^{d}	4.913^{abc}	2966^{bc}	2594^{cd}
CV (%)	18.10	27.7	15.34	19.82
LSD (0.05)	1.4977	2158.8	1089.8	999.35

Table 1.61. The effect of rhizobia spp. on yield of Common bean (*Phaseolus vulgaris* L.) var. Dursitu at Fedis and Haramaya experimental sites

	Biomass yield (ton/ha)		Grain yield (kg/ha)	
Treatment	Haramaya	Fedis	Haramaya	Fedis
Isolate 1	5.005^{c}	4.391^{b}	1957.0^{c}	1837.7^{b}
Isolate 2	10.679^{a}	8.895^{a}	4117.9^{a}	2755.3^{a}
Isolate 3	5.800^{c}	2.148^{cd}	2695.5^{bc}	999.5^{def}
Isolate 4	6.102^{bc}	3.759^{bc}	2496.6^{bc}	1338.2^{cdef}
Isolate 5	7.308^{bc}	2.434^{cd}	2447.4^{bc}	661.9^{f}
Isolate 6	7.408^{bc}	2.473^{cd}	2191.5^{c}	1178.7^{cdef}
Isolate 7	8.703^{ab}	3.465^{bc}	3257.4^{ab}	1585.4^{bcde}
Isolate 8	5.600^{c}	2.919^{bcd}	2480.8^{bc}	1696.7^{bc}
Positive Control (46kg N/ha)	6.844^{bc}	1.806^{d}	2762.3^{bc}	825.6^{f}
Negative control	5.065^{c}	1.665^{d}	2553.7^{bc}	709.7^{f}
CV (%)	23.5	28.26	22.6	25.63
LSD(0.05)	2.7412	1634.3	1035.8	593.25

Table 1.62. The effect of rhizobia spp. on yield of Common bean (*Phaseolus vulgaris* L.) var. Gofta at Fedis and Haramaya experimental sites

Treatment	Biomass yield(ton/ha)		Grain yield (kg/ha)	
	Haramaya	Fedis	Haramaya	Fedis
Isolate 1	5.6804^{b}	3.577^{bc}	3430.5^{d}	2243.2^{bc}
Isolate 2	6.1483^{ab}	5.232^{bc}	3574.3^{cd}	3117.0^{ab}
Isolate 3	6.0852^{ab}	4.304^{bc}	3410.7^{d}	2488.5^{bc}
Isolate 4	7.4254^{ab}	5.020^{ab}	4809.0^{b}	2947.0^{b}
Isolate 5	6.0680^{ab}	6.763^{a}	3554.3^{cd}	3906.3^{a}
Isolate 6	7.4003^{ab}	2.403^{c}	6049.3^{a}	1604.4^{cd}
Isolate 7	7.9060^{a}	4.280^{bc}	5120.7^{ab}	2597.3^{b}
Isolate 8	5.7694^{b}	5.327^{ab}	4481.6^{bc}	3119.5^{ab}
Positive Control (46kg N/ha)	6.3930^{ab}	2.403^{c}	3088.0^{d}	1143.3^{d}
Negative control	5.8893^{b}	4.343^{bc}	3788.1^{cd}	2765.6^{b}
CV (%)	17.52	28.29	13.31	21.64
LSD(0.05)	1.9331	1.634	936.08	955.57

Conclusion (overall assessment)

Isolates under control environment were performed better than the control. The technology is available at HARC microbiology research section only. The trial has to be repeated for another year in order to provide conclusive results.

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1.8.3 Evaluation of the Effect of Integrated Application of Nitrogen Fertilizer With and Without Inoculation of Effective Rhizobia Isolates on Yield and Yield Components of Common Bean (Phaseolus vulgaris L.) in Eastern Ethiopia Soils

Anteneh Argaw, Bulti Tesso, Ayele Akuma

Background and Justification

Common bean is widely cultivated in Ethiopia with attitude range of 1400-2000, as a sole crop or inter cropped with sorghum, maize and other. The Rift valley contributes 48% out of 163,688ha and 55% of 1,384,216 quintals production of the country (Teshale Assefa *et al.,* 2006). The Hararghe highland is also one of the major common bean producing areas in the country (Wortmann and Allen, 1994). It is estimated to cover 267,069 ha of land with a production of 1 ton per ha (CSA, 2009).

The yield is extremely low due to low soil fertility, smallholder farming and limited access to external inputs (Amare, 1987; EARO, 2000). One of the most important factors of soil fertility is nitrogen (N) and phosphorus (P) deficiency of most Ethiopian soils (Desta and Angaw, 1986). Nitrogen requirement of legumes can be met by both mineral N assimilation and symbiotic N2-fixation (George and Singleton, 1992). Most beans are produced by smallholder farmers who rarely neither inoculate with *Rhizobia* nor apply fertilizers. Most farmers in the developing countries such as Ethiopia are resource poor and cannot afford the required inputs, mainly in the form of chemical fertilizers. Legume-*Rhizobium* has been exploited elsewhere as a substitute for the N fertilizers (Anteneh, 2007; Asefaw and Angaw, 2006; Belaineh, 2009 and Aynabeba *et al.,* 2001).

Unlike many legumes, bean often does not derive much plant N from the atmosphere under low input conditions although biological N fixation can be enhanced by P application (Giller, 2001). Because bean N fixation levels are commonly low, there is often grain yield response to N and P application (Wortmann, 2006). Bean yield was increased with application of up to 80 kg ha^{-1} N in Malawi, largely associated with increased pods $plant^{-1}$ (Edje *et al.,* 1975).

General objective

- To evaluate different levels of nitrogen fertilizer with and without selected effective strain of *Rhizobium* sp. at Haramaya, Fedis, Babillea and Hirna experimental sites

Results

This experiment has been conducted to evaluate the effect of different levels of nitrogen with and without inoculation on common bean. This experiment is being evaluated under field condition at Haramaya, Fedis, Babile and Hirna experimental sites**.** So far, nodulation data and plant tissue samples for tissue analysis were collected from each experiment. Preliminary result indicated that isolates under control environment were performed better than the control. The trial has to be repeated for another year in order to provide conclusive results.

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1.8.4 Assessment and Evaluation of Need of Inoculation of Effective Rhizobia Isolates on Groundnut (Arachis hypogea L.) in Eastern Ethiopia Soils

Anteneh Argaw, Yemane Girma, Ayele Akuma

Background and Justification

Groundnut is a recent introduction to Ethiopia. It is widely grown in the eastern part of the country i. e. Hararghe (Yebio *et al*., 1987). Gradually it is well produced in the eastern, western and northwestern lowlands of Ethiopia (Getinet and Nigussie, 1992), and to some extent in the south (Elias, 1992). In Ethiopia, Groundnut is cultivated predominantly by the traditional and undeveloped farming community under rain-fed conditions. It occupies about 41,761 hectares of land with a corresponding gross annual production of about 46, 887 metric ton (CSA, 2009). The yields of groundnut in Ethiopia compared to other countries are very low i.e. below 1.1 ton ha^{-1} as compared to average yields on a global scale i.e. 1.52 ton ha^{-1} but with good management practices, yields can be increased to 3.0 ton ha^{-1} (CSA, 2009; FAOSTAT, 2009). This shows the yield in Ethiopia is extremely low mainly due to low soil fertility, smallholder farming and limited access to external inputs (Amare, 1987; EARO, 2000). One of the most important factors of soil fertility is nitrogen (N) deficiency of most Ethiopian soils (Desta and Angaw, 1986).

Most farmers in the developing countries such as Ethiopia are resource poor and cannot afford the required inputs, mainly in the form of chemical N fertilizers. Legume-*Rhizobium* has been exploited elsewhere as a substitute for the N fertilizers (Aynabeba, 2001). Inoculation with highly effective rhizobia, a common practice in agricultural production (Catroux *et al.,* 2001), requires survival and establishment of inoculated rhizobia in the soil environment (Da and Deng, 2003). Studies carried out by the National Soil Survey Project (NSSP 1990); by the Alemaya University of Agriculture (Mitiku, 1990) and Asfaw and Angaw (2006) clearly revealed that inoculations with rhizobia have improved the yield of legumes in Ethiopia. Therefore, biological nitrogen fixation should be more exploited to increase nitrogen for pulses cultivation in Ethiopia. The result of Okito *et al.* (2004) using the natural ^{15}N abundance techniques, estimated that the contribution of symbiotic nitrogen fixation (SNF) was 40.9 kg ha^{-1} for groundnut and the proportion of N derived from SNF (%Ndfa) ranged between 49 and 58%.

Identification of effective locally adapted strains with wide application could be useful in the development of inoculant strains, which can survive longer in agricultural soil and hence reduce the need for inoculant application each growing season. Ayele (2010) indicated the presence of highly effective bradyrhizobia nodulating groundnut in Eastern Ethiopia soils. Inoculation recommendations may be made depending on the populations, competitiveness, and effectiveness of the indigenous rhizobia in the soil. Therefore, we have characterized more than 60 isolates collected from Hararghe soil under control condition, of which the top eight symbiotically highly effective bradyrhizobia isolates have been selected for further symbiotic effectiveness characterization under field conditions

General objectives

- To assess and evaluate symbiotic effectiveness of effective bradyrhizobia isolates on yield and yield components of groundnut cultivated in eastern Ethiopian soils.

Specific objective

- To isolate and characterize effective strain of rhizobia nodulating groundnut.

- To evaluate the symbiotic effectiveness of selected strain of rhizobia at Fedis and Babillea experimental sites.

Materials and Methods

Source of bacterial isolates

Well characterized rhizobia nodulating groundnut under greenhouse condition on sand and soil cultures was obtained from Haramaya University, Biofertilizer Research and production centre. The isolates have been verified under laboratory and greenhouse condition at Haramaya University.

Experimental sites

The study of the effect of inoculation on groundnut growth was conducted at Fedis and Haramaya experimental fields. These are located in eastern Ethiopia, Hararghe Highland.

Soil Sampling and Analysis

Soil samples from a depth of 0-30cm were collected at random from each experimental site before and after planting. A subsample of the composite was air-died, sieved through a 2mm sieve and analysed for important soil physico-chemical properties such as soil pH, EC, available P, Total N, exchangeable bases (Na, Ca, Mg ,K), B, Mo, Total P (inorganic and organic P), CEC, and soil texture following the procedure indicated in Sahlemedhin and Taye (2000). The native rhizobial population nodulating groundnut was estimated using a fresh soil subsample according to the most probable number (MPN) method (Vincent, 1970).

Seed sources and Biofertilizer preparation

Seeds of improved groundnut cultivars were obtained from Werer agricultural research center and Haramaya University lowland oil crops improvement project. Whereas, the local varieties currently cultivated by local farmer's was used as local cultivars. Biofertilizer from highly effective Bradyrhiobia were prepared one month prior to seeding by adding 30ml rhizobial culture (grown to lag phase in yeast extract Manitol broth containing 10^8 of bacterial ml^{-1} of culture) to 200g sterile vermicompost prepared from parthinium weeds. These were well mixed and incubated for 14 days at 27°C (pryor *et a*l. 1970). Then seeds were planted manually to a depth of 1 cm.

Field experiment

In each experimental field, trial was carried out using selected highly effective eight Bradyrhizobia nodulating groundnut isolates. The experiment was laid out in RCBD fashion. All treatments were replicated three times. There are ten (10) treatments, and the treatments consisting of: T1- Bradyrhizobium Rhizobium inoculum 1; T2- Bradyrhizobium Rhizobium inoculum 2; T3- Bradyrhizobium Rhizobium inoculum 3; T4- Bradyrhizobium Rhizobium inoculum 4; T5- Bradyrhizobium Rhizobium inoculum 5;; T6- Bradyrhizobium Rhizobium inoculum 6; T7- Bradyrhizobium Rhizobium inoculum 7; T8- Bradyrhizobium Rhizobium inoculum 8; T9- positive control (with starter nitrogen i.e. 20kgN/ha); T10- Negative control (with no chemical and biofertilizer application). All seeds were surface sterilized with alcohol followed by 5% H_2O_2 to avoid contamination and then washed five times using sterilized water as indicated in Vincent (1970). Seed inoculation was performed before sowing using 10gm/kg of seed (to make approximately $1x10^6$bacterial cells/seed). For inoculated treatment, biofertilizers were separately mixed to the seeds with sucrose solution to increase adherence. All plots were fertilized with phosphorus fertilizer at rate of 46kg P_2O_5/ha as TSP and 20 KgN/ha Urea was applied for positive control plots.

Results

Eight isolates of rhizobia were selected based on their symbiotic effectiveness among 56 isolates collected from eastern Ethiopia under control environment (Tables 1.63 and 1.64). The result showed significant improvement of grain and biomass yield of two tested cultivars (Sedi and Werer 962) on both locations. These isolates were evaluated under field condition at Fedis and Babillea experimental sites**.** So far, nodulation data and plant tissues samples for tissue analysis were collected from each experiment.

Table 1.63. The effect of Bradyrhizobia spp. innoculation on yield of Groundnut (*Arachis hypogea* L.) var. Sedi at Fedis and Babille experimental sites

	Biomass yield(ton/ha)		Grain yield (kg/ha)	
Treatment	Babille	Fedis	Babillea	Fedis
Consortium of 7 isolates	6.5976^{abc}	4.881^{ab}	930.3^{cd}	906.3^{b}
Isolate 1	5.3097^{c}	4.819^{ab}	920.4^{dc}	907.7^{b}
Isolate 2	7.7392^{ab}	4.559^{ab}	1498.5^{a}	1077.4^{ab}
Isolate 3	8.0567^{a}	4.889^{ab}	1489.8^{ab}	1158.3^{ab}
Isolate 4	4.7797^{c}	5.519^{a}	994.4d^{c}	1165.7^{ab}
Isolate 5	4.8762^{c}	5.821^{a}	991.8^{cd}	1308.5^{a}
Isolate 6	5.7242^{c}	5.522^{a}	1106.6^{bcd}	1266.9^{ab}
Isolate 7	6.6571^{abc}	5.842^{a}	1307^{abc}	1306.1^{a}
Positive Control (46kg N/ha)	6.1088^{bc}	4.677^{ab}	1089.3^{cd}	1302.2^{a}
Negative control	5.8274^{c}	4.121^{b}	742.4^{d}	1217.5^{ab}
CV (%)	17.95	15.30	20.54	19.3
LSD(0.05)	1.89	1.320	387.37	381.25

Table 1.64. The effect of Bradyrhizobia spp. on yield of Groundnut (*Arachis hypogea* L.) var. Werer-962 at Fedis and Babillea experimental sites

Treatment	Biomass yield(ton/ha)		Grain yield (kg/ha)	
	Babillea	Fedis	Babillea	Fedis
Consortium of 7 isolates	8.837^{d}	12.543^{ab}	2163.6^{ab}	1460.0^{a}
Isolate 1	14.28^{a}	9.467^{b}	2331.0^{a}	1717.8^{a}
Isolate 2	11.83^{bc}	10.254^{b}	2196.0^{a}	1310.0^{a}
Isolate 3	8.64^{d}	11.492^{ab}	1816.4^{ab}	1497.8^{a}
Isolate 4	11.88^{bc}	13.932^{a}	1951.4^{ab}	1844.6^{a}
Isolate 5	10.27^{dc}	10.849^{ab}	2064.9^{ab}	1301.0^{a}
Isolate 6	11.30^{bc}	10.808^{ab}	1841.2^{ab}	1617.2^{a}
Isolate 7	9.66^{cd}	10.778^{ab}	2118.3^{ab}	1332.7^{a}
Positive Control (46kg N/ha)	13.50^{ab}	12.620^{ab}	2297.2^{a}	1638.4^{a}
Negative control	8.19^{d}	10.542^{b}	1575.0^{b}	1564.9^{a}
CV (%)	12.92	17.25	17.69	28.44
LSD(0.05)	2.385	3.33	592.62	740.44

Conclusion (overall assessment)

Isolates under control environment performed better than the control. The trial has to be repeated for another year in order to provide conclusive results.

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1.8.5 Evaluation of Selected Isolates of Rhizobium Leguminosarum bv. Vicea Nodulating Faba Bean (*Vicia faba* L.) in Hararghe Highland

Anteneh Argaw, Million Fikiresillassie, Ayele Akuma

Background and Justification

Faba Bean and field pea are some of the most important cool-season pulses grown in Ethiopia. They are essential part of the dietary protein requirement of most Ethiopians. Faba bean is the first most important pulse in Ethiopia in terms of production and area coverage. According to the report of CSA (2009), from about 1,585,236 of land under pulses 538,820 ha was occupied by faba bean, which is about 34% of the land under pulses with annual production of 6,959,837 quintals. Despite its importance, however, the productivity of the pulse crop is below 1 ton/ha, which fluctuates and is far below the potential. This is due to low soil fertility, smallholder farming and limited access to external inputs (Amare, 1987; EARO, 2000). One of the most important factors of soil fertility is nitrogen (N) deficiency of most Ethiopian soils (Desta and Angaw, 1986). Most farmers in the developing countries such as Ethiopia are resource poor and cannot afford the required inputs, mainly in the form of chemical N fertilizers. Legume-*Rhizobium* has been exploited elsewhere as a substitute for the N fertilizers (Aynabeba Adamu *et al.,* 2001). Inoculation with highly effective rhizobia, a common practice in agricultural production (Catroux et al*.,* 2001), requires survival and establishment of inoculated rhizobia in the soil environment (Da and Deng, 2003). Therefore, we have characterized more than 72 isolates collected from major faba bean growing area of Ethiopia under control condition, of which, the top eight symbiotically highly effective rhizobia isolates have been selected for further symbiotic effectiveness characterization under field conditions.

General objectives

- To assess and evaluate symbiotic effectiveness of effective rhizobia isolates on yield and yield components of faba bean cultivated in eastern Ethiopian soils

Specific objectives

- To isolate and characterized effective strain of rhizobia nodulating faba bean.
- To evaluate the symbiotic effectiveness of selected strain of rhizobia at Haramaya experimental sites.

Material and methods

Sources of bacterial isolates

Well characterized rhizobia nodulating faba bean.under greenhouse condition on sand and soil
Cultures was obtained from Haramaya university, Biofertilizer research and production center.

Experimental sites

The study of the effect of inoculation of rhizobia on faba bean growth and yield was conducted at Haramaya experimental field.

Soil sampling and analysis

A soil sample (0-30) was collected at random from each experimental site before and after planting. A sub sample of the composition was air-dried, sieved through a 2 mm screen and analyzed for important soil physico-chemical properties.

The native rhizobial nodulating faba bean was estimated using a fresh soil sub-sample according to the most probable number (MPN) method (Vincent, 1970).

Seed source and bio –fertilization

Seed of improved faba bean (var. Gachana) were obtained from Haramaya university highland pulses improvement project.

Field experiment

In each experimental, field trial was carried out using selected highly effective eight rhizobia noduling faba bean isolates. The experiment was laid out in a randomized complete block design. All treatments were replicated three times. There were 10 treatments which consists of T1-Rhizobium inoculums-1, T2-Rhizobium inculum-2, T3-Rhizobium inoculums-3, T4-Rhizobium inoculums-4, T5-Rhizobium inoculums-5, T6- Rhizobium inoculums-6, T7-Rhizobium inoculums-7, T8- Rhizobium inoculums-8, T9-positive control (with starter nitrogen i.e. 20 kg N/ha), T10-negative control (with no chemical and biofertilizer application).

Results

Eight isolates of rhizobia were selected based on their symbiotic effectiveness among the 85 isolates collected from major growing areas of Ethiopia under control environment (Table 1.65). Isolates 1 and Isolate 2 produced significantly higher grain and biomass yield as compared to internationally recommended isolate (TAL-1305) and the nitrogen fertilizer treated plot. These isolates were evaluated under field condition at Haramaya experimental site**.** So far, nodulation data and plant tissues samples for tissue analysis were collected from each experiment.

Table 1.65. The effect of *Rhizobium leguminosarum* bv. *Vicea* on yield of Faba bean (*Vicia faba* L.) at Haramaya experimental site

Treatment	Biomass yield (ton/ha)	Grain yield (kg/ha)
Isolate 1	13.845[a]	6439.0[a]
Isolate 2	12.366[ab]	6572.3[a]
Isolate 3	12.195[ab]	5521.5[ab]
Isolate 4	11.585[ab]	4891.6[ab]
Isolate 5	11.345[ab]	5317.6[ab]
Isolate 6	10.092[b]	4739.7[ab]
Isolate 7	9.857[b]	5576.4[ab]
TAL-1305	11.523[ab]	5676.4[ab]
Positive Control (46kg N/ha)	9.829[b]	4215.6[b]
Negative control	10.3004[b]	3993.6[b]
CV (%)	15.5	21.2
LSD(0.05)	2.985	1915.1

Conclusion (overall assessment)

Isolates under control environment performed better than the control. The trial will be completed after two months in order to provide conclusive results.

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1.8.6 Evaluation of Selected Isolates of Rhizobium Leguminosarum bv. Vicea Nodulating Field Pea (*Pisum sativum L.*) in Hararghe Highland

Anteneh Argaw, Million Fikiresillassie, Ayele Akuma

Background and Justification

Field pea is the third most important pulse crop in Ethiopia after faba bean and chickpea, in terms of both area and total annual production. According to CSA (2009), field pea covers about 230,749 ha of the total arable land with a total production of 267,093 tons. Despite its importance, however, the productivity of the field pea is below 1 ton/ha, which fluctuates and is far below the potential. This is due to low soil fertility, smallholder farming and limited access to external inputs (Amare, 1987; EARO, 2000). One of the most important factors of soil fertility is nitrogen (N) deficiency of most Ethiopian soils (Desta and Angaw, 1986). Most farmers in the developing countries such as Ethiopia are resource poor and cannot afford the required inputs, mainly in the form of chemical N fertilizers. Legume-*Rhizobium* has been exploited elsewhere as a substitute for the N fertilizers (Aynabeba *et al.,* 2001). Inoculation with highly effective rhizobia, a common practice in agricultural production (Catroux et al*.,* 2001), requires survival and establishment of inoculated rhizobia in the soil environment (Da and Deng, 2003). Therefore, we have characterized more than 55 isolates collected from major field pea growing areas of Ethiopia under control condition, of which, the top eight symbiotically highly effective rhizobia isolates have been selected for further symbiotic effectiveness characterization under field conditions.

General objectives

- To isolate and characterized effective strain of rhizobia nodulating field pea.
- To evaluate the symbiotic effectiveness of selected strain of rhizobia at Haramaya experimental site.

Material and methods

Sources of bacterial isolates

Well characterized rhizobia nodulating field pea under greenhouse condition on sand and soil
Cultures was obtained from Haramaya university, Biofertilizer research and production center.

Experimental sites

The study of the effect of inoculation of rhizobia on field pea growth and yield was conducted at Haramaya experimental field.

Soil sampling and analysis

A soil sample (0-30) was collected at random from each experimental site before and after planting. A sub sample of the composition was air-dried, sieved through a 2 mm screen, and analyzed for important soil physico-chemical properties. The native rhizobial nodulating field pea was estimated using a fresh soil sub-sample according to the most probable number (MPN) method (Vincent, 1970).

Seed source and bio –fertilization

Seed of improved field pea (var. metti) were obtained from Haramaya university highland pulses improvement project.

Field experiment

A field trial was carried out using selected highly effective eight rhizobia noduling field pea isolates. The experiment was laid out in a randomized complete block design. All treatments were replicated three times. There are ten treatments which consists of : T1- Rhizobium inoculums-1, T2- Rhizobium inculum-2, T3 Rhizobium inoculums-3, T4- Rhizobium inoculum-4, T5- Rhizobium inoculums-5, T6- Rhizobium inoculums-6, T7- Rhizobium inoculums-7, T8- Rhizobium inoculums-8, T9-positive control (with starter nitrogen i.e. 20kg N/ha), T10-negative control (with no chemical and biofertilizer application).

Results

Eight isolates of rhizobia were selected based on their symbiotic effectiveness among the 67 isolates collected from major field pea growing areas of Ethiopia under control environment. Isolate 3 scored significantly higher grain and biomass yield than the other inoculated plants and the nitrogen treated plants (Table 1.66). These isolates were evaluated under field condition at Haramaya experimental site**.** So far, nodulation data and plant tissues samples for tissue analysis were collected from each experiment.

Table 1.66. The effect of *Rhizobium leguminosarum* bv. *Vicea* on yield of Field pea (*Pisum sativum* L.) at Haramaya experimental site

Treatment	Biomass yield (ton/ha)	Grain yield (kg/ha)
Isolate 1	7.2[bc]	2806.8[abc]
Isolate 2	6.472[c]	2452.2[bc]
Isolate 3	10.517[a]	3686.9[a]
Isolate 4	7.937[bc]	2955.2[ab]
Isolate 5	5.876[c]	3092.5[ab]
Isolate 6	7.092[c]	2739.8[abc]
Isolate 7	6.318[c]	2373.2[bc]
Isolate 8	9.331[ab]	3570.1[a]
Positive Control (46kg N/ha)	5.959[c]	1874.0[c]
Negative control	5.720[c]	1821.0[c]
CV (%)	18.05	22.4
LSD(0.05)	2.227	1044.5

Conclusion (overall assessment)

Isolates under control environment performed better than the control. The trial will be completed after two months in order to provide conclusive results.

References

Amare Abebe (1987). Effect of inoculation and nitrogen fertilization on yield of common bean in Ethiopia. **In:** *Proceedings of a Workshop on Bean Research in Eastern Africa.* Mukono, Uganda, June 22-25, CIAT African Workshop Series 152-159.

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1.8.7 Evaluation of Selected Isolates of Rhizobium Leguminosarum bv. Vicea Nodulating Lentil (*Lens culinaris*) in Hararghe Highland

Anteneh Argaw and Million Fikiresillassie

Background and Justification

Lentil (*Lens culinaris* Medikus subsp. *culinaris*) is a lens-shaped grain legume well known for its nutritional value. India is the major lentil producing country, followed by Canada and Turkey, which collectively accounts for 68% of global production (FAO, 2008). Ethiopia is also the leading producer of lentil in Africa and accounts for 68% of lentil produced (CSA 2007). Lentil stands fifth both in acreage and in production after faba bean; field pea, chickpea, and common bean and occupy about 95,000 hectares of area with a gross annual production of about 94,773 metric tons (CSA 2009).

The productivity of lentil in Ethiopia is 0.7 t/ha which is very low compared to other neighboring countries such as Egypt where productivity is about 1.7 t/ha (FAO 2008; CSA 2009). This is mainly due to low soil fertility (Angaw and Asnakew, 1994). Nitrogen (N) deficiency is one of the most important factors that limit soil fertility in most Ethiopian soils (Desta and Angaw 1986). Stoorvogel and Smaling (1990) estimated soil nutrient losses from the highlands of Ethiopia to be in excess of 80 kg of N per cultivated hectare.

Application of chemical fertilizers have played a significant role to increase the productivity of soils, however, unbalanced use of fertilizers has led to reduction in soil fertility and environmental degradation. Moreover, the cost of chemical fertilizers have been increased many folds and made unaffordable in developing countries such as Ethiopia.

Therefore, the need to take advantage of inexpensive means of soil fertility enhancement through biological nitrogen fixation is becoming vital for increasing crop productivity and ensuring food security in the region.

General Objectives

- To evaluate the symbiotic effectiveness of selected strain of rhizobia at Haramaya experimental site.

Results

Eight isolates of rhizobia were selected based on their symbiotic effectiveness among 72 isolates collected from central and northern part of Ethiopia under control environment. These isolates wre evaluated under field condition on four promising verities of lentil at Haramaya experimental site**.** So far, nodulation data and plant tissues samples for tissue analysis were collected from each experiment.

Conclusion (overall assessment)

Isolates under control environment performed better than the control. The trial has to be repeated for another year in order to provide conclusive results.

References

Angaw Tsigie, Asnakew Woldeab. 1994. Fertilizer response trial on highland food legumes. In: Asfaw Telaye, Geletu Bejiga, Saxena MC, SolhMB, editors. Cool-season food legumes of Ethiopia. Proceeding of the National Cool-Season Food Legumes Review Conference; December 16–20, 1993; Addis Ababa, Ethiopia. p. 279–292.

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1.8.8 Evaluation of Selected Isolates of Rhizobia Nodulating Chickpea (*Cicer arietinum*) in Hararghe Highland

Anteneh Argaw, Million Fikiresillassie

Background and Justification

Chickpea is one of the food legume crops grown in the tropics, sub-tropics and temperate regions of the world. The average national chickpea yield in Ethiopia is less than one ton per hectare. The low yield is mainly due to low soil fertility (Angaw Tsigie and Asnakew Woldeab, 1994). Nitrogen (N) deficiency is one of the most important factors of limiting soil fertility in most Ethiopian soils (Desta Beyene and Angaw Tsigie 1986). Stoorvogel and Smaling (1990) estimated soil nutrient losses from the highlands of Ethiopia to be in excess of 80 kg of N per cultivated hectare.

Application of chemical fertilizers have played a significant role to increase the productivity of soils, however, unbalanced use of fertilizers has led to reduction in soil fertility and environmental degradation. Moreover, the cost of chemical fertilizers have been increased many folds and made unaffordable in developing countries such as Ethiopia. Therefore, the need to take advantage of inexpensive means of soil fertility enhancement through biological nitrogen fixation is becoming vital for increasing crop productivity and ensuring food security in the region.

General objective

- To characterize symbiotically effective isolates of rhizobia nodulating Chickpea isolated from major growing areas of Ethiopia.

Specific objective

- To isolate and characterized effective strain of rhizobia nodulating chickpea.
- To evaluate the symbiotic effectiveness of selected strain of rhizobia at Fedis, Haramaya and Hirna experimental sites.

Results

More than 150 isolates of bacteria were isolated from chickpea nodules collected from central and northern Ethiopia. Authentication and evaluation of symbiotic efficiencies of the isolates were done under control environment using acid treated and autoclaved sand.

Conclusion (overall assessment)

The trial has to be done under field condition for two years in order to provide conclusive results.

References

Angaw Tsigie, Asnakew Woldeab., 1994. Fertilizer response trial on highland food legumes. In: Asfaw Telaye, Geletu Bejiga, Saxena MC, SolhMB, editors. Cool-season food legumes of Ethiopia. Proceeding of the National Cool-Season Food Legumes Review Conference; December 16–20 1993; Addis Ababa, Ethiopia. p. 279–292.

Desta Beyene and Angaw Tsige, 1986. The response of pulse crops to N and P fertilizers.**In:** *Soil Science Research. Proceedings of the First Soil Science Research Review Workshop*, Addis Ababa, Ethiopia, 11-14 Feb.

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1.8.9 Effect of Co-inoculation of Rhizobium Leguminosarum bv. viciae and Phosphate Solubilizing Bacterium on Faba Bean (*Viciae faba L.)* Production in Eastern Ethiopia Highland

Anteneh Argaw, Million Fikiresillassie and Ayele Akuma

Background and Justification

Faba Bean and field pea are some of the most important cool-season pulses grown in Ethiopia. They are essential part of the dietary protein requirement of most Ethiopian's. Faba bean is the first most important pulse in Ethiopia in terms of production and area coverage. According to the report of CSA (2009), from about 1,585,236 ha of land under pulses, 538,820 ha was occupied by faba bean, which is about 34% of the land under pulses with annual production of 6,959,837 quintals. Despite its importance, however, the productivity of the pulse crop is below 1ton/ha, which fluctuates and is far below the potential. This is due to low soil fertility, smallholder farming and limited access to external inputs (Amare, 1987; EARO, 2000). The most important factor of soil fertility is nitrogen and phosphorus deficiency of most Ethiopian soils. Nitrogen and Phosphorus are essential nutrients required by both plants and microorganisms. Their major physiological roles are the accumulation and release of energy during cellular metabolism.

Phosphorus is generally deficient in most natural soils, because it is fixed as water insoluble iron and aluminum phosphates in acidic soils or calcium phosphate in alkaline soils. Similarly, the low productivity of crops, in acidic soils in Ethiopia, can mainly be attributed to the deficiency of phosphorus (Taye and Hofer, 1993). In order to solve such problems in order to achieve high yields require chemical fertilizers. Continuous and excess use of chemical fertilizers and other agrochemicals to increase yield may lead to ground water contamination and depletion of soil nutrients, eventually resulting in reduction of crop yield. The extensive use of chemical fertilizers in agriculture is currently under debate due to environmental concern and fear for consumers' health. Consequently, there has recently been a growing level of interest in environmentally friendly sustainable agricultural practices and organic farming systems. As a result, emphasis has been paid to the possibility of greater utilization of unavailable P forms by the action of biological organisms. Bacteria and fungi have been reported to be active in solubilizing insoluble inorganic phosphate with high efficiency (Gaur, 1990). Asfaw (2003) noted that acidic soils of Ethiopia harbored with highly efficient phosphate solubilizing microorganisms.

General Objectives

- To evaluate the effect of integrated application of *Rhizobium* and phosphate solubilizing *Bacterium* (PSB) on yield and yield components of Faba bean at Haramaya site.

Material and methods

Sources of bacterial isolates

Rhizobium (*Rhizobium* leguminosarum bv.viciae) nodulating Faba bean and PSB were obtained from Haramaya University Biofertilizer research and production center. PSB isolates have been proved as highly efficient inorganic PSB under laboratory and greenhouse experiment. Whereas, highly efficient rhizobia nodulating faba bean have been verified under laboratory and field condition at Haramaya University, Experimental site.

Experimental sites

The study of the effect of dual application of *Rhizobium* leguminosarum bv.viciae and PSB on faba bean growth was conducted separately at Boreda, Girawa and Arbarekete field condition. These are located in eastern Ethiopia, Hararghe highland.

Soil sampling and analyses

A soil sample (0-30) was collected at random from each experimental site before and after planting. A sub sample of the composition was air-dried, sieved through a 2 mm screen and analyzed for important soil physico-chemical properties such as soil pH, EC, available P, Total N, exchangeable bases (Na, Ca, Mg ,K), B, Mo, Total P (inorganic and organic P), CEC, and soil texture following the procedure indicated in Sahlemedhin and Taye (2000). The native rhizobial nodulating faba bean was estimated using a fresh soil sub-sample according to the most probable number (MPN) method (Vincent, 1970). The number of resident inorganic phosphate solubilizing microorganism was evaluated using pikovysikaya's medium following Somasergane and Hoben (1994).

Seed source and bio-fertilization

Seed of improved faba bean cultivars were obtained from Kulumsa Agricultural research center and Haramaya University Highland pulses improvement project. Whereas, the local varieties currently cultivated by farmers' were used as local cultivars. Both *Rhizobium* leguminosarum bv.viciae and PSB biofertilizer were prepared 1 month prior to seeding by adding 30ml bacterial culture (grown to log phase in appropriate broth containing 10^8 of bacterial ml^{-1} of culture) to 200g sterile vermicompost prepared from parthinium weeds. These were well mixed and incubated for 14 days at 27°C (pryor *et a*l. 1998). Then seeds were planted manually to a depth of 1 cm.

Field experiment

In each experimental field, a trial was carried out using selected highly effective *Rhizobium* leguminosarum bv.viciae and PSB biofertilizer isolates. The experiment was laid out in a split plot design. All treatments were replicated three times with inoculation and chemical fertilizer treatments in the main plot whereas improved and local varieties as subplot. There were eight treatments, and the treatment consists of T1- PSB inoculum; T2- recommended phosphate fertilizer (46 kgP_2O_5/ha); T3 Rhizobium inoculums, T4-Recommended starter Nitrogen fertilizer (20 KgN/ha); T5- PSB inoculums + Rhizobium inoculums; T6- PSB inoculums + Recommended starter Nitrogen fertilizer (20KgN/ha); T7- Rhizobium inoculums + 100 Kg TSP/ha; T8- with no chemical and biofertilizer application. All seed were surface sterilized with alcohol followed by 5% H_2O_2. Inoculations were performed before sowing using 10 gm/kg of seed (to make approximately $1x10^6$ bacterial cells/seed). For dual inoculated treatments, both Phosphate and *Rhizobium* biofertilizers were mixed at the same time to the seeds with 15% (W/V) sucrose solution to increase adherence. Fertilizer at the rate of 46kg P_2O_5/ha as TSP whereas 20 kgN/ha as Urea was applied according to the treatment layout.

Results

One effective isolate of *Rhizobium* and PSB bacteria has been evaluated with chemical fertilizer with different combination at Haramaya site. These experiments were evaluated under field condition at Haramaya experimental site**.** So far, nodulation data and plant tissue samples for tissue analysis were collected from each experiment.

Conclusion (overall assessment)

Isolates under control environment performed better than the control. The trial has to be repeated for another year in order to provide conclusive results.

References

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1.8.10 Effect of Co-inoculation of *Rhizobium Leguminosarum bv. viciae* and Phosphate Solubilizing Bacterium on Field Pea (*Pisum sativum*) Production in Eastern Ethiopia Highland

Anteneh Argaw, Million Fikiresillassie and Ayele Akuma

Background and Justification

Field pea is the third most important pulse crop in Ethiopia after faba bean and chickpea, in terms of both area and total annual production. According to CSA (2009), field pea covers about 230,749 ha of the total arable land with a total production of 267,093 tons. Despite its importance, however, the productivity of the field pea is below 1ton/ha, which fluctuates and is far below the potential. This is due to low soil fertility, smallholder farming and limited access to external inputs (Amare, 1987; EARO, 2000). The most important factor of soil fertility is nitrogen and phosphorus deficiency of most Ethiopian soils. Nitrogen and Phosphorus are essential nutrients required by both plants and microorganisms, their major physiological roles are the accumulation and release of energy during cellular metabolism.

Phosphorus is generally deficient in most natural soils, because it is fixed as water insoluble iron and aluminum phosphates in acidic soils or calcium phosphate in alkaline soils. Similarly, the low productivity of crops, in acidic soils in Ethiopia, can mainly be attributed to the deficiency of phosphorus (Taye and Hofer, 1993). In order to solve such problems and achieve high yields, application of chemical fertilizers is required. Continuous and excess use of chemical fertilizers and other agrochemicals to increase yield may lead to ground water contamination and depletion of soil nutrients, eventually resulting in reduction of crop yield. The extensive use of chemical fertilizers in agriculture is currently under debate due to environmental concern and fear for consumers' health. Consequently, there has recently been a growing level of interest in environmentally friendly sustainable agricultural practices and organic farming systems. As a result emphasis has been given to the possibility of greater utilization of unavailable P forms by the action of biological organisms. Bacteria and fungi have been reported to be active in solubilizing insoluble inorganic phosphate with high efficiency (Gaur, 1990). Asfaw (2003) found that acidic soils of Ethiopia are harbored with highly efficient phosphate solubilizing microorganisms.

General objective

- To evaluate the effect of integrated application of *Rhizobium* and phosphate solubilizing *Bacterium* (PSB) on yield and yield components of field pea at Haramaya site.

Materials and methods

Sources of bacterial isolates

Rhizobium (*Rhizobium* leguminosarum bv. viciae) nodulating Field pea and PSB were obtained from Haramaya University Biofertilizer research and production center. PSB isolates have been proved as highly efficient inorganic PSB under laboratory and greenhouse experiment. Whereas, highly efficient rhizobia nodulating Field pea have been verified under laboratory and field condition at Haramaya University Experimental site.

Experimental sites

The study of the effect of dual application of *Rhizobium* leguminosarum bv.viciae and PSB on Field pea growth was conducted at field condition at Haramaya site.

Soil sampling and analyses

A soil sample (0-30) was collected at random from each experimental site before and after planting. A sub sample was air-dried, sieved through a 2 mm screen and analyzed for important soil physico-chemical properties such as soil pH, EC, available P, Total N, exchangeable bases (Na, Ca, Mg ,K), B, Mo, Total P (inorganic and organic P), CEC, and soil texture following the procedure indicated in Sahlemedhin and Taye (2000). The native rhizobial nodulating faba bean was estimated using a fresh soil sub-sample according to the most probable number (MPN) method (Vincent, 1970). The number of resident inorganic phosphate solubilizing microorganism was evaluated using pikovysikaya's medium following Somasergane and Hoben (1994).

Seed source and bio –fertilization

Seed of improved Field pea cultivars were obtained from Kulumsa Agricultural research center and Haramaya University Highland pulses improvement project. Whereas, the local varieties currently cultivated by farmers' were used as local cultivars. Both *Rhizobium* leguminosarum bv.viciae and PSB biofertilizer were prepared 1 month prior to seeding by adding 30ml bacterial culture (grown to log phase in appropriate broth containing 10^8 of bacterial ml^{-1} of culture) to

200g sterile vermicompost prepared from parthinium weeds. These were well mixed and incubated for 14 days at 27°C (Pryor *et a*l., 1998). Then seeds were planted manually to a depth of 1 cm.

Field experiment

In each experimental field, a trial was carried out using selected highly effective *Rhizobium* leguminosarum bv.viciae and PSB biofertilizer isolates. The experiment was laid out in a split plot design. All treatments were replicated three times with inoculation and chemical fertilizer treatments in the main plot whereas improved and local varieties as subplot. There were eight treatments, which consists of T1- PSB inoculum; T2- recommended phosphate fertilizer (46kgP_2O_5/ha); T3 Rhizobium inoculums, T4-Recommended starter Nitrogen fertilizer (20KgN/ha); T5- PSB inoculums + Rhizobium inoculums; T6- PSB inoculums + Recommended starter Nitrogen fertilizer (20KgN/ha); T7- Rhizobium inoculums + 100Kg TSP/ha; T8- with no chemical and biofertilizer application. All Seed were surface sterilized with alcohol followed by 5% H_2O_2 to avoid performance of inoculation before sowing using 10gm/kg of seed (to make approximately $1x10^6$ bacterial cells/seed). For dual inoculated treatments, both Phosphate and *Rhizobium* biofertilizers were mixed at the same time to the seeds with 15% (W/V) sucrose solution to increase adherence. Fertilizer at the rate of 46kg P_2O_5/ha as TSP and 20 kgN/ha as Urea was applied according to the treatment layout.

Results

One effective isolate of *Rhizobium* and PSB bacteria has been evaluated with chemical fertilizer with different combination at Haramaya site. These experiments were conducted under field condition at Haramaya experimental site**.** So far, nodulation data and plant tissues samples for tissue analysis were collected from each experiment.

Conclusion (overall assessment)

Isolates under control environment were performed better than the control. The trial has to be repeated for another year in order to provide conclusive results.

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Amare Abebe, 1987. Effect of inoculation and nitrogen fertilization on yield of common bean in Ethiopia. In: Proceedings of a Workshop on Bean Research in Eastern Africa. Mukono, Uganda, June 22-25, CIAT African Workshop Series 152-159

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1.8.11 Effect of Integrated Application of Bradyrhzibium sp. and Iron Fertilizer on Two Varieties of Soybean at Shinile Demonstration Site Using Drip Irrigation

Anteneh Argaw

Background and Justification

Soybean (*Glycine max* L. (Merr.)) is a subtropics member of the Leguminosae family, an erect bushy annual crop with considerable morphological diversity. Grain legumes are a good source of protein. The protein content in the pulses seed is high, ranging from 17-42%. In Ethiopia, soybean occupies around 95 thousand hectares of land with a corresponding gross annual production of approximately 94, 773 metric tons (CSA, 2009). Despite the importance of the crop in the world as a rich source of protein and oil, the yield is generally very low in Ethiopia, i.e. below 1-ton ha^{-1} (CSA, 2009) as compared to the USA and Asian soybean producing countries. Poor soil fertility status is considered as one of the factors contributing to low yield. Nitrogen (N) and phosphorus (P), in that order, are the two plant growth limiting soil fertility factors in many soil types including those in Ethiopia. Moreover, Iron deficiency is a common problem when

soybean is grown on calcareous soil (Goos and Johanson, 2000). Considerable differences exist among soybean genotypes for susceptibility to iron deficiency in calcareous soils.

Objectives

- To evaluate the effectiveness of local and imported isolates of bradyrhizobia of soybean with different level of Iron fertilizer at Shinile demonstration site.

Results

Two imported isolates from UK and USA with one locally isolated *Bradyrhizobium* sp. are being evaluated for symbiotic effectiveness with three levels of Iron fertilizer (Fe-EDTA) on two varieties of Soybean at Shinile demonstration site. So far, nodulation data and plant tissues samples for tissue analysis were collected from each experiment.

Conclusion (overall assessment)

Isolates under control environment were performed better than the control. The trial has to be repeated in order to provide conclusive results.

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1.8.12 Integrated Application of *Rhizobium Leguminosarum bv. Vicea* and Vermicompost on Faba Bean (Vicia faba L.) in Hararghe Highland

Anteneh Argaw and Million Fikiresillassie

Background and Justification

Lack of nutrients, such as N and P, are the principal constraints to crop production under low input agricultural systems of Ethiopia. Agronomic practices aimed at reducing the dependence on chemical fertilizers need to incorporate crop residues or other forms of organic material, thus providing nutrients thereby improving soil structure while maintaining soil fertility (Prasad *et al.,* 1999). It is difficult to increase soil organic matter or even maintain it in the sub-tropics and tropics as organic matter turnover is high and crop residues are removed from the field, or used as fodder by roaming animals or burned.

Several studies show that organic farming improves soil fertility over time. However, lack of systematic research on organic farming and unavailability of package of practices for different crops limit the realization of higher yields under organic farming. As a result, its yield has frequently been reported to be lower than that with chemical farming (Aryal *et al.,* 2003). Rhizobia biofertilizer alone may not completely and effectively improve the crop yield and therefore they should be used as one of the components of the integrated soil fertility management strategies. Therefore, organic farming requires refining, and there is a serious need for consortium of biological methods of farming to create more productivity and competitiveness.

General objective

- To evaluate the effect of integrated application of *Rhizobium* and vermicompost on yield and yield components of Faba bean at Haramaya site.

Results

One effective isolate of *Rhizobium* with different level of vermicopost has been evaluated at Haramaya site. Six tons/ha vermicompost without inoculation scored significantly higher grain and biomass yield than all other treatments (Table 1.67). So far, nodulation data and plant tissues samples for tissue analysis were collected from each experiment.

Table 1.67. The effect of *Rhizobium* inoculation with and without different rate of vermicompost on yield of faba bean (*Vicia faba* L.)

Treatment	Biomass yield (ton/ha)	Grain yield (kg/ha)
Rhizobium + 2 ton vermicompost/ha	8.199^{bc}	4274.5^{b}
Rhzibium + 4 ton vermicompost/ha	10.011^{bc}	4876.6^{b}
Rhzibium + 6 ton vermicompost/ha	9.385^{bc}	4513.1^{b}
Rhzibium + 8 ton vermicompost/ha	8.700^{bc}	4516.1^{b}
Rhzibium	7.539^{c}	4665.7^{b}
2 ton vermicompost/ha	9.632^{bc}	4945.3^{b}
4 ton vermicompost/ha	10.922^{ab}	5201.5^{b}
6 ton vermicompost/ha	13.039^{a}	7191.2^{a}
8 ton vermicompost/ha	9.842b^{c}	4775.7^{b}
No amendment/ha	9.371b^{c}	5568.2^{ab}
CV (%)	17.2	21.5
LSD (0.05)	2.835	

Conclusion (overall assessment)

The trial has to be repeated for another year in order to provide conclusive results.

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1.8.13 Evaluation of Rhizobium Inoculation and Bone Phosphate (Orga fertilizer) Application on Nodulation and Yield of Field Pea (*Pisum sativum L.)*

Anteneh Argaw and Million Fikiresillassie

Background and Justification

Lack of nutrients, such as N and P, are the principal constraints to crop production under low input agricultural systems of Ethiopia. Agronomic practices aimed at reducing the dependence on chemical fertilizers need to incorporate crop residues or other forms of organic material, thus providing nutrients thereby improving soil structure while maintaining soil fertility (Prasad *et al.,* 1999). It is difficult to increase soil organic matter or even maintain it in the sub-tropics and tropics as organic matter turnover is high and crop residues are removed from the field, and used as fodder by roaming animals or burned.

Several studies show that organic farming improves soil fertility over time. However, lack of systematic research on organic farming and unavailability of package of practices for different crops limit the realization of higher yields under organic farming. As a result, its yield has frequently been reported to be lower than that with chemical farming (Aryal *et al.,* 2003). Rhizobia biofertilizer alone may not completely and effectively improve the crop yield, and therefore they should be used as one of the components of the integrated soil fertility management strategies. Therefore, organic farming requires refining. Moreover, there is a serious need to consortium biological methods of farming to increase productivity and competitiveness.

Objectives

- To evaluate the effect of integrated application of *Rhizobium* and bone meal on yield and yield components of Field pea at Haramaya site.

Results

One effective isolate of *Rhizobium* with different level of bone meal has been evaluated at Haramaya site. 200kg orga with inoculation of *Rhizobium* sp. scored significantly higher grain and biomass yield than the other treatments. So far, nodulation data and plant tissues samples for tissue analysis were collected from each experiment.

Conclusion (overall assessment)

Isolates under control environment performed better than the control (Table 1.68). The trial has to be repeated for another year in order to provide conclusive results.

Table 1.68. The effect of *Rhizobium* inoculation with and without different rate of Orga (bone phosphate) on yield of field pea (*Pisum sativum* L.)

Treatment	Biomass yield (ton/ha)	Grain yield (kg/ha)
Rhizobium + 100 kg orga/ha	4.079^{abc}	2285.6^{bc}
Rhzibium + 150 kg orga/ha	4.664^{ab}	2615.5^{b}
Rhzibium + 200kg orga/ha	4.080^{abc}	1527.1^{c}
Rhzibium + 200kg orga/ha	6.198^{a}	3596.8^{a}
Rhzibium	4.013^{bc}	2292.9^{bc}
100 kg orga/ha	3.843^{bc}	2229.6^{bc}
150 kg orga/ha	4.532^{abc}	2315.5^{bc}
200kg orga/ha	3.480^{bc}	1851.8^{bc}
200kg orga/ha	2.514^{c}	2237.1^{bc}
No amendment/ha	3.408^{bc}	1928.3^{bc}
CV (%)	30.8	22.5
LSD (0.05)	2.1426	876.5

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1.8.14 Evaluation of the Effect of Inoculated Faba Bean (*Vicia faba L.*) and Field Pea (*Pisum Sativum L.*) Precursor cCops and Different Rate of Bone Phosphate (Orga) on Yield of Maize (*Zea mays L.*) and Sorghum (*Sorghum bicolor L.*) at Haramaya Experimental Site

Anteneh Argaw

Background and Justification

The benefits of the pulse and oilseed grain legumes in cropping systems are well established. They can fix substantial amounts of atmospheric N_2, which allows them to be grown in N-impoverished soils without fertiliser N inputs. Growing concern about the sustainability of rice- based cropping systems, coupled with increasing prices for N fertilisers in relation to rice has led to renewed interest in biological nitrogen fixation (Becker et al., 1995). The positive effects associated with the inclusion of mainly tropical legume crops, in particular legume green manures, into tropical rice-based cropping systems have been well documented. Mineral N in root-zone soil following grain legumes is often 30–60 kg N/ha higher than after cereal crops in the same environment (Badaruddin and Meyer, 1994; Dalal et al., 1998). Rotation experiments involving sorghum (*Sorghum bicolor*) and maize (*Zea mays*) indicated grain yield responses to previous legume crops of 0.5–3.7 t/ha, or 30–350% (Gakale and Clegg, 1987; Armstrong et al., 1999; Varvel, 2000). Responses were equivalent to applications of fertiliser N of 40–170 kg/ha.

Objectives

- To evaluate the effect of residue of faba bean and field pea and different rate of bone meal on yield and yield components of Sorghum and Maize at Haramaya site.

Results

This experiment was conducted on field previously cultivated with faba bean and field pea inoculated with effective *Rhizobium* sp. Different rate of bone meal (orga) was tested and used as phosphorus sources. The treatments showed significant effect on grain and biomass yield of maize but not on sorghum. None of the treatments, including those with application of chemical fertilizer, did not show any significant effect on sorghum on previously faba bean and field pea cultivated plots (Table 1.69).

Table 1.69. The effect of inoculated faba bean (*Vicia faba* L.) and field pea (*Pisum Sativum* L.) precursor crops and different rate of Bone phosphate (Orga) on yield of sorghum (*Sorghum bicolar* L.) at Haramaya Experimental site

Treatment	Biomass yield (ton/ha)		Grain yield (kg/ha)	
	After faba bean	After Field pea	After faba bean	After Field pea
200Kg orga/ha	45.040[a]	46.794[ab]	4166.1[b]	6121.9[a]
400kg orga/ha	36.891[b]	53.104[a]	5421.0[ab]	5657.8[a]
600kg orga/ha	36.565[b]	43.652[b]	5411.7[ab]	5821.2[a]
150DAP+100 Urea	32.878[bc]	38.933[b]	6101.3[a]	5936.6[a]
Control	27.253[c]	27.163[c]	4616.4[b]	4414.3[b]
CV (%)	9.2	11.73	13.84	7.63
LSD (0.05)	5.978	8.948	1295	776.35

Table 1.70. The effect of inoculated faba bean (*Vicia faba* L.), field pea (Pisum Sativum L.) precursor crops, and different rate of Bone phosphate (Orga) on yield of maize (*Zea mays* L.) at Haramaya Experimental site

Treatment	Grain yield (kg/ha)	
	After faba bean	After Field pea
200 Kg orga/ha	9826[a]	9826[a]
400 kg orga/ha	9661[a]	8083[a]
600 kg orga/ha	9571[a]	7911[a]
150 DAP + 100 Urea	10909[a]	8887[a]
Control	8892[a]	8484[a]
CV (%)	24.2	14.22
LSD (0.05)	4301	2228

Conclusion (overall assessment)

Inoculation of legume improved the yield of subsequent crop in crop rotation. The trial has to be repeated for another year in order to provide conclusive results.

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1.8.15 Evaluation of Selected and Environmental-friendly Improved Biofertilizer (*Rhizobium leguminosarum bv. viciae*) for Highland Pulse Crops and Scaling out/up the Technology to Eastern Ethiopia

Million Fikiresillassie, Anteneh Argaw, Hiranmai Yadav, Ayele Akuma

Background and Justification

Faba Bean and field pea are some of the most important cool-season pulses grown in Ethiopia. They are essential part of the dietary protein requirement of most Ethiopian's. Faba bean is the first most important pulse in Ethiopia in terms of production and area coverage. According to the report of CSA (2009), from about 1,585,236 of land under pulses 538,820 ha was occupied by faba bean, which is about 34% of the land under pulses with annual production of 6,959,837 quintals. Field pea is the third most important pulse crop in Ethiopia after faba bean and chickpea, in terms of both area and total annual production. According to CSA (2009), field pea covers about 230,749 ha of the total arable land with a total production of 267,093 tons. Despite its importance, however, the productivity of the field pea is below 1ton/ha, which fluctuates and is far below the potential.

The yield is extremely low due to low soil fertility, smallholder farming and limited access to external inputs (Amare, 1987; EARO, 2000). One of the most important factor of soil fertility is nitrogen (N) deficiency of most Ethiopian soils (Desta, and Angaw, 1986). Most farmers in the developing countries such as Ethiopia are resource poor and cannot afford the required inputs, mainly in the form of chemical N fertilizers. Legume-*Rhizobium* has been exploited elsewhere as a substitute for the N fertilizers (Aynabeba *et al.,* 2001). Inoculation with selected rhizobia can improve the yield and yield components of legume plants. Asfaw and Angaw (2006) clearly revealed inoculations with *Rhizobium leguminosarus* bv. *viciae* have significantly improved the N_2-fixation, yield and yield components of faba bean and field pea in Ethiopia. Research carried out at Haramaya university experimental station revealed that rhizobia treated faba bean and field pea increased the grain yields up to 53% and 32% over the untreated plant, respectively (Anteneh, Unpublished data).

General objective

- To study the effect of rhizobial inoculation on the nitrogen nutrition and yield of faba bean and field pea and to teach/train the local farmers this novel and best alternative technology to improve their crop production by using this cost effective and renewable technology.

Specific objective(s)

- To evaluate the N_2 fixation and the potential to improve the pool of soil N by faba bean and field pea grown in three locations in eastern Ethiopia through measurement of the %N derived from the atmosphere (%Ndfa) using the ^{15}N isotope dilution technique.
- To observe the number of rhizobia nodulating faba bean and field pea in major growing area of Eastern Ethiopia using plant infection methods.
- To assess the impact of soil physical and chemical properties on indigenous population of rhizobia nodulating faba bean and field pea.
- To determine the influence of number of indigenous rhizobia on N_2 fixation and net N_2 fixed from atmosphere by faba bean and field pea.
- To popularize inoculant preparation (biofertilizer production) to rural farmers found in Eastern Hararghe Zone of Ethiopia.

Based on the success, to scale up the production at large scale at Haramaya University Research Center (Rare) and distribute the product to nearby farmers or throughout the country as supportive organic fertilizer that can be applied together with the synthetic one.

Materials and Method

Phase I

Sources of bacterial isolates

Well characterized rhizobia nodulating faba bean and field pea were obtained from Haramaya University, Biofertilizer Research and Production Center. These isolates have been verified as superior isolates which have been inoculated on test crop and improved the grain yield of faba bean and field pea by 53% and 32% over the uninoculated plant at Haramaya experimental site.

Experimental sites

The study of the effect of inoculation of rhizobia on faba bean and field pea growth was carried out at Boreda, Garamuleta and Alberekete. These are located in Eastern Ethiopia, Hararghe Highland.

Soil sampling and analysis

Soil samples (0-30 cm) will be collected at random from each experimental site before and after harvesting. A sub sample of the composite will be air-dried, sieved through a 2 mm screen and analyzed for important soil physico-chemical properties such as soil pH, EC, available P, total N, exchangeable bases (Na, Ca, Mg, K), B, Mo, total P (organic P and inorganic P), CEC and soil texture following the procedure indicated in Sahlemedhin Serstu and Taye Bekele (2000).

Inventory of number of rhizobia nodulating faba bean and field pea

The indigenous population of *Rhizobium leguminosarum* bv. *viciae* were estimated using the most probable number (MPN) method based on a 10-fold dilution series with faba bean and field pea as the trap host (Vincent, 1970). Plants were grown in sterile acid treated river sand with the addition of N-free nutrient solution during the experiment. For each dilution series, pots were established in quadruplicate plus a control. Surface sterilized and pregerminated seedlings were placed in each pot (three seedlings per pot) and each pot inoculated with 1 ml of soil solution. Pots were placed in a controlled environmental growth chamber with light-dark cycles of 14/10 h day/night at 25/20°C. Nodulation will be recorded after 3 weeks and examined again on the fourth week when the experiment will be terminated. The number of *Rhizobium* will be calculated using the MPNES computer program (Woomer et al., 1990).

Seed sources and biofertilizer preparation

Seeds of improved faba bean (var. Gachena) and field pea (var. Metti) were obtained from Haramaya University highland Pulses Improvement Project. The local varieties currently used for cultivation by local farmers were used as local cultivar. Biofertilizer from highly effective rhizobia were prepared 1 month prior to seeding by adding 30 ml rhizobial culture (grown to log phase in Yeast extract Mannitol broth containing 10^8 of bacteria ml^{-1} of culture) to 200 g sterile vermicompost prepared from *Parthinium* weeds. These was mixed and incubated for 14 days at 27°C (Pryor *et al.,* 1998). Then seeds were planted manually to a depth of 1 cm.

Multi-locational inoculum experiment

Multilocational field trials were carried out using selected highly effective rhizobia nodulating faba bean and field pea. These isolates have been characterized as very effective isolates earlier and they have increased the grain yield of faba bean and field pea by 53% and 32% over uninoculated plant at Haramaya experimental Site. The experiment was laid out in a randomized complete block design. All treatments were replicated three times. There were three treatments, which consisted:

- T_1-*Rhizobium* inoculum$_1$
- T_2-Positive control (with starter nitrogen i.e. 20 KgN ha^{-1})
- T_3-Negative control (with no chemical and biofertilizer application)

All seeds were sterilized with alcohol followed by 5% H_2O_2 to avoid rhizobial contamination and then washed five times using sterilized water as indicated in Vincent (1970). Seed inoculation was performed before sowing, using 10gm Kg^{-1} seed (to make approximately 1 x 10^6 bacterial cells/seed). For inoculated treatment, rhizobia biofertilizers were separately mixed to the seeds with a 15% (w/v) sucrose solution to increase adherence. All plots were fertilized with phosphorus fertilizer at the rate of 46 KgP_2O_5 ha^{-1} as TSP whereas 20 KgN ha^{-1} for positive control plots. A week before planting faba bean or field pea and reference plants, ^{15}N were applied as ammonium sulphate at a rate of 10 kg N ha^{-1}(10.2 atom %^{15}N) in solution mixed with sugar at a C: N ratio of 10:1 in order to immobilize the ^{15}N more rapidly into the soil microbial biomass (Giller and Witty, 1987).

Sampling preparation and analyses

Nodulation were assessed at late flowering stage of faba bean and field pea. Randomly selected five plants from border rows of each plot were uprooted. Soil adhering to the roots was removed by washing with tap water. Nodules attached to each plant were removed and the nodule color, nodule number, nodule fresh and dry weight, and nodule volume were separately recorded. At physiological maturity, plants were harvested, so that the outer rows are not used for analysis. Plants were separated into straw and pods or heads. These plant parts were oven-dried at about 70°C for 48hr. The dried plant materials were grounded to pass through a 0.5 mm sieve. Total N and % ^{15}N atomic excess (a.e.) of plant samples were analyzed following the procedure stated in Jensen (1991). Plants obtained from 1 m^2 were analyzed for grain yield and total biomass determinations and the results expressed in kg ha^{-1}.

Evaluation of BNF using ^{15}N –dilution method

The proportion of N in the faba bean and field pea derived from N_2 fixation were calculated by the ^{15}N-dilution methods, using wheat as a reference crop. Based on the assumption that the non-fixing reference plant takes up a similar proportion of soil-N: fertilizer-^{15}N as the fixing plant the proportion of N derived from the atmosphere can be calculated as suggested by McAuliffe *et al.,* (1958):

$\%Ndff_{faba\ bean\ or\ field\ pea/reference} = 100 \times [(\%^{15}N\ a.\ e.\ (faba\ bean\ or\ field\ pea/reference)/\ \%^{15}N\ a.\ e.\ (fertilizer)]$,

$$\%Ndfa = 100\ \frac{(1-\ \%^{15}N\ a.\ e.\ faba\ bean\ or\ field\ pea)}{\%^{15}N\ a.\ e.\ reference\ plant}$$

N_2 fixed (Kg ha^{-1}) = [(%Ndfa **x** total N in faba bean or field pea (Kg ha^{-1})]/ 100,
$\%Ndfs_{faba\ bean\ or\ field\ pea} = 100 - \%Ndff_{faba\ bean\ or\ field\ pea} - \%Ndfa$,
$B = (N_f + N_2\ fixed) - N_g$
Where: %Ndff is the percentage of N derived from fertilizer, %Ndfa is the percentage of N derived from the atmosphere, %Ndfs is the percentage of N derived from the soil, and B is soil N balance. The subscripts f and g denote applied fertilizer (Kg ha-1) and the N removed by faba bean or field pea grains or reference plant straw and grains, respectively.

Data to be collected

Composite soil samples before planting was collected for soil physico-chemical analysis and enumeration of resident rhizobia nodulating common bean.

At late flowering and early pod setting stage: numbers of nodule/plant, nodule dry weight/plant, nodule color, leaf color, shoot dry weight; total plant nitrogen and total plant phosphorus were recorded.

The following parameters were collected at harvesting time: total biomass ha^{-1}, grain yield ha^{-1}, number of seed pod^{-1} and number of pod $plant^{-1}$

Days to emergency, flowering and maturity were recorded.

Six months after harvesting, soil samples were collected separately from each plot, then important soil physic-chemical and soil biological properties were analyzed following the procedure indicated above.

Results

Six high yielding varieties of Faba bean and field pea were tested at two location (Haramaya and Albereket) using elite exotic and indigenous isolates of Rhizobia. These experiments were evaluated under field condition at Haramaya experimental site**.** So far, nodulation data and plant tissues samples for tissue analysis were collected from each experiment.

Conclusion (overall assessment)

Isolates under control environment and at Haramaya experimental site were performed better than the control. The trial will be completed after one year in order to provide conclusive results.

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1.8.16 Effect of Integrated Pest and Soil Fertility Management On Nodulation and Grain Yield of Groundnut (Arachis hypogaea L.) in Eastern Ethiopia

Anteneh Argaw, Mashilla Dejene, Million Fikiresillassie, Ayele Akuma

Background and Justification

Groundnut is a recent introduction to Ethiopia, and is widely grown in the eastern part of the country, i. e. Hararghe (Yebio *et al*., 1987). Gradually it is well produced in the eastern, western and northwestern lowlands of Ethiopia (Getinet and Nigussie, 1992), and to some extent in the south (Elias, 1992). In Ethiopia, groundnut is cultivated predominantly by the traditional and undeveloped farming community under rainfed conditions. It occupies about 41,761 hectares of land with a corresponding gross annual production of 46, 887 metric tons (CSA, 2009). The yield of groundnut in Ethiopia compared to other countries is very low i.e. below 1.1 ton ha^{-1} as compared to average yield on a global scale i.e. 1.52 ton ha^{-1} but with good management practices the yield could reach about 3.0 ton ha^{-1} (CSA, 2009; FAOSTAT, 2009). This shows that the yield in Ethiopia is extremely low mainly due to low soil fertility, prevalence of soilborne diseases, smallholder farming and limited access to external inputs. Groundnut root rot, caused by different soilborne pathogenic fungi is one of the important diseases resulting in heavy losses both in quantity and in quality (Amare, personal communication).

Control of soilborne pathogen requires an integrated approach that includes rotation with non-hosts, planting resistant cultivars, and applications of fungicides. However, the repeated use of such chemicals encourages the development of resistance in the target pathogen (Goldman et al., 1994), and has a negative effect on beneficial organisms and their physiological activities, which is important to soil fertility (Wani *et al.,* 2005). An alternative for protecting crops from diseases is biocontrol with organic amendments. Organic amendments are applied to induce the production of fungitoxic compounds such as organic acids or ammonia.

General objective

- To evaluate the effect of integrated pest and soil fertility management on prevalence of soil-borne pathogens, nodulation, grain yield and physico-chemical and biological properties of soils.

Specific objective(s)

- To assess the plant growth-promoting bacteria including rhizobia of groundnut and their antagonistic properties against soil-borne fungal pathogen;
- To investigate the interaction of fungicide seed treatment and rhizobia inoculation in the management of fungal root rot and their effects on nodulation and dry matter accumulation of ground nut;
- To determine the effect of carbamate fungicides on the incidence of soilborne fungal pathogens and microflora at Babille, and Gursum areas;
- To evaluate the effect of integrated crop management on soil-borne fungal pathogen, nodulation and grain yield of ground nut;
- To assess the effect of integrated crop management on soil total number of bacteria, fungal populations, total actinomycetes, aerobic N-fixing bacteria, denitrifying bacteria and nitrifying bacteria;
- To determine the suppressiveness of an array of composts against soil borne fungal pathogens of groundnut and to select compost characteristics that predict suppressiveness against soil-borne diseases.

Materials and Method

Phase-I

Screening of plant growth promoting microorganisms

Pathogenic Fungal strains

Fungal strain will be isolated from the naturally infested groundnut growing areas from Babile and Fedis, where groundnut infestation has been serious for several years. The fungus will be grown on potato dextrose agar (PDA) medium at 28±2°C in the dark. Fungal outgrowth will be subcultured in fresh media to obtain pure culture.

Collection of rhizosphere soils, nodule and plant specimens

Nodules samples were collected from Babille, Bisidimo, Gellemso and Fedis. Rhizosphere soil and plant specimen's samples were collected from peanut growing fields when the crop was 45 days old and brought to the laboratory in polythene bags. Root nodules were collected from field standing plants when available in the respective locations and stored in labeled McCartney bottles containing silica gel for later isolation of rhizobia following Somasegaran and Hoben (1994).

Isolation of plant growth-promoting rhizobacteria

Rhizosphere microbes were isolated from rhizosphere soils using the method of Glick et al. (1995). Bacteria, fungi and actinomycete were isolated using nutrient agar, potato dextrose agar (PDA) and GLM [yeast extract 3 g l^{-1}, malt extract 3

g l^{-1}, peptone 5 g l^{-1}, glucose 10 g l^{-1}, agar 20 g l^{-1} at pH 7.2] media, respectively. Inocula consisting of 0.1 ml of dilutions 10^{-3}, 10^{-4} and 10^{-5} in the physiological water (NaCl 9g l^{-1}) of the samples of soil were spread over the surface of the three culture media. The plates were incubated at 28±2°C. The GLM medium with inocula were incubated and observed after 2–4 weeks. The remaining plates were incubated. The colonies of actinomycetes and fungi were recognized according to their macroscopic characteristic aspect by light microscopy (magnification × 100), then purified, and transferred to GLM and PDA slants, respectively, and preserved at 4°C.

The 2-month old crops of groundnut were dugout carefully and placed in sterile polythene bags, taken to the laboratory and processed within 2 days after collection. For isolation of endophytic microbes, 5 g of leaves were separated by excising the leaf, stem and root to represent the sample to whole plant. Putative endophytic microbial strains were isolated separately from leaf, root, and stem of each groundnut plant by following the method of Zinniel et al. (2002). The plant parts were surface sterilized, 5 g of leaf, stem, and root sections were macerated individually with sterile mortar and pestle. The tissue extracts were diluted in 12.5 mm potassium phosphate buffer (pH 7.1) and plated on nutrient agar and potato dextrose agar media for isolation of endophytic microbes. The plates were maintained at 28±2°C for 48 –72 h, total colonies were enumerated and pure cultured on slants. Rhizobia were isolated from the preserved nodules following Somasegaran and Hoben (1994). All the isolates were sub-cultured at monthly intervals and maintained as stabs at 4°C in a refrigerator.

Nodulation and nitrogen fixation assay

The nodulation experiment was carried out on groundnut using the methods previously described by Somasegran and Hoben (1994). Surface-sterilized groundnut seeds were germinated axenically in Petri dishes. Seedlings were transferred to sterilized growth pouches and watered with N-free nutrient solution. Three plants on each growth pouch were inoculated with 1 ml of a bacterial suspension of each strain containing 8×10^8 cells/ml. The inoculated plants were placed for two months in a plant growth chamber. Finally, all-important parameters were evaluated.

Quantification of plant growth promoting attributes

Selected isolates, which resulted in the enhancement of root growth, was further tested for their ability to produce siderophore in CAS agar plates, typed, and quantified in broth, IAA-like substances, solubilization of tri-calcium phosphate and ammonification. Siderophore production was detected by observing orange halos around bacterial growth on CAS agar plates (Schwyn and Neilands, 1987) after 72 h of growth. Catechol type of siderophore was quantified by the method of Arnow (1937), modified by Carson et al. (1992) in iron-free liquid medium.

Production of IAA

The presence of IAA-like substances was detected and quantified following the method of Sarwar and Kremer (1995) in L-tryptophan agar. A 1ml each of 24 h growth of the isolates in Kings' B (King et al., 1954) broth was pour plated into L-tryptophan agar in triplicate and incubated at 28±2°C for 24h in the dark. After incubation, the agar growth beads (three beads, approximately 0.24cm^3) was placed in freshly prepared Salkowsky reagent (Sarwar and Kremer, 1995) in triplicate, from each Petri dish and incubated in the dark for 30 min for development of pink colour and measured spectrophotometrically at 595 m using IAA as standard. The amount of IAA produced was expressed as mg l^{-1}.

Phosphate solubilization

Solubilization of tri-calcium phosphate was quantified in Pikovskaya's (1948) broth. Each flask containing 100 ml of Pikovskaya broth having 500 mg of tri-calcium phosphate was inoculated with 0.5 ml of 24 h broth culture of each isolate in triplicate and incubated in a rotary shaker (240 rpm) at 28±2°C for 4 days. The culture was centrifuged at 15,000 rpm for 10 min and the supernatant collected in 100 ml volumetric flasks. Volume of the supernatant was filled to 100 ml with distilled water. Water-soluble phosphorus in the supernatant was determined by the chloromolybdic acid method of King (1932) modified by Jackson (1967). Spectrophotometric measurement was taken at 660 m.

Ammonia production

For the detection of ammonia production, all the isolates were grown in test tubes containing peptone water: 10.0 g peptone; 5.0 g NaCl; 1000 ml distilled water; 7.0 pH (Dye, 1962). The tubes were inoculated with 100 ml of 24 h grown cultures in broth and incubated at 30°C for 4 days. The accumulation of ammonia was detected by adding Nessler's reagent (0.5 ml $tube^{-1}$). A faint yellow colour indicated a small amount of ammonia, and deep yellow to brownish colour indicated maximum production of ammonia.

Cyanide production

Cyanide production was detected as described by Castric (1975). Petri plates containing 10% Trypticase soy agar supplemented with 4.4 g of glycine per liter was inoculated with the microbe and inverted after a piece of filter paper, impregnated with 0.5% picric acid and 2% sodium carbonate, placed in the lid of each Petri dish. The plates were

incubated at 28°Cfor 3 to 5 days. A change in color from yellow to orange-brown on the filter paper indicated cyanide production.

Volatile antifungal compounds

The production of volatile antifungal compounds by the isolate will be assayed by a sealed plate method as described by Fiddman and Rossal (1993). As a control, a Petri dish containing agar medium without antagonistic isolate will be placed over the PDA medium inoculated with the fungal pathogen. Fungal growth will be measured as increases in radial growth of the test fungus over 24h intervals for a period of 5 days. Each test was replicated 3 times.

Enzyme assays

The culture was centrifuged at 10,000g for 10 min and the culture supernatant used as a source of enzymes. Protease, chitinase and glucanase activities was determined as described by Oceguera-Cervantes et al. (2007), Vyas and Deshpande (1989) and Gohel et al. (2007), respectively. One unit of protease, chitinase and glucanase activity was defined as the amount of enzyme required to liberate 1 mmole of tyrosine, N-acetyl-D-glucosamine and glucose, respectively, per hour at 55 °C (protease) or 50 °C (chitinase and glucanase activity).

In vitro antagonism against soil borne fungal pathogenic

Inhibition of fungal pathogen by collected microbes was determined in vitro on PDA following Huanga et al. (2006). Plugs of 5-mm diameter mycelia was removed from the colony margin (5- to 7-dold cultures), inverted, and placed in the centre of the PDA plates. Four plugs of 5-mm diameter mycelia of four different antagonstic fungal colonies from each treatment was inverted and placed around fungal pathogen 24 h later. For antagonstic actinomycetes and bacteria, four agar plugs about 1–2mm from four different microbes placed around pathogenic fungi. As the control, pathogen was inoculated in the centre of the plates without any antagonstic microorganisms around it. Treatments were replicated three times. The plates were incubated for 5–7 d at 28±2°C. A test was considered positive when a clear inhibition zone (>2 mm) was observed around the plugs of rhizosphere microorganisms in three replicate plates.

Growth curve of plant growth promoting microbes (PGPM) isolates capable of utilizing seed leachates as the sole source of Carbon and Nitrogen

For determining the ability of the selected PGPM in utilizing the seed leachate as the sole source of C and N, seed leachate was extracted from 1 kg of peanut seed soaked overnight in 3 l of deionized water. The entire amount was sterilized by passage through membrane filter assembly (0.22 mm). The seed leachate (50 ml, pH 7.0) was taken in 250 ml Erlenmeyer flask. The PGPM isolates was grown overnight in Kings' B broth and 100 ml of each isolate (OD 1.2 at 600 μm) was used for inoculating the seed leachate, in triplicate. The flasks were incubated at 28±2°C in a rotary shaker (240 rpm). The OD of each isolate, in triplicate, was measured in a spectrophotometer at 0, 20, 26, 44 and 68 h of growth at 600 μm. The growth curve was prepared by plotting OD against time.

In vitro survival of rhizobia with fungicide

Recommended Groundnut variety seeds were surface sterilized according to Vincent (1970). The experiment was conducted with two treatments [*Rhizobium* (R), mancozeb + *Rhizobium*] in a complete randomized design (CRD). Each treatment has four replications. Sterilized seeds were treated with the fungicide mancozeb followed *Rhizobium* inoculant. In the *Rhizobium* alone treatment, 1 X 10^7 cells g^{-1} of charcoal-based inoculant will be applied to sterilized seeds. Seeds were air dried for 15 min and stored at 4°C. After 0, 4, 8, 12, 16, 20 and 24 h of inoculation, 40 seeds were picked randomly from each treatment aseptically and divided into four subsamples of 10 seeds. Each subsample were transferred to test tubes containing 10 ml of sterile water and shaken vigorously on a vortex for 30 s to wash the inoculum from seeds. One millilitre of the resultant suspension from each treatment was diluted serially and 0.1 ml of aliquout from each dilution was pipetted on yeast extract mannitol agar (YEMA) plates. *Rhizobium* colonies was counted after incubation at 28 ± 28°C for 7 days.

Phase-II

Preparation of compost and in vitro assessment of its antagonism against pathogenic fungi

Preparation of compost and vermicopost

The preparation of composts and vermicomposts will be processed locally available organic wastes (*Parthenium hysterophorus*) with different animal manure (cow dung, poultry manure and goat manure). The Parthenium plants will be collected before flowering to avoid the health consequences resulting from the pollen and also prevent an effective germination of the parthenium seeds during a favorable condition. These plants will be cut into smaller parts for easy degradation process. Water will be applied to the composts by sprinkling to maintain optimum moisture content. The African earthworm (*Eudrillus eugeniae*) will be introduced to materials after thirty days of degradation. Sampling for analysis of the vermicomposts and composts will be done in different stages of composting. The experiment will be processed with the following treatment:

- T_1- Organic waste + cow-dung
- T_2- Organic waste + poultry manure
- T_3- Organic waste + goat manure
- T_4- Organic waste + cow-dung + *Eudrillus eugeniae*
- T_5- Organic waste + poultry manure + *Eudrillus eugeniae*
- T_6- Organic waste + goat manure + *Eudrillus eugeniae*

In vitro inhibition assays of pathogenic fungi by water extracts from compost and vermicompost

Water extracts from different compost and vermicompost will be prepared using the following procedure: 10 g of dry compost or vermicopost powder will be suspended in 300 ml distilled water and the suspension will be boiled for 10 min, shaken for 24 h at 100 rpm. It will be briefly centrifuged and filtered through Whatman No. 1 filter paper. The filtrate will be then sterilized by a bacterial filter and stored as stock solution at 4^0C. In vitro inhibition assay will be assessed following the procedure of Huanga et al., (2006).

Compost and vermicompost quality assessment

The different composts and vermicomposts will be analyzed for their physico-chemical, macro and micronutrient contents, and microbial status and compared with their fresh form. The microorganisms will be enumerated by the standard 10-fold dilution method. Soil suspensions at appropriate dilution rates will be inoculated onto plates containing appropriate media. Agar media for growing bacteria and to actinomycota, fungi will be beef extract peptone, (soluble starch 20 g, KNO_3 1 g, NaCl 0.5 g, K_2HPO_4 0.5 g, $MgSO_4$ 0.5 g, $FeSO_4$ 0.01 g, agar 20 g, distilled water 1000 ml, pH 7.2), Martin medium (glucose 10 g, peptone 5 g, KH_2PO_4 1 g,$MgSO_4$ 0.5 g, rose bengal 30μg, streptomycin 0.03 g, distilled water 1000 ml).

Total lipid content will be determined by extraction with diethyl ether and later weighing. Water-soluble phenolic substances were measured by a modified version of the Folin method (Maestro et al., 1991). To determine the germination index (GI), eight Cress (*Lepidium sativum* L.) germination will be followed each Petri dish (10 for each stage) for 72 h, according to the method of Zucconi et al. (1981). Tap water will be used as control. GI will computed as the product of the percentage of viable seeds by the percentage of root length divided by 100. As in all tests noted above, these analyses will be performed in duplicate.

Phase-III

This phase is greenhouse and field in vivo experiment and data analysis is under way. The treatments for greenhouse experiment are:

- T_1- Organic waste + cow-dung
- T_2- Organic waste + poultry manure
- T_3- Organic waste + goat manure
- T_4- Organic waste + cow-dung + *Eudrillus eugeniae*
- T_5- Organic waste + poultry manure + *Eudrillus eugeniae*
- T_6- Organic waste + goat manure + *Eudrillus eugeniae*
- T7- Unamended treatment
- The treatments for Field trial experiment are:
- T_1- PGPM (rhizosphere microbe)
- T_2- PGPM (endophytic microbe)
- T_3-PGPM (effective *Rhizobium*)
- T_4- PGPM (rhizosphere microbe) + PGPM (endophytic microbe
- T_5- PGPM (effective *Rhizobium*) + PGPM (rhizosphere microbe)
- T_6-PGPM (effective *Rhizobium*) + PGPM (endophytic microbe)
- T_7- mancozeb
- T_8- PGPM (rhizosphere microbe) + mancozeb
- T_9- PGPM (endophytic microbe) + mancozeb
- T_{10}-PGPM (effective *Rhizobium*) + mancozeb
- T_{11}- PGPM (rhizosphere microbe) + PGPM (endophytic microbe) + mancozeb
- T_{12}- PGPM (effective *Rhizobium*) + PGPM (rhizosphere microbe) + mancozeb
- T_{13}-PGPM (effective *Rhizobium*) + PGPM (endophytic microbe) + mancozeb
- T_{14}- PGPM (rhizosphere microbe) + PGPM (endophytic microbe) + PGPM (effective *Rhizobium*)
- T_{15}- PGPM (rhizosphere microbe) + PGPM (endophytic microbe) + PGPM (effective *Rhizobium*) + Mancozeb

- T_{16}- Control (with no amendment)

Results

More than 60 rhizosphere soils were collected from major groundnut growing areas of Eastern Ethiopia (Gursum, Babile, Fedis and Awale). Symbiotic and rhizosphere microorganisms were isolated following formal procedure. Symbiotic Bradyrhizobia spp. was tested for symbiotic effectiveness in growth chamber. Integrated applications of soil management (compost, manure, *Bradyrhizobium* sp. and chemical fertilizers) were tested at babile and fedis. The number of wilted plant significantly reduced by good soil managements. Moreover, at the time of surveying of groundnut growing sites, co-existance of termite infestation at early stage of wilting with black rot of groundnut root at late stage was observed.

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1.8.17 Effect of Khat Compost on Yield and Yield Components of Potato at Haramaya Experimental Site

Anteneh Argaw and Eyasu Mekonnen

Background and Justification

Awaday city produce and accumulate enormous quantities of Khat leftover, the elimination of which causes tremendous environmental problems. This waste can be deposed of in controlled dumps, incinerated, or re-cycled into agriculture. First, the organic waste can be incorporated without relevantly altering the balance in the environment; and, second, the incorporation of organic waste increased organic matter as well as fertilizing constituents. The khat leftover compost is known to contain relatively high quantities of organic matter and offered organic carbon (C) and energy necessary for biologic activity in the soil (Eyasu, unpublished data). It also favorably affected the physical, physio-chemical, and chemical properties of agricultural soils. One major problem with the application of compost was the lack of consistency in crop response. In some cases, the application of compost improved the fertility of agricultural soils and increased crop productivity, while in other cases, the application produced no significant effect at all.

General objective

- To evaluate the influence of different rates of khat compost application on three varieties of potato at Haramaya University

Results

Well-prepared and stable compost prepared from khat left over was used to evaluate the effect on yield and yield components of three varieties of potato at Haramaya Experimental site. At vegetative stage, we have observed that pronounced improvement of potato biomass at higher rate of compost application.

Conclusion (overall assessment)

Compost was tested in soil laboratory and has low C/N ration with high plant nutrients. The trial will be completed after two months in order to provide conclusive results.

1.8.18 Evaluation of the Multiplication of Earthworm in Different Animal Manure

Anteneh Argaw and Eyasu Mekonnen

Background and Justification

The importance of earthworms in the breakdown of organic matter and the release of the nutrients that it contains has been known for a long time (Darwin, 1881). It has been demonstrated clearly that some species of earthworms are specialized to live specifically in decaying organic matter and can degrade it into fine particulate materials rich in available nutrients with considerable commercial potential as plant growth media and soil amendments (Edwards and Bohlen, 1996). Most organic wastes can be broken down by earthworms, but not all organic wastes will grow earthworms equally well.

Objective

- To evaluate the influence of different animal manure on the multiplication of earthworm under control condition.

Results

This experiment was conducted using plastic container under controlled management. The suitability of different manure (cowdung, goat manure, poultry manure and swine manure) were evaluated with *Parthenium* weed as bulking material. The experiment showed that number of earthworm and coccuns in cowdung and goat manure were scored significantly higher than swine manure and poultry manure. On the other hand, poultry manure killed all earthworms, which indicate that it is unsuitable medium for multiplication of earthworm.

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1.9.1 Animal and Range Sciences

Feeding Value of Ground *Prosopis Juliflora* Pods in Layers and Broiler Rations

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Abstract: This study was conducted to evaluate feeding value of ground Prosopis juliflora pods in layers and broiler rations at Poultry Farm of Haramaya University. The overall objective of the study was to generate information on chemical composition, and performance of layers and broilers fed ration containing graded levels of ground Prosopis juliflora pods (GPJP). One hundred eighty 26-week old Bovans Brown commercial layers (experiment one) and three hundred ninety six Hubbard Classic commercial day old broiler chicks (experiment two) were used for the experiment. The treatment rations contained GPJP at inclusion levels of 0 (T1), 10 (T2), 20 (T3) and 30% (T4) of the total ration. Both experiments were arranged in a completely randomized design and each treatment was replicated three times. The replicates consists 15 layers and 33 broiler chicks. The rations were formulated to be isocaloric and isonitrogenous with 2800 kcal ME/kg DM and about 16.0% crude protein (CP) to meet requirements of layers and about 3060 kcal ME/kg DM and 22% CP; 3100 kcal ME/kg DM and 18% CP to meet the nutrient requirements of broiler during the starter and finisher phases, respectively. Experiment one lasted for 12 weeks, during which dry matter intake (DMI), initial body weight, final body weight, body weight change, hen day egg production, egg mass, egg weight, feed conversion ratio, egg quality parameters were recorded and economic analysis were undertaken to evaluate the benefits of including GPJP in layers ration. Broilers experiment lasted for a total of 45 days (1-21 days starter, and 22-45 days finisher phase) during which feed and nutrient intakes, live body weight, feed conversion ratio, mortality, carcass yield characteristics, gastro intestinal tract weight and length were recorded as well as economic analysis. Fatty acids composition, sensory characteristics, and chemical composition of breast and thigh muscles and blood hemathology were also assessed to determine effect of GPJP on product quality and broiler health. Data were subjected to analysis of variance for all parameters considered. Chemical composition of GPJP used for layers ration were 12.1% CP, 7.3% ether extract (EE), 14.4% crude fiber (CF) and 82.3µg/100g β-carotene. Corresponding values for CP, EE and CF of GPJP used for broiler were 15.43, 6.01, and 14.6%, respectively. The results showed that dry matter intake and hen day egg production (HDEP) was lower ($P < 0.05$) for T4 than T1 and T2 and that of egg mass was significantly ($P < 0.05$) lower for T4 than T1 (DMI: 111.4, 111.8, 110.5 and 105.4 g/day (SEM = 1.92); HDEP: 67.2, 67.7, 62.7 and 60.0% (SEM = 0.02); egg mass: 44.0, 43.8, 41.3 and 39.6 g/day (SEM = 1.49) for T1, T2, T3 and T4, respectively). Except for egg yolk color, which was greater ($P < 0.05$) for T4 than other treatments, all egg quality parameters were similar among treatments. Therefore, the overall layers performance revealed that up to 20% GPJP inclusion in layers ration is recommendable, and treatment with 10% GPJP in the ration appeared to be more economical. Higher level of GPJP inclusion in broilers ration also impacted some performance parameters. Feed intake during finisher phase (3387, 3340, 3337 and 3280 g (SEM = 29.54)) and the entire experiment period (4369, 4321, 4313 and 4248 g (SEM = 27.41)), final live weight at the end of starter, finisher and the entire experiment (1837.6, 1854.1, 1798.2 and 1639.5 g (SEM = 63.55)) period, average daily gain (ADG) (40.8, 41.2, 39.9 and 36.4 g/d (SEM = 1.41)), and feed conversion ratio (2.3, 2.3, 2.4, and 2.5 (SEM = 0.070)) during the entire experiment period, for T1, T2, T3 and T4, respectively, were significantly lower ($P < 0.05$) in T4 than at least T1. Among carcass yield parameter, drum stick weight was significantly lower ($P < 0.05$) in T4 than T1 and T2. There was no adverse effect of GPJP inclusion in broiler ration on fatty acid composition, sensory characteristics and chemical composition of breast and thigh meat of broiler. Hematological responses of broilers was similar between the treatments, except monocyte percentage, which was significantly ($P < 0.05$) higher in T4 as compared to the other treatments, and more lesions were observed on the intestine of birds at higher level of GPJP inclusion (30%), which may indicate the negative effect of high level of GPJP inclusion in broilers ration on immune response of birds. Overall, the result showed that broilers performance, product quality, and health are not hampered by inclusion of GPJP up to 20% of the total ration. Therefore, we conclude that inclusion of GPJP in poultry ration at lower level (maximum of 20%) reduces feed cost and decreases the invasion of rangeland by Prosopis juliflora plant, since the seed is used after it is crushed.

Keywords: Ground Prosopis Juliflora Pods; Egg Quality; Growth; Fatty Acid Composition; Sensory Characterstics; Meat Composition and Hematology

Introduction

The average intake of protein of animal origin in developing countries is as low as 15 g per person per day, compared with almost 60 g in developed countries (FAO, 2011). Poultry meat and eggs are estimated to contribute about 33 % of the total animal protein supply in low income food deficient developing countries (FAO, 2010) indicating the role chicken can play in filling the discrepancy between demand for and supply of animal protein. However, feed among others became an important challenge for efficient and economical poultry production in such countries. Feed cost alone accounts for about 80% of the total animal production cost (El Boushy and Van Der Poel, 2000). Any attempt to improve poultry production and increase its efficiency therefore, needs to focus on the utilization of locally available and affordable new ingredients that can reduce the competition that exists between human and poultry for conventional ingredients (Kamalzadeh *et al*., 2008). As a result, there is a worldwide interest in the search for new feed resources that are capable of supplementing traditional poultry dietary ingredients (Jurgen *et al.,* 1998). This requires evaluation of the new feed and determination of optimum level of inclusion in diet formulation to achieve acceptable level of animal performance without jeopardizing animal wellbeing. In this context, ground *Prosopis juliflora* pod (GPJP) has been considered as one of the potential feed ingredient in poultry ration formulation.

Prosopis juliflora is a leguminous tree that is native to arid and semi-arid regions of the world (Harris *et al*., 2003). It is present in North America, Africa and Asia, having multi-seeded curved pods with hardened pericarp (Habit and Saavedra, 1988). In Ethiopia, *P. juliflora* is considered as one of the invasive weeds rapidly invading the agro and silvo-pastoral land, making the rangelands inaccessible to livestock (Sertse and Pasiecznik, 2005). The eradication of *P. juliflora* is posing a grave challenge because of the hardy nature of the plant. Eradication of the plant by cutting as well as burning has been proven extremely difficult. As such, its exploitation as a resource was proposed to be a better approach to reduce its invasiveness (Pasiecznik, 2002). Accordingly, several strategies of *Prosopis* utilization as a resource were designed and implemented by the government of Ethiopia in order to reduce its propagation (Dubale, 2006) Among these are economic utilization of the tree and its products (example, charcoal) and the use of the pod with the seed after grounding as one of the ingredient in animal feed.

Prosopis juliflora pods have been used in poultry diets and produced encouraging results. Studies in Brazil showed that 100% replacement of wheat bran with *P. juliflora* pod flour to have similar impact on most layers performance (Silva, 1984), although another study (Silva *et al*., 2002) reported that inclusion of *P. juliflora* pod at 30% of the ration reduced egg mass, weight, and feed to egg mass ratio. Zein Elabdin and Mukhtar (2011) reported that soaked *P. juliflora* seed flour replaced 50% of sesame meal in broiler diets without negative effect on performance. AL-Beitawi *et al.* (2010) noted heavier body weight, faster growth, and better feed conversion efficiency in broilers fed ration containing 20% GPJP as a substitute for corn without causing significant change on dressing percentage and carcass cut. Furthermore, replacing maize up to 20% with GPJP (Choudhary *et al*., 2005), and inclusion at a rate of 10% of GPJP in the ration (Vanker *et al*., 1998) resulted in no adverse effects on performance of broilers. Using *P. juliflora* meals is advantageous in that it bears its pods during the driest months of the year making it possible to use its pods in animal ration formulation when availability of other ingredients is scarce, thereby offsetting high cereal prices. However, information on the use of GPJP in layers and broilers ration in general is limited, and is non-existent in Ethiopia to convince feed manufacturers and farmers to use it as replacement for cereal grains in poultry ration formulation.

Although the use of *P. juliflora* meals as ingredient in the ration of animals is promising, there are problems reported to hamper its utilization at higher proportion in the ration of animals. Among the problems noted are its content of heat labile anti-nutritional factors such as trypsin inhibitor and hemagglutinin (Del Valle *et al*., 1983), which are capable of inducing adverse effects especially in monogastric animals when consumed without adequate processing (Apata, 2003). Moreover, few reports indicated that *P. juliflora* consumption has an adverse effect on livestock product quality (Beruk, 2003; Dawit, 2010). According to the perception of pastoralists in Amibara district, Afar region of Ethiopia, goat and camel milk obtained from animals fed *P. juliflora* has a bitter taste. They also claim that it reduces milk and butter yield, and meat from prosopis fed goat has poor quality in terms of appearance (pale color) and flavor (Dawit, 2010). Similarly, Beruk (2003) reported that milk obtained from goat, cow and camel fed diet based on *P. juliflora* has a bitter taste. Some health associated problems such as stomach poisoning by the pod is reported to induce a permanent impairment of the ability to digest cellulose due to depression of the rumen cellulolytic bacterial activity (Abiyot and Getachew, 2006). Disfiguration of goats' jaws due to consumption of hard pods of *P. juliflora* and tooth decay was perceived to be a major problem. These dental problems impair the health of the goats and in some cases causes' death due to starvation (Esther and Swallow, 2008). However, the above mentioned quality problems on livestock products are not supported by scientific justifications, and we could not find a quantitative study that shows the impact of *P. juliflora* pod consumption on livestock product quality and health. But, there are few evidences which show that animal performance, such as milk yield (Abedelnoor *et al*., 2009), egg production (Silva *et al*., 2002; Meseret *et al*., 2011a) and growth (Choudhary *et al*., 2005; AL-Beitawi *et al*., 2010; Meseret *et al*., 2011b) are hampered by high level of *P. juliflora* consumption or its inclusion in livestock diet at higher level. This work addressed effects of graded levels of *P. juliflora* pod inclusion in layers and broilers ration on performance, product quality and health status of animals.

General Background

Description and Properties of Prosopis juliflora

Prosopis juliflora is a perennial deciduous thorny shrub or small tree that can grow up to 10 m tall, with a trunk up to 1.2 meters in diameter. *P. juliflora* belongs to the family Fabaceae (Leguminosae), subfamily Mimosoideae and genus *Prosopis*. It is armed with stipular spines 0.5-5 cm long and leaves have 1-4 pair of pinnae. The number of leaflets could be 6-29 pairs with sizes 6-23 mm x 1.5-5.5 mm and glabrous surfaces. Flowers are yellowish in speciform racemes, 5-15 cm long. The pod is pale brown, linear, slightly curved, 8-29 cm x 0.8-1.7 cm, compressed and with a sugary-pulpy mesocarp. It has a deep about 53 m to very deep well meshed root system that grows deeply downward in search of water tables. *P. juliflora* is a rapidly growing plant, which starts to bear fruit starting from 2–3 years of age.

Prosopis juliflora is dry land tree or shrub native to South America, Central America and the Caribbean. It has been introduced and naturalized in many parts of the world (Pasiecznik *et al*., 2004). However, despite its qualities and uses in its natural range, *P. juliflora* has become a serious invading weed introduced into non-native areas without proper management (Hailu *et al*., 2004). Of the invasive woody weeds, *P. juliflora* is the one that forms dense jungles of brush, which sharply reduces range production, and its accessibility to browsing animals.

Prosopis juliflora is a plant adapted to rocky, warm and dry tropical climates. It is capable of growing on inhospitable habitats such as rocky and saline soils under adverse climatic conditions (Saxena, 1993; Dagar, 1998). It grows well in areas receiving low annual rainfall without losing any of its leaves during the long dry season. Due to its enormous potential for reproduction, it rapidly spreads and quickly occupies an area once it is established. In Ethiopia, it occurs at altitudes of 450 to 1000 m.a.s.l. currently; it invaded large areas in the Afar and Somali Regional States (Asfaw and Thulin 1989; Getachew, 2002; Pasiecznik *et al*., 2004). *Prosopis juliflora* is reported to grow in areas with annual precipitation of 150 to1670 mm, annual temperature of 20.3-28.5°C and a pH of around neutral (Duke, 1983). It often colonizes disturbed, eroded, and over-grazed lands, forming dense impenetrable thickets. Thickets of *P. juliflora* have become established in grazing lands, croplands and along river courses, alarming pastoralists, farmers and conservationists (WAC, 2009). According to the report of world agro forestry centre, experience of many countries showed that *P. juliflora* is extremely difficult and costly to eradicate once it takes root. A more sustainable option might be better management through collective use and harvesting of marketable products. Felker *et al.* (1984) reported the yield of pods to range from 7.2 to 90 kg/tree/year. According to Shukla *et al.* (1986) a hectare of *P. juliflora* plantation could yield about 12 tones of pods year.

Prosopis juliflora is propagated through its seeds, root suckers, and hardwood cuttings. The seeds can germinate under considerable moisture stress and temperature that ranges between 20- 40 ^{o}C (Hailu *et al.,* 2004). The most important reasons for its fast invasion into semiarid and arid ecosystems are due to the role of livestock and wild animals in dispersal of the seeds (Heady and Child, 1994). Accordingly, livestock trailed at the rate of 15 km per day would transport the seeds in their digestive tracts more than 100 km in a week's time.

Uses of Prosopis juliflora

The English, French, Spanish and Portuguese introduced *Prosopis* around the world over the past 200 years, as they were seen to be very useful and drought resistant species. In hot dry parts of the Americas, *Prosopis* are common, and are important for people providing many with much needed resources. The wood is an excellent fuel, the timber hard and comparable to the finest hardwoods. The sweet nutritious pods are relished by all livestock, and human are made it into different foods and drinks. Honey from the flowers is high quality, the gum is similar to gum arabic and leaves can be used as mulch, reducing pests and weeds. Also, as nitrogen fixing tree it improves the land and can reclaim saline soils (Sertse and Pasiecznik, 2005).

In Ethiopia *P. juliflora* has both economic and ecological benefits, which can be summarized as follows. It can be used for fuel wood, charcoal production, livestock feed (especially during drought periods when no other green feeds are available), live fence, honey production, shade to human and livestock, ornamental crafts, for changing the landscape of the arid region, changing the micro environmental condition, for soil protection and as wind break and for improving soil nitrogen and land reclamation of soil salinity problem that helps in mitigation of desertification (Abiyot and Getachew, 2006; Dubale, 2006). Prosopis also served for mitigation of desertification by colonizing abandoned farmlands due to salinity problems. Soils under the crowns of Prosopis in the desert usually have ten times more nitrogen (0.3%) than those under non-nitrogen fixers' trees (Bhatia, 1998).

Negative Impacts of Prosopis juliflora

Due to severe environmental degradation in arid areas, the ecosystem has lost its natural immunity to react against invasive species. Thus, *P. juliflora* has become a problematic species expanding at an alarming rate. It is fast growing, drought resistant, with a remarkable copping power. Such unique adaptive traits of the species have negative impact for local biodiversity and ecosystems (Getachew and Abiyot, 2004; Hailu *et al.,* 2004).

The sharp, strong, and poisonous thorns of *P. juliflora* were cited as a major problem. Thorns make it difficult for animals to penetrate the dense thickets of prosopis. Study in Kenya around Lake Baringo revealed that invasion of

prosopis on communal grazing lands reduced pastures available for livestock. According to reports by local Afar pastoralists, the ingestion of the pod over long periods of time results in death of cattle. Stomach poisoning by the pod may induce a permanent impairment of the ability to digest cellulose due to high sugar content of the pod that depresses the rumen celluiolaytic bacterial activity, finally causing mortality to animals (Abiyot and Getachew, 2006).

Livestock feeding on *P. juliflora* pods for extended periods, due to lack of pasture show health problems such as constipation, dental disfiguration and reduced overall productivity (Dubale, 2006). The disfiguration of goats' jaws due to consuming the hard pods of *P. juliflora* and the tooth decay resulting from the pods' high sugar content was perceived to be a major problem. These dental problems impair the health of the goats and in some cases causes' death due to starvation (Esther and Swallow, 2008).

Few reports indicated that *P. juliflora* consumption has an adverse effect on livestock product quality (Beruk, 2003; Dawit, 2010). According to perception of pastoralists in Amibara district, Afar region of Ethiopia, goat and camel milk from *P. juliflora* fed animals has a bitter taste. They also claim that it reduces milk and butter yield, and meat from Prosopis fed goat has poor quality in terms of appearance (pale color) and flavor (Dawit, 2010). Similarly, Beruk (2003) reported that milk obtained from goat, cow and camel fed diet based on *P. juliflora* has a bitter taste.

Prosopis juliflora has a negative impact on pasturelands or arable fields (Getachew, 2002), because it responds positively to overgrazing and denuded grassland ecosystems are subsequently converted to unusable bush lands. The invasion is aggravated by the aid of different dispersal agents such as cattle, camels, and goats. The conversion of *P. juliflora* invaded fields back to original condition would be very difficult and very costly. *P. juliflora* replaced the local biodiversity in several spots in Afar region, mainly rangelands and dry riversides. In such areas, the grasslands are no more used for grazing by the livestock. The species also reduced the total biodiversity of the arid and semiarid regions by reducing their abundance, distribution and more importantly by changing the ecosystem function from rangeland to *Prosopis* thicket. For example, *P. juliflora* eventually push out the local Afar pastoralists (that solely depend on natural pasture for their cattle) from their home and pasture fields aggravating food and feed shortage in the region (Hailu *et al.,* 2004).

Feeding Value of Prosopis juliflora Pod Flour for Livestock and Poultry

Knowledge regarding the utilization of *P. juliflora* as a source of animal feed is much wider, as its pods have long been used as feed for bovines, equines, ovines and caprines, pigs and fowl. The great value of *P. juliflora* as fodder is in its pods. Besides being a source of energy and having protein value, *P. juliflora* pod can be produced advantageously from ecologic and economic points of view, in the farm itself, even in years of abnormal rainfall rates (Mathur and Bohra, 1993). *P. juliflora* bears its pods during the driest months of the year, making it possible to use the pods as animal feed, thereby offsetting high cereal prices.

Several trials that evaluated the potential of *P. juliflora* based supplements in livestock production have shown positive results. Feeding fattening Awassi lamb with diets containing up to 200g/kg *P. juliflora* pod did not affect growth performance, nutrient digestibility, and carcass and meat characteristics while being cost effective (Belal *et al*., 2008). The replacement of up to 35% of maize in lactating sow rations in Brazil also clearly demonstrated the value of *P. juliflora* flour (Riveros, 1992). Study reported that concentrate mixture containing up to 30% GPJP as a substitute for wheat bran has positive effect on feed intake, digestibility, final body weight, average daily gain and carcass parameter in fattening ration of cattle (Yohannes, 2011). A crushed *P. juliflora* pod feeding trial was conducted by FARM-Africa in Afar, Ethiopia. Goats fed a mixture of 50% prosopis and 50% corn, showed considerably better performance as compared to the control groups on normal pasture grazing (Dubale, 2008).

Prosopis juliflora pods have been used in poultry diets and produced encouraging results. Studies in Brazil showed that 100% replacement of wheat bran with *P. juliflora* pod flour to have similar impact on most layers performance (Silva, 1984), although another study (Silva *et al*., 2002) reported that inclusion of *P. juliflora* pod at 30% of the ration reduced egg mass, weight and feed to egg mass ratio. Zein Elabdin and Mukhtar (2011) reported that soaked *P. juliflora* seed flour replaced 50% of sesame meal in broiler diets without negative effect on performance. AL-Beitawi *et al.* (2010) noted heavier body weight, faster growth, and better-feed conversion efficiency in broilers fed ration containing 20% GPJP as a substitute for corn without causing significant change in dressing percentage and carcass cut. Furthermore, replacing maize up to 20 % with GPJP (Choudhary *et al*., 2005), and inclusion at a rate of 10% of GPJP in the ration (Vanker *et al*., 1998) resulted in no adverse effects on performance of broilers. Therefore, available literature showed that ground *P. juliflora* pod or crushed seed could be important source of nutrients in a total ration or as a replacement for some common ingredients. However, the level of feeding should be clearly set for different livestock species and according to the environment where it is intended to be used.

Chemical Composition of Prosopis juliflora Pod Flour

Prosopis juliflora pods have characteristically high carbohydrate content and reasonable protein value. These pods lend themselves better to feeding livestock when ground and turned into flour. Pod drying/crushing does not influence voluntary intake by animals. *P. juliflora* pods present high digestibility coefficients (DM: 82.56%; CP: 80.13%; NFE (nitrogen free extract): 83.19%). In *P. juliflora* pod digestibility trial in ruminant rations, mean values of 71.1%, 69.8%, and 66.8 % were found for DM, GE (gross energy), and CP, respectively (Moreira *et al*., 1984). It was also noted that

fresh, ripe pods of *P. juliflora* contained 7-10% preformed water, and on a DM basis contain 9-17% CP, 1.2-4.3% EE, 16-34% CF, 47-61% NFE, 28% acid detergent fibre, 8% acid detergent lignin, 4-5% ash, 0.14-0.29% silica, 0.3-0.5% calcium and 0.40-0.44% phosphorus (Shukla *et al*., 1984). According to Vimal and Tyagi (1986), the pods are composed of 16.5% protein, 4.2% fat, 16.8% crude fibre, 57% carbohydrates, 5.4% ash, 0.33% calcium, and 0.44% phosphorus. Shukla *et al.* (1986) reported that the amino acid composition of *P. juliflora* on a dry matter basis is 0.99% aspartic acid, 0.28% threonine, 0.14% cystine, 0.43% valine, 0.10% methionine, 0.27% isoleucine, 0.52% leucine, 0.29% tyrosine, 0.33% phenylalanine, 0.37% alanine, 0.19% histidine, 0.32% lysine, 0.56% arginine, 0.41% serine, 1.4% glutamic acid and 0.51% glycine. Except lysine, methionine and cysteine, *P. juliflora* is found to be a good source of amino acids for livestock feeding. Although nutrient composition of *P. juliflora* pods varies from place to place, may be due to various factors including plants growing environment, harvesting stage, storage condition and processing (Annongu and Ter Meulen, 2001), available results of chemical analysis revealed that pods of *P. juliflora* is an important feed resource when appropriately used. The dry pods contained reasonable amounts of iron (208-639 ppm), copper (13-16 ppm) and manganese (22 ppm), but the zinc content (13-16 ppm) was below the level desired (40 ppm) for animal feeds (Vimal and Tyagi, 1986).

Fiber and Antinutritional Factors Content in Poultry Diet and their Effects

Plant fiber, enzyme inhibitors, saponins, tannins, and lectins are familiar compounds that inhibit efficient utilization of non-conventional feedstuffs for poultry. Krogdhal (1986) demonstrated that these compounds might reduce energy and protein utilization by poultry up to 20% with the most pronounced effect on the absorption of lipids and minerals. Unlike ruminants, the digestive system of bird is not designed to handle large amounts of fiber, but fiber quality is more important than fiber itself (King, 2012). Gut length and gizzard weights of chickens reflect the nature of their diet.

According to Iji (1999) fibrous diets have long been known to increase the full weight of the gut. A study by Smith *et al.* (1997) revealed similar effects of fiber on empty weights of the digestive organs, suggesting the occurrence of changes at the tissue levels. Siri *et al.* (1992) reported that the exclusion of pectin in the diets of white leghorn chickens resulted in increases in relative weight of internal organs, including crops, small intestine, ceaca, esophagus and rectum. Similarly, Jorgensen *et al.* (1996) observed increases in lengths and weights of the small intestine and ceaca in broiler chickens that had been fed diets supplemented with pea fiber, wheat bran, or oat bran. High intakes of the fibrous foods are broadly associated with long guts and heavy gizzards (Abdelsamie *et al*., 1983). Moss and Trenholm (1986) noted that as birds eat increasingly fibrous diets, the gizzard weights increased. This is apparently to accommodate the greater bulk of food eaten (Abdelsamie *et al*., 1983). Katanbaf *et al.* (1989) has also showed that a greater weight and length of crop and esophagus increased the capacity of these organs to retain and control the evacuation form the crop.

Increased fiber in poultry ration is known to hinder protein and energy digestibility, depresses feed intake as well as enzymatic activity that assist in carbohydrate, protein and fat digestion, and absorption of nutrients (McDonald *et al*., 2002; Mirnawati *et al*., 2011). It is, however, important that certain amounts be present in the feed for normal function of the digestive tract. In poultry nutrition, fiber is required to provide a certain amount of bulk in the diet and is necessary for efficient digestion, physical consistency and movement of food material through the digestive tract (Kekeocha, 1985).

Chemical composition might not indicate either availability or absorption due to the presence of anti nutrients that affect digestive functions and nutrient utilization. Among several plant components, saponins and lectins affect poultry production adversely and their mode of action looks a lot like the fibers and enzyme inhibitors (Moghazy and Elwatak, 1982). Heat labile anti-nutritional factors such as trypsin inhibitor and hemagglutinin are present in *P. juliflora* pod (Del Valle *et al*., 1983). Other anti-nutritional factors as lectins and phenols are also present in this seed.

Effects of Diet on Laying Performance and Egg quality

Egg production and egg quality traits change mainly as a result of nutrition, effect of environmental condition, genotype, age of hens and laying rate of hens. Based on birds' nutrient needs, feed ingredients composition and nutrient availability, it is possible to prepare diet specifications that result in high rate of eggs production of large size that have appropriate internal and external quality, including an egg shell that is strong enough to withstand the rigors of automatic collection, processing, packing, and transportation with least cost feed formulation (Pond *et al*., 1995; Leeson and Summers, 2001).

Solomon (2004) reported that egg production performance of layers linearly related to the level of supplements offered. Rahm (1991) noted that egg production could be limited not only by over all protein availability, but also the availability of essential amino acids. According to Van Eekeren *et al. (*2006) the synthesis of protein in the body tissues requires an adequate supply of about twenty different amino acids in appropriate proportions. Ten of these amino acids cannot be synthesized by the bird's metabolism and therefore, must be supplied in the ration of birds. These are called essential amino acids, the main ones being lysine and methionine. A shortage of essential amino acids reduces egg production of birds (Van Eekeren *et al.,* 2006). The quality of protein feed can be described in terms of such amino acids content. The same author reported that low level of lysine, methionine and cysteine amino acids in the diet results in reduction of egg production.

The provision of adequate dietary minerals and vitamins, especially vitamin D are essential for production of eggs with good eggshell quality. Calcium and phosphorous are essential macro minerals with calcium forming a significant component of the eggshell and phosphorous playing an important role in skeletal calcium deposition and subsequent availability of calcium for egg shell formation during the dark period (Fard *et al*., 2010).

Many factors are reported to affect albumen height. Some of these are, storage time, nutrition (dietary protein and amino acid content, e.g. lysine, methionine, ascorbic acid, vitamin E), heredity, age of birds, temperature, loss of carbon dioxide from egg, and disease (Roberts, 2010).

Yolk color depends on the diet of the hen. If the hens get plenty of yellow orange plant pigments known as xanthophylls, they will be deposited in the yolk. The incorporation of oxycarotenoids in to the diet can lead to the deposition up to one mg of pigment in the yolk and produce a deep orange color in the yolk (Hasin *et al*., 2006). As a general guide, NRC (1994) suggested that the energy and protein requirement of laying hens' ranges from 2700 to 2850 kcal/kg dry matter and 14.0 to 19.0 %, respectively.

Effects of Diet on Feed intake, Growth, Carcass Yield, Meat quality and Hematology

To achieve maximum efficiency in growth and production, properly balanced ration is a prerequisite. The ration should satisfy the nutritional requirements of the birds with regards to carbohydrates, proteins, fats, minerals and vitamins. For computing such rations, a good knowledge of the nutrient composition of the ingredients and the right proportions in which they are to be mixed is necessary (Thiele and Pottgüter, 2008). Energy is the main driving force of metabolism. As the level of energy increased feed intake decreases. Hence, the utilization of dietary proteins must be put in the context of the available energy supply. If energy is limiting, dietary protein will be used inefficiently as another source of energy instead of being converted into body protein (Miller, 2004). North (1984) indicated that the quantity of feed consumed is essentially controlled by the energy concentration and the requirement of chicks for protein in percent crude protein to achieve maximum growth increases as the density of dietary energy increases. However, with low protein diet body weight decreases, while high protein diet increases body weight. The decrease in weight gain for the low protein diet is probably the result of reduced protein intake as the level of energy in the ration increased. For, the high protein diet, energy is limiting in relation to protein and the protein is burnt for energy. With an increase in dietary energy, more protein is available for growth and hence weight gains increased on the high protein ration. Pellet feeds usually results in increased density and intake of the ration, and improves growth and feed efficiency (Esmail, 2001).

The presence of dietary fiber in protein feeds reduce amino acid digestibility, increase endogenous nitrogen loss with consequent reduction in growth rate. Greenwood (2005) indicated that when the diet becomes marginally deficient in lysine, the birds increased its intake of food, presumably in an attempt to ingest sufficient lysine to meet the demands of maintenance and growth. The recommendation is that the ratio between proteins (%) and metabolic energy (KJ) is from 1:570 in starter mixture to 1:649 in finisher (Steiner *et al*., 2008). Steiner *et al*. (2008) reported higher body weights as protein to energy ratio increased. Lower ratio decreases feed conversion. It is established that as the dietary calorie to protein ratio widen energy intake and carcass fat deposition increases, while body water content decreases. Decreasing the dietary energy to protein ratio will increase meat yield and decrease fat content (Mbajiorgu *et al*., 2011). There is a tendency for energy intake to increase with increasing dietary energy. This is also attributable to higher dietary fat content. As a consequence, food: weight gain ratio decreases when dietary energy level is high (Pesti and Flecher, 1984). Based on two energy levels, 3200 (high) and 2800 (low), Holsheimer and Veerkamp (1992) reported that high energy diets had a higher gain and better feed to gain ratio than chicks on the low energy diets.

Carcass yield is an important parameter to the economy of the poultry business, because it directly determines the amount of saleable product. Maximization of lean tissue growth rate is one of the fundamental objectives of any meat producing enterprise and abdominal fat pad is usually unacceptable to consumers and often represent a loss of yield when they are removed before sale. The abdominal fat pad is commonly employed as an indicator of total carcass fat content since correlations between the two are usually high. It is widely recognized that performance of broilers are influenced considerably by variations in energy and nutrient inputs during growth and consequently can affect edible carcass yield. High dietary levels of apparent metabolizable energy per se may promote excess lipid accretion in fast-growing broiler chickens fed under *ad lib* conditions and consequently relate to evisceration losses (Julian, 2001).

Although dietary protein affected performance, in terms of live weight gain and feed conversion ratio, very high protein diet is used less efficiently. This implies that the excess protein is carbonized rather than contributing to increased lean tissue deposition. Interestingly, this response is associated with a reduction in carcass fat, suggesting that dietary energy is used in catabolism of excess protein rather than being deposited as fat. This therefore, represents a further means of altering carcass quality, although feeding protein diets would be associated with increased nitrogen excretion and may be metabolically challenging to the bird as it attempts to accommodate excessive protein (Gonzalez-Esquerra and Leeson, 2000).

It is useful to specify total requirements for crude protein in addition to requirements for the main essential amino acids. There should be enough crude protein to supply the required amounts of these amino acids. Percent crude protein requirement of broiler chicks (0-6 weeks) is from 21 to 22 and for finisher from 18 to 20. The requirement of amino acids lysine and methionine is 1.2 and 0.45 percent, respectively (Enkreen *et al*., 2006).

High contents of Monounsaturated Fatty Acid (MUFA) in animal products are noted to be beneficial for human health. Several nutritional studies strongly support presence of relationship between SFA and the risk of cardiovascular heart diseases. In view of dietary health, food that contains more UFA (Unsaturated Fatty Acid) and relatively lower cholesterol contents can help in reducing the occurrence of cardiovascular heart diseases (Salma *et al.*, 2007). Osek *et al.* (2004) reported that the type of fat added to feed influenced the proportion of lipid fraction of meat and abdominal fat. Some of the anti nutritional factors like trypsin inhibitor and hemagglutinin are capable of inducing adverse effects especially in monogastric animals when consumed without adequate processing (Apata, 2003). Blood is a very good medium of assessing the health status of animals (Taiwo and Anosa, 1995). According to Karesh and Cook (1995) examining blood for their constituents is used to monitor and evaluate disease prognosis of animals. Hematological constituents reflect the physiological responsiveness of the animals to its internal and external environment including the type of feed the animal consumed and feeding practices (Esonu *et al.*, 2001). Packed cell volume (PCV), hemoglobin (Hb) and total protein which is within the recommended range for normal chicken is an indication of adequate nutrition. Ikhimioya *et al.* (2000) and Oladele *et al.* (2001) linked lower values of these parameters to inadequate nutrition.

Objective of the Study

- The overall objective of the study was to generate information on chemical composition and effects of feeding ground *Prosopis juliflora* pods (GPJP) on performance, product quality and health of chicken.

Specific Objectives

- To evaluate the effects of graded levels of GPJP inclusion in layers ration on egg production and quality parameters.
- To evaluate the effects of graded levels of GPJP inclusion in broilers ration on growth and carcass characteristics.
- To study the effect of feeding graded levels of GPJP on fatty acids of muscle, meat quality and some hematological response of broilers.

Materials and Methods

Study Area

The experiments were conducted at Haramaya University Poultry Farm, which is located at 42° 3' east longitude, 9° 26'north latitude at an altitude of 1980 meter above sea level and 505 km east of Addis Ababa. The mean annual rainfall of the area amounts to 780 mm and the average minimum and maximum temperatures are 8 and 24°C, respectively (Samuel, 2008).

Experimental Animals

In layer experiment (Meseret et al., 2011a) one hundred eighty Bovans Brown hens aged 26 week with body weight of 1.33 ± 0.022 kg (mean ± SD) were used. The birds were adapted to experimental diets for 7 days before the commencement of data collection. In broiler experiment (Meseret et al., 2011b; Meseret et al., 2012), 396 unsexed day old Hubbard Classic chicks with initial body weight of 45.98 ± 0.553 g (mean ± SD) were used. In both experiments, four dietary treatments consisted of GPJP at the level of 0% (T_1), 10% (T_2), 20% (T_3), and 30% (T_4) were used. The experimental animals were randomly divided into the four dietary treatments and three replications per treatment in a completely randomized design. In each replicate, there were 15 layers and 33 broiler chicks.

Ingredients and Experimental Rations

Common dietary ingredients used to formulate the rations in both experiments were GPJP, corn, wheat short, soybean meal, noug seed cake, and salt. In addition, vitamin premix, limestone, and dicalcium phosphate was added to layers ration as per the recommendation. Similarly, a recommended amount of methionine 0.2 % was added to broiler ration. Corn, *P. juliflora* pod and noug seed cake were ground to pass 5 mm sieve at the University feed mill before mixing to formulate the ration. The treatment rations were formulated to be isocaloric and isonitrogenous to meet the nutrient requirements of layers, and starter and finisher broilers (Leeson and Summers, 2005).

Samples of each ingredients and rations for each experiment were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF) and ash following the proximate method of analysis (AOAC, 1995). Calcium and magnesium content of GPJP were analyzed by atomic absorption spectrophotometer, total phosphorus content by SP75 UV/vis spectrophotometer, sodium by flame photometer and beta-carotene by spectrophotometer (AOAC, 1995). Metabolisable energy (ME) content of the experimental diets was calculated by indirect method according to Wiseman (1987).

Data Collection and Measurements

Layers and broilers experiments lasted for 90 and 45 days, respectively. In both experiments, feed was offered to the birds *ad libitum* twice per day at 0800 and 1700 hours and clean tap water was available all the time. The amount of feed offered and refused per pen was recorded daily. The amount of feed and nutrients consumed were determined as the difference between the feed and nutrients offered and refused. Feed offered and refused were sampled daily per pen and pooled per treatment for the entire experimental period for later chemical analysis. Mortality was registered as it occurred and general health status was monitored throughout the experiment.

Hens were individually weighed on a sensitive balance at the start and end of the experiment. Broilers were weighed every week in a group per pen. Pen average was determined and body weight change was calculated as the difference between the final and initial body weight.

Eggs laid by hens in a pen were collected three times a day at 0800, 1300 and 1700 hours, and daily egg production was taken as the sum of the three collections. Eggs collected daily were weighed immediately after collection, and average egg weight was computed by dividing the total egg mass to the number of eggs for each pen. Egg mass per hen was calculated as total egg mass divided by number of hens. Hen-day egg production as percentage was determined following the method of Hunton (1995). Feed conversion ratio was calculated as gram of feed consumed per gram of eggs produced. Egg quality characteristics, such as albumen weight, albumen height, egg shell weight, egg shell thickness, egg yolk weight and egg yolk color were determined at an interval of 3 days on freshly laid 6 eggs per replicate after breaking the egg and separating each of the components. Eggshell, albumen, and yolk weights were measured using sensitive balance. Albumen height was measured with a tripod micrometer. Eggshell thickness was measured by eggshell thickness micrometer gauge. Yolk color was determined by comparing the color of properly mixed yolk sample placed on white paper with the color strips of Roche fan measurement, which consist 1-15 strips ranging from pale to orange yellow color. Haugh unit was calculated from the egg weight and albumen height using the formula suggested by Haugh (1937), $HU = 100 \log (H + 7.57 - 1.7 W^{0.37})$, where, HU = Haugh Unit, H = albumen height, W = Egg weight (g).

For broilers, feed conversion ratio was calculated as the proportion of gram feed consumed per gram weight gain. At the end of the experiment, four randomly selected broilers from each replicate (12 per treatment group) were starved for 16 hours, weighed immediately before slaughter and exagguinated by severing the neck, and dressed. Dressed and eviscerated weights were calculated following the method of FAO (2001). After dissection, and individually weighed, the breast and thigh muscle carcass were tagged with coded bands, packaged, and transported to Animal physiology laboratory of Haramaya University pending analysis. Carcasses were evaluated for chemical composition, fatty acid profile, and sensory characteristics following standard procedures.

Blood samples were collected from all birds slaughtered into two labeled sterile universal bottles. One set of the bottles contained Ethyldiamine tetra acetic acid (EDTA) powder as anti-coagulant, while the other set did not contain any anticoagulant. Hemoglobin (HB) concentration was determined by the method of Actin hematin (Davice and Lewis, 1991). Total protein was determined by refractometer (Leica Inc. Buffalo NY USA 14240-0123). The PCV was determine by spinning blood filled capillary tubes in a centrifuge at 1200 revolution per minute (rpm) for 5 minute and reading on hematocrit reader. Differential white blood cell counts were determined by blood smear with Wright's stain. The hematological parameters were determined as described by Davice and Lewis (1991). At the time of slaughter, gastrointestinal tract and organs were examined for any pathological symptoms and gross lesions were recorded when observed.

Statistical Analysis

Except yolk color, which was analyzed by logistic regression, all other parameters were statistically analyzed using the general linear model procedure of SAS (SAS, 2002). Differences between treatment means were separated using Tukey Test (SAS, 2002).

Results

Chemical Composition

The CP content of GPJP is 12.10 and 15.43 % for that used in layers and broilers ration, respectively. The CF content of GPJP (14.40 %) is the highest compared to the other major dietary ingredients used for compounding ration in the present experiment. Beta-carotene content of GPJP was 82.31 µg/100 g. The mineral matter content of GPJP was 5.80 and 6.13 in layers and broilers experiment, respectively**.** The four treatment rations of layers and broilers were formulated to be isocaloric and isonitrogenous. As planned, the rations were somehow isocaloric and isonitrogenous. As the inclusion level of GPJP increased, the percentage composition of wheat short and maize grain decreases. The calculated CP and metabolisable energy contents of the layers ration ranged 16.09-16.99% and 2800-2896 kcal/kg DM, respectively. In broilers ration, crude protein and metabolisable energy contents for the treatment diets ranged 21.4-22% and 2969-3097 Kcal/kg dry matter (DM) for the starter, and 19-20% and 3037-3130 Kcal/kg DM for finisher phases. In general, the nutrient contents of the experimental rations including calcium and phosphorous contents were within the recommended values for layers, starter and finisher broiler diets (Leeson and Summers, 2005).

Nutrient Intake

Intake of DM in layers was lower ($P < 0.05$) for birds that consumed the diet containing the highest level of GPJP (30%) as compared to those fed diets containing 0 and 10% GPJP, while DM intake for the 20% GPJP containing ration was similar ($P > 0.05$) with all other treatments. Broilers that consumed ration containing the highest level of GPJP (30%) reduced ($P < 0.05$) feed intake during the finisher phase and the whole experimental period as compared to T_1, while values for T_2 and T_3 were similar with other treatments. There were no significant differences ($P > 0.05$) among treatments in feed intake during starter phase.

Body Weight Change and Average Daily Gain

There was no significant difference in body weight change ($P > 0.05$) among layers that consumed rations containing graded levels of GPJP. Final live weight at the end of starter phase was lower for T_4 as compared to T_2, while at the end of finisher phase, body weight for T_4 was lower ($P < 0.05$) than T_1 and T_2, and value for T_3 was similar with all other treatments. Average daily gain (ADG) during the starter phase and the entire experimental period was significantly affected by treatment ($P < 0.05$), and followed a similar trend like that of final body weight.

Dry Matter Conversion Ratio and Economics

There was no significant difference among treatments ($P > 0.05$) in feed conversion ratio of the hens. Analysis of economics of egg production indicated that the ration containing 10% GPJP is the least cost ration followed by 0%, 30%, and the ration containing 20% GPJP. Effects of treatment on feed conversion ratio in broilers were significant ($P < 0.05$) during the starter phase and the entire experimental period**,** and T4 was the least efficient feed converter group. The economics of weight gain determined from ratios of cost of the total feed consumed and the weight gain produced from that amount of feed indicated that the ration containing 20% GPJP is the least cost ration.

Laying Performance and Egg Quality of Bovans Brown

Hen day egg production and egg mass were greater ($P < 0.05$) for the control treatment (0% GPJP) than layers that consumed ration containing 30% GPJP. There was no significant difference among treatments ($P > 0.05$) in egg weight. Graded levels of GPJP inclusion in layers ration did not significantly affect ($P > 0.05$) egg quality parameters, except yolk color. Yolk color tended to increase with increasing levels of GPJP in the ration, but it was statistically higher ($P < 0.05$) only for the 30% than other treatments.

Carcass Yield and Gut Weight of Broilers

Graded levels of GPJP inclusion in broilers ration did not significantly impact ($P > 0.05$) dressed and eviscerated carcass weight, and percentage yield of different broiler carcass cut, except drum stick weight, which was heavier in T2 than T4**.** Among the gut content, only crop and esophagus weights were influenced by treatment and it was greater in T4 than T_1.

Muscle Fatty Acid Composition, Sensory Quality, and Hematology of Broilers

There were no significant differences ($P > 0.05$) between broilers fed the control diet and that contained varied levels of GPJP for fatty acid composition in breast and thigh muscle, juiciness, tenderness, flavor and overall acceptance and chemical composition of the muscles meat.

Contents of palmitic acid, 11, 14 eicosadienoic acids and saturated fatty acids (SFA) such as arachidic acid were higher in breast muscle, while contents of all other fatty acids are higher in thigh muscle. Graded levels of GPJP inclusion in broilers ration did not significantly ($P > 0.05$) affected the hematological indices and total protein of broiler chicks blood, except monocytes. The value for monocytes was higher ($P < 0.05$) for the ration containing the highest level (30%) of GPJP. No symptom of gastro intestinal tract infection was observed up to 20% of GPJP inclusion in the ration. However, intestine of birds fed with diet containing higher level of GPJP inclusion (30%) has lesions and intestinal hemorrhages were visible. The content of the intestinal lumen also consisted visible blood (Patra *et al*., 2009). The caeca were not severely affected.

Discussion

The DM and CP contents of GPJP determined in the present experiments are within the range but, EE and ash contents were higher and CF, calcium and phosphorus levels were lower than that reported in previous studies (Shukla *et al*., 1984; Choge *et al*., 2007; Abedelnoor *et al*., 2009). Calcium and phosphorus content of GPJP used in the present experiment were lower than the range of value given by Shukla *et al*. (1984). Various factors including the plant's growing environment, harvesting stage, storage condition and processing could possibly be responsible for the differences in chemical composition of GPJP recorded in different studies.

Significant reduction in feed consumption was not apparent in layers and broilers up to 20% GPJP inclusion in the ration. However, 30% GPJP inclusion in the ration was able to significantly induce reduction in DM intake of birds compared to the ration containing no GPJP. In accordance with the current study Oliveira *et al*. (2001) noted reduction

in feed intake of quails when *P. juliflora* pod meal was included at 25% of the ration as compared to the one that did not receive the pod meal. However, Silva *et al.* (2002) did not found significant difference in feed intake between hens fed ration containing 30% *P. juliflora* pods meal as compared to the diet without the pod meal. The layers, starter, and finisher rations contained about the same values of ME, CP, calcium and phosphorus across the treatments. But, CF content in the diets containing 30% GPJP was greater by about 34% as compared to the ones with 0 and 10% GPJP inclusion levels. CF content above the maximum (5-6%) recommended limit is noted to reduce feed intake in broiler chicks (Mirnawati *et al.*, 2011). Increased fiber in poultry ration is known to hinder protein and energy digestibility, and depress feed intake as well as enzymatic activity that assist in carbohydrate, protein and fat digestion (McDonald *et al.*, 2002; Mirnawati *et al.*, 2011). The high CF content of the ration at higher level of GPJP inclusion might have contributed to the reduction in DM intake at the highest level of GPJP inclusion. Thus, the lower feed intake and growth performance of chicks fed ration containing higher level of GPJP may be partially attributed to the high fiber content of the diet. The presence of heat labile anti-nutritional factors, such as trypsin inhibitor and hemagglutinin has also been reported in *P. juliflora* pod (Del Valle *et al.*, 1983). Such naturally occurring compounds are innate natural components of particular feed ingredients that can impair the availability of nutrients, depress feed intake, and reduce growth of animals (Thorne *et al.*, 1992; Shahidi, 1997). Essential amino acids such as lysine, methionine, and cysteine are known to enhance feed intake (Melesse *et al.*, 2011). However, *P. juliflora* meal is deficient in these essential amino acids (Bhatt *et al.*, 2011), which could have been contributed to the low feed intake of broilers at higher level of GPJP inclusion. Lower ADG and poor feed utilization efficiency at higher level of GPJP inclusion is in line with the finding of Yusuf *et al.* (2008) and Choudhary *et al.* (2005). At 30% GPJP inclusion, there was moist, sticky droppings and wet litter, which created sanitation problem, particularly in broiler experiment. This could be due to the presence of insoluble non-starch polysaccharides in *P. juliflora* pods (Bhatt *et al.*, 2011). Insoluble non-starch polysaccharides at higher proportion were shown to cause moist and sticky droppings and resulted in wet litter (Pottguter, 2008). Similar to previous work, 10 and 20% GPJP inclusion did not have detrimental effect on broiler performance as compared to the control (Vanker *et al.,* 1998). Improved live body weight, and body weight gain in broiler fed diet containing 10 and 20% pods in replacement for maize was noted by previous studies (Choudhary *et al.,* 2005; AL-Beitawi *et al.*, 2010). Absence of difference in feed conversion ratio may indicate that the advantage of GPJP inclusion in the diet of broilers can be partly due to sparing effect of conventional energy rich diets and in part associated to reduction in cost of the ration thereby improving the profitability of the enterprise.

Lower hen day egg production and egg mass at 30% GPJP inclusion level is consistent with the finding of Silva *et al.* (2002) who reported similar result in pullet fed ration containing 30% *Prosopis juliflora* meal. The reduction in the laying performance of hens at high level of GPJP inclusion might be due to the negative effects of the high non-starch polysaccharides (fiber) contents in the ground pods on feed intake as observed in the present study, and due to the possible effect of the fiber on nutrient digestibility that might have limited the supply of essential nutrients to satisfy the performance requirements of the birds. *Prosopis juliflora* meal contains adequate amount of essential amino acids, except lysine, methionine and cysteine (Bhatt *et al.*, 2011). The potential low level of such amino acids in the diet containing 30% GPJP might have in part contributed to the reduction in egg production, egg mass and nutrients intake.

Values for egg weight and egg quality parameters, including Haugh unit recorded in the present experiment were within the ranges reported for Bovans Brown breeds (Koreleski and Świątkiewicz, 2010; Świątkiewicz *et al.*, 2010). Except for egg yolk color, significant differences were not apparent in egg quality parameters. The absence of treatment differences in most egg quality measures suggest that up to 30% level of GPJP inclusion in the layers ration is possible without significant impact on such egg quality parameters. The reason for the increased Roche fan measurement for diet with the highest level of GPJP is obviously associated with the high beta carotene content of the GPJP (Hasin *et al.*, 2006). Thus, GPJP can be a potential ingredient for egg yolk coloration as many consumers prefer eggs with more yellow yolk color. Despite such possible advantages of GPJP as ingredient in the ration of layers, the potential of any dietary ingredient has to be determined by the price of the ingredients and its effect on laying performance.

Carcass yield recorded in the present experiment is within the range reported for Hubbard Classic breed (Abdullah *et al.*, 2010; Islam *et al.*, 2010). In accordance with the current finding, Choudhary *et al.* (2005) and AL-Beitawi *et al.* (2010) did not found significant difference in carcass parameters between groups fed ration containing *P. juliflora* pods and the control. The fatty acids composition of breast and thigh muscles recorded in the present experiment are within the range reported for broiler meat (Cherian *et al.*, 2002; Salma *et al.*, 2007). In the present study, graded levels of GPJP in broiler diets did not significantly affect the ratio between polyunsaturated fatty acid (PUFA) and saturated fatty acids (SFA) in thigh and breast muscle. Similarities in the composition of fatty acids among all treatments indicated that inclusion of GPJP up to 30% in the diet of broilers do not affect the quality of fatty acid of the muscles. The result of the present study confirmed the existing evidences which reported that tissue concentration of fatty acids are less altered by dietary changes (Cortinas *et al.*, 2004). Furthermore, Jamroz (1997) noted that body lipid ratio is more influenced by genetic factors and depended on poultry species, but not on the type of feeding. Osek *et al.* (2004) reported that the type of fat added to feed influenced the proportion of lipid fraction of meat and abdominal fat, indicating that GPJP with lower ether extract content (Meseret *et al.*, 2011a; b) is not expected to alter fatty acid composition of meat.

Conclusion

In layers experiment egg quality parameters except egg yolk, egg weight and body weight of the layers was not negatively impacted by inclusion of GPJP up to 30% level. However, egg production and egg mass is significantly reduced when the ration contained 30% GPJP. Broilers trial indicated that carcass yield, fatty acid composition, sensory characteristics and chemical composition was not negatively affected by inclusion of GPJP up to 30% in the ration of broilers. However, feed intake and live weight gain was reduced and feed conversion ratio was increased at 30% level. Mild reduction in hematological indices with increasing level of GPJP and significantly higher monocyte at 30% GPJP inclusion in the ration, and intestinal lesion was observed indicating that higher level of GPJP inclusion in broilers ration has negative effect on immune response of birds. Therefore, it can be concluded that inclusion of GPJP in poultry ration at lower level (maximum of 20%) reduces feed cost and decreases the invasion of rangeland by *Prosopis juliflora* plant, since the seed is used after it is crushed.

Recommendations

It can be recommended that:-Up to 20% GPJP inclusion in layers ration is recommendable based on the performance of the birds, although the treatment with 10% GPJP in the ration seems to be more economical. About 20% of conventional broilers diet can be substituted by GPJP to reduce feed cost. This study indicates that 30% inclusion of GPJP could be safely used in broilers diet without any effect on meat quality.

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2. College of Buisness and Economics

2.1 Is Ethiopia Ready to Commence Capital Market? An Analysis of Opportunities, Constraints and the Dubious

Mebrahtu Leake Teklehaimanot

Astract: After the fall of the Derge regime in 1991, Ethiopia has re-oriented its command economy into a market-led economy. Since then gradual structuring and changes have been made in the diverse constituents of the country's economy. The financial system was liberalized to quill the demand of the market economic model and hasten development though its growth, in terms of diversity and quality, is dawdling. Despite the financial liberalization, which enables private firms to emerge, Ethiopia still does not have capital market, as the government does not recognize its significance to the country's development. Debates, however, have been made by the wider academic community, experts and researchers on the importance and development of capital market and pressures on the government to initiate the market have been made by international and national stakeholders. This squabble was the prime reason for undertaking this study to identify the promising factors bedding for the establishment, diagnose constraining factors of the same and why the government is ambivalent based on the primary and secondary data collected from major companies established through shares in an initial public offering, government institutions, officials, academicians, financial experts, proclamations and other official documents. The findings of the study depict that the country's fast economic growth, expansion of energy, initiators and public inclination to incorporated companies, invest than save push and increase of capital flow to the country are seminally backing capital market development while government's reluctance, underdeveloped legal and physical infrastructure, immature financial sector, uninformed and small-base domestic investors and nonexistence of skillful and institutionalized market makers are delaying for its development. The study recommends the establishment of market as it is significant to mobilize domestic savings and huge capital to clinch financial gap of financing huge national projects, enhance access to equity finance of the private sector and promoting rapid economic development by suggesting possible ways of doing it.

Keywords: Capital Market; Financial Liberalization; Economy, Ethiopia

Introduction

Poverty is widespread and remains a major challenge of sustainable development and stability in Ethiopia, the second populous country in Africa (Easterly, 2002; LWFE, 2006). It is estimated that close to half of the population in urban and rural areas of the country live in absolute poverty due to limited economic opportunities, decades political unrest, inadequate basic household income, and poor means of survival (Serneels, 2004; Eshetu and Mammo, 2009). Thus, poverty reduction has become the top agenda of the Ethiopian government by redirecting the economy into market-oriented economy, by implementing different policies and initiating poverty alleviating plans in different periods. Since 1991, the government has pursued Agricultural Development Led Industrialization (ADLI) as a major policy framework to accelerate economic growth and to eradicate extreme poverty. Besides, the Plan for Accelerated and Sustainable Development to End Poverty (PASDEP), 2005/6-2009/10 was initiated. For these or other reasons, the country has been registering an enticing economic growth over the recent years (MoFED, 2011). In line with this, official government reports and a study made by Devereux and Sharp (2003) indicated that the dreadful nature of poverty, in the country, is declining due to progressive economic growth and positive policy directions, but still remains the chronic problem in the country.

Other efforts are also made to achieve the long dream of transforming the country into industrialization and middle-income nation though little is achieved in this regard. The Growth and Transformation Plan (GTP), 2010/11-2014/15, which actually demands huge resource mobilization for realization, is among the recent efforts. The government claims that this plan is instrumental to bring accelerated, sustained, and transformative economic growth to end poverty in the country. When officially announced in November 2010, however, stakeholders like the World Bank and IMF said it is very ambitious plan demanding huge resource for which the country cannot afford. Thus, financial sector development is at the heart of resource mobilization, industrialization, boosting investment and accelerating economic growth. Bekaert and Harvey (1997) also stated that economic growth depends on efficient financial sector in order to pool domestic savings and mobilize foreign capital for productive investments. Hence, it seems difficult for the government to achieve the government's accelerated, sustained, and transformative economic growth without a vibrant, efficient, and enabling financial system. Thus, the establishment of strong, reliable, and accessible financial institutions and markets is

indispensible to channel resources from unproductive excesses (suppliers) to productive investment (demanders) and enhance foreign capital flows. In doing so, Ethiopia has been engaged in gradual liberalization of its financial sector since 1992 which enables private institutions to flourish (Alemayehu, 200X), but does not allow capital market to exist.

Capital markets are markets that trade equity (stocks) and debt (bonds) instruments with maturities of more than one year (Saunders and Cornett, 2004). A capital market is vital to mobilize huge capital, improve financial access to private sector, and improve liquidity and risk sharing in an economy. Hence, with the emergence of capitalism, many countries around the world have been moving toward market-oriented economies and securities markets sprang up recognizing their significance in an economy (Asrat, 2003). Stiglitz *et al.* (1993) described that financial markets are essential for mobilization and allocation of resources for industrialization and can be thought as the "brain" of the whole economic system. Literature also reveals that there exists a positive correlation between economic growth and capital market development (see Beck *et al.,* 2006 and Base, 2005), but Beckaert et al (2005) put financial liberalization as key and determinant factor for efficient capital market development to lead into economic growth. Despite the advocated benefits, however, Ethiopia does not launch capital market worrying for its curses. Nowadays, pushes have been coming from stakeholders for the establishment of the market in order to mobilize sufficient financial resources even to finance the ambitious government plans and to ignite economic growth in the nation. This has become worthy studying to reconcile the trade-offs by assessing some fundamental factors that either promise or defy the development of the market.

Role of Capital Market in Developing Economies: the Dubious

Studies have been made to analyze the impact of establishing capital market on economic growth of countries. Those studies conducted in advanced economies have substantiated the significance of capital markets in such economy. Ouandlous (2010), for example, underlined that without the establishment and development of capital markets, none of the advanced economies have achieved outstanding economic development. Mishra *et al.* (2010), Asrat (2003), and Bekaert and Harvey (1997) stated also that development of securities market contributes to economic development by pooling domestic savings and attracting foreign capital and channels for productive investments. Walter (cited in Mishra, 2010) argued, in his book *Lombard Street* published in 1873, that it was England's efficient capital market that made the industrial revolution possible. Levine (1996) also indicate that countries which had liquid capital markets such as USA, UK and Canada, grew economically much faster than countries with illiquid or no markets (developing countries) over the period of 1974-94. Capital markets in the UK and US dominate these countries financial system and are the main reasons for higher productivity growth, greater employment opportunities, advanced technology, and economy (Dudley and Habbard, 2004). However, investigations in developing countries have varied results.

Stiglitz (1989) and Singh (1999) revealed that establishment of capital market in developing countries has little relevance in economic growth. Some studies, made in the African content, claim that securities market could not be a backbone of the African countries economy as these countries did not ripe and well positioned socially and economically, and capital markets may not sufficiently be liquid. Singh (1999), for example, explained that establishing a capital market, for African economies particularly those in Sub-Saharan African (SSA), at this stage of their development is likely to do more harm than good, because they are prone to political instability, and to highly volatile and unorganized institutions. African countries would do better to use their human, material, and institutional resources to improve their banking systems than to promote capital market.

More opponents of the capital markets establishment in developing countries evidence their argument saying that these countries do not have well organized institutions and markets, and markets are less well regulated and more poorly organized than their counterparts in developed countries. Hence, they can lead the economy into perplexing crisis. For developing countries to establish financial market, they must invest and improve their infrastructure, make changes in their policy and uphold activities that can attract the private sector cross-border fund flows and make them competitive and preferable of their counterparts. For this or other reasons, many countries, including Ethiopia, have locked their doors leaving the banking sector to dominate in the financial intermediation of the continent. Africa has about 23 stock markets most of which initiated by governments for technocratic and political reasons Moss (2003), or established during the colonial era. They are characterized as illiquid and inefficient with rarely traded shares (Yartey and Adjasi, 2007), contributing only less than 2% of global securities market transaction. Thus, Africa has been heavily dependent on official development assistance (ODA) to finance persistent balance of payments deficits. With low incomes, generally weak economic and investment policies, and financial services, most African countries and mainly the Sub-Saharan Africa (SSA) have been unattractive to private investors, and thus received little private capital.

Proponents of capital market development in developing economies, on the other hand, argue for its contribution in liquidity, private sector development, risk diversification, acquisition of information about firms, corporate governance, capital efficient use, savings mobilization and reducing dependency on banking sector by complementing it, not substituting. Murinde (2006) noted that capital market development is important in developing countries to complement and facilitate reforms in the banking sector. It is also noted by Ouandlous (2010) for emerging economies to imitate the achievements of the advanced economies, they have to establish and develop capital markets. Thus, philosophical changes and shift in recent years have happened in many African countries by refreshing their economic and political

systems (Asrat, 2003). Financial sector reform has become part of the development agenda. A study made by Murinde (1999), for example, indicated that most African governments are now keen to develop capital markets as a direct way of mobilizing risk capital for the corporate sector. They have begun to consolidate the importance of capital market in attracting foreign portfolio investment, private sector development and the integration of domestic economies to the wider world (Murinde, 1999). Nevertheless, the importance of the market in developing economies is still blurred.

Methodology

Description of the study Area

Ethiopia, a country with over 84 million population and one of the poorest countries with USD 350 per capita income (WB, 2011), is located in the Horn of Africa. This study was mainly undertaken in the capital city of Ethiopia, Addis Ababa, owing to the following reasons. Addis Ababa, established in 1886 and with the population about 4 (four) million, is the seat of the African Union (AU), United Nations Economic Commission for Africa (UNEC), NGOs and other international organizations (UN-HABITAT, 2008). It is also the seat of all federal ministries, head offices of major businesses, consultancies, and major business centers persuading capital market development. For instance, from the total of 17 banks and 14 insurance companies in the country, 52.9% and 50.7% are concentrated in Addis Ababa, respectively (NBE, 2011) and all the head offices of the banks and insurance companies are situated in the city. Addis Ababa is also considered as a land of opportunity, where hundreds of thousands of people coming from all corners of the country in search of better employment opportunities and services.

Historically, Addis Ababa had opened up a stock market in the Imperial era in 1950s. A short-lived stock market started informally in the late 1950s and was formally established in 1965 (Asrat, 2003). In February 1963, the NBE took the initiative to set up the share-dealing group called the Addis Ababa Share Dealing Group. The share-dealing group facilitated operation of the shares of mainly banks and government bonds (Pischke, 1968). The National Bank of Ethiopia (NBE) was responsible to set rules and regulations for the market. However, in 1974 the military government came to power and declared a centrally planned command economy and nationalized all foreign owned companies. Hence, the infant stock market ceased to exist.

Data Sources, Collection, and Analysis Methods

In a one and half-year study period, both primary and secondary data were collected. The study was conducted from July 2010 to December 2011 gathering data to acquire first hand information through different data collection methods and enriched by reviewing secondary sources. Primary data were collected using questionnaire, focus group discussion, key informants interview, and personal observation. Currently, shares are traded in order to establish new companies in a very traditional primary market by opening temporary offices for a fixed short period of time. Recent banks, insurance, transportation, oil, and real estate and construction companies has been established predominantly through initial public offering. Thus, due to this solitary inclination, they are purposively included in the study. Six banks, four insurance companies, two oil and four construction companies were judgmentally selected based on their year of establishment in order to solicit information about the blessings they are enjoying and pains they feel. In doing so, a questionnaire interview was first developed, pre-tested, and employed to collect data from 160 randomly selected employees working at the head offices of these organizations to gather information regarding the crystal balls and obstacles of the financial sector and share based establishments. Besides, interviews and discussions were made with managers of the companies. Interviews were also conducted with officials and representatives of the National Bank of Ethiopia, Financial Intelligence Center, Ministry of Trade, Ethiopian Investment Agency, and Ethiopian Commodities Exchange (ECX) in order to grip on government's views, and to identify the reasons thereof on initiating the market and draw a lesson from the later.

As triangulated data gathering system is advantageous to balance the limitation of one by the merit of the other and to enrich the study with more and deep information, three different focus group discussions (constituting 8 individuals each, purposively selected senior and experienced academicians of business schools in public universities and private university colleges, consultants and experts) were administered to identify enablers beddings for the market development or pains demoting it. Different financial proclamations, economic policies, plans, regulations and directives as well as media products were consulted and critically reviewed, as a secondary source, to substantiate the first hand information. The study investigated the determinants that either enable to promote or relegate the bubbling idea of commencing the capital market in the country which can be justified qualitatively. Hence, the collected data was concretely analyzed qualitatively supplemented by descriptive statistics.

Conceptual Framework: Establishing Efficient and Liquid Capital Market

Every day and in every transaction, in the money and capital markets, individuals, financial investors, and other participants are to make important financial decisions and transactions. These participants are interested to be sure that the market functions smoothly. Among other things, capital markets require sound legal and physical infrastructure to demonstrate transparency, protect participants, and undertake seamless transactions. Liberalization theory, which was

developed as Washington consensus after the works of John Williamson (1989), calls for price and market to dictate the economy. Nevertheless, any developmental model existing in a particular state of economy cannot be applicable to another as the reality depends on the economic, social, and cultural perspectives of each nation while benchmarking the best practices of the developed nations. Advocators of regulated capital market evident that the wave of major economic crises of the recent past (1970's, 1990's, and 2007) has emerged from the highly liberalized economies. Mishkin (2007) put preconditions for capital markets and Stiglitz (2004) suggested the IMF not to pressure developing countries to liberalize their capital market rather work together to design the interventions that properly address failures. Owing to their weak institutional system, low human capital development, and technological immaturity, market regulation (government intervention) is contended as a path of prosperity for developing economies. What is more, the teleological perspective of capital market regulation is better seen for creating efficient and liquid capital market in developing nations though the degree of regulation is of a contemporary debate among scholars. Debaters side on opposite side of a coin, some seek dynamic and effective regulation to promote public confidence, protect inventors from malpractices and the economy from wild conditions of the cashless society and imperfect market. The main emphasis of the regulation is on full and fair disclosure of information on securities issues to actual and potential investors. That is creation of efficient market where traders have full information regarding the securities to be traded and avoids insider information that maximizes the advantages of few. Generally, according to Franklin and Richard (2001), with securities markets it is usually argued the main purposes of regulation are investors' protection and enhancing the efficiency of markets to achieve broader social objectives.

Market infrastructure constituting the institutions and systems that facilitate trade and custody of securities is mandatory for the smooth functioning and acceleration of market transactions. An efficient and well-functioning market infrastructure reduces obstacles to trading flows, allows for low-cost settlement of financial transactions, and raises investor confidence. A study conducted by UNECA (1999) disclosed that for a capital market to operate with some degree of efficiency, infrastructure, both physical and legal, are among the essential factors. Public awareness including investors understanding of value creation is also among the vital factors for capital market development. As Rose (2000) indicated because economic conditions exert a profound impact on the money and capital market, the investment decision maker must be aware of economic data series that reflect trends in employment, prices, and related types of information. The role of financial institutions and media is significant in this regard by propagating information to savers, increase awareness on public, increase financial access, mobilize financial resource from excess areas and channel it to shortage areas where investment opportunities are ample. Economists like Stein (1995) describe institutions enable to reduce transaction and information costs and make markets operate with efficiency and liquidity. Yartey (2007) also explained that the existence of well-developed financial intermediary institutions, particularly the banking sector, to be important for stock market development.

The active act of market exchange, without causing a significant movement in price and with minimum loss of values, is significantly determined by the existence of professionals, specialist, and brokerage companies (Asrat, 2003). Market liquidity is seminal to create ready and willing investors all the time since such market makes investment less risky and more attractive. This enables companies to enjoy permanent access to capital from investors and households as saving remains less attractive. Market liquidity is firmly associated with the availability of smooth and sophisticated exchange markets coupled with public awareness, investors' protection and skillful and able intermediaries. Azu (2009) states that capital market liquidity can be improved through reducing monetary policy, creating awareness, building confidence, potentially growing economy, reducing transaction barriers, and aligning of banks to support the market. Market makers serve as liquidity providers and increase trading volume in developed market (Andreas and Marios, 2009). The existence of experts and specialists who devotedly make market analysis and justification of prevailing and new developments is critical for capital market. Based on this conceptual scanning, the basics for the establishment and development of capital market are structurally modeled as below (Figure 2.1).

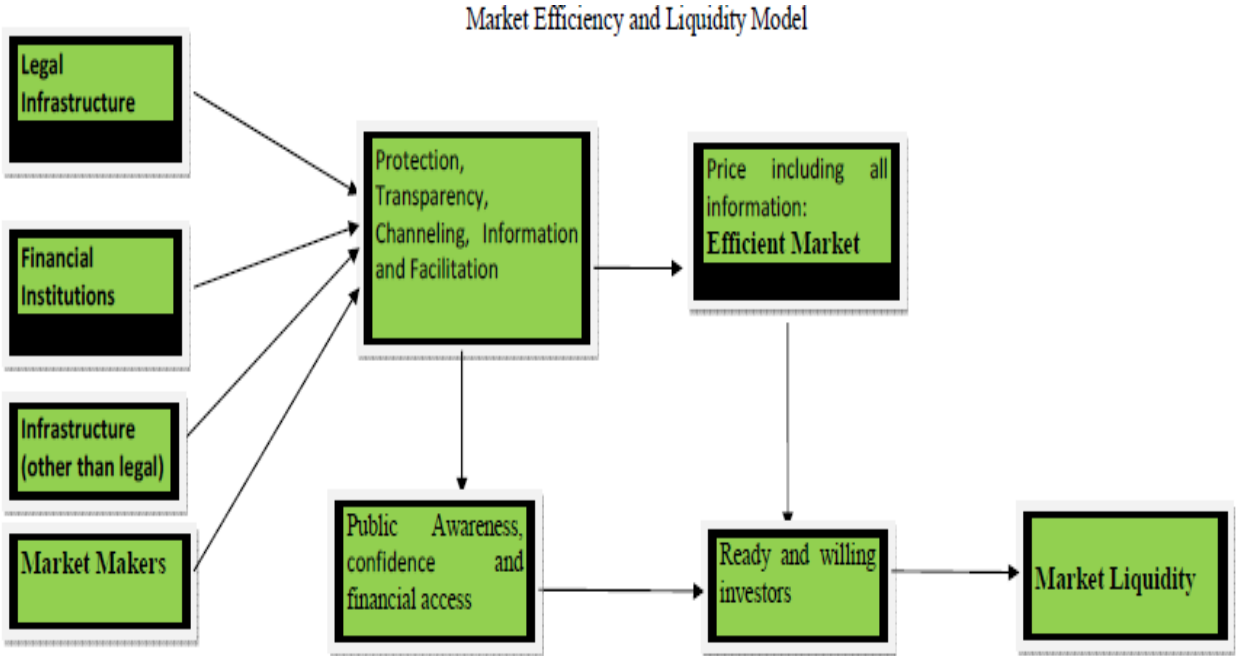

Figure 2.1. Market efficiency and liquidity model

Results and Discussion

To establish a well functioning and vibrant capital market, the fulfillment of certain preconditions potentially promise for its launching and identification of bottlenecks that hinder the realization is essential. In this study, potential factors smoothening and others constraining capital market establishment are identified and explicitly explained.

Potential Beddings

Growing economy: Ethiopia has been registering an enticing economic growth and it is one of the fastest growing in the world notwithstanding the global economic shock and financial crisis. According to the government official reports, the country's economy has been growing at about 10 to 11% for the last seven (7) years since 2004/5 though the World Bank and IMF limit the economic growth within the range of 7 and 9% during these times. Even by the latter growth rates, the country's economy has been growing high as compared to the 2015 5% and 4.4% economic growth projections for Sub-Saharan Africa and the entire world, respectively as averagely expected by IMF. This invites foreign investors and the Ethiopian Diaspora to invest in diverse investment potentials including agriculture, manufacturing, tourism and others investment opportunities open for foreign investors. This increasing trend of investors prefer to establish large scale companies through issuing shares in an initial public offering to take the advantages of corporations. This entrepreneurial and forward-looking investment by the Ethiopia Diaspora is putting a pressure on the government to establish a secondary market.

Relatively Stable Political Environment: Political environment is factorial to every moment. In unstable political environment, investment is less likely to happen and become pillar of an economy. Investors' willingness of investment on risky financial assets such as stocks and bonds depends on domestic speculation of the future political situation of countries. In this regard, Ethiopia enjoys relatively stable political system domestically as compared to its neighbors. But there are frequent claims on human rights and elections plagued by claims of irregularities by watchdog groups like EU. The region, East Africa, is also among the unstable area of the world.

Privatization Scale-up: Among the appealing economic measures, promoting private sector development is the privatization program that the Ethiopia government has been working by establishing a privatization agency. So far, the government is a major actor in the economy as it has monopolized varied crucial sectors like sugar, cement and beer factories, telecom services, etc., and its institutions and agencies play a seminal role in the market. Recently, however, many state-owned companies have been privatized. Since 1995, the Privatization and Public Enterprises Supervisory Agency has privatized 287 enterprises including breweries. This is seen as a positive move surfacing an enabling ground for the private sector to play and have an influential role in the economy.

Increasing capital flow to the country: In countries like Ethiopia, where saving is low, foreign direct investment is an alternative means to improve investment. The investment by the foreign investors and the Ethiopia Diaspora is increasing overtime being slightly affected by the global economic downturn that happened since 2007. According to the consulted official reports of the NBE and Ethiopian Investment Agency, FDI has shown an increasing trend as more investors from Turkey, China, India, and the Middle East are investing mainly in agriculture, textile, hotels, and restaurants. The total FDI inflows into Ethiopia have increased continuously from US$ 135 million in 2000 up to US$ 545 million in 2004. But the yearly FDI inflows have shown fluctuations between US$ 545 and US$ 206 million in the period of 2005-2011. FDI inflows into the agricultural sector, which is about 45% of GDP, 80% export and more than 80% of employment, account for 32% of the total Ethiopian FDI inflows. Despite the increasing trend, FDI in Ethiopia is very low even by African standard. Remittance has been also growing from the Diasporas. The NBE reported that official receipt of remittance to Ethiopia grew to US$1.5 billion in 2011 showing a growth of 87.4% as compared to the previous year.

Invest than save payoff: saving is not encouraging in the country as real interest rate is negative. The interest rates on deposits do not compensate the high inflation rate in the country. The national Bank has set the minimum interest rate on deposits at 5%, but inflation rate is fluctuating between 20% and 30% and even was beyond 30% in 2009. Due to this handicap, experts and individuals involved in this study say that households prefer to put their money under their mattress or invest it in other potential and less risky investment opportunities. This has become, in recent years, an advantage for initiators of incorporated companies.

Inclination to incorporated companies: During the derge regime, most companies were sole proprietorships and partnerships or national corporations. But after the liberalization process, many private companies flourish in the country. With the establishment of Awash International Bank (AIB) in 1994 through initial public offering, incorporated companies, particularly banks, insurances and construction companies began to exist. Ethiopian Diaspora and Ethiopians experienced advanced markets and economies have become the actors in initiating incorporated companies. This brings a new paradigm to citizens to invest their petty money on shares of these companies than putting in negative earning deposits. Except for security and liquidity reasons, many prefer to put their money on shares of companies. This is the bold reason pressurizing the government to set regulations and launch capital market to end-up chilling the private sector.

Ethiopian Commodity Exchange (ECX), a vibrant lesson: Ethiopia has established a commodity exchange with the proclamation number 550/2007 with an initiative of revolutionizing the traditional agriculture through creating a new market place to serve all actors and add value to the primary producers. This market is the first of its kind not only in Ethiopia but also in Africa. Many consider the establishment of this unique platform to all in the agricultural value chain as madness as they believe it does not work in the 85% uninformed rural and immature infrastructure. But it has become a rubber bridge bringing diverse partners, from farmers to traders to processors to exporters and consumers. It is praised for its exemplary works of providing reliable end-to-end system and linking financial services, transportation, etc. Though it is few years since establishment, EXC has become an institution to be benchmarked by many African nations and scale up best practice within the nation. Therefore, it is a vibrant and lively lesson that the country could learn to much to launch the capital market.

Energy Expansion: Energy is the backbone of economic development. Ethiopia, the water tower of East Africa, has immense potential for hydroelectric power, wind, and geothermal energy generation. Most of its major rivers are suitable for the generation of hydroelectric power with the total capacity of 45,000 MW, but able to produce only 2,000 MW (4.4%), getting more than 90% of energy from bio-mass accelerating the destruction of the country's forest resources. Over the last ten years, efforts have been made to shore up the energy capacity of the country in order to increase the population access to electricity, promote the establishment of large scale industries and advocates green economy. To this effect, the government has initiated hydroelectric and wind power projects in different parts of the country. By this effort, the energy capacity of the country has increased from 250 MW (1991) to 2,000 MW (2011). The government has planned to ignite the power generation into 10,000 MW at the end of the Growth and Transformation Plan (GTP) in 2015. To achieve this target, it has already started a grand dam (Abay Renaissance Dam) expected to generate about 6,000 MW. This self-financed project is anticipated to quench the huge energy demand of the country, attract foreign investors and generate income by exporting to neighboring countries, and is assumed to play a vital role in the regional integration.

Constraints

Government Reluctance and Ambivalence: Since the fall of the Derge regime in 1991, Ethiopia has directed its command economy into a market-oriented economy. The financial sector was liberalized to uphold the economy but this lubrication was not extended to the establishment of capital market. Despite pressures from domestic and

international stakeholder, the Government of Ethiopia has remained reluctant and ambivalent to launch the securities market (specifically the secondary market) in the country. As discussions with government officials and official documents indicate, the government presently has no intention to launch the market. What is looking askance and dubious to the government is the importance of the market to the country's economy as it is sleeping over the dynamics and fickle behavior of the capital market than on the prolific palettes. The government connotes almost frequently such statements: "We have limited resources and it is a choice where and how to use them," and this is "a priority dilemma". "We have other basic and obligatory functions to do first in order to enhance social welfare". "Thus, capital market is not the government's priority at this moment and it is untimed to the country". This ambivalent stance of the government and disaccording resources towards furnishing basic capital market constituents is seminally quash the existence of the market. *In anyways, the government, at present, is not generous to establish securities market in the country*.

Underdeveloped Infrastructure

Legal and Regulatory frameworks and body: The importance, extent, and form of regulating capital (securities) market are among the critical global agenda. But after the 2007 global financial crisis, the significance of market regulation has been highly promoted. Market regulations are believed to improve market efficiency, protect investors, and enhance public confidence. Accordingly, for countries like Ethiopia where systems and structures are not well cultivated the availability of legal framework and supervisory bodies is essential for the establishment and development of capital market, and ensure the macro and microeconomic stability. Safeguarding of the stability of the system translates into macro-controls over the financial exchanges, clearing houses and securities settlement system.

Despite market regulation is regarded to envisage transparency in the market and intermediaries to protect the participants from information asymmetry and market anomalies, currently, Ethiopia has no sufficient and up-to standard proclamations, legal and regulatory frameworks to regulate the exchange of securities, even issued in the initial public offering (primary market). Under the proclamation no. 166 of 1960, Book-II (Business organizations), Title-VI (companies limited by shares) describes only the functions of companies to raise capital through initial public offering (primary market) and it fails to explain the subsequent transactions of the securities in an open market (secondary market), and ways of regulation. The commercial code pinpoints the formations of partnerships, joint venture, private limited companies, and share companies. It further details the provisions for the establishment of private limited and share companies. Despite the detail information required to get license, there are no regulations that can protect the investors. There are requirements for documents (such as audited financial statements and confirmation with international/ national standards and principles) that the initiators or issuers to file to a separate regulatory body (commission) for further investigation and approval before issuing initial offering to the public. However, there are no criteria for listing and delisting of companies in the market. There are also no adequate anti-fraudulent activities of the share issuing companies. This absence of regulatory body for non-banking sector makes difficult to introduce a well-grounded market and sheds-down the confidence of domestic investors to take part on such market. Generally, the country does not design any regulation in tandem with the unique dynamics of the securities market and no independent supervisory body (like the SEC in the united state) designated to govern the modus operandi of the market.

The other proclamation is the proclamation of Banking Business and Service, which deals only about banks. The country has a regulatory body only for the banking sector. Banks offering and selling securities are required to comply with the bank proclamation under the watchdog of the National Bank of Ethiopia. However, regulatory agency and regulations are totally absent for the non-bank share issuing companies. These proclamations are inadequate to supervise and regulate the primary shares offering and do not meet international standards which makes it difficult for the secondary market to exist.

Initial public offering companies are operating traditionally and through window-type shopping of shares under informal and unregulated market. Thus, thousands of small base investors remain uncertain whether their future contracts will be recognized and enforced. Seminally important to the development of securities market is the suitability of the country to do business. Doing business is a fundamental factor on how easy to do business when complying with relevant regulations. According to the World Bank's partial and relative measures affecting 10 areas in the life cycle of a business: starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting investors, paying taxes, trading across borders, enforcing contracts and resolving insolvency, Ethiopia's world ranking is far behind demanding more to do. The country is ranked, overall, out of 183 countries in 2012, 111 sliding down from its previous year's position (104) and following from behind its neighboring countries, Rwanda (45) and Kenya (109), but relatively at faire position vis-à-vis to Uganda (122) and Sub-Saharan standard (137).

Table 2.1. Comparison of Ethiopia with other countries in capacity of doing business

Country	Starting a business	Dealing with construction permits	Getting electricity	Registering property	Getting credit	Protecting investors	Paying taxes	Trading across borders,	Enforcing contracts	Resolving insolvency
Ethiopia	99	56	93	113	150	122	40	157	57	89
Rwanda	8	84	50	61	8	29	19	155	39	165
Uganda	143	109	129	127	48	133	93	158	116	63
Kenya	132	37	115	133	8	97	166	141	127	92
Sub-Saharan Africa	123	112	122	119	110	112	115	134	117	127

Source: Doing Business/World Bank, 2012

Comparatively, within the developing world, particularly Sub-Saharan Africa, the relative position of Ethiopia in ease of doing business seems fair (Table 2.1). Except Rwanda, the comparators have expectedly lower rankings in most of all the factors indicating that the Sub-Saharan African countries have a long way to go to bestow conducive environment and develop enabling regulations to protect investors, reduce transaction costs, reduce inconveniences, and overall ease doing business for citizens. Even though investor protections is essential for companies to raise the capital they need to grow, innovate, diversify and compete, Ethiopia's commercial code is inadequate to protect investing citizens. Articles 381-389 of the code give rights: to at least 10% holding shareholders to ask for investigation in the company's state of affairs if they believe it is going wrong (Art. 381); to be a member, to vote, and to challenge a decision of the company or to receive dividends and a share in a winding-up (Art. 389). Art. 333 also give shareholders the right to transfer unrestricted shares. However, the code deprives shareholders the right to be informed and get relevant and timely information, restricts the free transfer of shares, and does not minority shareholders the right to be protected. Generally, the old commercial code is insufficient to protect investors and promote transparency in the function of companies. This existence of gap in the legal infrastructure hinders investors to invest.

In today's globalized world, making trade between economies easier is increasingly important for business. Excessive document requirements, burdensome customs procedures, inefficient port operations, and inadequate infrastructure all lead to extra costs and transactional processing. Ensuring formal property rights is fundamental. If strong administrative organs are not well-established, formal property transfer becomes costly and complicated, and might go through informal ways, diminishing its importance to the economy. Improving access to finance enables citizens to exchange resources and share risk. Institutionalizing credit information systems enables lenders to view potential borrowers' financial history (financial positions, liquidity, and obeying to former contracts). This is instrumental in allowing market to act and react by its own and channel resources to their best of use. Conclusively, regulatory framework is one of the strong foundations of a capital market that protects investor assets and promotes confidence in the public. The stock exchange operates within a certain legal framework. The exchange has its own regulations, including membership regulations, listing regulations, trading, settlement rules, mergers, and takeover rules. Ethiopia's decades-old and unmodified code, to include recent and dynamic phenomena, is not giving a strong jolt to establish and operate a full-fledged securities market. Generally, Ethiopia does not have adequate proclamations and directives for the development of well-functioning primary securities market nor have adequate legal, regulatory, and supervisory framework, which can lay down for the foundation of a secondary market.

Business Orienting Media, a Missing Link: Media (newspapers, TV, online, etc.) has an influential role on the public and companies. It plays a vital role in enhancing the public awareness and informs individuals, groups, entities, and governments about developments. Media influences the investment behavior of citizens. It propagates information that could be incorporated in prices of commodities and assists for the existence of efficient market. Media updating stakeholders and the public about the commonplace of the business and finance sector is totally absent in Ethiopia. Information about the list of companies that are offering shares to the market, the amount of shares sold, money mobilize, status of formation, and any returns after establishment is not readily available to the public. Almost all share companies promise mouth-watering returns and profits during their establishments. All share companies unilaterally set birr 1,000, which is about USD $55, as the par value of the share. But there is no professional media that defines about the credibility and reliability of the promises, and updates about the success or failure story of the companies. There also no professional explanations and interpretations about why all companies take a similar fixed par value of their shares.

Unfortunately, the media that thousands of people with shares in a number of businesses dream printing and airing share prices, and business climate like in elsewhere shares are traded is a missing link.

ICT, Unripe Infrastructure: Information and communication technology (ICT) has become a powerful tool for development extending its role from improving education and health system to widening business opportunities. For participants in the capital market, ICT is vital as it enable to communicate and exchange information swiftly; hence, make capital markets more efficient by including all information in stock prices. Though improvements in ICT development and expansion have been seen, the public and more particularly the business community is not blessed to modern, fast, fair and equitable use of ICT in Ethiopia. The state-owned telecommunication company, Ethio-telecom the sole telecom service provider, provides sluggish, unreliable, and expensive internet and phone services. As of September 2011, there were only 10.5 million mobile phone, 0.854 million fixed line and 0.128 million internet subscribers which account 12%, 1% and 0.15% of the population. This coverage is very low by any standard. The farmer, the backbone of the country's economy accounting more than 80% of employment, is scantly addressed by the ICT territory and internet is unthinkable in rural areas.

Immature Financial Sector: In order to establish and develop a full-fledge and well functioning capital market, the existence of strong financial institutions such as banks, mutual funds, pension funds, credit unions, saving associations, and others is inevitable. Financial institutions are significant in that they mobilize financial resources from households and channel the fund back to the capital market. However, most African countries in general and Ethiopia in particular have no diverse and well-developed financial institutions. The Ethiopian financial sector consists of only microfinance institutions, insurance companies, and banks. Ethiopia has 17 banks, 14 insurance companies and 30 micro-finance institutions as of 2011. Similar to many African counties, the sector is bank dominated. Banks play a key role in mobilizing, intermediating and channeling resources into diverse uses in the economy. The banking sector has relatively shown improvements in terms of bank numbers, branch networking, capital, profitability, deposit mobilization, non-performing loan minimization but still small by African standard. Nonetheless, performance evaluation is difficult due to the absence of relevant performance benchmarking tools (such as industry average, competitors' performance, country standards, etc.) helpful to assess each firm's and/or industry performance. Despite relative improvements in the sector, still it is in its infant stage and is distinguished with the following standings.

Dominant but Untested Banking Sector: The banking sector, the major player in the economy, is not open to foreign investors. Even though the country directed its economy into market-orientation in 1991, there are several sectors only privileged to domestic investors, the banking sector is one. The performance of this sector is untested by fierce competition, which is the common characteristics in most part of the remaining world and deprives citizens to get access alternative services from diversified banks. Thus, the sector is simply functioning as bears market becoming difficult to turn it into bullish market as it should be to pace with the dynamic global market.

Limited Access: Since 1991, the banking sector has been performing well showing an increase in the number of banks, branch networking, and deposit mobilization. The number of banks and braches increase from 3 and 200 (in 1994) into 17 and 970 (2011), respectively. However, Ethiopia is still one of the most under banked countries in the world with 970 bank branches serving about 84,975,606 populations (one branch serving over 87,000 people). As compared to some African countries such as Kenya (one branch serving 37,630 people), Ghana (one branch to 54,000 people), and Nigeria, the most populous country in Africa (one branch is for 27,591 people) in 2010, Ethiopia has a lot to accomplish to enhance banking access. Bank branches are also unfairly distributed and concentrated in major cities and towns of the country, and 38% of bank branches are concentrated in Addis Ababa, the capital city, with residents only 2% of the country's population. Similarly, there are only 221 branches of 14 insurance companies that one insurance branch serves over 380,000 people.

Public Banks Outdo: As of 2011, there are 17 banks operating in the country. Of these 3 are public banks. This number indicted that the number of public banks operating in the country seems too small reflecting private sector is dominant. However, the fulcrum of rotating the axis of financial sector is in the hand of the government banks. They are dominant in terms of bank branches, capital and deposit mobilization. Of the total 970 bank branches, in 2011, throughout the country, Commercial Bank of Ethiopia (CBE, a government bank) alone has 547 branches. CBE has also been mobilizing about 60% to 70% of the domestic saving between the periods of 2005 to 2011. The banking sector is characterized by its low capital base. For example, the total capital of the sector in 2011 is 15.9 billion Ethiopian birr (which is about 92 million dollars). The share of the 14 private banks is only 44%, which the major share is held by the three public banks, mainly by the Commercial Bank of Ethiopia. This is an indication that there is a long way that the country should go to promote the private sector to play a significant role in the economy.

Low Deposit Mobilizing Status: Domestic saving in Africa is in its lowest standard. The lower saving culture has been the chronic problem to finance national development endeavors and large scale national projects in Africa. African nations have a very wide gap between the domestic savings and required/invested capital and such gap (deficit) is financed by borrowings to the larger extent supplemented by foreign aids and assistances. Ethiopia's domestic saving is also at its lowest rate by any standard. At the end of the PASDEP period, gross domestic saving was only 5.5% of GDP. The construction of the Ethiopian Grand Abay Renaissance dam, in the Nile river, the largest project in the history of the country, is believed to boost saving in the country as it is constructed by issuing long-term government bonds. According to government official reports, gross domestic saving went up to 8.8% of GDP due to this effect.

This rate, however, is by far lower than Sub-Saharan standard (17.9%) and other developing countries like Angola and Gabon where domestic saving is as high as 40% of the GDP. Beside to the limitation of financial literacy, low income and high inflation rate exhaustively swallowing income for consumption, the inability of banks to mobilize resources from households is of no doubt. Citizens are not ready to save due to higher inflation rate and comparatively lower saving interest rates. So, there is a doubt that the targets of the ambitious five years GTP will be achieved as the government may suffer huge financial gap. Thus, professionals and experts have been recommending the government to launch capital market to mobilize required capital from internal and external sources as major domestic investors are not willing to make huge investments in the government bonds issued for the dam due to liquidity problems.

Excessive Liquidity: According to the Licensing and Supervision of Banking Business Proclamation No. 84/1994, and Banking Business Proclamation No. 592/2008, all licensed banks are strongly required to transfer to their legal reserve accounts in the National Bank of Ethiopia a sum of not less than 25 percent of their net profit at the end of each financial year, and as pursuant of banking business proclamation (art. 20), directives No. SBB/45/2012 requires banks to maintain liquid assets not less than 20% of their total current liabilities. However, banks are liquid much higher than the requirement. On yearly averages, less than 50% of deposits mobilized are extended as loan. Thus, above half of deposited amounts in commercial banks remain unproductive. This unexploited liquidity discourages banks to undertake intensive deposit mobilization movements. This is a clear indication for the thinness of the financial market that banks have nowhere to channel financial resources. Securities market is suggested by many to counterpart the banking business in this regard.

Acute and Technology Shy Banking Service: The financial sector in general and the banking system in particular is underdeveloped in that it lacks diversified and alternative services. Banks and insurance companies provide very scant products and services to the public. Commonly the public uses banks for (i) temporary deposits and (ii) loan facilities. Ethiopian banks are also technologically backward and sluggish service deliverers. Some modern banking services such as Automated-Teller Machine (ATM), internet banking and SMS banking have been started in some banks very few years back. Bust most payments and settlements are still paper based. The service system is backward that all types of customers appear in person in physical operational areas for settlement, clearances, and other banking services. However, it is worth mentioning that the National Bank of Ethiopia and the Commercial Banks are taking encouraging measures to modernize their service delivery system, but demanded a long way to go to join the advanced trajectory of banking system.

Deficient Inter-bank Transaction: Commercial transactions (such as lending, exchange of currency, money market, etc) is almost rare, if not exist at all among the commercial banks. In financial market, this is considered to take the lead in activating the market to warm the exchange in the securities market. This is the missing link to create capital market that stakeholders need to sleep on it.

Uninformed and Small Base Investors: The domestic investors in Ethiopia are not well informed and not aware about trading securities and the functionalities of capital market in particular and financial market in general due to lack of public awareness campaigns, limited exposure to global markets and for educational matters. It is uncommon that concerned institutions conduct vigorous seminars, conferences, and workshops to spark, extend, and enhance the concept of capital market in the public and investors. What is more, the inexistence of institutional investors due to lower level saving capacity and practice is another limiting factor to put a baseline for the establishment of the capital market. Many companies have been and are established under conservatively financed initially publicly traded companies in a traditional window-shopping system, shares held by thousands of investors none of whom hold a large percentage of shares and nowhere to sell then after to get back even the principal. Due to the small base of domestic investors and limited capacity of the private sector, acute shortage of capital is a constraining reason to ensure rapid economic development in the nation.

Shortage of Professionals, the human element: In Ethiopia, universities and other higher learning institutions do not specialize and excel in some specific disciplines. Almost all are multidisciplinary offering wide range field of studies. Most senior scholars and experts of the country are educated and specialized in foreign universities in untailored system to the country's interest and situation. The education system of business and economics is also adapted from advanced

economies specifically the United State and is trivially reflecting the actual practice in the ground. All the 31 universities offer business and economics courses at undergraduate level in a holistic approach. Universities are not producing today's and tomorrow's brokers, specialists and dealers (market makers) who serve as a bridge in connecting demanders and suppliers, mediate transactions and set prices in response to excess demand and supply, and accumulate stock inventory to make market operate in equilibrium. Students are not shaped to become tomorrow's entrepreneurs, businesspersons, and open brokerage companies. Thus, the commitment of government to refresh its education policies and responsibility of higher learning institutions to produce innovative and skillful professionals and experts to surface a ground for the establishment of vibrant and economically worthy capital market is unconsidered issue.

Conclusion and the Way Forward

Although the capitalization of all African stock exchanges represented less than 2% of the world total, and are characterized by their low liquidity with low volume of transactions, they are expected to accelerate the transformational process of Africa and envisage the economic growth of the countries as Africa is booming and viewed as future destination of the investment eyes of global investors. Ethiopia can take good lessons from the already established markets in developed and developing countries, especially emerging markets. It has to benchmark the practice to launch the market apart from 'learning by doing'. Most of the capital markets in Africa are under the umbrella of the African Stock Exchanges Association (ASEA, representing 27 countries). ASEA was registered with the objective of, inter alia, establishing an association for systematic cooperation, exchange of information, materials and persons, mutual assistance and joint programs between the members. The membership of the association is open to any Stock Exchange or nascent Stock Exchange located in the African region. Thus, it is another prima face opportunity for Ethiopia if it seeks technical assistant to establish the market either unilaterally or jointly with other member states until it is ripped for the sector running independently. Ethiopia has pioneered Commodities Exchange market (EXC) that many African countries are nowadays aspiring to learn from. Scaling up of the good lessons of this vibrant EXC is another fortune for the country to establish the capital market. Taking the tantalizing opportunities, Ethiopia should establish the capital market in order to scream the elite of the market while remaining vigilant on its curses. While recommending the establishment of the market, however, it is worth mentioning that the country should do its home work to bestow the ground by modernizing and advancing, at least the bare minimum, its infrastructure (Payment and settlement, ICT, physical market, etc) in order to smoothly facilitate the transactions if not making seamless. Developing regulatory framework and designating an independent regulatory body to modestly watchdog the activities of the market to create public confidence, protect investors, and at least minimize market anomalies. Alongside, the establishment of institutions and training centers and introduction of professionalism in the area to promote public awareness, to assist the market, and produce skillful and competent workforce to this world of work is also necessary to do activity. Gradualism loosening of the arresting economic regulations and relaxing the closed sectors to foreign investors and markets is also relevant to attract large scale investors able to transact huge capital in the economy. Finally, as there is nothing evergreen by itself, the country should learn by doing and do the best it can to integrate itself with the global market to benefit from it.

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2.2 Income Diversification Pursuits of Khat (*Catha edulis*) Cropping Households in Eastern Hararghe Highlands

Temesgen Keno

Abstract: This study was aimed at identifying the demographic, socio-economic, agro-ecological, and institutional factors that largely determine the probability and intensity of income diversification among khat cropping households in eastern Hararghe highlands. Primary data were collected from a cross-sectional survey of 117 households in Aweday and Haramaya districts where farm households are intensively engaged in khat cropping. Tobit censored regression model was employed to analyze the determinants of households' decision and intensity of income source diversification. Twenty explanatory variables were tested, out of which ten were found statistically significant in determining the probability and intensity of income diversification. Age of the household head, level of education, leadership experience, access to training, frequency of shocks and future risk perceptions were found to be positive while total family size, income from khat sales, size of land allotted for khat cropping and extension contacts were found to be negative in significantly influencing the probability and intensity of income diversification. The findings of the study suggest that income source diversification policies that couple household socio-economic and khat cropping motive with predictions on external climatic risk factors should be crafted for better stability and sustainability of income generation among khat cropping households.

Keywords:Income Diversification; Kaht Cropping, Tobit

Introduction

Household income diversification is the pursuit of generating cash and in-kind income at household level from conglomerate sources. Income diversification has intrinsic potential for protecting the livelihoods of the poor from the risks of hostile ecological and biophysical changes. Various studies recognize farm household's engagement in diversifying income sources, assets and occupations as an economic adaptation behavior to cope with changing livelihood conditions (Barrett *et al*., 2000; Block and Webb, 2001; Canagarajah *et al*., 2001; Olale and Nazli, 2010). Thus, household income diversification serves rational risk management mechanism to smooth income and consumption. As a household response to risks of changing socio-economic and livelihood conditions, farm households are usually 'pushed' to diversify their income sources due to climatic uncertainty and covariate risk reduction (Alderman and Paxon, 1994; Tassew and Oskam, 2001), land constraints driven by population pressure and diminishing landholding due to fragmentation (Deininger *et al*., 2003; Holden *et al*., 2004; Jayne *et al*., 2006), responses to diminishing factor returns in any given use like family labor supply (Reardon *et al*., 2006; Bryceson, 1996), liquidity constraints and high transaction costs that induce households to self-provision in several goods and services (Dercon, 2002; Dercon and Krishnan, 1996).

On the other hand, to exploit opportunities of stable and better income generation, farm households in developing countries were evidenced to be 'pulled' to diversify their income sources in scenarios like limited risk-bearing capacity in the presence of incomplete or weak financial systems that create strong incentives to select a portfolio of activities that stabilize income flows and consumption patterns (Barrett and Reardon, 2000; Bryceson, 1996; Escobal and Javier, 2001). In addition, local engines of economic growth including commercial agriculture (Abdulai and Crolerees, 2001, Pingali *et al*., 1995), proximity to an urban area that create opportunities for income diversification in production and expenditure-linkage activities (Adams, 1998), realization of strategic complementarities between activities like crop-livestock integration, milling and hog production (Reardon *et al*., 2006) were also identified as "pull factors" for income diversification.

Diversification and specializations accorded by superior technologies or business skills were evidenced to lead households with scarce productive resources to greater endowments through considerable inter-individual diversification of investment activities and alternative sources of income (Ellis, 2000). This is especially true in rural areas of low-income countries like Ethiopia, where high transaction costs induce many households to self-provision in several goods and services (Adugna, 2006; Tesfaye *et al*., 2004). Higher levels of diversification reduce production risks because of lower vulnerability to extreme weather events. Likewise, a broader product portfolio reduces market and marketing risks (e.g., price variability). On the consumption side, more diversification may contribute to better income, higher dietary diversity, and micronutrient consumption. In general, diversification enhances household income generation capacity and help for efficient inter-temporal transfer of resources and risk coping strategies providing for more stable and sustainable income generation at household level particularly under the current farm scenarios where changing climate conditions aggravate farmers' uncertainty and farm production risks.

Despite the significance of diversification, there is no clear identification of factors determining effective income diversification mechanisms among rural households. For instance, cash cropping households, including coffee and *khat*[1] producers, ignore diversification due to lucrative profitability of such cash crops. These households usually undermine the fact that diversification is a household response to risks. In eastern Hararghe highlands where this study is carried out as its setting, households are intensively engaged in *khat* production and as a result have income sources large enough for investment above their consumption. This provides them with ample opportunity to diversify their income sources into petty trade activities, micro- and small-scale enterprises (MSEs) and other alternative income generating activities (IGAs) that provide more stable, sustainable and reliable earnings.

Strategies that help these households to channel their earning from khat sales into saving, asset accumulation, and investment are not in place. Household well-being in terms of food security and poverty reduction are substandard and the level of development of MSEs which are the 'incumbents' of growth is very low. Such paradox of ample income generation and lack of economic wellbeing together with the low level of saving, MSE and IGAs development requires special policy attentions. Empirical studies that investigate the underlying factors for the low level of diversification and risk mitigation among these households were very scant. Hence, this study was aimed at identifying the determinants of households' willingness to diversify (WTD) income and intensity of income diversification.

Modeling *khat* producing household's income diversification behavior

Khat cropping households were expected to reasonably show their decision to diversify or not to diversify their income sources with the objective of minimizing the risks of undue reliance on *khat* and with the aim of improving the smooth flow, stability, and sustainability of income generation. Opting for diversification implies interest for pursuing petty trade, alternative IGAs or MSEs. Households' diversification pursuits are rational decisions made based on expectations of the benefits and costs of undertaking the diversified activities. Hence, households decide to diversify their income sources if and only if the utility they derive (in terms of income) from the diversified activities is higher than not diversifying. This decision can be represented by a utility function and the problem can, therefore, be modeled as a utility maximization problem. Accordingly, *khat* producing households maximize their utility from diversifying their income source portfolio given their resource endowment.

Let the household decision to diversify income sources is represented by f where $f = 1$ if the households decides to diversify and $f = 0$, otherwise. The resource endowment of the household is represented by r and vector v represents other observable attributes of the farm household that might potentially affect diversification decisions. If a *khat* cropping household is willing to diversify its income sources, the household's utility is given by $U_1 = U(1, r, v)$ and, if the household is not willing to diversify, the utility is given by $U_0 = U(0, r, v)$. Therefore, based on the existing farm household economic theory, households are expected to be rational decision makers who prefer the best option from the stated alternatives, subject to their demographic, socio-economic and institutional constraints.

This provides the basis for household income diversification behavior as an additively separable utility function in the deterministic and stochastic components where the deterministic component is assumed to be linear in the explanatory variable (Colin *et al*., 2005). Accordingly, the probable two decisions of the *khat* cropping household to diversify or not to diversify its income sources are represented by $U_1 = U(1, r; v) = D(1, r; v) + \varepsilon_1$ or $U_0 = U(0, r; v) = D(0, r; v) + \varepsilon_0$, respectively, whereas $U_t(.)$ is the utility that a household derives by generating stable and sustainable income from diversified income source portfolio, $D_t(.)$ is the deterministic part of the utility and ε_t is the stochastic component representing the component of utility known to the households but unobservable to the economic investigator. Without specifying the choices of income source diversification, it is expected that *khat* cropping households are assumed to know their resource endowment r and implicit cost of diversification in terms of commitment of resources. Representing the household's implicit cost of diversification decision by c, then, the household will decide to diversify its income source if $U_1(.) \geq U_0(.)$ which means if $D(1, r - c; v) + \varepsilon_1 \geq D(0, r, v) + \varepsilon_0$.

The presence of a random component permits to make probabilistic statements about the behavior of *khat* cropping household's decision to diversify their income sources. If the household decides to diversify, the probability distribution

[1]'Khat' (Catha edulis) is a shrub or small tree with ever-green leaves native to the tropical East Africa and the Arabian Peninsula, chewed for its use as a mild to moderate stimulant. It is one of the cash crops extensively grown in Ethiopia with a rapid expansion in different parts of the country. It generates the highest foreign exchange earnings next to coffee for Ethiopia in exports to some Middle-East and European countries. Khat is an important and potentially lucrative cash crop and Hararghe farmers have tenacious attachment with khat more particularly for consumption and income generation (Dechassa, 2007).

is given by $P = \Pr\left[D(1, r-c; v) + \varepsilon_1 \geq D\ (0, r, v) + \varepsilon_0\right]$ and if the household decides not to diversify, the probability distribution is given by $P = \Pr\left[D\ (0, r, v) + \varepsilon_0 \geq D(1, r-c; v)\right]$. Based on the assumption that the deterministic component of the utility function is linear in the explanatory variables, the utility functions represented above can be given as: $U_1 = \beta_1' Y_i + \varepsilon_1$ and $U_0 = \beta_0' Y_i + \varepsilon_0$ where β_1' and β_0' are the vectors of response coefficients while ε_1 and ε_0 are stochastic or random disturbance terms. The probabilities given above can be estimated from a probability cumulative distribution function (index) of willingness to diversify (WTD) as follows:

$$
\begin{aligned}
& P(WTD) = \Pr\left[U_1(.) \geq U_0(.)\right] \\
\Rightarrow\ & P(WTD) = \Pr\left[\beta_1' Y_i + \varepsilon_1 \geq \beta_0' Y_i + \varepsilon_0\right] \\
\Rightarrow\ & P(WTD) = \Pr\left[\beta_1' Y_i - \beta_0' Y_i \geq \varepsilon_1 - \varepsilon_0\right] \\
\Rightarrow\ & P(WTD) = \Pr\left[Y_i(\beta_1' - \beta_1') \geq \varepsilon_1 - \varepsilon_0\right] \\
\Rightarrow\ & P(WTD) = \Pr\left[Y_i \alpha > e_i\right]
\end{aligned}
$$

where P is the probability function, $e_i = \varepsilon_1 - \varepsilon_0$ is a random disturbance term $\alpha = \beta_1 - \beta_0$ is K*1 vector of parameters to be estimated, Y_i is an n*K matrix of explanatory variables. $\mathrm{P}\ (Y_i \alpha)$ is the cumulative probability distribution function for e_i evaluated at $Y_i \alpha$.

Empirical model specification, variables, and hypotheses

Econometric model: Identification of the determinants of the household's decision and intensity of income source diversification was the main objective of this study. For this purpose, Tobit censored regression model was used. This is particularly meant to understand why some households are better able to derive income from diversified sources and there could be a large share of observations with zero values for those households who decide not to diversify their income sources. Hence, Tobit model, which has been originally developed for censored data and also used for corner solutions (Green, 2000) is selected for the data analysis in this study. The general Tobit model representing households' income diversification decision is given as:

$$Y_i^* = X_i' \beta' + \varepsilon_i' \qquad (1)$$

For Tobit model, the dependent variable, Y_i, can take zero or positive values as:

$$Y_i = Y_i^* \ if\ X_i' \beta' + \varepsilon_i' > 0 \quad \text{and } Y_i = 0 \ if\ X_i' \beta' + \varepsilon_i' \leq 0 \qquad (2)$$

where, Y_i^* is a partial latent dependent variable that capture the i[th] household decision to diversify its income source, X_i' is a matrix of vector covariates that influence households' diversification, β' is a parameter to be estimated, ε_i' is a random stochastic or disturbance term such that ε_i' is normally distributed with mean 0 and standard deviation of δ^2, i.e. $\varepsilon_i' \sim N(0, \delta^2)$. To estimate the coefficients of this model, the maximum likelihood estimation (MLE) method with the log-likelihood function in equation (3) was employed.

$$InL = \Sigma_{y_i > 0} - \frac{1}{2}\left[\ln(2\pi) + ln\,\delta^2 + \frac{(Y_i - \beta' X_i')^2}{\delta^2}\right] + \Sigma_{y_i = 0} \ln\left[1 - \phi\left(\frac{\beta' X_i}{\delta}\right)\right] \qquad (3)$$

where ϕ is the cumulative distribution function of the standard normal distribution. The first part of this likelihood function is essentially the classical regression model for the non-zero observations while the second half represents the probabilities for the censored observations. The maximum likelihood estimator has the desirable properties for being both consistent and asymptotically efficient (Greene, 2000). Hence, the estimated coefficients identify two effects i) the effect of an independent variable on the probability of diversification for households decided not to diversify (the censored observations), and ii) the effect of the explanatory variable on the probability of diversification for households who decide to diversify. In addition to the households' diversification decisions, it is also important to make marginal effect analysis to understand the extent to which each explanatory variable influence the probability and intensity of income diversification.

Thus, the total marginal effects of explanatory variables on the expected value of the dependent variable are given as:

$$\frac{\partial E(Y_i)}{\partial X_i} = F(z)\beta_i \qquad (4)$$

The above specification allows us to analyze the khat producing household's decision to diversify as well as the intensity of diversification given the decision to diversify. Hence, the total marginal effect or elasticity in equation (4) can be decomposed into two effects as follows:

$$\frac{\partial E(Y_i)}{\partial X_i} = F(z)\left[\frac{\partial E(Y_i^*)}{\partial X_i}\right] + E(Y_i^*)\left[\frac{\partial F(z)}{\partial X_i}\right] \qquad (5)$$

The first marginal effect or elasticity stands for the effect of change in explanatory variables on the expected level of probability of diversification, while the second marginal effect stands for the conditional expected value of intensity of diversification.

Variables and hypotheses: In this study, two dependent variables, the households' income diversification decisions (D_i) and intensity of diversification (Y_i) were identified. D_i is a dichotomous variable that takes the value of 1, if the household is interested to diversify, but 0 otherwise, while Y_i is a continuous variable measuring the magnitude (intensity) of households' income that can be invested in diversified activities. Corresponding to the two dependent variables, a number of explanatory variables believed to have significant influences on the dependent variables were identified and summarized in Table 2.2.

Data

Empirical analysis was implemented using primary data collected through a survey of 117 households engaged in *khat* cropping in *Aweday* and *Haramaya* districts of eastern Hararghe zone. A three-stage sampling technique was employed to select the final unit of observation. First, the two districts *Aweday* and *Haramaya* were purposively chosen, as khat cropping in this area is very intensive. Secondly, 3 *kebeles* from Aweday and 2 *kebeles* from Haramaya district were randomly selected. Finally, a random sample of 64 households from *Aweday* and 53 households from *Haramaya* district were selected based on probability proportional to size. A structured questionnaire was designed to elicit information on a wide variety of topics including household income generation, resource endowment, access to markets and financial services, saving behavior, investment motive, and demographic characteristics. The survey questionnaire was pre-tested and actual field survey was done in April and May 2011. In addition, secondary data were collected from various published and unpublished documents and materials from secondary sources. As the data contains explanatory variables of varying nature, multicollinearity and hetroscedasticity tests were made for all explanatory variables before undertaking econometric analysis.

Table 2.2. Summary of variables and hypotheses

Variables	Code	Hypotheses (H_o)		Variable type and measurement
		D_i	Y_i	
Age of the household	AGE/AGE²	+	-	Continuous, age of the household head in years
Sex of household	GENDER	+	+	Dummy, 1 for male headed, 0 otherwise
Family size	FAMSIZE	-	+/-	Continuous, number of household members
Active age family size	MANEQVLENT	+	+	Continuous, measured in man equivalent
Education of household	EDUCATION	+	+	Continuous, formal education of the household head in years
Leadership participation	LEADERSHIP	+	+	Dummy, 1 if the household has leadership participation, 0 otherwise
Land holding	LNDHOLD	+	+	Continuous, land of the household in hectares
Land allotted for *khat*	KHATLND	-	+	Continuous, land allotted for khat production
Livestock holding	TLUOWNED	+	+	Continuous, number of livestock in TLU
Household income	TOTALINCM	+	+	Continuous , amount of total annual income
Income from *kaht* sales	KHATINCOME	-	+	Continuous, annual income from non-farm activities
Access to extension	EXTENSION	+	+	Continuous , extension contact per three months time
Distance from the market	DISTMARKET	-	-	Continuous, distance measured in walking hours
Sale of crops	MDRNCRPSLE	+	+	Dummy, if the household sold modern crops, 0 otherwise
Frequency of shocks	SHOCKFREQ	+	+	Continuous, frequency of shock that astonish khat, crop/livestock
Expected losses	LOSSEXPECTED	+	-	Dummy, 1 if the household experienced severe losses, 0 otherwise
Risk perception	RISKPERCV	+	+	Dummy, 1 if the household perceives future risks, 0 otherwise
Diversity of crops grown	CROPDIVSTY	+	+	Continuous, 1 if the household has diversified farm, 0 otherwise
Access to training	TRAINING	+	+	Dummy, 1 if HH is ever trained about environment , 0 otherwise
Expenditure on festivals	CRMEXPNS	-	-	Continuous, total annual expenditure on social ceremonies in ETB

Results and Discussion

Characteristics of sample households

The descriptive statistics showing the characteristics of the sample households is given in Table 2.3. As the table indicates, an average sample household was headed by a 44-year-old person who attended about 2 years of formal education, has a household size of about seven persons, three of whom were in the productive age and the rest were school or pre-school dependents.

In terms of resource endowment, the average farm household operated 1.125 hectares of land out of which about 0.872 hectares were allotted for khat production and owned about 3.72 TLU of livestock. The farm household generates annual farm income of about 28125 ETB out of which about 18050 was generated from *khat* sales. But, the farmer's annual expenditure on social festivals was significant as compared with its income amounting to 9025 ETB. As an indicator of degree of access to infrastructures, the household was far away from the nearby town market center at a distance of 3.866 kilometers. Due to the recurrence of climate change induced drought, the household reported to face severe shocks of idiosyncratic and covariate nature almost twice per year. As an indicator of low level of income diversification, the average household was observed to grow only about two diversities of crops on the land not covered by *khat*.

Determinants of income diversification decision

The result of the Tobit maximum likelihood estimation of the determinants of the households' income diversification decision is presented in Table 2.4. Age of the household head, formal years of education, participation in local leadership roles, frequency of shocks experienced, future risk perception and access to training were found to be positive and significant in influencing diversification decisions. On the other hand total family size, income generated from khat sales, values of modern crops sold, size of land allotted for *khat* production and extension contact were found to be negative and significant influencing households' decision for diversification. Significance of age variable may indicate that older farmers are more likely willing to diversify their income sources, perhaps due to their experience of observing changing nature and livelihood risks.

Table 2.3. Summary results of the sample descriptive statistics for continuous variables

	Aweday (n = 64)		Haramaya (n=53)		Total (n = 117)	
Variables	Mean	Stand. Dev	Mean	Stand. Dev	Mean	Stand. Dev
Age of the household in years	39.911	8.671	40.130	12.711	44.373	13.122
Family size	6.390	4.021	8.110	3.411	7.230	3.331
Active age family size	3.191	2.012	4.053	1.710	3.152	1.511
Household education in years	2.674	0.985	2.691	0.982	2.683	0.981
Land holding in hectares	1.217	0.947	1.031	0.646	1.125	0.814
Land allotted for *Khat* in hectares	0.980	1.361	0.764	1.733	0.872	1.585
Livestock holding in TLU	3.578	2.498	3.869	3.090	3.723	2.805
Household total income in birr	30425	23675	25775	16150	28125	20380
Income from *kaht* sales in birr	14950	13010	21180	17330	18050	15850
Expenditure on social festivals	7475	6805	1059	8665	9025	7925
Distance from the market	3.381	1.646	4.355	2.058	3.866	1.921
Frequency of shocks	2.298	1.292	3.472	1.719	2.882	1.626
Diversity of crops grown	1.495	1.361	2.118	1.733	1.805	1.585

Similarly, the significance of household heads' formal years of education, participation in local leadership activities and training on environment are indicators of better human capital development. This may provide *khat* cropping households with better insights about the benefits of diversification as a risk mitigation tool. The enhanced level of education, training, and leadership experience help the households to draw comparisons about costs and benefits of each of the diversification opportunities. Household's drought-induced risk perception about future crop/livestock collapse and frequency of covariate shock were found to be positively and statistically significant in determining the households' diversification decisions. The significance of these factors may imply the households' economic uncertainty about the effect of changing climate on farming activities, which further pushes them to decide to diversify their income sources.

Table 2.4. Maximum likelihood estimates of Tobit regression for household income diversification

Variables	Coefficients	Standard error	Marginal Effect (probability)	Marginal Effect (intensity)
AGE/AGE²	0.019471**	0.04873	0.00221	0.03421
GENDER	-0.17043	0.05947	-0.07400	-0.00910
FAMSIZE	-0.31120	0.04321	-0.0031	-0.00149
EDUCATION	0.0340**	0.04670	0.01680	0.01342
LNDHOLD	0.26500	0.42380	0.16840	0.00104
KHATLND	-0.04511**	0.00923	-0.00421	-0.00532
TLUOWNED	0.13070	0.40020	0.04080	0.01064
LEADERSHIP	0.07401*	0.76140	0.08042	0.00613
NONFARMICM	0.62480	0.00020	0.00060	0.05500
KHATINCOME	-0.0073***	0.54730	-0.02310	-0.00651
SHOCKREQ	0.010140**	0.56870	0.01830	0.00340
LOSSEXPECTED	0.18500	0.54320	0.07430	0.00391
MODNCROPSALES	-0.03792**	0.78520	-0.00041	-0.00007
DISTMKT	-0.34120	0.24510	-0.35120	-0.04055
RISKPERCV	0.00923***.	0.35280	0.00430	0.00812
EXTENSION	-0.08140*	0.74630	-0.009430	-0.00520
TRAINING	0.01301**	0.62892	0.01654	0.02742
CRMEXPNS	-0.21010	0.4532	-0.00326	-0.00713
CROPDIVSTY	0.81742	0.76892	0.06442	0.00282
CONSTANT	2.41**	4.8634		

****, ** and * represent significance at 1%, 5% and 10% levels, respectively, the number of observations = 117, log likelihood = -13.64 and the restricted l log likelihood = -19.28, chi-square = 94*

On the other hand, the negative relationship between diversification decision and income generated from *khat* sales is the outcome of the households' expectations of these directs economic sacrifies as they pursue diversification. The size of land allotted for *khat* production was negatively and significantly related to the probability and intensity of diversification. This implies that those farmers that use more of their land for *khat* production are expecting income sacrifice as a result of diversification than those that do not use their land intensively for *khat*. Total family size of the households was also negatively and significantly related to diversification decisions. This might be because when compared to households with small family size, large family sized households have larger cash expenditures to meet household needs such as clothing and education, the cumulative effect of which depletes the household's cash deposit for diversification. Unexpectedly, the model result also showed that extension contact has a negative and significant influence on diversification decisions. This is contrary to the accepted theory. The probable reason might be even though farmers have access to the service (as access does not adequately measure quality), the quality of service might not be to the interest of farmers, and hence there had no substantial change in attitude of the farmers. The other possible reason might be that extension service is not provided on on-farm agro-biodiversity

Marginal effects of changes in explanatory variables

Change in explanatory variables results into cumulative changes, which can be decomposed into the effects on probability and intensity of diversification. This is summarized in the last two columns of Table 2.4. Change in age of the household was found to positively and significantly affect the probability and intensity of diversification. The results computed indicate that keeping other factors constant a one year increase in household's age experience would increase the probability and intensity of diversification by 2.2% and 3.4%, respectively. A one percent increase in formal education level of the household was found to change the probability and intensity of diversification by 1.7% and 1.3%, respectively. Similarly, a change in the leadership roles of a household (years of experience in local leadership) results in 0.08% increase in the probability of diversification and 0.006% increase in the intensity of diversification. The estimated increase in the probability and intensity of diversification from a one percent change in the households' training exposure on environmental conservation were 1.6% and 2.7%, respectively. A percent increase in frequency of shocks experienced by the households increase their probability and intensity of diversification by 1.8% and 0.3%, respectively. Similarly, a percent change in a household's perception of future risks results in 0.43% and 0.81% change in probability and intensity of diversification, respectively.

On the other hand, the model output also showed that income from *khat* sales was positively and significantly related to the probability and intensity of diversification. This might be because in terms of monetary contribution for diversification practices households whose incomes sources are dominated with *kaht* sales have better potential than others do. The marginal effect value shows that a 1% increase in income from khat sales decreases the farmer's probability and intensity of diversification by 2.3% and 0.065%, respectively. The size of land allotted for *khat* production was also negatively and significantly related to the probability and intensity of diversification. The marginal effect results showed that as the size of land allotted for khat production increase by 1%, the probability and intensity of diversification decreases by about 0.42% and 0.53%, respectively. One percent increase in value of crops grown with modern technologies decreases the household's probability and intensity of income source diversification by 0.04% and 0.007%, respectively. A one-percentage increase in family size reduces the households' probability and intensity of diversification by 0.31% and 0.14%, respectively. Similarly, the probability and intensity of diversification were also observed to decrease by 0.94% and 0.51%, respectively, for a one percent increase in extension contact per three months time.

Conclusion and recommendation

The farming system in eastern Hararghe highland is characterized by gradual conversion of arable land into khat cropping resulting in diminishing land allocation for staple food crop production. Undue reliance on this cash crop often results in high risks of loss of livelihood income in events when climate change induced drought and wrist astonishes the plant. Income generation and better earning from khat sales was also found to be paradoxical with food security and poverty reduction in the absence of appropriate saving and channeling of such income into productive investment activities. Mechanism of effective income source diversification that provide for stable and sustainable income generation are prioritized policy concerns. Thus, the main purpose of this study was to identify the determinants of the probability and intensity of income source diversification using cross-sectional data collected from random sample of households engaged in khat cropping in two districts of the eastern Hararghe zone. Results indicated that khat cropping household's income source diversification decisions and the intensity of resources to be channeled into diversified income generating activities are influenced by a range of demographic, socio-economic, agro-ecological and institutional factors. The findings of the study imply that in the current faces of depleting livelihood conditions driven by agro-ecological, biophysical, and environmental changes, income diversification should be persuaded as a household response to risk and rational adaptation behavior. The specific demographic, socio-economic, and institutional factors identified in this study are suggested to be coupled with predictions on external climate risk factors in crafting polices aimed at optimizing household income source diversification for better stability and sustainability of income flows.

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3. College of Education and Behavioral Sciences

3.1 Challenging Behaviors in Preschool Children: Teachers' Perceptions and Experiences in Preschool Settings of Dire Dawa, Ethiopia

Aschalew Teshome

Abstract: The perceptions and experiences of challenging behaviors were explored among 64 staff working in 11 preschools. Semi-structured interviews were conducted to ascertain what behaviors in children are found most challenging and their possible causes; how they were managed and effectiveness of management strategies; and concerns communicated to parents. In addition, observation and open-ended questionnaire were employed to support the interview. Results showed that aggression, over-activity and bully/manipulative behaviors were perceived as the most prevalent and worrying. Exclusion, explanation, and occupying misbehaving were the most frequently used strategies for managing such behaviors. Staff communicated their concern with parents about behaviors that endangered the child's safety, out-of-character and persistent bad behaviors. Finally, social modeling and reinforcement strategies excluding punishment; a well designed classroom that is engaging and developmentally appropriate; teacher training and technical support in the area of children's social and emotional development and classroom management; and emphasis on the development of social and emotional skills in early education curriculum were forwarded as remedial solutions that might help to reduce the problem under study.

Keywords: Behavior management, Challenging behaviors, Preschool children, Staff-parent Communication, Staff perceptions

Introduction

Starting preschool education is supposed to be an enjoyable time, a time for playing, making friends, and learning for most young children. But this is not true for all children. Some of them may encounter difficulties to adjust themselves to the new environment. Others may be in conflict with others or they may be so shy and withdrawn that they seem to be in their own worlds. In either case, playing with others, making friends, and learning all the things a child must learn are extremely difficult for these children (Tirussew, 2000; Blasco, 2001). These problems arise from conditions within the child or external influences, which are not often noticed or understood by others. As a result, their behavior violates expectations for what is accepted as a "normal" and causes concern for their teachers, peers and parents (Hughes and Dunn, 2000; Babu et al., 2007).

Challenging behavior has been defined as behavior emitted by a learner that results in self-injury, or injury to others, causes damage to the physical environment, interferes with the acquisition of new skill, and/or socially isolates the learner (Emerson, 1995; Doss and Reichle, 1991). Similarly, Kaiser and Raminsky (2003) define challenging behavior as any behavior that interferes with children's learning, development, and success at play and harmful to the child, other children, or adults, which puts a child at high risk for later social problems or school failure.

Challenging behavior is likely to have onset in childhood and may be highly persistent over time. The consequences of it can include significant impairment of the health and/or quality of life of the persons themselves, those who care for them and those who educate them or work in close proximity. Social responses to it may include abuse, inappropriate treatment, deprivation and systematic neglect (Emerson, 1995). Within the care sector staff working with a child who shows challenging behavior have reported feelings of anger, annoyance, anxiety and being upset (Hastings, 1993). In an educational setting challenging behavior may cause severely restricted access to the curriculum or exclusion of the pupil from school. Pupils displaying challenging behavior are also a major source of intense stress in the lives of teachers (Hastings and Remington, 1994).

With increasing number of children attending preschool education in the urban communities, there is an increased prevalence of children whom staffs perceive as presenting challenging behaviors. These behaviors create chaotic school and classroom environments and overwhelm the capacity of schools to accommodate such kind of children effectively. Furthermore, there is strong evidence for continuity in disruptive behavior among children who display early anti-social behavior, with these children at a higher risk for persistent and severe disorders than children who show later onset of behavioral disturbance (Hughes et al., 2000; Kaiser and Raminsky, 2003).

Social, emotional, and behavioral difficulties may prevent children from participating fully in the preschool curriculum and from maximizing their abilities and educational opportunities. As a result of their challenging behavior, such children are seldom liked by their peers, teachers, brothers or sisters, or even parents. Moreover, such children are rejected, verbally abused, physically punished, excluded from class and play field most of the time (Babu et al., 2007). Such difficulties may be an early indicator of potentially more serious psychological problems. Failure to recognize and address these difficulties may adversely affect not only educational attainment result in poor academic outcomes but also

leads to the development of serious psychological and adjustment problems in both the short and the long term (Hughes and Dunn, 2000; Hastings and Remington, 1994).

On top of this, a country's economy depends on the competencies of its citizens and those competencies are set early in life. This means that in the lifecycle of human development, early childhood is a critical period that requires serious attention and investment. The investment made by society at early stage of human development pays back later through the productive contribution of today's children to the society. If a typical children at this stage of development are not provided with appropriate intervention, a country will set the condition for producing non-productive citizens who will not enjoy quality of life and whose contribution to the societal growth will be minimal (Tirussew, 2005; Blasco, 2001; Babu et al., 2007).

If there is no research input that addresses the problems and the needs of such kind of children within their social and cultural context, by the time they start elementary school, precious learning time has passed and opportunities for providing vital early intervention experiences and services are lost. Therefore, the main intent of the study was to explore challenging behaviors exhibited by preschool children in preschool settings and to forward remedial solutions that might help to reduce the problem under study with particular reference to some selected preschools in Dire Dawa, Ethiopia. Thus, the following research questions were set to be answered at the end of the study:

- What types of behaviors are perceived and experienced by the staff as challenging ones?
- What are the possible causes of challenging behaviors?
- What types of management strategies do staffs use to handle these challenging behaviors?
- Do staff members perceive these strategies as effective in promoting social inclusion and well-being of these children?
- What types of communication strategies are used by the staff with parents over their concern?

Objectives

- The general objective of this study was to explore the perceptions and experiences of preschool staff in relation to children with challenging behaviors and to suggest remedial measures. More specifically, it was designed to investigate; types of behavior most experienced by the staff as challenging ones; possible cause of challenging behaviors; management strategies that the staff use within the preschool micro system; effectiveness of management strategies as perceived by staff; and types of communication exist between the staff and parents over their concern.

Significance of the Study

The findings of the study might help to:

- empower teachers, schools, and parents on the management of challenging behaviors of preschool children;
- indicate the role and responsibilities expected from schools, teachers, administrators and parents concerning care and education of young children;
- detect challenging behaviors in children and intervene to minimize its impact on the learning and social development of young children and can be used as reference by similar institutions that are working closely with the issues of child care and education and base for further research.

Materials and Methods

The fundamental objective of this study was to explore the perceptions and experiences of staff in relation to children with challenging behaviors; possible causes, management strategies and their effectiveness; and the nature of communication that exist between staff and parents in some selected preschools of Dire Dawa and Model Preschool of Haramaya University. To do so, qualitative research approach was employed.

Sample and Sampling Techniques: Ten preschools were selected randomly from Dire Dawa and a model pre-school of Haramaya University was selected purposely as a sample (totally 11 preschools were selected). All the heads, main, and assistant teachers of the selected preschools were participants (informants) of the study

Methods of Data Collection: Observation, focus group interview, and open-ended questionnaire were employed as major tools to collect the necessary data from the participants of the study.

Observation: Observation was made by the investigators to identify types of challenging behaviors frequently exhibited, management strategies used by the staffs, the physical environment of schools; and the overall activities of the schools.

Focused Group Interview: It was the primary tool of the study to collect the necessary data from the participants. Semi-structured interview was prepared to ensure that all topics raised by the research objectives are covered. However,

considerable flexibility was permitted to enable the interviewers' to probe and follow up on specific themes that staff members were keen to discuss. There were 17 groups for the focused interview with a total of 64 participants; each of them consisting of 3-4 staff members. The number of staff in each group was minimized principally to place the staff at ease, stimulate confidence, and create a fluent stream of ideas within a range of 60-90 minutes per interview. The interview themes were structured around the four main objectives below but also flexible to allow participants to discuss on issues of their interests and concerns:

- Staff perceptions, understanding and experiences of challenging behaviors and their possible causes;
- Management strategies used to handle such kind of behaviors;
- Perceptions of the effectiveness of these strategies, especially in terms of social inclusion and social well-being; and
- Communication with parents concerning challenging behaviors

All interviews were audio taped for transcription and coding. In addition, the interviewers took notes to record ethos, mood, and affective aspects of the interviews.

Open Ended Questionnaire: It was administered to all teachers to elicit information /data that are not addressed through interview in case. The questionnaire had 8 questions including guiding questions that were covered through interview.

Data Collection Procedure: First, formal letter from the Department of Special Needs Education was sent to each school requesting to provide access to the setting. Then, community of each school was informed about the overall purpose of study and its importance. Observation was the first phase of data collection procedure. Then, focus group interviews were held with the staff in their respective schools. Finally, open-ended questionnaire was administered in each school.

Methods of Data Analysis: The audiotapes were fully transcribed and coding frame was generated and subsequently refined through discussion between the investigators. A *frequency count of the coded responses* was produced and coding categories were summarized into generic units or expanded to better reflect the subtle pattern of the information emerged during discussions. Since the 64 staff members were interviewed in groups in their 17 respective preschools, there were only 17 interviews to be coded. To best represent the pattern of responses from the interviews both *frequency data* and characteristic *qualitative comments* from the interviews were conveyed in the results. Categories in which frequencies of responses that were very low have mostly been omitted from the tables. In addition, data obtained from interview was supported by observation and open-ended questionnaire. Finally, based on the findings of the study conclusions were drawn and recommendations were forwarded.

Results and Discussion

Perception and Experience of Challenging Behaviors

Table 3.1 lists those behaviors which staff reported as most challenging behaviors expressed as percentages of the total number of behaviors reported, and adjusted to take account of the different numbers of groups interviewed across different preschools. From the initial interview transcripts, 23 challenging behaviors were identified and coded but they were later condensed into 9 main categories. Most of the behaviors are self-evident, but some need clarification. Refusal refers to children being totally uncooperative and not doing what they are told; social difficulties implies withdrawal and communication failure; emotional volatility means over-excited, or swinging from tears to wildness; over- activity refers to an inability to settle and distractedness which can be disruptive for others.

Table 3.1. Frequency of reported challenging behaviors

Challenging Behaviors	Frequency
Aggressiveness	57
Over-activity	46
Bully/manipulation	44
Inability to share	37
Emotional volatility	35
Refusal/uncooperative	31
Attention-seeking	28
Social difficulties	26
Language difficulties	26

As evident from Table 3.1, aggression, over-activity, and bully/manipulative behaviors are far more prevalent than all the reported challenging behaviors. Aggression may be directed in all sorts of ways (all the following quotes refer to comments by staff):

Pushing, hitting, being disruptive, disrupting other children, throwing furniture, throwing toys, hitting other children with toys . it can be at the adults or at the children.

Even if it is not easy to distinguish between those behaviors that are problematic for the future and those that may reflect purely transitory phases at preschool level, staff differentiated between more enduring and temporary behaviors. The inability to play properly with other children or to share appropriately is, for example, commonplace when children first enter preschool, but normally dissipates as a result of maturation and effective behavior management. One staff member reported that:

They just don't know how to share and play with other children when they first come into nursery . . . Sharing is a big problem which goes with age.

Generally, there were no observable differences in the kinds of activities that were associated with the occurrence of challenging behaviors, but staff commonly reported time-of-day or time-of-week effects as related to these behaviors and especially among children who typically have a much longer day in preschools.

For example:

Most difficult . . . probably when they are tired . . . towards the end of the day . . . at the end of the week . . . they are very tired on Friday.

Where staff did mention activities that made the children more disruptive, it was likely to be those associated with periods of over- or under-activity and those associated with tructure, for example, not being allowed to finish what they were doing because of an impending snack-break or the need to 'tidy-up'. Staff expressed their most concern about those challenging behaviors that were most prevalent, particularly aggressiveness, over-activity and bully/manipulative. Inability to share was viewed as a transient behavior and not, therefore, a large cause for concern. The criteria that staff used to judge whether a behavior was worrying fell into four categories: the nature of the behavior, its severity, frequency, and persistence.

I'm concerned about all kinds of behaviors . . . But it's the extreme behavior that makes me worry about why the child is doing something. Some of them come in and do things but they learn and then it stops. But, these kids. . . have been coming a long time and doing what they did the day they started.

Staff also expressed concern if behavior was a threat to the well-being of other children in the class, particularly when they were left to their own devices while the disruptive behavior was being dealt with:

Other children are not getting the attention they deserve. . . he really needed one-to-one, because when you were dealing with him there were another 34 children getting left . . .

From investigators' observation, the views about the impact on other children were voiced strongly in play field and assistant teachers appear to be generally less tolerant of challenging behaviors than the main teachers, may be due to lack of experience and training.

Perceived Causes of Challenging Behaviors

Staff reported that the causes of such behaviors fell into five discernable categories (Table 3.2). Perceived causes that are *child-related* are associated with a distinct medical condition and include children with language problems and other special needs. Causes of the child's behavior that are associated with the home are of two general types: *poor parental management strategies* (such as spoiling, absence of discipline, inconsistency in strategy, lack of experience), and *poor home circumstances* (such as neglect, family split- up, bad sibling relationships). The fourth category of attribution is to *childcare related* causes (the preschool itself), including lack of facilities, insufficient discipline or inadequate attention by staff, curriculum that does not address the needs of children and childcare hours that are too long. The fifth category relates to more generalized *society-related* attributions of blame including lack of basic values and surfeit of television, although these could arguably be ascribed to parental influence.

Table 3.2. Perceived causes of problematic behaviors

Causes Associated with	Frequency
The child	22
Parental management	51
Family problems	51
The preschool itself	34
Society	26

What is clear from Table 3.2 above is that home-based attributions are far more prevalent than any other type, divided equally between poor parental management strategies and poor home circumstances. Staff repeatedly suggested that

parents are inconsistent in the rules they apply at home, that they reward bad behavior, or are just too inexperienced to cope.

For example:

If you tell a child you are not doing something because he's done something wrong, you have to carry it through – which I don't think a lot of parents do. That is probably what is happening at home with a lot of them-the inconsistent rules and sometimes the extended families as well. . . so it's different rules in different houses.

The children themselves and society are afforded very little blame and the preschool system within which the staff operates was afforded little blame with staff viewing the challenging behaviors stemming from home environment than their own. There is less awareness among staff that behavior can be affected by the setting, and that challenging behaviors may just as likely stem from the preschool setting as from home. This may arise because in one setting children lack the competency that they have in another setting (adjustment problems). However, some staffs, especially main teachers, were more disposed to view the cause of these behaviors as lying within their own provision. Perhaps this is not surprising when children spend so much of their working day at preschool system.

They are here more than they are at home . . . and sharing space and time with so many adults and children.

Staff Management Strategies

Management strategies are aimed specifically at ensuring that the planned daily activities within preschool run smoothly and without disruption. Hence, they are directed at maintaining the children's performance in relevant tasks and facilitating their competence. However, different preschools have different cultures and differing degrees of tolerance for challenging behaviors.

From the initial interview transcripts, 18 management strategies were identified and coded but were later collapsed into five main categories. Table 3.3 summarizes the reported adoption of these strategies by the preschool centers.

Table 3.3. Behavior management strategies used by staff

Strategies	Frequency
Exclusion of child from activity or room	64
Explanation of inappropriate behavior	49
Occupying misbehaving child with another activity	40
Removing item causing dispute	34
Ignoring misbehavior	27

As it is evident from Table 3.3 above, all centers used exclusion as a strategy for dealing with difficult behavior. This ranged from exclusion from the room and contact with other children, through exclusion within the classroom (e.g., alone in a quiet corner), to excluding the misbehaving child temporarily from the activity but allowing unsupervised participation in another task. Availability of rooms and staff were factors to be taken into account in deciding management strategy at any specific time.

We take the child out; we'll ask them to go to the story corner and think about what they're doing. Then we tell them: 'I'll come back in two minutes to speak to you' – so we try to get away from their attention seeking . . .

Exclusion was usually just for a few minutes at most. Staff acknowledged social inclusion as an important principle in preschool provision, but felt that temporary removal of a disruptive child did not oppose this principle when emphasis was placed upon reintegration into the social group. For example, one staff member said:

The child is never actually taken away from the actual situation . . . Sits to the side, so that he can still hear the story, see the book.

Some staff spontaneously pointed out that children only learn what behavior is appropriate and inappropriate if they are included. Excluding them from the presence of other children does not teach them anything of use. Explanation to the child was another popular strategy focusing on explaining the practical implications of their behavior:

We explain the effect of why they might hurt themselves or somebody else is going to get hurt, that sort of thing . . .

Explanations also help the child understand how their behavior makes others feel:

It is trying to get them to think about what they have done . . . and to appreciate that other people have feelings.

Aggression, attention-seeking behavior and refusal to cooperate are behaviors for which staff required to use the full range of strategies presented in Table 3.3, although exclusion was reported as the approach most commonly used in dealing with aggressive behavior. For example:

Exclusion is used with situations where they were fighting, punching, kicking, shouting. This is really disruptive behavior that you just could not find acceptable because it would put someone in danger of getting hurt.

Table 3.3 also draws attention to ignore misbehavior as a strategy for dealing with difficult behaviors that are reported by several centers. This may reflect staff tolerance, or may be used strategically to offer no reinforcement at all to the child who is playing up simply to gain attention, or indeed may reflect avoidance of taking any action at all. Other strategies might have to be used if the challenging behavior persists. However, from investigators observation, other than the above listed management strategies almost all staff employed corporal punishment. As an indication, all staff

carries stick everywhere in the classroom, play field and so forth, which really contradict with what was reported during interview.

All centers reported consistency in their use of management strategies across staff in particular preschool settings. Various explanations of how this consistency was built up were reported. Some respondents viewed it as stemming from having worked together for so long that even when they started off with different ideas, over time, the staff share their own experiences of handling disruption, and develop consistent policies which reflect their corporate competency in handling challenging behaviors.

We have all just rather worked around each other and we all had our own way of doing it, and now we all do it the same. Moreover, we discuss how we are going to deal with certain situations so that we are all doing the same thing.

All centers recognized the need to be flexible as well as consistent in their management. Staff commonly changed their strategy if it was unsuccessful, or they tried different strategies with different children.

You try it. If it were something that is working, then I would not say there is any need to change it. But if it is not working, you have to change . . .

With respect to drawing upon internal resources for seeking advice on management of behavior, staff in all centers reported that they would consult fellow staff, preferring to consult a more senior colleague. Opportunities for staff discussion ranged from informal chats during class-time, lunch- time, or at the end of the day, to regular, formally scheduled staff meeting. Most discussion of behavior management issues took place at formal meetings. Sometimes informal discussion during class-time pre-empted the need for a formal meeting. Referring back to Table 3.1 and looking at the pattern of challenging behaviors across different centers, a strong impression emerges that the more such behaviors are reported, the more likely it is that staff will address them at formal staff meetings. In addition to eliciting staff views about how they managed disruptive behavior, the interviews also tapped into strategies for encouraging positive behavior . From interview analysis, praise emerged as a universally used encouragement and as a means of modeling desirable behavior and promoting competence.

We just catch them in good behavior and praise them. Every member of staff is very aware that if they see something that we want to encourage, they immediately draw everyone else's attention to it.

Praise was followed by public acknowledgement of good behavior and the awarding of stickers, stars and points on wall charts. Star charts were also popular:

We have a star chart where the children can be rewarded, like concern for someone else. If they do something special, if they're helpful at tidy-up time, things like that, you give them either a sticker or a star.

Many centers also employed activities to reinforce socially responsible behaviors towards others, or else encourage them to do positive things for themselves. It is significant that praise for these kinds of activities are declared very openly and publicly so that other children are encouraged to learn by example. Staff then encouraged children to accept society's behavioral norms while trying to reduce deviancy through modeling and reinforcement. This approach was geared towards promoting children's social inclusion and well- being.

Effectiveness of Management Strategies

Staff were asked about their perceptions of the efficacy of the strategies they employed to encourage positive behaviors. Most of the centers (7 of them) rated their strategies as moderately effective, and the remaining four rated their strategies as highly effective. Staffs were then drawn into a more general discussion about their behavior management policies. Staff in some centers acknowledged that they had a written policy but they varied in how useful they found these guidelines, some being very conscious of keeping practice in line with policy. Staff in three preschools, which claimed to have no policy, indicated the need for a vision of what the nursery believes is important, but stated that children's needs change so rapidly that a policy may hinder responding to such change:

Definitely with the two difficult children we've got this year, it's a different way of handling them from the ones we had two years ago.

Staff in all centers reported that management strategies were essential and beneficial to children. Table 3.4 below presents the factors, in rank order, most commonly cited as the outcomes of managing misbehavior. Social inclusion and preparation of children for their future responsible role in society are emphasized.

Table 3.4. Impact of behavior management strategies on misbehavior

Factors	Frequency
Improving understanding of acceptable behavior	39
Improving behavior in the long run	28
Continuity of activities in nursery	27
Better transition to primary school	26

At the top of the list comes improving understanding of acceptable behavior, which reflects staff awareness of the higher order objectives of education towards a regulated society.

They are able to tell you why it's wrong, when they've done it, and how the other person will feel. . . . So that when they do go to school . . . they are only going to have one teacher, so they're able to do everything for themselves.

Staff also reported that all children benefited from seeing behavior management strategies in operation, because they learn vicariously what the boundaries of acceptable and unacceptable behavior are:

You have to set goalposts. Children have to know . . . it's important to let them hear what's happened so that they know that they won't get away with it either.

It is interesting that different schools place their emphasis in different ways from teaching acceptable and unacceptable behaviors through reducing disruption to class, ensuring other children's safety and releasing staff time for other children.

Staff-Parental Communication

In the present esearch, our interest lies in staff perception of the communication they have with parents about challenging behaviors and the extent to which they try to engage parents in managing such behavior (Table 3.5). To explore these issues aseries of questions were included in the interview schedule with the general purpose of assessing whether staff encourage parents to become involved in the management of their children's behavior and how they do this. Most centers stressed the importance of reciprocal conversations in which parents or staff are equally likely to raise issues with each other, from the school or home perspective.

. *It works both ways. Most parents will say: how have they been today? Or sometimes, if the child does something at home, they'll ask if they maybe do it here, and the other way around? We are building up relationships with parents, so that if something negative is happening, we can approach the parents.*

The primary reason for staff to approach parents is for behavior which endangers the child's safety, or the safety of other children, and for out-of- character behavior and persistent misbehavior, although if staff are having routine regular conversations with particular parents, then any of the child's behaviors may come up for discussion.

Table 3.5. Circumstances for staff approaching parents about challenging behavior

Circumstances	Frequency
Endangering safety	54
Out of character	51
Persistent bad behavior	47
Constant communication	39
Positive feedback	37

With regard to staff perceptions of parents' receptivity, many centers reported that parents were very or quite receptive to approaches by staff about their child's behavior. However, staff from two centers reported a significant number of their parents being very unresponsive. This caused considerable problems because staff requires parental support to access external professional help:

I'm having problems trying to get the parents' permission for the help needed . . . If you have problems, then you can openly talk about the difficulties with the parents. When the parents haven't acknowledged that there are difficulties that make a huge difference.

When asked how they approach parents most staff interpreted this in terms of time of the day and social context. Generally, staff from all but one centre reported that their conversations occur at the end of the day/session rather than at any other time. Staff in one center reported that they expected parents to make an appointment. Staff in several centers reported that they would not speak to the parents about their child in front of the child or in front of other parents.

It depends on what it (the problem) is. We'll speak to parents . . . so that the child cannot hear…. other times we'll get the child to tell them what they've been doing.

Some centers reported a relatively high degree of consistency between home and preschool, though it was lower in some centers. The relationship between staff-parent communication and consistency of behavior between school and home appears to be relatively straightforward. Those centers which have poor communication (i.e., where parents seldom seek advice) tend to be those that show the least consistency. Similarly, those that have the most effective communication (i.e., where parents are most likely to seek or be given advice) tend to be those with the highest degree of consistency:

If we are having problems in the classrooms, we try to work out a strategy so that it is consistent at home as well.

Assistant teachers reported relatively little consistency between school and home. Good staff-parent relationships are much more visible between main teachers and mother of the child and parents may never or only occasionally seek advice from assistant teachers. Some assistant teachers do not see it as their role to give advice to parents about managing children at home:

No, I don't think I would be prepared to give a parent advice. In the class room it is my responsibility but at home I don't think it is my place.

Communication between staff and parents may not be as prevalent in some preschool settings as in others. However, it is clear that staff generally believe that challenging behavior requires to be tackled at home, whether or not they feel it is their place to discuss it with parents.

Conclusions and Recommendations

Conclusions

The main results related to the four primary interview themes can be summarized as follows:

Perceptions of Challenging Behaviors and their Possible Causes

- Aggression, over-activity and bully/manipulative were seen as the most prevalent and worrying types of challenging behaviors.
- Children's challenging behavior was attributed mainly to the home micro- system.
- Staff do not always appreciate that children's behavior is affected by the setting, nor that competency in one setting is not necessarily matched by competency in another.

Staff Management Strategies

- Six management strategies emerged for coping with challenging behaviors: exclusion; explanation; distraction; removal of items(s) causing dispute; ignoring misbehaviors; and social approaches.
- Centers were generally consistent and flexible in their use of management strategies. Main teachers were the most consistent and least flexible; assistant teachers were the least consistent and somewhat more flexible.
- Staff in centers that had most challenging behaviors were more likely to discuss behavioral management issues at formal staff meetings than through informal discussion.
- All centers encouraged positive, socially responsible behaviors. Whole-class management strategies were used to address the needs of specific children with challenging behaviors.

Perceived Effectiveness of Management Strategies

- All centers rated their management strategies as moderately or highly effective.
- Staff in some centers acknowledged that they had a policy which they treated as a broad framework; most saw the need to develop their own culture to meet their own circumstances.
- Staff acknowledged their role in relation to their children as socializing agents, for example, by helping children to learn acceptable and unacceptable behaviors of the society.
- Staff believed fundamentally that children's sense of social responsibility can be learned by example from other children.
- Although staff made frequent use of brief periods of exclusion to curb disruptive behavior they were very concerned about the need for social inclusion and participation in group activities.

Staff Communication with Parents

- Staff communicated most with parents over behavior which endangers the child's safety, where the behavior is out-of-character or persistently problematic, and least in relation to positive feedback on their child.
- Parents were generally receptive to feedback on their children and were willing to discuss and respond to behavior management issues.
- Staff generally reported moderately high degrees of consistency in management strategy between home and school.
- Some parents only occasionally sought advice from staff. Some staff especially assistant teachers did not see it as their role to offer management advice to parents.

Recommendations

A relatively unstructured interview approach was adopted so that preschool staff used their own constructs and concepts to describe how they managed difficult behaviors. Our focus was specifically upon active processes engaged in by staff arising from their perceptions, beliefs and experiences. The findings of the study may offer considerable support for staff on how to manage challenging behaviors that take account of children's behavior in preschool and the impact that this behavior has on other participants in preschool environment. Therefore, based on the findings of the study, the following recommendations were given:

The finding of the study revealed that consistency among all adults involved with the child's behavior management is essential. If teachers, parents and caregivers show consistency in how they respond, then the child is more likely to use the skills that he/she learns in his/her homes, preschools and in the community. Therefore, family and preschool teachers have to work together for the betterment of children with challenging behavior.

The findings of the study showed that all the preschool centers use exclusion as the primary strategy to manage children with challenging behaviors. This may leads to high rate of removal of children from preschool classrooms and activities due to their behavior problems. However, exclusion is against the principle of social inclusion. Children need to be included and can only learn their responsibilities in the process of interacting with other children, and socialized into acceptable behaviors within the school community. Children should be treated with dignity and respect and their needs should be met. Strategies to manage challenging behaviors have to exclude corporal punishment. This means that physical, verbal, or emotional punishments should not be used (i.e., smacking, shaking, verbal reprimands, shouting or any punishment that frightens, humiliates, or threatens the child). Rather, social modeling and reinforcement strategies should be employed so that children develop appropriate social skills that help them minimize the development and long-term effect of ongoing challenging behaviors.

The single best way to address challenging behavior in young children is to take steps to decrease the likelihood that it will occur. Prevention, early detection, and intervention of challenging behaviors in young children should be part of an effective preschool classroom. Creating a well-designed classroom that is engaging and developmentally appropriate and implementing schedules, rules, rituals, and routines can help create a positive classroom communicating to children how to act appropriately. When children understand what is expected and are provided the opportunity and know the appropriate behaviors in which to engage, they are more likely to choose this behavior, reducing their challenging behaviors.

Even if it is problematic to distinguish between behaviors that are temporary and in part developmental and those, which may be precursors of more serious behaviors, the finding suggested that challenging behaviors, which are apparent in early childhood, tend to persist and may become more severe in later years. Teachers who wrote comment were indeed concerned about the issue, and were glad they were being asked about it; clearly feel that the issue of managing children's behavioral problems is an important one. Therefore, teacher training and technical support in the area of children's social and emotional development and classroom management should be provided, ideally on an on-going basis and this may present an opportunity for further research.

Attending preschool education is sometimes linked to higher rates of challenging behaviors; especially in programs of lower quality. What is important here is that early childhood education experience should be of high quality. With regard to challenging behaviors, high quality means paying special attention to the social-emotional needs of children spending long hours in the presence of a group of peers. Childcare that does not adequately address the social-emotional needs of young children runs the risk of contributing to the development and expression of challenging behaviors. Any curriculum implemented in an early childhood education-setting needs to, along with a cognitive and academic focus, emphasis on the development of social and emotional skills.

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3.2 Internal Quality Assurance of Science and Technology Education in Ethiopian University: The case of Haramaya University

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Abstract: This paper focuses on assessing the internal quality assurance systems availability and identifies how much the university is aware of the quality of education they are delivering. For this, the perception of the students, course instructors, and respective college management on quality of science and technology education, the status of quality of education the departments are delivering along indicators of internal quality assurance and roles University management is playing in ensuring internal quality assurance of Science and Technology in Haramaya University was assessed. Three research objectives were developed to study the perception of the different stakeholders. About 1000 students, 5 lab assistants, 62 teachers, 6 department heads, 2 college deans, one University Central laboratory Head, one academic programs development and promotion director, and one University Academic vice-president took part in the study. Thirty-two item structured questionnaires were adapted for students and instructors based on European National Quality Assurance (ENQA, 2007) as modified by HERQA and experts suggestions. A simple random sampling was used for students and teachers and the management group was selected through purposive sampling. Frequency, percentages and weighted mean were used for data analysis. The study revealed that the students do not have the confidence that science and technology education offered in the University is up to their satisfaction. Similarly, majority of the teachers and University management lack confidence in the competency of the graduates despite the escalating number of students in science and technology fields in Ethiopian Universities. Moreover, the university does not have education quality assurance system at University level, and as a result do not know whether they are on the right track or not. Moreover, the role and commitments made by the University Management towards improving the quality of science and technology education were minimal. Thus, the result of this study urges the University management, teachers, and students to engage in establishing quality assurance mechanisms together with HERQA so that the university achieves its objectives of creating a basis for sustainable development.

Keywords: Quality Assurance; Quality Indicators; Science Education; Technology Education; Management.

Introduction

Higher education is increasingly required to overcome its problems, reorganize and be responsive to the needs of the society and the country. The sub sector focused on revisiting the vision and missions of the sector, improving quality and relevance, expanding, diversifying and ensuring equity of access, diversifying financial resources and improving efficiency of the system, as well as enhancing leadership and management (Ministry of Education, Ethiopia, 2010).

Ministry of Education, with an intention that education at all levels has to contribute to the development of the country has designed a reform on program and professional mix. Higher education institutions in particular have to train qualified man-power which goes with the real country's demand. Thus, according to the official document issued in March, the annual intake and enrollment growth and professional and program mix of Ethiopian Public Higher Education is according to the 70:30 percent professional mix (Strategy and Conversion Plan, 2010-2014). This indicates that the enrollment of new students into public universities will be on the basis of 40 percent into engineering and technology stream, 30 percent into the science streams (natural and computational sciences), 5% into pharmacy and health sciences, 5% into agricultural and life sciences and 30 percent in to the social sciences and humanities stream (MoE, 2008). In relation with this, Science and Technology Minister revisited its vision and policy and planned to achieve major objectives to build capability to generate, select, import, develop, disseminate, and apply appropriate technologies, in order to improve the knowledge, culture, and the scientific and technological awareness of citizen (Ayalew, 2008).

For the national policy paradigm to take place, the government is making a number of attempts. Among these, increasing students' enrollments, construction of new buildings (including dormitories, classrooms, and administration buildings), training, and supplying human resources are some of the changes being made together. Higher education is the second in receiving investment budget, next to primary education (Education Sector Development Program III, 2005/06-2010/11). The government is in intense condition of advancing intake capacity of universities, especially in science and technology. As stated in Education Sector Development Program (ESDP III, 2005/06-2010/11), the education sector with special focus on higher education and technical and vocational education (TVET), has the goal to contribute to poverty reduction and for the achievement of the Millennium Development Goals (MDG's). For reducing

the country's poverty level, quality education is the sole alternative, especially with more focus on science and technology. The summary report of the 6th Science and Technology Ministers' Round Table Meeting (October 4, 2009), on which Ethiopia participated stated that: *'To overcome the current economic situation, investment in science and technology is essential for sustainable medium- or long term economic development, not only looking to the short- term economic recovery.'*

Higher Education Relevance and Quality Agency (HERQA) when mentioning the attention the government to give for the implementation of the policy stated that: *'Unless the government is able to give priority to address the problems of quality, its planned reform in professional mix is unlikely to achieve its intended target of producing the necessary stock of expertise that can transform the nation's economy.'*

Based on these, higher learning institutions, which are the core for the delivery of trained manpower for industries have to check at what quality level they are delivering the training, which should be the concern of the 21st century institutions. Quality is the single most important issue in education, business, and government today. There are however, problems with today's education system. Jerome (2006) when stating about the education quality condition noted that students are graduating from university unprepared to meet the demands of the society. Quality in higher institution is explained by Ivancevich and Matterson (2002) as any organization including higher learning institutions to be effective and serve the purposes they are meant for and they must translate quality improvements into results. Campbell (2009) stated that an institution, which does not have a sound quality assurance and cannot ensure what it is doing is appropriate and relevant, and is being undertaken to an acceptable standard, could not easily demonstrate its worth. Thus, we can have only a limited confidence in a higher institution that does not ensure the quality of its activities and is unable to evidence that its activities and the attributes of its graduates meet the acceptable standards.

As indicated in Haramaya University strategic plan document (2007/08-2015/16), the University has put quality education as its number one overarching vision (Haramaya University, 2007). But the University does not have functional internal quality assurance system or policy to ensure how much they are executing their responsibilities. Therefore, the driving force behind the study is that unless we ensure the quality standard at which we are training trainees and support it with research based evidences, higher education institutions cannot be sure that they are on the right track of achieving the intended outcome. In order to address the above problem in this study, the following specific objectives were set.

Objectives of the Study

The study was designed to assess Internal Quality Assurance of Science and Technology Education of Haramaya University. Specifically, the study was sought to:

- Investigate the perception of the students and course instructors and respective college management on quality of science and technology education.
- Identify the status of quality of education the departments are delivering along the indicators of internal quality assurance.
- Examine the roles University management is playing in assuring internal quality assurance of Science and Technology education in Haramaya University.

Research Methodology

Descriptive survey method was used. The principal advantage of survey studies is that they help to collect information from large groups of peoples' behavior, attitudes, and opinions with very little effort, and in a cost effective manner.

Sample and Sampling Techniques

College of Natural and Computational Sciences & Institute of Technology students and teachers were selected using simple Random Sampling as there are no significant differences among the students and teachers and each of them gets equal chance to be selected. Out of 186 teachers, 62 teachers, which is about one third (1/3) of the population were taken. Fifteen management teams including University President, Vice-Presidents (Academic and Administration), two Deans, two Haramaya University Central Laboratory Heads, and Eight Department Heads were selected purposively because of their position and are among the respondents, which have central importance in assuring the quality of science and technology education.

Data Collection Tools

Based on the nature of data, the following data gathering instruments were selected.

Questionnaire

Questions were developed based on the European standards for internal quality assurance within higher education institutions were taken as a framework and the indicators were developed with the consideration of the recommendation of Higher Education Relevance and Quality Assurance (HERQA) of Ethiopia. The tool's reliability was checked through Cronbach alpha at 0.75 and its validity was checked through experts' opinions and necessary corrections were

made. Questionnaire was employed for instructors and students. Questionnaire was chosen because it helps the researchers to collect data from large number of respondents.

Interview

Interview was employed for some selected university management, the university president, vice presidents, selected college deans, lab assistants, instructors from some well established programs, program coordinators, department heads and deans, central laboratory heads, academic development and program director since their positions and their decisions affects academic issues. Interview was selected in order to get the respondents opinion and attitudes about the quality standard the programs under the college and institute are being run against the profile of the graduates and the expectations of the society.

Document

Documents used were: graduates' profile, university/colleges' memos related to quality education, HERQA publications and other available related documents. These documents help the researchers at least as a benchmark against which we may see the University's destiny in producing the desirable graduate and substantiate the primary data.

Data Analysis Technique

Quantitative data were analyzed using SPSS using frequency, percentage, mean and weighted mean. The qualitative data collected through interview were triangulated with the quantitative data. HERQA institutional quality audit report and college minutes of discussions regarding quality and quality enhancement on science and technology were also assessed.

Results and Discussion

As indicated in Table 3.6**,** 701 (70.1%) of the respondent students said that they strongly disagree and disagree with the idea that they are getting quality education. Similarly, 36 (58%) of the instructors reported that the education they are delivering does not satisfy them. It is only a small proportion of students and teachers who believed that the education they are getting and delivering is of quality. The interview result collected from different level university management also revealed that the management does not have the confidence for the existence of quality education in the college of natural sciences and technology.

Table 3.6. The perception of the students, course instructors and university management on the quality of Science and Technology Education.

		Students		Teachers	
Item		Frequency (N=1000)	Percent	Frequency (N=62)	Percent
Perception of students and teachers on the status of quality of science and technology education	SA	133	13.3	12	19.3
	A	135	13.5	9	14.5
	DK	31	3.1	5	8.06
	DSA	251	25.1	15	24.19
	SDA	450	45	21	33.8
Total		1000	100	62	99.89

SDA = Strongly disagree, DSA = Disagree, DK = Don't know, A = Agree, SA = Strongly agree

Indicators of Internal Quality Assurance

As indicated in Table 3.7 to Table 3.12 below, different items were asked regarding the indicators of internal quality assurance.

Table 3.7. Availability of policy and procedures for Internal Quality Assurance

		Students		Teachers	
Rating		Frequency (N=1000)	Percent	Frequency (N=62)	Percent
Valid	SA	205	20.5	19	30.6
	A	111	11.1	9	14.5
	DK	78	7.8	15	24.1
	DSA	316	31.6	8	12.9
	SDA	290	29	11	12.2

SDA = Strongly disagree, DSA = Disagree, DK = Don't know, A = Agree, SA = Strongly agree

Regarding the availability of policy and procedures for quality assurance in the University, the students and instructors rated it similarly. Accordingly, bout 290 and 316 students strongly disagree and disagree, respectively and about half of the instructors interviewed also disagree to the question regarding the availability of policy and procedures. Contrary to this, it is suggested that institutions should have a policy and associated procedures for the assurance of the quality and standards of their programs and awards. They should also commit themselves explicitly to the development of a culture, which recognizes quality and quality assurance in their work. To achieve this, institutions should develop and implement a strategy for the continuous enhancement of quality. The strategy and procedures should also have formal status and be publicly available. They should also include a role for students and other stakeholders (ENQA, 2007). To substantiate the case with primary data, the researcher could not get any clear policy and procedures through which the departments or programs assess the quality of education they are providing to their students.

Table 3.8. Mechanisms of program approval, monitoring and periodic review and awards

Rating		Students Frequency (N=1000)	Percent	Teachers Frequency (N=62)	Percent
	SA	107	10.7	14	22.5
	A	67	6.7	9	14.9
	DK	255	25.5	6	9.7
	DSA	268	26.8	11	17.7
Valid	SDA	303	30.3	22	35.5

SDA = Strongly Disagree, DSA = Disagree, DK = Don't know, A = Agree, SA = Strongly agree

Institutions should have formal mechanisms for the approval, periodic review and monitoring of their programs and awards. As one can see from Table 3.8, 303 (30.3%) and 268 (26.8%) students strongly disagree and disagree, respectively and even a significant amount of the respondents do not know that there exists an approval, monitoring and periodic review of programs and awards. A small number of respondents (107, 10.7%) strongly agree and 67 (6.7%) of them agree related t the issues under discussion.

One of the indicators for the presence of quality assurance mechanism is the presence of clear, simple, and transparent grading complaint handling mechanism. However, 531 (53.3%) of students strongly disagree that there is a pre-established grading criteria and transparent compliant handling mechanism (Table 3.9). On the other hand, about 1.2% of them reported that they do not know the existence of pre-established mechanism. About 19.5% of the students agree that there is a clear, simple and transparent grading complaint. The students' response in the open-ended question showed that the majority believe that they have the right to complain. However, they do not feel easy to pose their complaint to the teachers or departments, because the teachers may be annoyed against the students and suspect that it may affect their later achievements.

Table 3.9. Higher education students' sssessment as Internal Quality Assurance indicator

Item	Rating	Students		Teachers	
		Frequency (N=997)	Percent	Frequency (N=62)	Percent
There is a pre-established grading criteria, and also clear and transparent grading complaint mechanism	SA	124	12.4	31	50
	A	191	19.5	18	29
	DK	12	1.2	5	8
	DSA	139	13.9	7	11
	SDA	531	53.3	11	17.7

SDA = Strongly disagree, DSA = Disagree, DK = Don't know, A = Agree, SA = Strongly agree

Department heads and teachers noted that students pass or fail is decided by the will of the teacher or depends on the relative performance of the other students. There is no pre-established grading range used. Marking and grading is highly susceptible to bias, which may lead to unfairness as the names of students are found on assignments and examination papers. Moreover, the teachers responded that the so-called normal distribution 'all grade letters are there' regardless of the students' performance, which means teachers do not have a predetermined learning outcome. In relation with this, majority of the students are not satisfied with the grades and grading systems in the different programs.

Grading is a crucial element of assessment; particularly it is the determination of pass/fail boundary. If all students demonstrate achievement of the required number of learning outcomes of a course, then clearly all should pass the course. Similarly, if no students demonstrate the

required level of achievement, no student should pass. The decision as to whether a student should pass or not a course should not depend on student relative performance, but the extent of achievement of their learning outcomes. Grades should not be norm referenced, but has to be criterion referenced. When talking about grading, we have to know that the marking of exams and assignments should be standardized. This takes place, when students name does not appear on the exam and assignment. In addition, students' right of appeal should be clearly respected. All this could reduce the grading bias or unfairness (Cambel, 2007).

Teachers assess students through different mechanisms and students' assessment could be for different reasons: to identify how much the students are learning and show them their performance and to decide pass or fail results. However, what matters is not only assessing the students, but also providing the necessary feedback to the students since they learn out of it for the next learning, and since it is an integral part of students' assessment. Based on this, the students do not feel they are learning from assessments and at the same time do not know whether teachers feedback is useful or appropriate for their continuous learning.

Table 3.10. Quality assurance of teaching staff

			Students		Teachers	
Item	Rating		Frequency (N=1000)	Percent	Frequency (N=62)	Percent
There is quality assurance of teaching staff.	Valid	SA	89	8.9	6	10
		A	101	10.1	7	11.2
		DK	51	5.1	1	1.6
		DSA	119	11.9	23	37
		SDA	637	63.7	25	40.3

SDA = Strongly disagree, DSA = Disagree, DK = Don't know, A = Agree, SA = Strongly agree

Majority of the students, 637 (63.7%), strongly disagree with the teachers' use of active learning methodology (Table 3.10). The rest 119 (11.9%) disagree and 51 (5.1%) could not identify which teaching methodology the teachers are using. About 89 (8.9%) and 101 (10.1%) of the students strongly agree and agree, respectively in the teachers' use of active learning methodology. Similarly, majority of the teachers reported that the number of students in the class is large and active learning methodology could not be properly used. Whereas, 3 (0.003%) of them did not return the questionnaire. According to the data from HDP (2011) the background of the teachers in the two colleges showed that the majority of them have not attended pedagogical trainings except few refreshment trainings given by college of education at the time of recruitment.

Teaching requires knowledge of the subject matter to be taught, the pedagogical knowledge, and practical skills to teach and help students learn and abilities to assess students appropriately against developed learning objectives. Learning takes place through the active behavior of the student. It is what he does that he learns, not what the teacher does (Ralph, 1909). Moreover, if students are to learn desired outcomes in a reasonably effective manner, then the teacher's fundamental task is to get students to engage in learning activities that are likely to result in achieving those outcomes. Thomas (1986) adds that it is helpful to remember that what the student does is actually more important in determining what is learned than what the teacher does.

Teachers and department heads also reflected that the teachers preparation and the training they have got on active learning methods and the classroom supervision to be made is minimal or close to nil. In addition, the students also reflected that they were not comfortable with the subject matter knowledge of majority of the instructors. They further noted that some of the instructors were fresh graduates who do not have rich experience on the practical part of the courses they deliver. To substantiate this, the researcher investigated the profile of some instructors and found that many of them are first-degree holders, especially those in the institute of technology.

Table 3.11. Availability of learning resources and student academic support services

		Students		Teachers	
Item	Rating	Frequency (N=998)	Percent	Frequency (N=62)	Percent
Ther is sufficient learning resources and student academic support services	SA	110	11	12	19.3
	A	84	8.4	9	14.5
	DK	15	1.5	4	6.4
	DSA	229	22.8	16	24.8
	SDA	560	56.1	21	33.8

SDA = Strongly disagree, DSA = Disagree, DK = Don't know, A = Agree, SA = Strongly agree

As one can see from Table 3.11, 56.1% of the students strongly disagree with the availability of adequate and appropriate laboratory for their practical learning, and 22.8% DSA, and 1.5% do not know about whether there are adequate laboratory or not. Only 11% strongly agree and 8.4% agree with the statement that the department in which they are learning has appropriate and adequate laboratory to change the theory into practice. Whereas 0.02% of the respondent have not responded. In the contrary, it is believed that institutions should ensure that the resources available for the support of student learning are adequate and appropriate for the program offered. The interview result of department heads and deans also revealed that there is a serious problem of learning resources especially for practical activities in the workshops and laboratory facilities. The college management further added that they are not comfortable with the quality standard at which they are training the trainees, because of different reasons like lack of appropriate field attachment, laboratory equipment, and necessary facilities. However, the problems differ among the departments.

Physics Department

An interview result with the physics head and lab assistant concerning the practical aspects of physics subjects revealed the relative existence of some basic laboratory equipments. As to the researchers' observation of physics laboratory, the students were practicing measurement in physics. Their total numbers were about 23. There were two groups. The numbers of students in both groups were very small. This could enable every students the chance to practice through hands on approach learning. Moreover, the good side with this group of students was that they joined the field by their choice or first preference, which could directly contribute to their future academic success (Source: Physics laboratory, 2011).

The interview result conducted with the laboratory assistant and course teacher highlighted that, modern laboratory equipment in physics are still missing. Moreover, the department was also not daring to say that the students have acquired the necessary practical skills stipulated on the curriculum. The curriculum puts what and where the graduates are going to work on areas like 'computer interfacing', as medical physician in hospitals. They have not observed hospitals, had no practical exercise for example in observing and working on x-rays and any physics application in hospital. On top of this, their curriculum says that the graduates work in ministry of defense, but they have observed no physics application in defense ministery, and so on. Moreover, result of the interview conducted with key graduating physics students (2011) showed that the students do not know what they are expected to do or practice unless the department takes the initiative, which means the department is giver or depriver of knowledge. In addition, high knowledge and skills in computer technology are expected from the physics graduates, as they are highly demanded in high technology companies after graduation. However, students are not confident enough in skills in computer technology since they have not even got basic computer skills. The instructors, lab assistants and the college management themselves have similar feeling regarding students computer skill. The severity of the problem especially in the practical skills deficiency increased more after the high number of students enrollment in science and technology have started. The key informants among instructors in the College of Natural and Computational Sciences noted that the confidences they have on graduates' have been highly declining from time to time.

Chemistry Department

Interview result of the chemistry department revealed that there are chemicals to do some of the experiments, but there is no water. The laboratories are very narrow, unable to accommodate the increasing number of students. The department head said that one set up should be used by only two to three students, but currently the number of students on one set up is more than ten. In addition, there are no well-trained lab technicians both in quality and in quantity. Thus, in the presence of such multifaceted problems in the laboratory, it would be easy to guess the kind of science or chemistry education the department has been offering. As to the knowledge of the chemistry department head, there are no partner institutions locally or internationally which works with the department, which is similar to what is said by the top college management.

Concerning his knowledge of quality assurance, the head responded saying *'forget about quality, if we at least cover the portion, it would be great.'* At last, the department does not have the perception that the graduates received the required practical skills in campus and off campus, which the program requires, the graduate profile stipulates, and the market demands. For example, the 2003 E.C. batch was expected to visit 'industry on the course 'industrial chemistry' and also see about 'waste management in industries'. The nature of most of the courses calls for off campus visits to industries, but that visit and training did not took place.

On top of this, due to the high number of students, the University was not willing to allow the students for field trips as it incurs high cost and difficult to process the field trips and the industries themselves may not be willing to accommodate, assist, explain and show them so many things. When in campus and off campus practical skills that should be acquired by the students or graduates are compromised, one can deduce the likely graduate to be produced and obviously education quality is affected adversely. Respondent instructors further pointed out that the absence of standardized internal quality assurance mechanisms for the programs aggravated many of the education quality problems.

Institute of Technology

Civil engineering and electrical and computer engineering are the relatively old and well-established departments in the Institute of Technology. The numbers of students graduated up to now were also large. However, the workshops were not proportionally developed over the years, but numbers of students keep on increasing. Students' admission to IOT especially Civil engineering in Haramaya University is very high, close to 46%. But, when one sees the workshop/laboratory, it is not proportional to the number of students. One lecturer in the department pointed out that like other engineering and science fields, almost all of or majority of the courses demands practical learning. The workshop assistant also added that the workshop was not well equipped with the appropriate equipments the students are expected to see and perform, and even some of the very expensive equipments do not function. He further added that some of the workshop equipments were not known to the lab assistant and instructors themselves do not know how to operate. As a result, there are equipments which are not functioning for many years. For example, Tresial test apparatus, which is used for Road Quality Control, which the students are highly interested to see and practice was long kept not functioning. Abrasion test apparatus, which is used for road technology, functions but no one has the knowledge of it and they could not operate and practice. The intention of acquiring such equipment through government fund or donors was that the students work on and practice and thereby the quality of education or programs could be met. But, it is up to the University to train appropriate manpower with the necessary knowledge and skills to operate the workshop materials and workshop technologies and help the students to practice.

One lab technician said that I do not know operating Compacting Test instrument as a lab assistant *'I don't have the knowledge of it, but I operated through intensive reading and I am showing to the students more or less" he explained'.* There is also another apparatus called 'oven**'** which is used to see the soil water content, but the students' number and the apparatus number does not match, the knowledge of the assistant about it is also less.

Surprisingly, there are equipments, which the assistant does not know by name. The workshop assistant was asked about the frequent students complain in the workshop and said that 'they complain for all what they see, but, the students do not know what they are expected to do, what they have not done and 'we show them by being loyal to our profession. The workshop assistant accomplish many of the things through reading, especially those in 'soil and water engineering' stream. It is almost two years since he joined the university as a technical assistant, till now he have not got any training to improve his skill and update himself with new technologies. He expects an experience sharing with other better established Universities workshops. He also said that the purchasing committee has to include individuals from the profession when some materials are bought. He strengthened this by saying that there are relatively enough surveying materials, but easily broken due to low quality standard, because comments from professionals were not sought during purchasing and evaluation of the equipment. In general, it seems that the practical aspects or the workshop is given less emphasis and nobody discussed and worried or asked me the challenges the students face with regard to laboratory practical.

Institute of Technology has been exerting an effort to compensate workshop equipment shortages by using workshops of 'Menchen for Menchen' Harar. 'Menchen for Menchen' institute of technology has the necessary workshop equipment. But the number of students who uses the workshop is very large and the number of equipment does not match with the number of students. Although the students appreciated the effort made, they complained that going there, doing the practice and going back to University is very difficult and tiresome. The instructors also said that they feel tired supervising them going that much distance where they have no additional incentive or recognition from the university or the college. In general, the students who practice in 'Menchen for Menchen' said that the effort made by the University to minimize the theory-practice gap of engineering and technology education is appreciable and it could not be achieved otherwise.

Electrical and Computer Engineering

Electrical and Computer Engineering is one of the programs of IOT since 1997 E.C. An interview conducted with the program coordinator indicated the existence of relatively better books or reading materials, qualified teachers (about 10 MSc and one Expatriate PhD), which give the confidence to say that graduates are qualified. The coordinator said that even though the department did not conduct tracer study, graduates informally told the department that they are employed in many organizations. The coordinator further said that they did not conduct discussion at department level on how to enhance the quality of education. With regard to resource, for about 4000 students there are only 50 computers, which are mainly used by graduating students, and those who take computer courses. The theory-practice gap is reduced by taking some students to 'Menshen fur Menshen', but still there are gaps. Different equipment in electrical engineering laboratory are known to anybody. No one knows whether it is functioning or not. Like the other natural and computational science lab assistants, the lab assistants in the Institute of Technology also reported that the materials are very expensive and it should not be operated by trial and error. The lab assistants did not get up-to-date training on new technology, apparatus, and equipments. Students of Electrical and Computer Engineering have to be updated with new technology. As a result, instructors and lab assistants should have updated knowledge both theoretically and practically to help the students. However, students are not satisfied with the knowledge of most instructors. This can be understood from what two students explained:

Electrical student A: As a critical analyst, I do not have the required practical skills. However, with my effort, I have tried to fulfill many gaps. I would like to acknowledge very few teachers whom I can say **'excellent teachers –who taught me a lot'!**

Electrical student B. As a student, I have to take part in teachers' evaluation, and students and teachers should sit together and evaluate one another formally. The serious problem is the block courses which adversely affected the performance of the students which should be avoided if possible, otherwise reduced. Courses which we took through block are not covered sufficiently and it does not cover the lab hours. There should be well-equipped laboratory with internet access. The respondent believes that the management does not follow up the teachers in general.

Table 3.12. Information systems and public information

		Students		Teachers	
Item	Rating	Frequency (N=1000	Percent	Frequency (N=62)	Percent
College publish up-to-date information	SA	198	19.8	24	38.7
	A	113	11.3	13	21
	DK	96	9.6	3	4.8
	DA	243	24.3	14	22.5
	SDA	350	35	8	12.9

SDA = Strongly disagree, DSA = Disagree, DK = Don't know, A = Agree, SA = Strongly agree

The students said that they do not know whether the college publishes up to date information on the quality of education they are delivering (Table 3.12). One of the internal quality assurance standards of higher education is that they have to publish up to date information on quality education they are providing. However, 350 (35%) and 243 (24.3%) respondent students strongly disagree and disagree, respectively to the statement saying their college publishes up to date information on the education they are delivering. However, more than half the teachers said that the college publishes up to date information regarding the quality of education. Contrary to the teachers' response, department heads and some of the college's management indicated that there is no publication periodically in promoting quality and appreciated if it existed. As *Campbell (2007) puts, literatures reveal that institutions should be able to publish up to date, impartial and objective information, both quantitative and qualitative about the programs and awards they are offering. As some literatures put 'If an internal quality assurance system is to operate efficiently and effectively, it needs to be supported by a strong information system. Such a system can inform those responsible for quality assurance in areas such as students' progress in relation to entry grades and choice of programs, the attainment of students, staff qualification, experience and teaching loads, teacher evaluations, students' attrition, and destination will be that quality assurance relies on evidence.* In general, the absence of this kind of publication in the institution implies that there is no quality assurance mechanism, thus quality of education is not prioritized.

3.3 The Role of University Management in Internal Quality Assurance of Science and Technology Education in Haramaya University

The university leaders (department heads, deans, concerned academic vice presidents, and the president) were asked on how much they have been contributing to quality of science and technology education in such an aggressively emerging fields in relation to the 70:30 program and professional mix.

They said that their University has been working better in all regards and new buildings are under construction. The university is also aggressively recruiting qualified staff for the profession and purchase up to date books. But, they do not feel the challenge of quality is fully addressed, thus the qualities of graduates they are training have been deteriorating. In some cases, institutions or educational leaders only consider quality issues or standards when it is time for the annual accreditation review. While accreditation is a potential and valuable result, it is not an absolutely necessary impetus. Striving for quality assurance is a process that can be started at any time and can be continued with leadership and support. Educational leaders in institutions play a key role in this process. Bryman (2009) reported that one of the three top qualities of successful leaders in education is the ability to promote excellence in teaching and learning in a department or program.

The researcher tried to assess if the established quality assurance system are developed based on the culture, administrative, resource, and economic contexts. But, there was no clear and explicit system to all stakeholders. There was just a talk about quality. Each educational institution exists in a unique context, with accompanying restrictions and limitations on resources and flexibility of operations. The challenge for educational leaders is to find the balance, determine what is feasible at a particular time and encourage quality, while taking care to avoid stifling innovation and creativity at the same time. This is a global issue that all educational leaders face.

Many institutions cannot address all aspects of the administrative and program management at once, but must prioritize them based on where the greatest need may exist, and where the most beneficial impact could be realized. There are a number of reflective questions for educational leaders when considering the quality assurance process. The key to quality assurance is to start the process. Quality assurance is a system, and starting at one point within the system will lead to significant changes in other parts of the system, hence one must start somewhere (Leadership Foundation for Higher Education, 2006). The top management and the middle management of the University did not usually discuss on issues related to quality education and quality assurance mechanisms.

Conclusions

This paper focused on the massification of Ethiopian higher education institutions visa-vis education quality, with special emphasis on Science and Technology Education. The result showed that the high pressure placed on higher education of the country in student enrollment lead to declining quality of education. Thus, there is a need for internal quality assurance systems at the university level to ensure the quality of education in general and Science and Technology education in particular. Areas of focus for improvement includes availability and proper functioning of laboratory facilities, students assessment mechanisms, policy and procedures for quality assurance, public information, quality of teaching staff, approval, monitoring and periodic review of programmes and awards, learning resources and students support services. In conclusion, the researcher stress that there should be internal quality assurance system to ensure the standard of the graduates. If not Universities cannot dare to say, they are accomplishing their mission.

Recommendations

- The students should be concerned about their education, how much they are getting quality education, which would make them competent in the world of work.
- All instructors especially teachers in the science and technology education should be sure that they are delivering education as per the standard set on the curriculum. Moreover, the respective instructors should be concerned with the quality of education delivered to students in the department and need to have confidence in the theoretical knowledge, the attitude towards their profession and their practical competence.
- The program leaders or the department or respective school heads as the case may be should make sure that the students are getting the necessary knowledge and skills as per the competency set and the standards for ensuring quality of education. On top of this, the department heads should work to the maximum in giving support to the teachers so that they utilize their maximum effort to help the students.
- Above all, multiple roles are expected from the respective colleges management. They should play an intermediary role between the top university management and the program heads and/or the teachers and students in realizing the universities vision through creating a forum for discussion among the students, teachers, program leaders, lab assistants, and even the top university management when necessary.
- In order to achieve the Ethiopia Growth and Transformation Plan (GTP) and for Haramaya University vision to put basis for sustainable development, all concerned bodies, especially University officials should work in harmony towards enhancing the quality of education to be winners in the era of flourishing number of graduates in Science and Technology field.

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4. College of Natural and Computational Sciences

4.1 Department of Biology

4.1.1 The potential and Traditional Medicinal Values of High Niche Genus of *Aloes* in Eastern Hararghe Lowlands, Ethiopia

Anteneh Belayneh, Negussie Bussa and Sintayehu Workineh

Abstract: Ethiopian plants have shown remarkably effective medicinal values for many human and livestock ailments. That is why the main thrust of this study centres on the potential and use of traditional medicinal value of the genus Aloes in the eastern Hararghe lowlands. Seventy five systematically selected informants including twenty traditional herbalists (as key informants) participated in the study. Semi-structured interviews, discussions and guided field walk constituted the main data collection methods. Techniques of preference ranking, factor of informant consensus and spearman rank correlation test were employed in data analysis. A total of eight Aloe species were identified from the study area. These are Aloe pirottae Berger, A. pubescens Reynolds, A. bertemariae Sebsebe & Dioli and A. ruspoliana Baker (From Erer and Daketa Valleys), and A. harlana Reynolds, A. megalacantha Baker, A. trichosantha Berger subsp. longiflora Gilbert & Sebsebe and A. retrospiciens Reynolds & Bally (from Dengego Valley). Three of them are endemic Aloes (Aloe pirottae, A. trichosantha subsp. longiflora and A. harlana). All these aloe species are used as traditional medicinal plants for both human and livestock ailments. Among these, Aloe pirottae is the most popular and highly valued medicinal plants in Babile Wedera. It is a species endemic to Ethiopia and valued as a remedy for malaria, tropical ulcer, gastro-intestinal parasites, gallstone, eye diseases and snake bite. The jel extracted from dried and ground plant material, called SIBRI (Oromo language), was used to clean the colon. In addition, a total of 51 traditional medicinal plant species in 39 genera and 28 families were recorded. This underscores the importance of genus Aloes for the people living in the area and the potential of the resource for development. Consequently, the study area deserves urgent conservation priority coupled with mechanisms for the protection of the associated indigenous medical lore.

Keywords: Aloes; Endemic Aloes; Erer Valley; Ethnomedicine; Eastern Ethiopia

Introduction

There are over 450 species of *Aloes*, in which 200 are concentrated in the southern and eastern Africa (Reynolds, 1996; Newton, 2003). Most of these *Aloes* are exploited for medicinal purposes. The genus Aloes have high international market demand for their products like *Aloe* gum, *Aloe* jel, live plants, leaves, etc., which are used by cosmetics and pharmaceutical industries in Africa, Europe, middle east and Asian countries. That is why *Aloe* sap harvesting for export supports thousands of poor inhabitants in Eastern Africa (Wabuyele and Kyalo, 2008). For example, Uganda, Karamoja district has the potential of exporting about 10,000 tons of crude Aloe gum and Kenya about 2,200 tons. With the price of USD 5/kg, Uganda can easily earn about USD 50,000,000 and Kenya USD 11,000,000 from sales of *Aloe* crude gum (Mukonyi *et al.,* 2007). This shows that sustainable utilization of *Aloe* resources in the dry lands is capable of contributing to improve livelihoods, local and regional development as well as enhance resource conservation.

Ethiopian plants have shown remarkably effective medicinal values for many human and livestock ailments. Some research results are found on medicinal plants of the south, south west, central, north and north western parts of Ethiopia. However, there is lack of data that quantitatively assesses the resource potential, the traditional indigenous knowledge on the use and management of medicinal plants in eastern Ethiopia. In the drylands of Ethiopia, many species of *Aloe* exist on less fertile and rocky areas which are not suitable for agricultural activities (Sebsebe *et al.,* 2000). Some research works done in the drylands of Ethiopia indicate that there exist huge potential of *Aloe* spp. in the wild and the local communities make use of them for traditional medicines to treat major health problems like malaria, tropical ulcer, etc. In addition, they make use of some *Aloe* spp. for soil conservation/compaction, food and cosmetics/beauty therapy. For example, *Aloe harlana* Reynolds is an endemic species found in Dengego valley specifically around Harla (the small village found between Dengego and Dire Dawa, Eastern Ethiopia) (Hedberg & Edwards, 1989). The specific epithet '*harlana*' refers in Latin to the fact that the plant is endemic and originated from Harla area. However, there is no information about the current status and distribution of this endemic species except that few professionals from their personal communication indicated that it is used as a traditional medicine for human and livestock by the local communities.

The fact that lowland of East Hararghe zone of Oromia region is well known for huge potential of various species of *Aloe* (Sebsebe *et al.,* 2000; Anteneh, 2006) made us plan this study aimed to investigate the current status, distribution and potentials and traditional medicine values of the high niche genus of *Aloes* in the Eastern Hararghe lowlands, specifically in the wider habitats of the Erer and Daketa Valleys, and the Dengego-Kersa drainage basin towards Dire Dawa. The local communities (Oromo and Somali) in these areas make use of different species of *Aloe* for various purposes such as traditional medicine for both human and livestock, food and cosmetics (Anteneh, 2006). The tendency of *Aloe* spp. growing on less fertile, rocky and non-agricultural area, that constitute considerable portion of the east Hararghe lowland is a good opportunity for rehabilitation of such areas with large scale cultivation for commercialization. The main thrust of this study centres on the potential and use of traditional medicinal values of Aloes and existing local knowledge in eastern Hararghe lowlands. The results will be used to fill knowledge gaps and recommend further research direction for future development of *Aloe* species as well as for setting up of conservation priorities, preservation of local bio-cultural knowledge, sustainable use and development of the Aloe resource and its ecology.

Materials and Methods

Study area description

This study was conducted in the lowlands of East Hararghe zone mainly in the Erer and Daketa Valleys which is part of the Wabi-Shebele drainage basin and the Kersa-Dengego Valleys and mountain chains which is the Awash drainage basin (Figure 4.1). Most of these areas have an elevation above sea level that ranges from 1,500 meters in the northwest (Kersa Valley), falling to about 900 meters above seas level; along the southern limits of Erer and Daketa Valleys.

Data collection

A reconnaissance survey of the study area was conducted in order to identify all stockholders, determine the major centre of the study, sampling areas/sites, informant sampling, etc. Ethnobotanical data were collected in two different seasons, from September to November 2010 and June to August 2011. Participatory Rural Appraisal (PRA) techniques were employed to collect data, as recommended by Martin (1995) and Cunningham (1996). Eight sampling sites were identified from Babile Wereda in Erer and Daketa Valleys where settled farmers and trans-human pastoralists were found and indicated on the location map of the study area (Figure 4.1). Ethnobotanical information was collected from 75 informants (57 male and 18 female). Among the 75 informants, 20 were key informants (traditional healers) selected with the assistance of clan leaders, peasant association leaders and members of the local community following Hedberg (1993), Martin (1995) and Cotton (1996). Purposive sampling technique was used for selection of key informants while for the others stratified random sampling was employed. The informants were grouped into three age groups, young (20-35), adult (36-50) and elderly (above 50) to see how the knowledge varies with age.

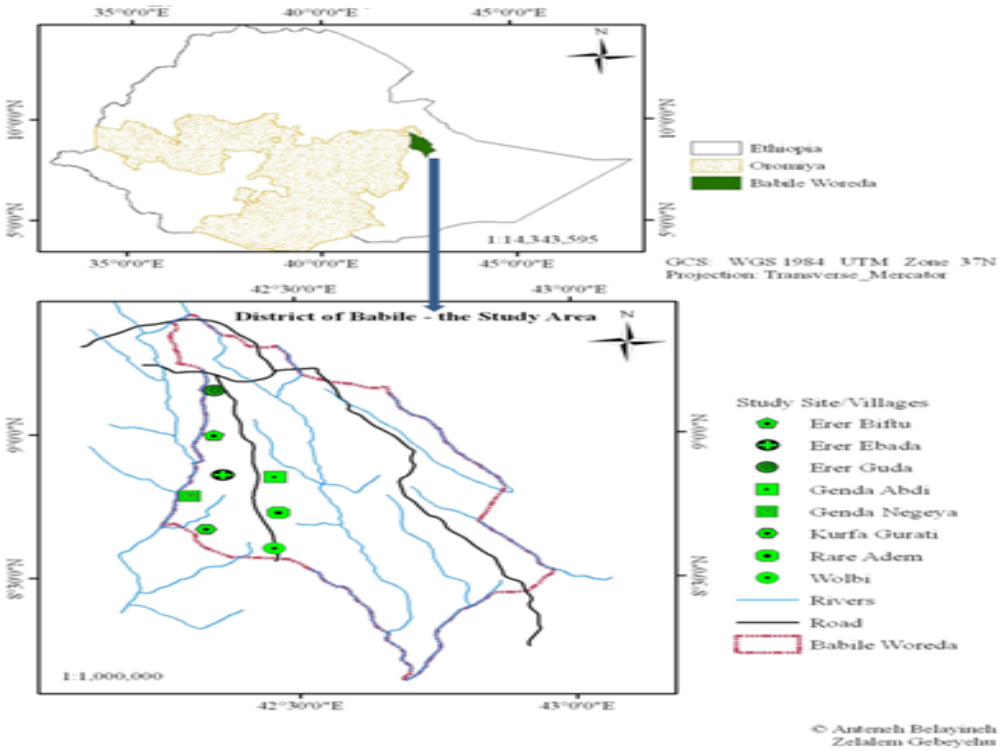

Figure 4.1. Location of study areas in Babile District

Before carrying out the interviews and group discussions, an oral Prior Informed Consent (PIC) was sought from every respondent. Semi-structured interviews and group discussions were administered in the local (Oromo and Somali) languages to collect basic information on the Indigenous Knowledge (IK) and use of Aloes species including their local names, diseases treated or controlled, part used, conditions and method of preparation, part administered, dosage used and major drawbacks. In addition, practical observation sessions and guided field walks with key informants were employed to collect voucher specimens of each medicinal plant species more of which were the genus Aloes. Most of the interviews were made in the field in order to avoid the risk of confusing identity of plant species by repeated inquiries at least three times with the same and different informants so as to confirm the validity and reliability of the recorded information.

A total of 60 quadrats, each 20 x 20 m, were laid out to make plant species inventory and Aloe species density data collection as recommended by Kent and Coker (1992). On each quadrats and specimen collection sites, data on altitudinal range, grid references and habitat notes was collected with Garmin 48 GPS. Specimens were collected and numbered on the quadrats, later identified using taxonomic keys in the relevant volumes of the Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989, 1995; Edwards *et al.,* 1995, 1997, 2000; Hedberg *et al.,* 2006) and through visual comparisons with authenticated plant specimens kept at National Herbarium (ETH) of Addis Ababa University and at the Herbarium of Haramaya University. The identification was finally confirmed by a senior plant taxonomist and voucher specimens of the medicinal plants deposited at both herbaria.

In some selected site in the field, leaves of Aloe species was harvested for sap field analysis and collected on a plastic basin. After 30 minutes, the volume of sap released was measured using a calibrated measuring cylinder.

Data analysis

Ethnobotanical data were analyzed using both qualitative and quantitative methods following Martin (1995) and Cotton (1996). For each medicinal plant, the proportion of informants who independently reported its use against a particular disease/disease category, the informant consensus factor (F_{ic}) was calculated using the formula: $F_{ic} = n_{ur} - n_t / n_{ur} - 1$ (Heinrich, 2000).Where, n_{ur} is the "number of use-reports" in each disease category and n_t is the number of taxa used.

Based on the general informant consensus, the preference ranking technique was employed to rank the priority medicinal plants as given by key informants' preferences indicating the degree of efficacy (Cunningham, 2001). In the preference ranking exercise, an integer value (1, 2, 3, 4 and 5) was given, where the most important medicinal plant was given the highest value (5), while the least important is assigned a value of "1". These numbers were summed for all respondents, giving overall ranks to the medicinal plants. Spearman rank correlation test was run in SPSS 18.00 to analyze the correlation of the informant consensus value and the informant preference ranking value, and binomial test was run in SPSS 18.0 to evaluate the depth of knowledge with age categories in which pair wise age category test was considered. P-value of less than 0.05 was considered a statistically significant difference. MS Excel Spreadsheet was used to generate bar graphs.

Results and Discussion

Eight Aloe species (Family Aloaceae) were documented as traditional medicines against human ailments (Table 4.1). Out of these, three are endemic Aloes (Figure 4.2).

Table 4.1. List of Aloe species and their distribution

Species name	Collection area	Endemicity
A. pirottae Berger	Erer Valley	Endemic
A. pubescens Reynolds	Erer and Daketa Valleys	Not endemic
A. bertemariae Sebsebe & Dioli	Lower Erer Valley	Not endemic
A. ruspoliana Baker	Lower Daketa Valley	Not endemic
A. harlana Reynolds	Harla village and Dengego mountains	Endemic
A. megalacantha Baker	Dengego mountains	Not endemic
A. trichosantha Berger subsp. *Longiflora* Gilbert & Sebsebe	Dengego drainage	Endemic
A. retrospiciens Reynolds & Bally	Dengego Valley and mountains	Not endemic

Though these eight Aloe species were recorded from the study areas, their population structure and density showed significance difference ($p > 0.05$). The density per ha indicated that *Aloe megalacantha* has the highest density whereas *A. trichosantha* subsp. *longiflora* the least (Table 4.2).

Figure 4.2. Endemic *Aloes*: i) *Aloe pirottae* ii). *Aloe harlana*

Table 4.2. Population density per ha of the Aloe species in the study areas

Species	Mean ± S.E. individuals ha^{-1}	Minimum individuals ha^{-1}	Maximum individuals ha^{-1}
A. pirottae	31 ± 9.93	4 ?	117
A. pubescens	219 ± 83.3	64	543
A. bertemariae	115 ± 51.4	33	235
A. ruspoliana	285 ± 98.2	12	443
A. harlana	22 ± 7.76	2 ?	107
A. megalacantha	419 ± 103.3	64	1343
A. trichosantha subsp. *longiflora*	7 ± 3.4	1	21
A. retrospiciens	385 ± 88.2	92	943

The result of the population density showed that the three endemic species i.e., *Aloe pirottae, A. trichosantha* subsp. *longiflora* and *A. harlana* are locally threatened. This might be related to over use of these two species for medicinal purpose. Some popular works on the Ethiopian plants indicated that many endemic plant species are highly threatened (Ensermu, 1996; Sebsebe and Nordal, 2010).

Medicinal plants that are more popular and widely used by the local community have been prioritized based on frequency of citations. Species that received more than 75% informant report are given in Table 4.3. For these species, the results show high frequency of citations ranging from 76-96. This shows that there is a considerable level of agreement on the therapeutic worth of these species in the study area. The greater independent citations a particular species receives for the treatment of a certain illness category, the greater is the cultural importance (Berlin and Berlin, 2005a). In this respect *Aloe pirottae* has been highly cited indicating the therapeutic worth of this plant.

There was repeated mention of the extract from *Aloe pirottae* for use to treat tropical ulcer, eye diseases, malaria, snake bite, gastro-intestinal parasites, gallstone and the jel is dried and ground to produce a product locally known as SIBRI in the Oromo language, which is used as a colon cleaner. The reports also showed that the leaf, seed and flower of *Azadirachta indica* were concocted and used against malaria, fungal infections and intestinal worms while the root of *Hydnora johannis* was used to treat wound, haemorrhage, diarrhoea and painful body swelling, locally known as GOFLA in the Oromo language (Anteneh *et al*., 2012).

Preference ranking value obtained based on the degree of efficacy didn't show a significant correlation (Spearman correlation test, $r = 0.188$, $\alpha = 0.05$, $p = 0.275$) with that of the informant consensus value. Pharmacologically effective remedies are expected to have greater informant consensus (Trotter and Logan, 1986). *Aloe pirottae*, *Balanites aegyptiaca* and *Tamarindus indica* are the three leading species for being used as effective remedies against the corresponding ailments (Table 4.4).

Table 4.3. List of ten medicinal plants cited by more than 75% of the informants

Scientific name	Ailment	No. of informants	% of total
Aloe pirottae	Tropical ulcer, Eye disease, Colon problem (SIBRI), Malaria, Snake bite, Gallstone and Insect repellent	48	96
Azadirachta indica	Malaria, Fungal infection, Intestinal worms	47	94
Hydnora johannis	Haemorrhage, Diarrhoea, Swollen body part (GOFLA), Wound, and Mouth infections	45	90
Tamarindus indica	Stomachache/parasite, Malaria, Dysentery, Wound, Fever and Haemorrhoids	44	88
Balanites aegyptiaca	Snake bite, Premature ejaculation, Influenza, Malaria and Wound	42	84
Acacia albid	Stomachache, diarrhoea, Haemorrhage, Cough, pneumonia, Postpartum complications and Kidney disease	41	82
Portulaca oleracea L. subsp. *oleracea*	Gastritis, peptic ulcers, Constipation, and fungal infections	40	80
Acacia nilotica	Mouth infection, Toothache, Bad breath (Halitosis), Dysentery and Haemorrhoids	39	78
Acacia senegal	Eye disease, Backbone pain, Constipation and Stomachache	38	76
Asparagus leptocladodius	Kidney & liver disease, Vomiting of children (Emesis)	38	76

Conclusion and recommendation

Obviously, the genus aloes are very important as herbal medicines in the study area, which is an integral part of their culture and also modern medicine is unavailable and unaffordable for most people in the study area. In the lowlands of East Hararghe, there is a considerable potential of the genus aloes which are promising for development. Most of the species are in use for various purposes by the community, food, medicinal and cleansing. Most of the species in the genus Aloes investigated in this study are growing on less fertile, rocky and non-agricultural areas, so not competing with croplands. The existing Aloe resource and indigenous knowledge will attract the emerging food processing, cosmetic and pharmaceutical industries in Ethiopia. It is worth noting that the endemic Aloes need immediate attention for their conservation.

Table 4.4**.** Preference ranking of most preferred medicinal plant species based on overall effectiveness to treat human ailments

Species name	Respondents (Traditional healers)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Score	Rank
Aloe pirottae	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	74	1
Balanites aegyptiaca	5	5	5	5	5	5	5	5	4	4	5	4	5	5	5	72	2
Tamarindus indica	5	5	5	5	5	5	5	5	4	5	5	4	5	3	5	71	3
Azadirachta indica	4	3	5	5	5	5	4	4	5	5	5	5	5	5	3	68	4
Acacia albida	5	4	5	5	3	5	5	3	3	5	4	3	5	3	4	62	5
Hydnora johannis	5	5	5	3	3	3	5	5	3	5	4	3	4	3	5	61	6
Portulaca oleracea	4	3	3	2	3	2	4	3	3	5	4	3	3	3	4	49	7
Acacia robusta	5	4	3	3	1	2	3	2	4	5	4	3	2	3	4	48	8
Withania somnifera	5	4	2	2	3	2	5	2	3	4	4	3	2	3	4	48	9
Cucumis dipsaceus	5	4	3	3	4	2	2	2	3	2	4	3	2	3	4	46	10

Out of these top ten preferred and efficient medicinal plants, some including *Azadirachta indica, Portulaca oleracea* and the *Aloes* are also included in the WHO list of most used medicinal plants (WHO, 1999-2001).

Finally, we recommend that there is a need to prepare the full package on the genus Aloes in east and west Hararghe lowlands and highlands to fill the following knowledge gaps to support the livelihood of smallholder families and due to its potential for conservation of degraded lands.

- Identify and document the genus *Aloe* spp. which are potential for commercialization and to assess the Indigenous Knowledge (IK) related to the various uses of aloes, local processing techniques of aloe extracts, existing domestication, conservation and management practices.
- Evaluate the aloe jel and sap yield per leaf and whole plant to determine the feasibility of Aloe jel productivity.
- Analyze the chemical composition of Aloe extracts and compare with the international standard of traded Aloes.
- Analyze of the Aloe extracts qualities (color, viscosity, odour, etc.), from the various highland and lowland Aloe spp. in eastern Ethiopia, in reference to the internationally traded types.
- Develop the geographic distribution map with the existing level of plant population potential of Aloe spp. in eastern Ethiopia so as to show the resource base to the emerging investors in the aloe latex and aloe jel commercial sector.
- Develop domestication techniques for high priority *Aloe* spp. to meet a standard for commercialization.
- Conduct trainings and workshops for appropriate stakeholders based on innovation and knowledge obtained from the research.
- Recommend further knowledge gaps and research direction for sufficient knowledge on aloe extracts for future development so as to back-up the current sustainable economy of Ethiopian.

Acknowledgement

We are grateful to Haramaya University (HU) 'HU-Young Faculty Grant' for the financial support, the local communities in the study areas for their collaboration and valuable Indigenous knowledge and Herbarium staffs of HU and AAU for their keen assistance in identification of the aloe.

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4.1.2 Arbuscular Mycorrhizal Fungal Diversity of Some Traditional Coffee Agroforestry Gardens in Western Hararghe, Ethiopia

Tadesse Chanie and Fassil Assefa Tuju

Abstract: To understand interactions between Coffee arabica trees and mycorrhizae, an investigation of the current mycorrhizal colonization status of roots in soils in the rhizosphere was undertaken. A sample of 5 dominant shade tree species occurring in coffee populations in Western Hararghe, Ethiopia were taken. Acacia albida, Cordia Africana, Croton macrostachyus, Erythrina burana, Milletia ferruginea and the coffee trees sampled under each shade tree were all shown to be colonized by arbuscular mycorrhizal fungi (AM fungi). Four genera and 9 different species of AM fungi were found in the soils. Glomus (Sp1, Sp2, and Sp3 & Sp4), Scutellospora (Sp1 & Sp2) and Gigaspora (Sp1 & Sp2) were found at all locations, whereas Acaulospora (Sp1) occurred only under two of the sample shade tree species (C. africana and C. macrostachyus). Generally, roots of coffee trees were more heavily colonized by arbuscules, as arbuscular colonization percentage (AC%) was higher than that of their respective shade trees ($P<0.05$). Though it was not statistically significant in most cases overall general hyphal colonization percentage (HC%) and mycorrhizal hyphal colonization percentage (MHC%) were also shown to be slightly higher in coffee trees than in their respective shade trees. The incidence of specific spore morpho-types varied along with shade trees. Results indicate that AM fungi could potentially be important in aforestation and to promote coffee production activities in the country in order to bring an alternative to expensive chemical fertilizer use, and would offer management methods that take advantage of natural systems that could potentially preserve and enhance coffee production.

Keywords: Arbuscular Mycorrhizae; Coffee Management; Root Colonization; Soil Ecology; Spore Density; Sustainable Agriculture; Symbiosis

Introduction

Forests are important gene reservoir and natural regeneration areas for many economically important plants around the world (Wolf, 1999; Daba, 2002). Arabica coffee is a non-alcoholic stimulant beverage crop and one of the most valued crops in world trade. It has in many years remained second in value only to oil as a source of foreign exchange to developing countries (Tefestewolde, 1995; ICO, 2007). Ethiopia is believed to be the country of origin of arabica coffee (Paulose and Demel, 2000) that represents over 70% of the world's coffee production (ICO, 2009). In Ethiopia, it contributes to more than 60% of the country's foreign exchange earnings, over 5% of the GDP, 12% of the agricultural output, and 10% of the government revenues (CSA, 2002). Previous data showed that coffee employs 25% of domestic

labour force (EIAR, 1996). About 55% of Ethiopia's production is exported, whereas the rest is consumed locally (Mesfin, 1991). In Ethiopia, coffee grows in natural coffee groves and managed agroforestry systems, totaling about 500,000 hectares (Aga *et al*., 2003).

More than 60% of coffee plants grow under shade trees in evergreen forest areas situated in southwestern Ethiopia (Paulose and Zebene, 1994). Shade trees include *Albizia*, *Acacia*, *Bersama*, *Cordia*, *Croton*, *Dracaena, Entada, Erythrina, Ficus, Leucaena, Millettia,* and *Syzygium* species (FAO, 1968; Demel and Tigeneh, 1991). Like many crops, coffee and shade trees associate symbiotically with arbuscular mycorrhizal fungi (AM fungi) (Sieverding, 1991; Cardoso, 2003; Muleta *et al*., 2007).

Mycorrhizae are thought to influence plant community composition and plant productivity (Van der Heijden *et al*., 1998). Moreover, success of any reforestation intervention is likely to depend on the co-establishment of diverse AM fungi together with seedlings in the nursery (Sieverding, 1991; Francis and Read, 1994). Benefits from mycorrhizae are greatest and most obvious under low input subsistence agriculture growing conditions in developing countries in the tropics (Sieverding, 1991). Propagules of mycorrhizae in coffee soils enhance coffee plant growth, increase P and Zn uptake of young coffee seedlings in nursery conditions and improve their establishment after transplantation (Lopes *et al*., 1985; Rivera *et al*., 2003; Vaast and Zasoski, 1992). They also impart tolerance against a number of plant parasitic nematodes (Vaast *et al*., 1998). These positive effects of mycorrhizal fungi could have agro-biotechnological importance for low input agriculture (Douds *et al*., 2000).

A few recent studies indicate the general status of mycorrhizal symbiosis with *Acacia polyacantha* obtained from a dry savannah woodland ecosystem (Yonase, 2005) and *Erythrina brucei* from a highland woodland ecosystem (Shasho, 2002). The mycorrhizal colonization rates of some tree species in an afromontane forests were also estimated (Tesfaye *et al.,* 2003a). In Brazil, Cardoso *et al.* (2003) noted that greater numbers of spores in the deeper soil layers may be due to greater amounts of roots whereas it may also account for a greater incidence of mycorrhiza in agroforestry than in monocultural coffee systems. Similarly, the same authors explained that greater mycorrhizal incidence at deeper soil layers in the agroforestry system may change the dynamics of phosphorus cycling in soil, making this nutrient more available to plants. However, in Ethiopia there exist almost no information on the diversity of AM fungi, their density and root colonization rate (RCR) of coffee and their shade trees. Thus, the present study was initiated with the following objectives to: (a) quantify and identify spores of AM fungi occurring under each species; and (b) investigate the relationship between AM fungi and root colonization.

Materials and Methods

Study area description

This study was conducted in some selected traditional coffee agroforestry gardens around Mesella special kebeles called ***'Gende Deneba', 'Gende Awusherif', 'Gende Burka' and 'Gende Maderia'***, Western Hararghe, Ethiopia. It is situated 300-400 km from Addis Ababa over a range of 1671 to 2121 meters above sea level. Generally, the area lies within a range of 09°04'48.0"- 09°05'47.5"N and 041°07'11.3"- 041°08'56.0"E geographical coordinates where relics of Harar coffee trees are found.

Sampling roots and AM fungi

Root samples of 5 dominant species of shade trees (Table 4.5) and coffee trees (3 coffee plants under each shade tree) were collected by excavating soil using a handheld hoe starting from the trunk base and working out towards the fine roots within 3 meters radius. Excavated soil samples were washed over 2 and 0.5 mm sieves. Twenty fine roots were collected from the 0.5 mm sieve and brought into the laboratory, carefully washed with tap water, cut into 1cm pieces and placed in 50% alcohol until processed (Frioni *et al*., 1999). Three samples of 200 g of soil were collected at 50 cm depth from under the canopy of each tree for spore extraction.

Spores of AM fungi were separated from the soil by the wet-sieving/gradient centrifugation technique (Brundrett *et al*., 1996). Spores were counted from 100 g aliquots of soil using a dissecting microscope with a magnification of 4x. Spores were grouped into genera of different species according to morphological characteristics mainly spore size, shape, colour, wall structure, hyphal attachment (simple, swollen or bulbous) and Melzer's solution reaction (INVAM, 2004; Merryweather, 2004). Permanent slides were prepared for each different spore morphotypes with polyvinyl-alcohol and polyvinyl-alcohol plus Melzer's solution (Merryweather, 2004), and diameter of spores was measured using camera (cc12) mounted Olympus Bx 51 microscope which was connected to a software program (AnalySIS ® Soft Imaging Systems GmbH version 3.2).

Roots were cleaned in 10% KOH (Kormanik and McGraw, 1982; Brundrett *et al.,* 1994). Darkly pigmented roots were further bleached with 10% H_2O_2 and acidified with 1% HCl. Cleaned roots were stained in trypan blue (0.05% in 14:1:1 lactic acid: glycerol: water). Proportional colonization (colonization of roots by AM fungi) was estimated using the magnified intersection method. A hair line graticule inserted into eyepiece acted as the line of intersection with each root at 200x magnification under the compound microscope (McGonigle *et al*., 1990). A reasonable estimate of percentage of root length colonization (%RLC) was done from 100 or more intersections for each root sample (around 10 fine root

pieces per slide). At each intersection, there were six possible mutually exclusive outcomes. The line might intersect at (p, q, r, s, t and u). Where: "p" represents intersection at no fungal structures, "q" arbuscules, "r" mycorrhizal vesicles, "s" arbuscules and mycorrhizal vesicles at a time, "t" mycorrhizal hyphae but no arbuscules or mycorrhizal vesicles, and "u" hyphae not seen to be connected to arbuscules or mycorrhizal vesicles.

Data were statistically analyzed using the program SPSS V.11.0 (SPSS Inc., Chicago, IL., USA). Analysis of variance (ANOVA) was applied to spore numbers and colonization percentages, and the means were compared by Duncan's Multiple Range Test, P≤0.05.

Table 4.5. Coffee shade tree species and their respective geographical locations in Western Hararghe coffee agroforestry studied for AMF colonization

Scientific name	Family name	Location
Acacia albida	Fabaceae	09° 05' 47.5" N 041° 08' 06.3"E
Cordia africana	Boraginaceae	09° 05' 47.5"N 041° 080'7.9"E
Croton macrostachyus	Euphorbiaceae	09°.05' 15.1"N 041⁰ 07' 11.3"E
Erythrina burana	Fabaceae	09°04' 48.0"N 041°08' 57.2"E
Milletia ferruginea	Fabaceae	09°04' 56.3"N 041° 08' 12.4"E

Results

AM spores

Four genera and 9 species of AM fungi were identified from the different rhizosphere soils (Table 4.6). Characteristics exhibited by the different spore types are also indicated. Type 1 (*Glomus spp.)* with four different species, type 2 (*Gigaspora spp.)* with two different species and type 3 (*Scutellospora spp.)* with two different species were found under all tree species. Spores of type 4 (*Acaulospora spp.)*, which is of only one species, were found under 40% of tree species and at lower densities than the first three types (genera) (Table 4.6 and Table 4.7).

Table 4.6. Characteristics of arbuscular mycorrhizal (AM) fungi spores

Genera	Colour	Shape	Diameter (µm)	Subtending hyphae	Hyphal attachment	Species
I(Glomus)	Light yellow (Honey) to Brown (even Black)	Spherical	150-175	+	Simple	Sp_1, Sp_2, Sp_3, Sp_4
II(Gigaspora)	White to Gray	Globose	350-600	+	Bulbous /Swollen	Sp_1, Sp_2
III(Scutellospora)	Brown	Globose to Ellipsoidal	100-150	+	Bulbous /Swollen	Sp_1, Sp_2
IV(Acaulospora)	Brown to Black	Round to Oblong	> 400	-	-	Sp_1

Where: + = presence of subtending hyphae - = absence of subtending hyphae (sessile) Sp = species

Even though generally high spore densities were recovered as compared to previous local studies (Muleta *et al*., 2003; Yonase, 2005), spore densities varied under tree species (Table 4.7). The highest spore density was found under *A. albida* and the lowest under *C. macrostachyus*. Spore density also varied significantly among different members of the same family of shade trees: *A. albida*, *E. burana and M. ferruginea* in Fabaceae.

Table 4.7. Spore density in the rhizosphere of shade trees (spores per 100 g dry soil, n=6)

Species	Total	Type 1	Type 2	Type 3	Type 4
Acacia albida	1313±36[a]	1089±17[a]	171±7[a]	53 ± 2[c]	-
Cordia africana	760±17[d]	576±10[d]	101±8[d]	68 ±3[a]	15±2[a]
Croton macrostachyus	670±17[e]	521± 14[e]	86±5[e]	56± 3[bc]	7 ± 2[b]
Erythrina burana	997±11[c]	807±12[c]	129±4[c]	61 ± 3[b]	-
Milletia ferruginea	1098±31[b]	892 ±15[b]	149± 8[b]	57± 2[bc]	-

Means followed by the same letter in the same column are not significantly different at 0.05 level, ± s.d.

Root colonization

All shade tree species were colonized by mycorrhizae (Table 4.8). Arbuscules and vesicles were observed in all tree species. General hyphal colonization (HC%) varied between members of shade trees. While in Fabaceae, colonization of *A. albida, E. burana* and *M. ferruginia* was statistically similar.

Table 4.8. Root colonization percentages of shade trees

Species	HC (%)	MHC (%)	AC (%)	VC (%)
Acacia albida	81±3[a]	62±4[a]	3 ±0.5[de]	16±0.6[a]
Cordia africana	67±3[bc]	47 ±2[bc]	7 ±0.3[a]	10 ±0.1[bc]
Croton macrostachyus	69 ±3[bc]	51 ±3[bc]	5 ±0.9[bc]	11 ±2[bc]
Erythrina burana	76 ±7[ab]	57 ±2[ab]	6 ±0.6[b]	12 ±3[bc]
Milletia ferruginea	81 ±5[a]	60 ±4[ab]	4 ±0.5[cd]	14 ±0.6[b]

*Where: **HC**, = Hyphal Colonization = 100[(G-p)/G]; **MHC** = Mmycorrhizal Hyphal Colonization = 100[(q+r+s+t)/G]; **AC** = Arbuscular Colonization = 100(q+s/G); **VC** = Vesicular Colonization = 100(r+s/G).Where: G = (p+q+r+s+t+u) intersections inspected, **p**_ no fungal structures, **q** _ arbuscules, **r** _ mycorrhizal vesicles, **s** _ arbuscules and mycorrhizal vesicles, **t** _ mycorrhizal hyphae but no arbuscules or mycorrhizal vesicles and **u** _ hyphae not seen to be connected to arbuscules or mycorrhizal vesicles.*

Percentages of coffee roots colonized by total hyphae (HC%) was generally higher than for the tree species with which they were respectively associated. Mycorrhizal hyphal colonization (MHC%) of coffee trees under the canopy of all shade trees presented the highest colonization percentage. Arbuscular colonization (AC%) is found to be greater in coffee trees than respective shade trees in almost all the cases (Tables 4.8 and 4.9). On the contrary, vesicular colonization (VC %) seemed to be larger in shade tree species than coffee trees underneath in many of the cases.

Table 4.9. Root colonization percentages of coffee plants under shade trees

Shade trees over Coffee	HC (%)	MHC (%)	AC (%)	VC (%)
Acacia albida	87±5[a]	64±9[a]	18±2[ab]	4±0.3[d]
Cordia africana	73±3[bc]	55±5[ab]	12±2[bc]	7±0.3[ab]
Croton macrostachyus	76±4[b]	56±4[a]	13±2[bcd]	5±2[bcd]
Erythrina burana	80±5[ab]	60±4[a]	15±2[bc]	4±0.3[d]
Milletia ferruginea	83±5[ab]	61±7[a]	16±2[ab]	2±0.6[e]

Where: HC = Hyphal Colonization = 100[(G-p)/G]; MHC, = Mycorrhizal Hyphal Colonization = 100[(q+r+s+t)/G]; AC = Arbuscular Colonization = 100(q+s/G); VC = Vesicular Colonization = 100(r+s/G).Where: G = (p+q+r+s+t+u) intersections inspected, p_ no fungal structures, q _ arbuscules, r _ mycorrhizal vesicles, s _ arbuscules and mycorrhizal vesicles, t _ mycorrhizal hyphae but no arbuscules or mycorrhizal vesicles and u _ hyphae not seen to be connected to arbuscules or mycorrhizal vesicles.

Discussion

Four genera totaling 9 species of mycorrhizae were recovered from soils sampled from Western Hararghe coffee agroforestry, Ethiopia. *Glomus* was the most dominant genus in all soils under each tree species both in species diversity and spore density (Tables 4.7 and 4.8). Spores of *Glomus* was also found to be dominant not only in dry afromontane forests of Ethiopia (Tesfaye *et al.,* 2003b) and Bonga natural coffee forest (Muleta *et al.,* 2007), but also in the tropical rain forest of Xishuangbanna, China (Zhao *et al.,* 2001), tropical rain forest in Mexico (Guadarrama and Alvarez-Sanchez, 1999), and arid and semi-arid lands of north Jordan (Mohammad *et al*., 2003). Generally, the acidic nature of the rhizosphere soil in the present study might have favoured this genus. Because it was indicated that generally, Glomus species (with the exception of *Glomus mosseae*) were found to be distinctly acid-tolerant (Mosse, 1972; 1973).

The least-occurring spore type, *Acaulospora*, was absent under *A. albida, E. burana* and *M. ferruginea* and when present at low spore densities. The reasons for low occurrence of this spore type are unclear. It may be influenced by host types as

a number of hitherto studies indicate that host-plant preferences exist (Halgason *et al*., 2002; Vandenkoornhuyse *et al*., 2003; Johnson *et al*., 2003). This could either be due to differences in root anatomy or exudates from plant roots (Gamalero *et al*. 2004; Norman *et al.,* 1996). Cardoso *et al*. (2003) also indicated that spore production or colonization could be influenced by the length of root of the plant.

The number of species (especially *Glomus*) isolated from any forest is always lower than that of pot cultures (Brundrett *et al*., 1999). Thus, the number of species recovered in this study might be underestimated due to the fact that some species may not produce their spores in the soil. In support of this, it was investigated that count on mycorrhizal propagules is found to give more realistic estimate than spore density because it considered the life cycle of the fungi (hyphal growth) in the soil that it also includes non-sporulating mycorrhizal species (Mitiku and Osrio, 2001).

The overall distribution of mycorrhizal spores was found to be different. For instance, *A. albida, E. burana* and *M. ferruginea* harbored relatively greater number of spores than other hosts. Smallest number of spores was encountered under *C. africana and C. macrostachyus*. Generally, a large number of mycorrhizal spores were extracted under each tree per 100 g of soil in this study than in other studies. In this work, the least average number of AM fungi spores extracted (670/100 g) was larger as compared with the previous findings of Yonas (2005) who reported 57.9 spores per 100 g dry soil of *Acacia polyacantha* in a dry savannah woodland ecosystem. Similarly, Shasho (2002) reported more than 300 spores per 100 g soil beneath *E. brucei* from a highland woodland ecosystem. These differences in spore density may be due to variations in environment, host trees, and edaphic factors among the study places. The population of spores in these coffee gardens is the largest, may be due to the low level of disturbance in the soil. Similar results were obtained in Brazil by Cardoso *et al.* (2003).

The pattern of root colonization was also found to vary among shade trees (even between members of the same family). The variations in some species with relation to the degree of colonization and presence/absence of AM fungi in the same or different collecting places indicate that environmental factors (the host environment) influence the presence or absence of mycorrhizae and its colonization level (Alexander, 1989). Similarly, St. John (1980) indicated such a variation of root colonization at genus and family levels.

A direct relationship was found between colonization percentage and spore density in soil in each tree species. Jasper *et al*. (1993) and Frank and Morton (1994) have similarly observed sporulation to be correlated positively with mycorrhizal colonization. Therefore, this may indicate that most of the spores in this study are colonizing ones. We can also speculate co-colonization among different genera. The coffee tree roots were more heavily colonized by arbuscules (AC%) than their respective shade trees ($P<0.05$). General hyphal colonization (HC%) and mycorrhizal hyphal colonization (MHC%) were also seen to be slightly higher in coffee trees than respective shade trees.

The reasons for relatively heavier coffee root colonization are unclear. However, the implications may be important for the coffee plant. Greater colonization in coffee may indicate lower relative available P, Zn and N for coffee than its companion. Alternatively, this may be because of ecosystem functioning of the increased plant diversity around the coffee tree. Grime *et al*. (1987) showed that the transfer of assimilates from one plant to understorey component is facilitated through a common mycorrhizal network that may necessitate more mycorrhizal colonization. The differences are important since mineral deficiency may result in lower productivity of coffee trees, or access to greater carbon may increase production.

Similarly, it is not clear why AC% seems higher in coffee roots than in tree roots and VC% is lower in coffee than in shade trees. However, this may be either because coffee tree roots are more colonized by non vesicle forming mycorrhizal species, or may be due to the fact that coffee trees need to have nutrients immediately than to store it in vesicles (nutrient storage sites). This supports the idea that transfer of assimilates from one plant to understory component is facilitated more through arbuscules than vesicles (Grime *et al.,* 1987). AM fungi could enhance plant uptake of P and other nutrients, especially in nutrient deficient environment (Smith and Read, 1997). Similarly, Cardoso *et al*. (2003) noted that greater mycorrhizal activity in the deeper soil layers may be important to make more P available to the plant and thus increases the efficiency of nutrient recycling processes in the agroforestry systems. This again may be related to root architecture. Nutrient availability had a much stronger effect on root architecture than the arbuscular mycorrhiza (Cruz *et al.,* 2004). The role of mycorrhizae was to increase the uptake capacity of the active zone. Hence, the association might have favoured by the root architecture created under conditions of low resource availability. Otherwise, it is well known that high soil P suppresses mycorrhizal activity mainly through its effect on the P concentration in plants (Bowen, 1987; Menge *et al.,* 1978).

The importance of mycorrhiza to coffee has been reported by several investigators indicating that coffee plants are heavily mycorrhizal under natural conditions. These benefits include enhanced growth and increased P and Zn uptake of young coffee seedlings in nursery conditions (Lopes *et al*., 1985; Siqueira *et al.,* 1998); enhanced tolerance to nematodes (Vaast *et al.,* 1998) and increased survival of coffee plants after field transplanting and in agroforestry systems (Vaast and Zasoski, 1992). Agroforestry systems can increase soil nutrient availability and accelerate P cycling because the deeper tree roots can retrieve nutrients from lower soil horizons (Young, 1997); enhance the chemical and physical quality of soils and increase soil microbial activity (Cooper *et al.,* 1996).

Conclusion

A diverse population of mycorrhizae was observed as spores in coffee agroforestry gardens of Western Hararghe, Ethiopia. Presence of spores was associated with high levels of mycorrhizae in the roots of both the shade tree species and coffee plants growing under the shade species. Mycorrhizal colonization in coffee was higher than in the companion forest species, indicating that mycorrhizae may be more helpful for coffee than the companion. These observations indicate that management of coffee agroforestry gardens must consider the impact of various practices on the mycorrhizae, and manage to maintain high levels of colonization in coffee. The specific management practices needed to maintain mycorrhizae in this system are unclear, but lack of soil disturbance and management of litter fall (OM) may be important and are worth further investigation.

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4.2 Department of Chemistry

4.2.1 The Effect of Cooperative Learning on Students' Achievement in Organic Chemistry: A Case Study of Haramaya University First Year Chemistry Students

Ayalew Temesgen

Abstract: The purpose of this research was to investigate the effect of cooperative learning style on achievements of first year chemistry students' learning outcomes in organic chemistry at Haramaya University. Forteen female and 91 male students participated in the study. The sample students were randomly divided into experimental (51 students) and control (54 students) groups based on their section. The subjects in both the treatment and control groups were exposed to the same study unit covered in organic chemistry-I. For the experimental group, the contents of the unit were treated with cooperative learning style, while for the later, the same contents were dealt using the traditional lecture method. To measure differences between experimental and control groups, identical pre-test, quiz, assignment, and post-test evaluations were administered before and after treatment. The results obtained indicated that there was no significant difference in the pre-test and assignments achievement scores of students between the experimental and control groups, whereas, statistically significant difference was observed between experimental and control groups with the two sample t-tests ($p<0.05$) taken on the quiz and post-test achievement scores. Responses to the questionnaires from the experimental group analyzed qualitatively indicated that cooperative learning style was effective in acquiring chemistry concepts as they worked together in their group.

Keywords: Cooperative Learning,; Lecture Method; Pre-Test; Post-Test; Attitude; Achievements

Introduction

Organic Chemistry is one of the major courses offered to students majoring chemistry. It is also offered to other natural science students as a supportive course in all Ethiopian universities. However, students' reflection and some study revealed that Organic Chemistry course is considered as a difficult subject and students' performance in this subject is relatively low. According to Girija and Deepa (2004), the meetings held in the SADC region recognized that Organic Chemistry is a difficult subject on teaching learning surface.

An important objective in teaching science in higher education is to enable students to acquire knowledge in order to understand the nature of the world. In contemporary perspectives on education, knowledge cannot automatically be transmitted from one person to others (Herron, 1996). Knowledge is constructed in the mind of the learner based on the existing knowledge and understanding. But, most course materials in science education has typically been "taught" by the lecture method (Cooper, 1995). In the lecture method, students go to class, listen, and take notes on the lecture of the instructor. The lecture has been considered an efficient method to present the fundamentals of science, to emphasize the key concepts and to model problem solving skills. However, the lecture method has many weaknesses in terms of the learning processes. The lecture method allows students to passively receive information from teachers, and it pays little attention to the processes of constructing knowledge and developing the cognitive abilities of students (Tesfaye, 2007).

Novak (1998) accentuated the need for educators to take advantage of the available knowledge base of learning, learners' knowledge construction, and instructional tools to improve educational quality, and a knowledge base that has not been tapped sufficiently. Improving educational quality requires designing strategies, which can be used to improve the teaching-learning of chemistry, and to make it more attractive to students, at least, placing learners in active rather than passive roles (Moore, 2005). To improve the problem of teaching/learning process, educators suggested that cooperative learning to be useful in enhancing meaningful learning. Cooperative learning is an approach to group work that minimizes the occurrence of those unpleasant situations and maximizes the learning and satisfaction that result from working on a high-performance team. A large and rapidly growing body of research confirms the effectiveness of cooperative learning in higher education (Johnson et al., 2000).

In Haramaya University Chemistry department, I have seen many students working hard with course materials in Organic chemistry. But, their examination results reveal that some students cannot express their answers clearly and logically. They seem to work hard, but do not acquire the necessary knowledge. Some instructors are very keen to facilitate students' learning, to make them actively engaged in constructing their own knowledge, and to help them develop their abilities in reasoning and logical thinking. We agree with Ruggiero's statement (cited in Le Thi So Nhu, 1996) "the only significant change that is required is a change in teaching methodology". Even though we require students to have abilities of reasoning, logical thinking, and working independently, we still mainly lecture to them. But, there is no significant difference observed in this manner. So, as a teacher we should have to change our methods,

because".---teaching of higher level reasoning and critical thinking does not depend on what is taught, but on how it is taught".

A number of research results provide empirical evidence that cooperative learning is a useful learning strategy in many content areas such as mathematics, physics, and chemistry in developed countries. As such, no systematic study could be located in Ethiopian higher education to evaluate the effect of cooperative learning in undergraduate organic chemistry course. Thus, this study attempted to investigate the effect of using cooperative learning style in Organic Chemistry-I on students' achievements and assessed students' attitudes toward cooperative learning style in Organic Chemistry.

Research Methodology

Description of Research Area

This research is a part of an experimental research that was aimed at investigating the effect of cooperative learning as a tool in teaching-learning Organic Chemistry and its effect on the learning outcomes of first year chemistry department students at Haramaya University, Ethiopia.

Sampling Procedure

The sample size for this study was determined based on the number of students' enrolled at chemistry department for 2011/12 academic year. The nature of this study is quasi experiment design and the sampling procedure was quasi-experimental sampling method. That means, first year students were completely assigned into two groups, i.e., experimental and control groups, in accordance with their section. The instructor (researcher) formed teams rather than permitting students to choose their own teammates. When students self-select into teams, the best students tend to cluster, leaving the weak ones to be left to themselves, and friends cluster leaving some students out of groups and excluding others from cliques within groups. In this experiment, there are nine groups in case of experimental group, which were formed randomly according to their sitting in the class. From these groups (nine), there were six groups containing six members each while, three groups containing five members each, which give a total of 51 students.

The Experimental Design

During this study, the *cooperative learning approach* was utilized for the experimental group as a teaching-learning tool. There was no such special treatment provided for the control group during the whole treatment period. The lecture teaching-learning approach remained as teaching method for control group students. The same Chemistry lesson topics prescribed for the experimental groups were administered to the control groups as well.

Group Design in Cooperative Learning Environment

In this study, combination of peer-led-team learning with mini lecture were used. Because these structures promotes both individual and group thinking and reflection on issues, questions, or problem-solving. Among the group members one is assigned as the leader/manager (manages the group and ensures that members fulfill their roles and work cooperatively in a timely manner); and another one is given a responsibility of recordering group activities (records the group's answers and discussion outcomes); and the rest are reflectors (ensures that all possibilities have been explored by posing questions such as "What other idea are there?" or "How can we look at this problem in another way?").

Depending on the lesson objectives assignment, quiz is given to them in the class at the end of the lesson. This trend is also followed outside the class and the researcher follow up activities. For convenience, one preliminary session were assigned in the beginning of the first week to introduce cooperative learning approach to experimental group students to minimize difficulties toward the method. According to Hardwick (2000) as cited in Ai Bin (2009), for cooperative strategies to work, careful planning, inconspicuous observation and evaluation and preplanned adjustments (alternative activities) are essential to help learners move consistently forward. So based on this, in this research the training of cooperative learning is given to students based on Johnson and Johnson (1998) model. Cooperative learning is instruction that involves students working in teams to accomplish a common goal, under conditions that include the following elements:

- Positive interdependence
- Face-to-face promotive interaction
- Individual accountability (Personal responsibility)
- Interpersonal and small-group skills (Teamwork skills)
- Group processing

After ensuring that students of the experimental group had enough time for understanding the process of cooperative learning, they were continuously encouraged to meet with their group two times per week for two hours. After they finished their training, quiz and assignment were given based on Organic Chemistry lessons that covered in actual class for both groups at the same time. During that period, each student in the control group and experimental group were asked to submit their assignment on a series of learning tasks that was covered in actual class. To maintain uniformity,

the treatment time for both groups is the same. At the end of this treatment period, the same post-test were administered simultaneously to both groups of students.

Data Gathering Instruments

The relevant data from the subjects of the study were collected using multiple instruments listed below.

Achievement in Chemistry Assignment

The dependent variable in this study was the students' test results in Organic Chemistry class. Two tests (pre-test and post-test) were constructed by the researcher in order to measure students' achievements. Both the pre-test and post-test examinations were evaluated by organic chemistry teacher who has teaching experience, in addition to the researcher. The reason for evaluating the tests were to make sure that the questions were aligned with the course content and level as well as designed along with the detailed description of the course content. After getting approval from Organic Chemistry teachers, the test was administered to the students. The pre-test was offered to assess students' prior knowledge of the topics covered during the study (stereochemistry). The post-test measured students' achievement generally on the topic they learned (stereochemistry) at the end of the study period.

Questionnaires

Questionnaires were used as tools to gather relevant information from the subjects of the study. Therefore, two sets of questionnaires, open ended and closed ended, were prepared to collect data on:

- Whether or not the method improves their achievement in organic chemistry
- Generally their opinion toward the method
- In responding to the questionnaires, all experimental group students were involved

Interviews

Interviews were used as data collecting instrument to get the views and opinions of students in addition to questionnaires about: the effectiveness of cooperative learning as a teaching-learning tool, to what extent the method enhances students' understanding of Organic Chemistry concepts and its appropriateness in group work. For the purpose, three students from the experimental group were randomly selected and interviewed in this regard.

Methods of Data Analysis

The data were analyzed using both quantitative and qualitative analysis methods. The quantitative data were analyzed using both descriptive and inferential statistics to describe the data in terms of the mean, and percentage. From inferential statistics, the t-test was used to test if there exists any statistically significant difference between the experimental and control groups.

Results and Discussion

Comparison between experimental and control group students on the pre-test

One can see clearly from Table 4.10 that the mean score results and the two tailed t-test is not significant ($p>0.05$) between the two groups of students and the two groups exhibited comparable characteristics. The result of two-sample t-test on assignment (Table 4.11) indicates no significant difference. This could be because students might have copied the assignment from each other or worked together. But as shown in Table 4.12, and Table 4.13, there is highly significant difference between the two groups ($p < 0.05$) on the quiz and post test. This result revealed that the experimental groups scored higher than the control group indicating the effectiveness of cooperative learning in enhancing students' achievement than traditional lecture method. In accordance with the present result, Emily (2006) noted that cooperative learning model is ranked first in teaching approaches and it promotes greater higher-order thinking, problem solving, and achievement.

Table 4.10. Comparison of pre-test results for experimental and control group students by using two sample t-test

First year chemistry students	N	Mean	Variance	t-value	p-value
Experimental group	51	1.35294	1.19294	0.34797	0.72858
Control group	54	1.42593	1.11705		

N=Number of experimental and control group students, P = probability. Comparison between experimental and control group students on assignment

Table 4.11. Comparison between experimental and control group students on assignment by using two sample t-test

Firstyear chemistry students	N	Mean	Variance	t-value	p-value
Experimental group	51	8.35294	0.91294	-1.7681	0.08
Control group	54	8	1.16981		

At the 0.05 level, the two means are NOT significantly different. Comparison between experimental and control group students on Quiz

Table 4.12. Comparison results of experimental and control group students on quiz by using two sample t-test.

First year chemistry students	N	Mean	Variance	t-value	p-value
Experimental group	51	4.17647	0.55824	-8.97554	1.3953E-14
Control group	54	2.40741	1.45353		

At the p <0.05 level, the two means are significantly different.

Table 1.13. The two-sample t-test results on post-test for experimental and control group

First year chemistry students	N	Mean	Variance	t-value	p-value
Experimental group	51	28.12745	33.12843	-3.10437	0.00246
Control group	54	24.74074	29.41265		

N=number of experimental and control group students, P= probability, SD = standard deviation. Survey of students' opinions about cooperative learning experience

The Likert scale employed has five levels of responses ranging from strongly agree to strongly disagree. In this study, the scale was further rescaled into three for the sake of convenience. If the average obtained were above three (strongly agree and agree), it was taken as a positive statement. If it were below three, it indicates negative response and opposes the idea or the given statement. Three is considered as neither positive nor negative, but as an undecided.

Generally one can see from Table 4.14 that students have positive attitude in the organization of the group, their role in their group, their contribution towards the success of the group, the approach in enhancing their achievement, the effectiveness of the cooperative learning approach comparative to individual work, contribution of the approach to understand the subject better, the contribution of the approach in bringing students that came from different nations and nationalities together and work in group for common goals.

Table 4.14. Students' response to questions related to cooperative learning experience

No.	Statements	% of respondents		
		Positive	Undecided	Negative
1.	The groups formed represented multiple students	96	2	2
2.	All members of my group were committed to the success of the group	90	2	8
3.	I felt responsible for the success of each individual in the group	94	6	0
4.	My group has sufficient time to complete the activities	88	4	8
5.	The cooperative learning approach forced me to take on more responsibilities for learning organic chemistry	92	6	2
6.	The cooperative learning experiences in my class enhanced my learning	96	4	0
7.	I listen to, and respect, the others' ideas and resolve conflicts in a positive manner during cooperative learning	98	2	0
8.	I share the load of my group in seeking solutions and in making suggestions in organic chemistry class	94	2	4
9.	I share my information, and take into account information from others	98	0	2
10.	I contribute towards making each member of my group to do his/her set piece of work	96	0	4
11.	I am happy about the success of my group in organic chemistry assignment	100	0	0
12.	I get more work done when I work with others	100	0	0
13.	I learn organic chemistry more when I studied with a group	100	0	0
14.	Cooperative learning helped me to develop social skills with my group member	96	4	0

Students' perceptions toward cooperative learning on open ended questionnaire

The following are some of the open-ended questions to which responses were given by the respondents.

1. Do you think cooperative learning would help you in your study and to achieve a good result in organic chemistry test?
2. Do you think cooperative learning helped you to understand the subject better as opposed to individual work?
3. Do you have any other comments about cooperative learning from your cooperative learning experience? Explain.

All of the experimental group students render appreciation to cooperative learning technique in Organic Chemistry. Respondents of these questions gave their comments briefly by using their own language (Afan Oromo, Amharic) and with English. Among students comment addressed on the questionnaires, some of them are discussed below.

Majority of students addressed "Yes, and when they explained their reason "…cooperative learning helped us to share idea with our partner without any fear or with freedom". They continued "…when we want to ask question in class we are ashamed of our instructor or our class mates, due to different factors such as language difficulty,…etc. But, now it is better to ask our partner or group members and share idea easily when we discussed with each other, which in turn help us to improve our achievement".

Other students indicated that working cooperatively with their own partner had helped them to dig out problems and find the answer for that problem. For example, one student said, *"Doing cooperatively, with my partner helps me to know things that I am unsure more clearly, how they are solved."* Also another student wrote, *"When I shared my idea to my group members they also share me their idea and experience, so this highlights gaps in my knowledge that I need to go back and read."*

The meta-analysis of vast research study on cooperative learning was done by *Roger and David Johnson (1997)* and the result indicated that cooperative learning seems to be much more powerful in producing achievement than the other interaction patterns and students are more positive about school, subject areas, and teachers or professors when they are structured to work cooperatively.

Interview results of students' opinion about effectiveness of cooperative learning

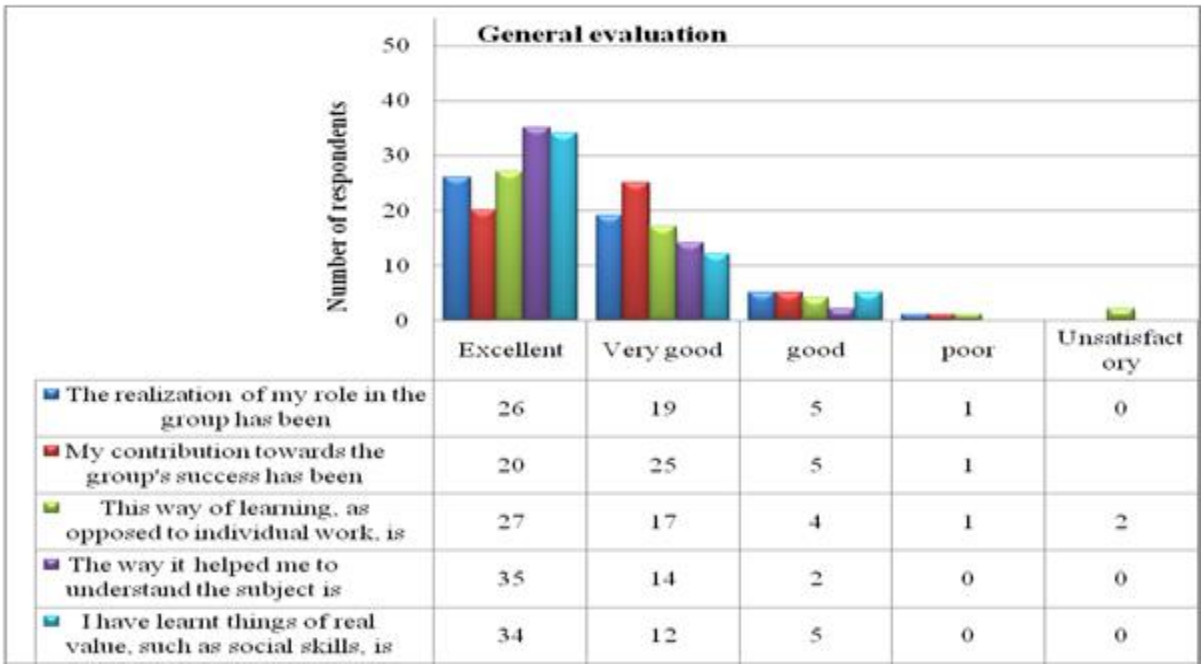
To gather relevant information on the effectiveness of the cooperative learning in Organic Chemistry class and to know the attitude of the students toward the method, two students were interviewed from the experimental group. The questions were the same with open ended ones. The three students felt that cooperative learning tutorials helped them to understand the lecture content more clearly, because they made brief discussion on each topic and on each question with their group members in class and out of the class. Among the interviewed students, one student said that:

"I have got an interesting experience from cooperative learning approach during Organic Chemistry class, because certainly I knew that it is an enriching program/approach. Cooperative learning was extremely useful as it allowed me to discuss my idea with my friends, organizing the concepts discussed, separating what was more and less important, which in turn enhance my achievement. It is a great tool for learning and studying."

This result is also in line with others researchers work. Conwell *et al.* (1988) interviewed 28 students who worked in cooperative learning groups in intermediate science classrooms in an urban school and he reported that students perceived their science achievement positively. Nearly two thirds rated their level of self-esteem as high, felt positive about themselves when working in groups. More than three fourth of the students interviewed enjoyed working with everyone in their group and they had no preferences based on race or sex for team mates.

General evaluation of the experimental group students on cooperative learning

General evaluation of the experimental group students on cooperative learning refers to the role of the group members, their contribution towards the success of the groups, cooperative learning approach comparative to individual work, the contribution of the approach to understand the subject better, the contribution of the approach in bringing students who came from different nations and nationalities to work together for common goals. Cooperative learning is generally a better approach as compared to the traditional method (Figure 4.3).



	Excellent	Very good	good	poor	Unsatisfactory
The realization of my role in the group has been	26	19	5	1	0
My contribution towards the group's success has been	20	25	5	1	
This way of learning, as opposed to individual work, is	27	17	4	1	2
The way it helped me to understand the subject is	35	14	2	0	0
I have learnt things of real value, such as social skills, is	34	12	5	0	0

Figure 4.3. General evaluation of the experimental group students on cooperative learning in organic chemistry class

Conclusion

From the comparison analysis between experimental group and control group students on the results of the quiz, and post tests, the two sample t-test indicates that the experimental group students who were using cooperative learning tool performed better than those who have learned with lecture method, but not on assignment. Therefore, it is suitable to teach Organic Chemistry with cooperative learning method since it improves students' achievement than the lecture method. Similarly, qualitative analysis of the data gathered from students through questionnaires and interview indicated that cooperative learning is effective tool in engaging students, helping each other, in helping them solve problems together, to improve their achievement as well as communication and social relations, while no negative response was reported concerning the effectiveness of the cooperative learning.

Recommendation

On the basis of their observation and active engagement in study, the researchers recommend:

We encourage Chemistry department teachers to interject cooperative learning approach wherever possible in their lecture class.

It would be better if Chemistry teachers arrange their laboratories and classrooms in such a way as to give more effective interaction among students.

For future work, we recommend that the structure of the groups to be arranged according to students' relationship, and to combine cooperative learning approach with other active learning approach such as problem based learning in all natural science class in higher education, especially in developing countries like Ethiopia.

Acknowledgements

We would like to express our deep gratitude to Mr. Ayalew Debebe, the former head of Department of Chemistry at Haramaya University for his continuous professional guidance on matters pertaining to this paper. Also we would like to forward our warm appreciation and great thanks to our friends: Mengistu Tulu and Meseret Amde, for their moral and material support. Our thanks go to **'Young Faculty Research Fund of Haramaya University'** through Collage of Natural and Computational Sciences for sponsoring this research work.

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5. COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

5.1 School of Foreign Language studies

5.1.1 Assimilation in Oromo Phonology

Dejene Geshe

Abstract: This study investigates the assimilatory processes taking place in the major Oromo dialects. The area has not been thoroughly treated in some previous works. Thus, this work will throw light onto the description of the language. The study describes the assimilatory processes prevailing in the language in general and discusses some facts dialect specifically only when they are common in the dialect in question. The study is a descriptive work and attention has been given to describing surface realizations rather than theorizing the process. To conduct the study, the data have been elicited from eight less educated speakers of the major dialects. The speakers were those who have not been away for long time from their home villages so that they give appropriate data synchronically spoken. The data have been phonemically and phonetically transcribed and descriptively analyzed. In Oromo, bilabials and labiodentals in the Guji Oromo and velars in the Macha Oromo assimilate to alveolar sounds. In this study, alveolar sounds assimilate to many sounds and act as the conditioning environment for many assimilatory processes.

Keywords: Assimilation; Voicing, Devoicing; Glottalization; Deglottalization; Palatalization; Nasalization; Coalescence; Vowel Raising

Introduction

The Oromo[2] are one of the largest tribal groups in Ethiopia. Scholars such as Bender (1976) claim that "The Oromo probably comprise the largest single tribal group in Africa." The People inhabit large area "stretching from close to the Sudan border in the West, through Addis Ababa, and beyond Harar in the East, from Northern Kenya in the South, up and East of the Rift valley, and to Wallo in the North" (Gragg, 1982).

According to the recent population census, the language is spoken by around twenty-seven million speakers in Ethiopia (Dejene, 2010). The language belongs to the East lowland Cushitic. Different scholars held different views on the dialectal variations of the language. Gragg (1976) categorizes the language into three major dialects: "western, eastern and southern." Bender (1976), on the other hand, categorizes the language into eight major dialects: "Macha (western), Tulama (central), Wello, Rayya (both northern), Eastern, Arsi, Guji and Borena (the last three southern)."

Some scholars have tried to study assimilation in Oromo, at least in passing. Waqo (1981) describes the phonology of Macha Oromo. In this work he overviews the segmental assimilation of the dialect. This work would be a good input for the present study and also helps to indicate gaps. Benyam (1988) superficially highlights the assimilation of segments in the Rayya dialect. Benyam's finding shows difference with the present study because he claims that the Rayya dialect is influenced by Semitic languages. For instance, in the Rayya dialect vowel harmony, which is the typical feature of Tigrigna (a Semitic language), occurs. But in other Oromo dialects this process is less evident. Dejene (2010) describes assimilation in Kamisee Oromo Phonology. This study does not treat the assimilatory processes such as the assimilation of velars to alveolars, the assimilation of bilabials and labiodentals to alveolars and others which have been given considerable attention in the present study. Dejene's work was dialect specific phonological description, while the present study attempts to describe assimilation in the language in General.

The previous major findings, summarized above, reveal that assimilation in Oromo has been treated only superficially and has not been investigated in detail and the assimilatory processes of many dialects have not been described properly. Dejene (2010) argues that assimilation is the typical feature of the Kamisee Oromo Phonological processes, which is once again a case in this study. But the previous findings did not give considerable attention to the process and they also lack descriptive adequacy. The purpose of this study is then, to deeply investigate and describe the assimilatory processes taking place across the major dialects in Oromo.

Methods

To conduct the study, the data have been elicited from eight speakers of the major dialects. The informants were less educated and are those who have not been away for long time from their home villages so that they would give the actual data synchronically spoken. To be sure that the data gathered from the eight informants is reliable, some more other speakers of the language were asked. Moreover, as a speaker of the language and based on the researcher previous

[2] The word *Oromo* refers to both the people and the language in the study.

experience, the appropriateness of the data gathered were carefully checked. In this study, phonemic description was mainly used so that one could see the underling realizations. The Phonetic description was used only to show the surface form in the assimilation processes under question. The data have been analyzed by using descriptive method. Little apple has been made to theoretical analysis as the study is a descriptive work.

Phoneme Inventory

Consonant Sounds

Oromo has twenty-nine consonant phonemes. Five of them */v, p, ʒ, s', ʒ/* are loan segments and used only in loan words.

Table 5.1. Oromo consonant phonemes[3]

		Labial	Dental	Alveolar	Palatal	Velar	Glottal
Stops	Vd	b	d		ʤ	g	
	V1	p	t		ʧ	k	ʔ
	Ejc	p'	t'		ʧ'	k'	
Implosive				ɗ			
Fricatives	Vd	v		z	ʒ		
	Vl	f		s	ʃ		h
	Ejc			s'			
Nasals		m		n	ɲ		
Lateral				l			
Tap/trill				r			
Glides		w			j		

In Table 5.1, labial includes bilabials */p, b, m, p, p'/,* labiodentals */v, f/* and the labiovelar approximant */w/*, and palatal includes palatals */ɲ, j/* and postalveolars /ʒ, ʃ, ʤ, ʧ, ʧ'/. Nasals, laterals, taps/trills and glides in the language are all voiced, and there is no voiced-voiceless dichotomy.

Vowel Sounds

The language has five vowel phonemes presented in Table 5.2. The vowel phonemes have short vowels and corresponding long vowels.

Table 5.2: Vowel phonemes of Oromo

i		u
	e o	
	a	

Vowel length in Oromo is phonemic and the short and long vowels in identical environment contrast.

(1) *lama* 'two' *laama* 'hunger'
hidi 'You (SG) tie.' *hidii* 'lip'

Assimilation in Oromo

In Oromo, assimilation is a popular phonological process. The process predominantly takes place contiguously and mainly at word or morpheme boundaries, hence mainly morpho-phonemic in nature. There are different types of assimilation processes such as voice assimilation, glottalization, palatalization, etc. Each of these has been discussed in the study with ample examples from the language. Though the interaction between consonants is keen, there are assimilation processes which take place due to the interaction between consonants and vowels in processes such as nasalization and vowel rising.

Voicing

In Oromo, the voiceless alveolar stop /t/ regressively and completely assimilates to voiced velar, alveolar and bilabial stops /b, d, g/ and becomes [d].

[3] Vd: voiced, Vl: voiceless, Ejc: ejectives

(3)[4] */ʧ'ab- t- Ø - e/ ⟶ [ʧ'abde]*
break- 3SF/ 2- SG- PRV 'She was/ you were broken.'
/fid- t- an/ ⟶ [fiddan]
bring- 2- PL: PRV 'You brought.'
/fiig- t- Ø- e/ ⟶ [fiigde]
run- 3SF/ 2- SG- PRV 'she/you ran.'

In this process, one may wonder whether the underlying phoneme is /t/ or the variants /b, d, g/ because when the phoneme comes after these sounds, it never occurs as /t/. But it could be readily traced from other environments. It occurs as /mt, rt, lt/ etc. with the similar grammatical function. Thus, we can conclude that /t/ is the underlying phoneme while [b, d, g] are the surface forms.

The following rule says that /t/ becomes [d] when it occurs after /g, d, b/.

$$/t/ \longrightarrow [d] \;\; / \;\; \begin{pmatrix} b \\ d \\ g \end{pmatrix}$$

Consonant Devoicing

In Oromo, the voiced bilabial and velar stops /g, b/ become voiceless when they occur after the voiceless alveolar fricative /s/, as shown in (4).

(4)[5] */ʤig- s- Ø- e/ ⟶ [ʤikse]*
fall- CAUS- 1SG/3SM- PRV 'He/I made fall.'
/gogs- i -t- Ø e/ ⟶ [goksite]
dry- EPN- 3SF/ 2- SG- PRV 'She/you made dry.'
/ʧ'ob- s- Ø - e/ ⟶ [ʧ'opse]
pour- CAUS- 1SG/3SM- PRV 'I /he poured (some liquid).'
/raab- s- Ø- an/ ⟶ [raapsan]
distribute- CAUS- 3- PL: PRV 'They distributed.'

Devoicing in some dialects, especially in Tulama around salaalee, is accompanied by metathesis. The above words will be pronounced as follows in the dialect.

/ʤikse/ ⟶ [ʤiske] 'He/I made fall.'
/goksite/ ⟶ [goskite] ' He/I made dry.'

The examples reveal that metathesis takes place at the end; otherwise, it would have blocked the devoicing process. The pattern could be summarized as follows:

/gs/ ⟶ [ks] ⟶ [sk]

The following rule illustrates that /b/ and/g/ surface as [p] and [k], respectively when they are preceded by /s/.

$$\begin{vmatrix} b \\ g \end{vmatrix} \longrightarrow \begin{pmatrix} k \\ p \end{pmatrix} \_\_\_\_\_ \begin{pmatrix} s \end{pmatrix}$$

Vowel devoicing

Constituent final short vowels in Oromo are devoiced and become breathy in citation form. Andrzejewski (1957) and Dejene (2010) claim that the process occurs in Borena and Kamisee Oromo dialects, respectively. This study also affirms that the feature occurs in the major Oromo dialects. The process has been described as follows following Andrzejewski (1957).

(5)[6] */ʤimma/ ⟶ [ʤimmᵃ]* 'Jimma' (name of a city)
/Ambo/ ⟶ [Ambᵒ] 'Ambo' (name of a town)
/fardi/ ⟶ [fardʲ] 'horse'(NOM)
/gadde/ ⟶ [gaddᵉ] 'He mourned.'
/jaadu/ ⟶ [jaadᵘ] 'They think.'

[4] 2: second person
[5] CAUS: causative, 1SG: first person singular, 3SM third person singular masculine, EPEN: epenthetic, 3: third person, PL: plural
[6] NOM: nominative

The devoicing of constituent final short vowels in Oromo is not conditioned by the influence of other neighboring segments. Rather it is because of the word boundary effect[7].
The following rule reads that short vowels in Oromo are devoiced when they occur constituent finally.

/cv/ ⟶ [cᵛ] / #_____

Glottalization
In the language, the voiceless alveolar stop /t/ is glottalized when it occurs after glottal sounds

/p', t', ʧ', k', ɗ/. The process has been illustrated in (6).

(6)[8] a) */rip'- t- Ø- e/* ⟶ *[rip't'e]*
hide- 3SF/2- SG- PRV 'She/you hid.'
/lit'- t- Ø- e/ ⟶ *[litt'e]*
enter- 3SF/2- SG- PRV 'She /you entered.'
/miiʧ'- t- Ø- e/ ⟶ *[miiʧʧ'e]*
wash- 3SF/2- SG- PRV 'She /you washed.'
/milik'- t- u/ ⟶ *[milik't'u]*
escape- 2- PL: IPV 'You will escape.'
b) */baat- ɗ-e/* ⟶ *[baaɗɗe]*
carry- 1SG- PRV I carried.'
/laat- ɗ- a/ ⟶ *[laaɗɗa]*
give- 1SG- IPV 'I will give (something to somebody else.)'

In (a) the assimilation is mainly phonetically triggered because in all the given environments, except after /ʧ'/ in which /t/ completely assimilates to the sound, it assimilates to the airstream mechanism (glottalic pressure initiation) of the ejectives. The sound does not change its place of articulation and manner of articulation except after /ʧ'/. In example (b), on the other hand, the assimilation is a total assimilation in which /t/ assimilates to the airstream mechanism and voicing of the voiced alveolar implosive /ɗ/.
The following rules reveal that /t/ becomes [t'] when it occurs after /p', t', k'/; it becomes
[ʧ'] when it occurs after /ʧ'/, and becomes [ɗ] when it occurs after /ɗ/.

a) /t/ ⟶ t' / { p', t', k' } _____

b) /t/ ⟶ [ʧ'] / [ʧ'] _____

c) /t/ ⟶ [ɗ] / [ɗ] _____

Glottalization of Long Vowels
Long vowels are glottalized when they occur constituent finally in citation form. But they are not glottalized in genitive constructions and when they are followed by another constituent. The process has been discussed in (7).

7) a) */kutuu/* ⟶ *[kutuuʔ]* 'cutting'
/duʔuu/ ⟶ *[duʔuuʔ]* 'to dye'
/hoolaa/ ⟶ *[hoolaaʔ]* 'sheep'
/k'alɗoo/ ⟶ *[k'alɗooʔ]* 'thin'
/ʔadii/ ⟶ *[adiiʔ]* 'white'
/reʔee/ ⟶ *[reʔeeʔ]* 'got'
b)/ʔadii- fi diimaa ⟶ *[ʔadiif diimaaʔ]*

[7] Word boundary effect is a process in which the word boundary or morpheme boundary itself will be a trigger, without influence of a specific segment in the environment.
[8] IPV: imperfective

white-CONJ- red 'white and red'
/ʃamarree bareedduu/ ⟶ [ʃamarree bareedduuˀ]
girl beautiful ' a beautiful girl'

c)/ hoolaa koo/ ⟶ [hoolaa koo]
sheep : SG - GEN 'My sheep.'
/nama ʤimma- a/ ⟶ [nama Jimmaa]
person Jimma- GEN ' a person from Jimma'
/hoolaa gurraʧiʧa/ ⟶ [hoolaa gurraʧiʧa
sheep black 'black sheep'

/ʔegee ɗeeraa/ ⟶ [ʔegee ɗeeraaˀ]
tail long 'long tail'

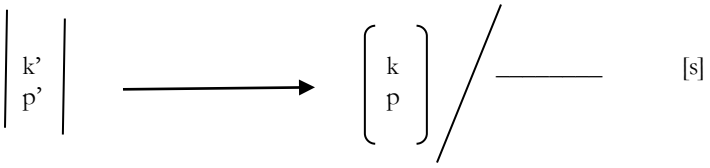
The fact emerging from example (a) is that constituent final long vowels are glottalized while in example (b) they are not glottalized because of the genitive construction, and in example (c) the terminal long vowels in the first words are not glottalized because they are followed by other words.

Deglottalization

In Oromo, as shown in (8), the voiceless velar and bilabial ejective stops /k', p'/ are deglottalized when they occur after the voiceless alveolar fricative /s/.

8) */ʧ'op'- s- Ø- e/ ⟶ [ʧ'opse]*
pour- CAUS- 1SG/3SM- PRV 'He poured.'
/milik'- s- Ø- e/ ⟶ [milikse]
escape- CAUS- 1SG/3SM - PRV 'He hid (something).'
/dammak'- s- i- n- e/ ⟶ [dammaksine]
scar- CAUS- EPN- 1PL- PRV ⟶ 'He scared (somebody).'
/lip'- s- Ø- e/ ⟶ [lip'se]
blink- CAUS- 1SG/3SM- PRV 'He/I blinked.'

The following rule illustrates that /k'/ and /p'/ become deglottalized to [k] and [p] when they are followed by /s/.



Deglottalization in Oromo also can be conditioned by the word or morpheme boundary effect. It is evident in the following personal names illustrated in (9). The names have been formed from different words, but synchronically used as a single compound word. The first element in the compounds is underlyingly *Wak'a* 'God'. In relaxed speech, the glottal sound becomes deglottalized and the terminal vowel is clipped in the word formation process. The /k'/ of the word *Wak'a* 'God' is always a glottal sound in a citation form.

The other remarkable feature in the process is the complete progressive voicing assimilation of the voiceless velar stop /k/ to voiced velar stop /g/, as shown in the first two examples. Based on the pattern in this process, deglottalization of /k'/ into [k] first takes place, and /k/ finally undergoes voicing due to the influence of /g/.

Underlying form	**Surface form**
(9)*/waak' gaarii/ ⟶*	*[waggaarii]*
/waak' gaʃʃaa/ ⟶	*waaggaʃʃaa]*
/waak' tolaa/ ⟶	*[waaktolaa/waattolaa[9]]*
/waak' ʃuuma/ ⟶	*waakʃuumaa]*
/waak' ʤiraa/ ⟶	*[waakʤiraa]*
/waak' kennee/ ⟶	*[Waakkennee]*

Nasal Assimilation

The voiced alveolar nasal /n/ assimilates to many obstruents and sonorants in the language.

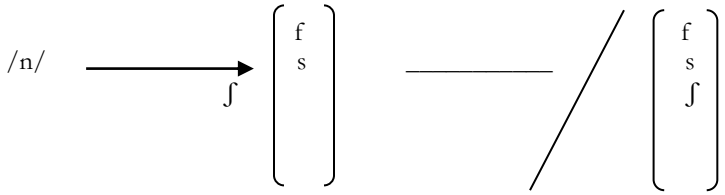
Assimilation of /n/ to Fricatives

[9] Because velars assimilate to alveolars, /kt/ surfaces as /tt/ in Macha Oromo.

In the Tulama dialect, especially in Salale area, the sound undergoes complete progressive place and manner assimilation with voiceless labiodental and palatoalveolar fricatives /f, ʃ/ and manner assimilation with the voiceless alveolar fricative /s/.

(10)[10] */danf- Ø- e/ → [daffe]*
boil- 3SM- PRV 'It become boiled.'
/hin- ʃakk- Ø- u/ → [hiffakku]
NEG- hesitate- 1SG/3SM- NEG:IPV 'He /I will not hesitate.'
/hin- saam- Ø- u/ → [hissaamu]
NEG- rob- 1SG/3SM- NEG: IPV 'He/I will not rob.'

The following rule reads that /n/ becomes [f, s, ʃ] when it occurs before this sounds.

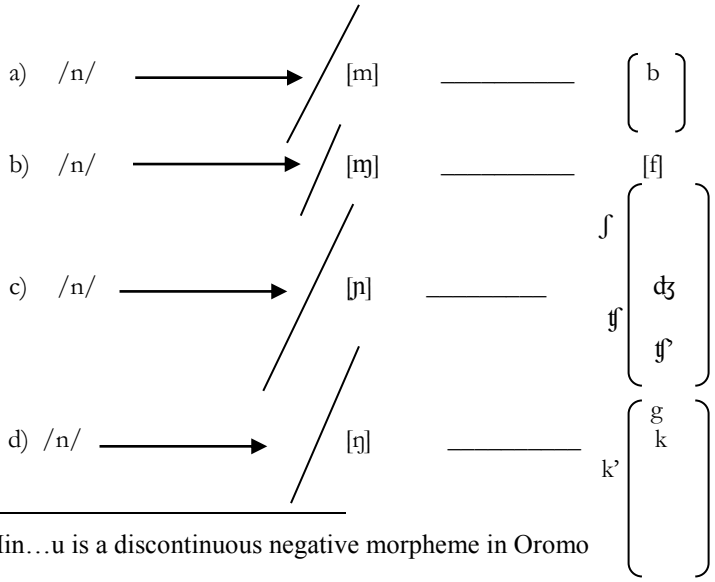


Assimilation of /n/ to Places of Articulation of Obstruents

Under this process, the sound progressively assimilates to the places of articulation of the obstruents. As given in (11), the assimilation in this process is partial and the products are nasal sounds throughout.

(11) */hin- beek- Ø- u/ → [himbeeku]*
NEG- know- 1PL/3SF- NEG: IPV 'I do not/he does not know.'
/ʧ'uunfaa/ → [ʧ'uuɱfaa] 'juice'
/sangaa/ → [saŋgaa] 'ox'
/saank'aa/ → [saaŋk'aa] 'timber'
/hin- kenn- Ø- u/ → [hiŋkennu]
NEG- give- 1SG/3SM- NEG: IPV 'He/I will not give.'
/leenʧ'a/ → leeɲʧ'a 'lion'
/hin- ʃaakal- t- Ø- u/ → [hiɲʃaakaltu]
NEG- practice- 3SF/2- SG- NEG: IPV 'You (SG)/She will not practice.'
/hin- ʤaam- t- Ø- a/ → [hiɲʤaamta]
FOC- blind- 2- SG- IPV 'You will be blind.'
/hin- ʧaappaa- esss- Ø- u/ → [naɲʧaappessu]
FOC- seal- CAUS- 3SM/1SG - IPV 'He will not stamp it.'

The following rule illustrates that /n/ surfaces as [m] when it occurs before /b/, [ɱ] when it comes before /f/, [ɲ] when it occurs before postalveolars /ʃ, ʤ, ʧ, ʧ'/ and [ŋ] when it is followed by velars /k, k', g/.



[10] Hin…u is a discontinuous negative morpheme in Oromo

Assimilation of /n/ to Sonorant

As (12) reveals, the voiced alveolar nasal sound /n/ regressively and progressively and totally assimilates to /l/ and /r/, and progressively and totally assimilates to /j, w, m, ɲ/.

(12)[11] /*hin- raf- Ø - u*/ → *[hirrafu]*
NEG- sleep- 1SG/3SM- NEG:IPV 'He/I will not sleep.'
/*waan jabbuu*/ → *[waajjabbuu]*
thing thick 'thick thing'
/*kan Lataa*/ → *[kallataa]*
GEN Lata 'Lata's'
/*gal- n- e*/ → *[galle]*
enter- 1PL- PRV 'We entered.'
/*ʔidʒaar- n- a*/ → *[ʔidʒaarra]*
build- 1PL- IPV 'We will build.'
/*kan Waak'aa*/ → *[kanwaak'aa]*
GEN God 'God's'
/*kan Murteessaa*/ → *[kammurteessaa]*
GEN Murtessa 'Murtessa's'
/*sun ɲaata*/ → *[suɲɲaata]*
DEM food 'That is food.'

The following two rules show that /n/ becomes [l] and [r] when it precedes and follows them, whereas it becomes [j, w, m, ɲ] when it is preceded by these sounds.

a) /n/ → [l, r, j, w, m, ɲ] / ____ [l, r, j, w, m, ɲ]

b) /n/ → [l, r] / ____ [l, r]

Assimilation of Velars to Alveolars

In this process, velars /k, k', g/ sounds totally and progressively assimilate to alveolar sounds. This process is common in the Macha variety of Oromo. The process has been discussed in (13).

(13)[12] /*gog- s- Ø- e*/ → *[gosse]*
dry- CAUS- 1SG/3SM- PRV 'He/I made dry.'
/*milik'- s- Ø- e*/ → *[milisse]*
escape- CAUS- 1SG/3SM- PRV 'He /I let escape.'
/*ɗoks- i- t- Ø- e*/ → *[ɗossite]*
hide- EPN- 3SF/ 2- SG- PRV 'You (SG)/She hid.'
/*dugda*/ → *[dudda]* 'back'
/*gog- t- e*/ → *[godde]*

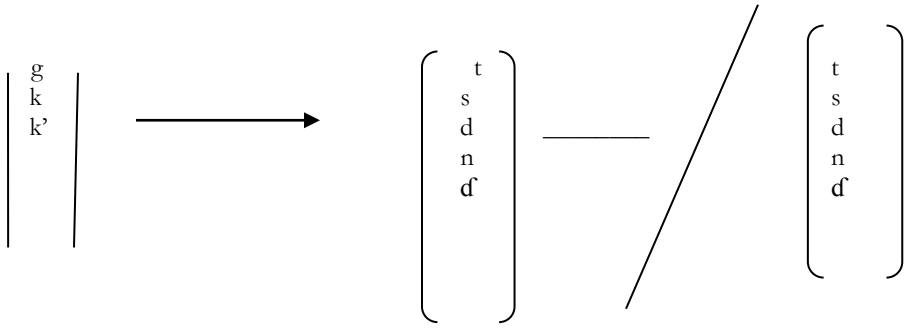
[11] GEN: genitive, DEM: demonstrative
[12] DIM: diminutive, SG: singular

dry- DIM- PRV 'It became dry.'
/*ɗug- n- e/* ⟶ *[ɗunne]*
drink- 1PL- PRV 'We drank.'
/sik'- t- Ø- e/ ⟶ *[sitt'e]*
move- 3SF/ 2- SG- PRV 'She/you moved.'
/ɗak'na/ ⟶ *[ɗanna]* 'body'
/mak- t- Ø- e/ ⟶ *[matte]*
mix- 3SF /2- SG- PRV 'You (SG)/She mixed.'

As the assimilatory process in (13) reveals, the combination of /gt/ does not surface as [tt]. This is because the process has been blocked by the voicing assimilation which takes place before the assimilation of velars to alveolars. Then, the order will be:

/gt/ ⟶ [gd] ⟶ [dd].

The following rule reveals that velars become alveolars when they are followed by the alveolar sounds.

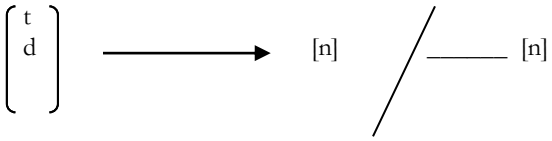


Assimilation of the Alveolar Stops /d, t/ to /n/

In many dialects of Oromo, the voiced and voiceless alveolar stops /d, t/ regressively and completely assimilate to the manner of articulation of the voiced alveolar nasal /n/ as shown in (14).

(14) */fid- n - e/* ⟶ *[finne]*
bring- 1PL- PRV 'we brought.'
/bad- n- a/ ⟶ *[banna]*
disappear- 1PL- IPV 'We will disappear.'
/hat- n- a/ ⟶ *[hanna]*
steal- 1PL- IPV 'We will still.'
/hirmaat- n- e/ ⟶ *[hirmaanne]*
share- 1PL- PRV 'We shared (something among/between us .)'

The following rule says that/ t/ and /d/ become [n] when they are followed by /n/.



Assimilation of Labials and Labiodentals to Alveolars

In this process, bilabials /b, m/ and the voiceless labiodental fricative /f/ progressively assimilate to alveolars. This feature is highly prevalent in the Guji dialect. As illustrated in (15), the voiced bilabial nasal /m/ partially undergoes place assimilation with alveolars and surfaces as [n]. But the voiced bilabial stop /b/ and the voiceless labiodental fricative /f/ undergo complete progressive assimilation with alveolars.

(15) */k'ab- n- a/* ⟶ *[k'anna]*
have- 1PL- IPV 'We do have.'
/ʧ'im- t- Ø- e/ ⟶ *[ʧ'inte]*
strong- 3SF/ 2- SG- PRV 'She/you (SG) became strong.'
/haam- n- e/ ⟶ *[haanne]*
mow- 1PL- PRV 'We mowed.'
/lik'ims- Ø- e/ ⟶ *[lik'inse]*
swallow- 1SG/3SM- PRV 'He/I swallowed.'

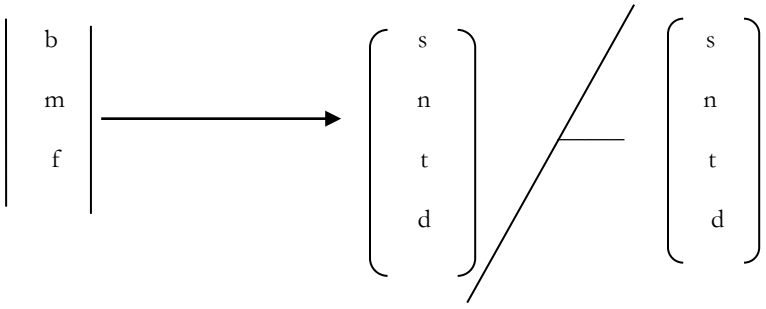
/ʧ'ab-	*s-*	Ø-	*e/*	⟶	*[ʧ'asse]*	
break-	CAUS-	3SM/1SG-	PRV		'He/I broke.'	
/gub-	*t-*	*i/*	⟶	*[guddi]*		
burn-	3SF-	IPV		'She will burn.'		
/ɗuf-	*t-*	Ø-	*e/*	⟶	*[ɗutte]*	
come-	3SF/2-	SG-	PRV	'She/you (SG) came.'		
/raf-	*n-*	*e/*	⟶	*[ranne]*		
sleep-	1PL-	PRV		'We slept.'		
/haf-	*t-*	Ø-	*e/*	⟶	*[hatte]*	
remain-	3SF/2-	SG-	PRV		'She/you (SG) remained.'	
/kaas-		*t-*	Ø-	*e/*	⟶	*[kaatte]*
wake up-	3SF/2-	SG-	PRV		'She/you (SG) made wake up (somebody).'	

In the above process, one may expect that /bt/ would surface as /tt/. But before the assimilation of bilabial to alveolar takes place, the voicing assimilation, i. e, /bt/ ⟶ [bd], takes place and such a sequence of voiced stops further undergoes a place assimilation and surfaces as [dd].

Another interesting feature in the above process is the dissimilation of the sequence of /st/ into [ft], which gives input for assimilation as in the word *kaaste* 'she made wake up (somebody else)'. In this case two phonological processes, dissimilation and assimilation, take place consecutively. The underlying form */kaaste/* undergoes dissimilation and surfaces as [*kaafte]*. The sequence of segments /ft/ will be further subject to assimilation and surfaces as [tt]. Thus, the order is illustrated as

/st/ ⟶ [ft] [tt]. ⟶

The following rule says /m/ becomes [n], and /b/ and /f/ become alveolarized[13] after alveolars.

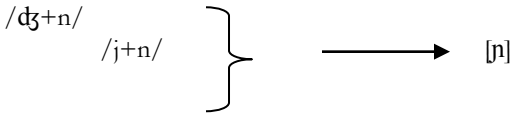


Reciprocal Assimilation or Coalescence

(16) Shows that when/n/ is preceded by /ʤ/ and /j/ the combinations results in the voiced palatal nasal /ɲ/.

(16)	*/kabaʤ-*	*n-*	*e/*	⟶	*[kabaɲɲe]*	
	respect-	1PL-	PRV		'We respected.'	
	/faʤaʤ-	*n-*	*e/*	⟶	*[faʤaɲɲe]*	
	dizzy-	1PL-	PRV		'We became dizzy.'	
	/gaj-	*n-*	*e/*	⟶	*[geeɲɲe]*	
	arrive-	1PL-	PRV		'We have arrived.'	
	/booj-	*n-*	*e/*	⟶	*[booɲɲe]*	
	weep-	1PL-	PRV		'We wept.'	

The following rule reads that the combinations of /ʤn/ and /jn/ surface as [ɲ].



[13] This terminology is not popular in linguistics, but I used it from the analogy of platalization, velarization, etc. because this process is common in Oromo.

In the above assimilatory process, the other interesting feature is *compensatory lengthening*. In Oromo if the stem final segment is one of /j, w, ɗ, h, ʔ/, the terminal consonants are deleted and the root vowels undergo lengthening when an affix which begins in a consonant sound is attached to the stem (Dejene, 2010). In above examples, one may argue that there is no deletion because the consonants involve in assimilation. But I argue that there is deletion plus compensatory lengthening but the trace is still there in coalescence. For instance *baj- t-e* 'she went out' would surface as *baate* 'she went out.' While in the word *gaj-t-e* 'she arrived' the surface form will be *geesse* 'she arrived'. In *baate* the terminal consonant segment has been deleted while in *geesse* the sequence /jt/ softens into [ss]. The vowel length in both cases resulted from the compensatory lengthening, while the softening process is conditioned from the trace of voiced palatal approximant /j/. Thus, we could conclude that there is compensatory lengthening in all environments, but the consonants are sensitive to some phonological processes (assimilation in the above case) when the environment influences them.

In Arsi-Bale, Guji and Borana dialects, the combination of /j+n/ surfaces [nn]. It may give us the impression that the voiced palatal approximant /j/ undergoes complete assimilation with the voiced alveolar nasal /n/ in the dialects under question unless we critically investigate the underlying realization.

If we consider the relationship between /n/ and /ɲ/ in the aforementioned dialects and the other dialects in the language, we learn that they are free variants. Let us substantiate our claim by the following examples:

/keeɲɲa/ ⟶ *[keenna]* 'ours'
/k'abeeɲɲa/ ⟶ *[k'abeenna]* 'property'
/ɗageeɲɲe/ ⟶ *[ɗageenne]* 'We heared'

Words in the first group are spoken in the Macha, Tulama, Kamisee and Hararghe dialects, while words in the right-hand are mainly spoken in Arsi-Bale, Guji and Borena dialects. Whether a word is grammatical or lexical, it is predominantly pronounced, based on the above analysis.

Thus, in the light of this analysis, we can argue that the combination of /j+n/ surfaces as [ɲɲ] in all dialects and finally free variation will take place in Arsi-Bale and other aforementioned dialects. We can sum it up as follows:

/j+n) ⟶ [ɲɲ[⟶ [nn]

Assimilation of /t / to /ʔ/

In this process, the voiceless alveolar stop /t/ of the preposition *ʔitti* 'at' distantly assimilates to the word initial voiceless glottal stop /ʔ/ in some areas in Tulama dialect. As (17) illustrates this process always takes place at morpheme boundaries as follows.

(17)[14]	*/si-*	*itti*	*ʔoʔ-*	*e/*	⟶	*[sitt'oʔe]*
you-	at	hot				'you felt hot.'
/na-	*itti*	*ʔaare/*			⟶	*[natt'aare]*
me-	at	smoke				'Smoked at me.'
/ʔiʃee-	*itti*	*ɗeerate/*			⟶	*[ʔiʃeett'eerate]*
her-	at	long				'The size (of cloth)exceeded her.'
/si-	*itti*	*ɗaamote/*			⟶	*[sitt'aamote]*
you-	at	cold				'You felt cold.'
/nu-	*itti*	*utaale/*			⟶	*[natt'utaale]*
1PL: OBJ-	at	jump			⟶	'It jumped at us.'
/na-	*itti*	*ʔiyye/*			⟶	*[natt'ijje]*
me-	at	shout				'Shouted at me.'

It may be argued that the voiceless glottal stop / ʔ/ and the voiceless alveolar ejective stop /t'/ have a weak relationship. But I claim that the conditioning factor for the glottalization is the voiceless glottal stop / ʔ/, which is orthographically not yet recognized in the writing system of the language, but phonetically there. Their relationship is that / ʔ/ is a glottal sound, while /t'/ is formed by glottalic egressive airstream mechanism. Thus, the underlining combination of /tʔ/ will surface as [tt'] because /t/ assumes a phonetic feature of the glottal sound /ʔ/ and become glottalized. The process results in reciprocal assimilation.

The following rule reads that /tʔ / becomes [tt'] at a word boundary.

/t/ ⟶ [t'] ____ / ʔ #

Vowel Nasalization

In Oromo, all vowels are nasalized when they occur before or after the nasal sounds /n, ɲ, m/. Dejene (2010) claims that vowels in the Kamisee dialect are nasalized when they occur after nasal sounds. But the finding has been refuted by

[14] OBJ: objective

the present study that vowels are nasalized when they occur before and after the nasal sounds. The process has been discussed in (18) as follows:

(18)/*nama*/ ⟶ *[nãmã]* 'person'
/*lilmoo*/ ⟶ *[lilmõõ]* 'needle'
/*lammii*/ ⟶ *[lãmmĩĩ*] 'relative'
/*ʔamma*/⟶ *[ʔãmmã]* 'now'
/*manneen*/ ⟶ *[mãnnẽẽn]* 'houses'
/*fuŋŋaan*/ ⟶ *[fũŋŋããn]* 'nose'

The following nasalization rules say that vowels are nasalized when they are preceded and followed by nasal sounds.

a) /v/ ⟶ [ṽ] / ____ [m, n, ɲ]

b) /v/ ⟶ [ṽ] / [m, n, ɲ] ____

Palatalization

Dejene (2010) claims that the superimposition of the front high unrounded vowel /i/ or the palatal approximant /j/ onto consonants preceding front high and front mid unrounded long vowels /iː, eː/ remarkably takes place in the Kamisee Oromo dialect. Compared to the Kamisee Oromo dialect, palatalization in other dialects is fairly moderate, but the colour is there. The process has been shown in (19).

(19) /*diida*/ ⟶ *[ʤiida]* 'outside'
/*fiige*/ ⟶ *[fʲiige]* 'He/I ran.'
/*deemte*/⟶ *[ʤeemte]* 'You(SG)/she went.'
/*seente*/⟶ *[sʲeente]* 'You(SG)/she entered.'

The following rule says that a consonant sound becomes palatalized when it is followed by front high and front mid unrounded long vowels.

/c / ⟶ [cʲ] / ____ [iː, eː]

Palatalization of /t, t', d, l/

The remarkable palatalization process in the language takes place when the *causative* process occurs. (20) Shows that in this process when /t, t', d, l/ are followed by causative markers, *-s, -sis, -siis, -sisiis*, the consonants surface as [ʧ, ʧʼ, ʃ].

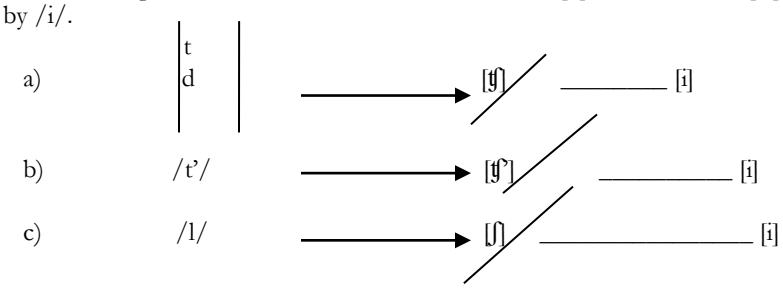
(20)[15] /*kut- sisiis- Ø- e*/ ⟶ *[kuʧʧisiise]*
cut- CAUS- 1SG/3SM- PRV 'He/I made cut.' /*fit'- sisiis- Ø - e*/ *[fiʧʧʼisiise]*
finish- CAUS- 1SG/3SM- PRV⟶ 'He/I made finish.'
/*fid- sisiis- - e*/ ⟶ *[fiʧʧisiise]*
bring- CAUS- 3SM- PRV ⟶ 'He/I made bring.'
/*gal- s- i- n - e*/ ⟶ *[gaʃʃine*[16]*]*
enter- CAUS- EPN- 1PL- PRV ⟶ 'We made enter.'
/*k'al- siis- Ø- e*/ ⟶ *[kʼaʃʃiise]*

[15] The causative markers have different roles in Oromo. Because it does not serve any purpose here to mention the function of the causative markers in glossing, I just used CAUS to mean *causative marker*.

[16] Some speakers of Oromo pronounce *gaʃʃe* as *galʧine*. In both cases *the* palatalization process takes place, but the former shows complete assimilation, while the later is partial assimilation.

kill - CAUS- 3SM/1SG- PRV 'He/I let (someone) slaughter (something).'

The following rules shows that /t/ and /d/ become [ʧ], /t'/ becomes [ʧ'] and /l/ becomes [ʃ] when they are followed by /i/.



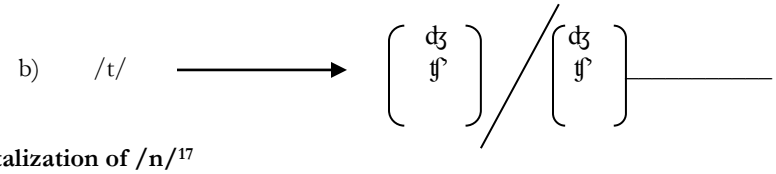
Kebede (1994) argues that there is /i/ sound before the causative markers *-s, -sis*, *-siis, -sisiis* as *-is, -isis -isiis -isisiis*. But Dejene (2010) argues that the synchronic fact does not support the position held by kebede. Logically speaking there may not be any palatalization without some trigger (likely to be /i/ in the present case). But the departure point between the two scholars is whether /i/ is synchronically there or not. The claim behind Dejene's (2010) and the present study is that the sound /i/ does not exist in any underlying realization in other environments. Thus, it is really difficult to readily conclude that it is there synchronically. Therefore, it is argued that/ i/ is the conditioning factor, but it might have been diachronically deleted and the palatalizing trace remained.

Palatalization of /t/

(21) Reveals that /t/ completely and regressively assimilates to the two postalveolar sounds /ʤ, ʧ'/.

(21) */kabaʤ- t- Ø- e/* ⟶ *[kabaʤʤe]*
respect- 3SF/2- SG- PRV 'She respected.'
/waʧ'- t- Ø- e/ ⟶ *[waʧʧ'e]*
disturb- 3SF/2- SG- PRV 'She/you disturbed.'

The following rule reads that /t/ becomes [ʤ] and [ʧ'] when it is preceded by these sounds.



Palatalization of /n/[17]

In the Macha and Tulama dialects, the paltalization of /n/ is accompanied by metathesis and dissimilation. In this process, the voiced alveolar nasal /n/ regressively assimilates to the voiceless palatal ejective affricate /ʧ'/ and becomes [ɲ]. Another interesting feature in the process is metathesis accompanying the assimilation and the dissimilation of the voiceless palatal ejective affricate /ʧ'/. When the underlying trigger of palatalization /ʧ'/ undergoes such a metathesis process, it surfaces as a voiceless glottal stop /ʔ/. The process has been substantiated in (22).

(22) */miiʧ'ne* ⟶ *[miiɲʔe]* 'We washed (something)'.
/waʧ'ne/ ⟶ *[waɲʔe]* 'We shouted or disturbed.'
/k'iʧ'ne/ ⟶ *[kiɲʔe]* 'We poured (some liquid) in a little amount'

Waqo (1988) thinks that the above process, i.e, when /n/ is preceded by /ʧ'/, /n/ is glottalized as [nˀ]. But the fact emerging from the present study refutes the finding. As the examples in (22) reveal it is not the colour of the glottal stop [ʔ] which is superimposed onto /n/; rather /ʧ'n/ results in fully flagged combination of [ɲʔ].

The order of the three processes will be as follow:

/ʧ'n/ [ʧ'ɲ] ⟶ [ɲʧ'] ⟶ [ɲʔ]

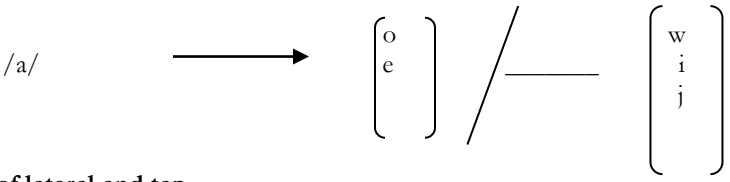
Vowel raising

[17] While it is possible to treat this feature under nasal assimilation or assimilation of /n/ to obstruents, I deliberately treated it separately because it has a remarkable feature to be discussed as assimilation plus metathesis and dissimilation.

The low mid unrounded vowel /a/ rises to the mid back rounded vowel [o] when it is followed by a voiced labiovelar approximant /w/, and rises to the mid front unrounded vowel [e] when it is followed by the high front unrounded vowel /i/ and the voiced palatal approximant /j/, as has been given in (23).

(23) a) */matʃaaj- t- Ø- e/* ⟶ *[maoofte/matʃootte*[18]]
intoxicate- 3SF/2- SG- PRV 'You/She became intoxicated.'
/ʔurgaaw- t- Ø- e/ ⟶ *[urgoofte]*
smell good- 3SF/2- SG-PRV 'You (SG)/she smelt good.'
b) /murtaaj- s- Ø- e/ ⟶ *[murteesse]*
decide- CAUS- 3SM /1SG- PRV 'He/I decided.'
/haɗɗaaj- s- i- n- e/ ⟶ *[haɗɗeessine]*
sour- CAUS- EPEN- 1PL- PRV 'We made (something)sour.'
c) /gaj- n- e/ ⟶ *[geeɲɲe]*
arrive- 1PL- PRV 'We have arrived (at somewhere).'
/kaaj- t- e/ ⟶ *[keesse*[19]*]*
put- 3SF- PRV 'She put (something somewhere).'
/taaʔ- t- e/ ⟶ *[teesse]*
sit- 3SF- PRV 'She sat.'

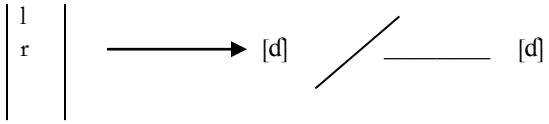
As we observe from example (b), the stem final segments are /j/ and /w/ though it has been argued that the stem final /w/ conditions the vowel rising. The reason here is that /w/ and /j/ are free variants in different dialects (Dejene, 2010), and the underlying segment to trigger the vowel raising process, thus, is the voiced labiovelar approximant /w/. By the same token, the conditioning and the underlying stem final segment in example (c) is /j/, which surfaces as /j/, and /ʔ/in different dialects.
The following rule illustrates that /a/ rises to [o] after /w/ and rises to [e] after /i/ and /j/.



Assimilation of lateral and tap
(24) shows that in the Guji dialect of Oromo the voiced lateral alveolar approximant /l/ and the voiced alveolar tap or trill /r/[20] completely and progressively assimilate to the voiced alveolar implosive /ɗ/.

(24) */hirɗuu/* ⟶ *[hiɗɗuu]* 'not full'
/birɗate/ ⟶ *[biɗɗate]* 'He/I glimpsed.'
/falɗaana/ ⟶ *[faɗɗaana]* 'spoon'
/walɗaansoo/ ⟶ *[waɗɗaansoo]* 'struggle'

The following rule shows that /l/ and /r/ become [ɗ] when they are followed by this sound.



Assimilation of /k'/ and /t'/ to /n/
In many dialects of Oromo, the voiceless alveolar ejective stop /t'/ undergoes progressive voice assimilation with the voiced alveolar nasal /n/ and surfaces as the voiced alveolar implosive [ɗ], while the voiceless velar ejective stop /k'/ undergoes progressive place and voice assimilation with /n/ in the Macha dialect. The other remarkable feature in this

[18] It is pronounced as matʃootte in the Guji dialect because of the assimilation of bilabials and labiodentals to alveolars.
[19] /jt/ and /ʔt/ softened into [ss].
[20] In Oromo the sound/r/ is an alveolar tap /ɾ/ when it is not geminated, and an alveolar trill when it is geminated. But for simplicity's sake, I used the same symbol /r/ in both cases.

assimilatory process is that it is accompanied by metathesis, in which the sequences of /t'+ n/ and /k'+ n/ result in [n+ ɗ]. The process has been discussed in (25).

(25)

	/lit'-	*n-*	*e/*	⟶	*[linɗe]*
	enter-	1PL-	PRV		'We entered.'
	/fit'-	*n-*	*a/*		*[finɗa]*
	finish-	1PL-	IPV	⟶	'We will finish.'
	/hak'-	*n-*	*a/*	⟶	*[hanɗa]*
	delete-	1PL-	IPV		'We will delete.'
	/laak'-	*n-*	*e/*	⟶	*[laanɗe]*
	mix-	1PL-	PRV		'We have mixed.'

The following rule shows that the combinations of /t'n/ and /k'n/ surface as [nɗ].

/t'+n/
/k'+n/ } ⟶ [nɗ]

Conclusion

Assimilation in Oromo is more of morpho-phonemic process and takes place mainly at morpheme boundaries. With regard to the direction of assimilation, both progressive and regressive assimilations are evident in the study and predominantly take place contiguously. The fact emerging from the study reveals that though assimilation mainly results from the influence between consonant sounds, there are also assimilatory processes, which involve the interaction of consonants and vowel sounds. In the process, the voiced alveolar nasal /n/ actively assimilates to sonorants and obstruents. Many processes in the assimilation occur across the dialects while some processes are dialect specific. For instance, velars in the Macha dialect and bilabials and labiodentals in the Guji dialect assimilate to alveolars.

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5.2 Department of History and Heritage Management

5.2.1 Socio-economic Conditions of the Peasants in Hararghe Highland, 1941-1974

Reta Duguma Keneni

Abstract: This paper attempts to throw light on the condition of peasants' life in Hararghe after 1941. An attempt is also made to shade light on the period of conquest in 1887 until 1941. The people of Harar suffered first under Egyptian rule and then under neftegna-gebbar system with the conquest of Harar by Menelik in 1887. As a region that resisted Menelik's forces, the state confiscated all lands in the region and granted it to those who helped in the conquest (governors, officials, soldiers, Church, etc.) and to the growing influx of settlers until the occupation of Italian in Ethiopia. After the liberation of the country, the state declared its reforms with a semblance that it was dedicated to relieve the peasants of the malkagnas who demand various payments and services from the peasants. Notwithstanding, however, the state wanted to quench its appetite by augmenting the tax collected from the peasants to its treasury and to reduce those intermediate officials who alienated the state from the tax. After 1941, the state resorted to granting the land to the patriots, soldiers, exiles and others. The net effect of this land policy was that peasants in Hararghe were alienated from their land and reduced to the status of servitude. Tenancy was a ubiquitous phenomenon. In most cases land was curved out under the blurred term of 'government land', 'state domain' and the state granted it to whom it wished but the peasants had to be evicted from their land or become tenant. Intensified land measurement and its classification made the peasants still targets of exploitation and oppression since tax assessors were not honest in the classification of the quality of their land. Owing to onerous tax and various demands from the tenants by the government and the landlords in Hararghe, the peasants were compelled to move to Ramis valley to resort to pastoralism or moved to Bale and Arsi to work simply as tenants on qalad. Eventually, on the eve of the coming to power of the Derg peasant revolt which broke out in Garamulata spread to Mechara, Michata, Habro, and Guba Koricha though it was short-lived. The Derg eradicated the gebbar system, exploitative tenancy, extensive holdings and absentee landlordism altogether. But the revolt leaders were decimated by the Derg on grounds of allegedly supporting the bourgeoning nationalist organization.

Keywords: Socio-economic; Peasants; Tenant; Hararghe

Introduction

In former times, Hararghe was one of the 14th provinces in Ethiopia during the imperial and Dergue periods. Historically, the region which is customarily dubbed Harar plateau has at no time constituted homogenous political entity. Currently, the region of Eastern Ethiopia hosts four neighboring National Regional States: Afar, Somali, Oromia (East and West Hararghe) and Harari, and Dire Dawa Administrative Council.

In general the physical landscape of eastern Ethiopia can be divided into hot and arid climatic conditions settled by the Afar and Somali pastoralists, and Oromo settled areas which include the largest geographic area that runs east-west direction ranging from hot lowlands to wet highlands, where agriculture is highly practiced (Emiru, 2001). According to the Central statistical Agency (CSA, 2008), the total population of Eastern Ethiopia is 10,995,191. According to this census, more than eighty ethnic groups are found in Eastern Ethiopia together with foreign nationals. Accordingly, ethnic diversity is high together with the somewhat ancient population of the region and thriving trade in the region lured more recent population settlement. Since the region is a vital outlet to the outside world, both legal and illegal trade configuration must have created a good opportunities for new comers into the region from elsewhere in Ethiopia (FDRE, Population and Housing Census Report, 2008). Even in the medieval period of Ethiopian history the region remained a bone of contention between the Muslim state of Adal and the Christian highland kingdom over control of the lucrative trade route leading to Zeila and Berbera. This eventually led to the war of Ahmed 'Gragn' in the 16th century (Trimingham, 1953; Tadesse, 1972). Another major development during this time was the Oromo population movement, which brought the Barentu Oromo to the region of Hararghe. The first Oromo-Harari contact was in 1559 after Amir Nur succeeded Ahmed Gragn. Initially, relations between the Harari and the Oromo were not easy, but it later developed into negotiated market relations despite the fact that it was not always smooth. While, the Hararis and Oromo maintained and formed alliances and market relations over a long period of time, the Egyptian occupation of the region from 1875-1885, adversely affected the relation between the two peoples. Nevertheless, with the Egyptian evacuation from Harar in 1885, the independent existence of the emirate of Harar was restored under Emir Abdullahi though short-lived until its conquest by Menelik after the bloody battle of Chelenqo that took place on 6, January 1887 (Sydney, 1984; Mohammed; 1973). It is with this later development, which has a long standing repercussion on the life of the people in the region that this paper is intending to deal with.

Objective of the study

The overwhelming majority of studies conducted on Hararghe region focus on the political, social, economic and cultural aspects of the people of Harari though studies on the condition of the life of the peasant masses in Hararghe is scarce and at best fragmentary. Both expatriates and nationals have produced much works on Harar city and its peoples from the ancient to the relatively more recent periods. These studies made a mere mention of the surrounding Oromos in relation to the Harari, deals not so much about the Oromos outside the city and its surroundings. The only exception is Professor Mohammed Hassen, who devotes his work to the traditional social, political and military institutions of the Oromo outside the city making sober treatment on the subject. This study is an effort to fill in the gaps that intrigued fuller understanding of the situations of peasant life in Hararghe albeit I do not claim that this study is exhaustive and complete.

Generally the study has the following objectives:

- To trace the overarching impacts of Menelik's conquest on the peasant masses of Hararghe from 1887 up until the Italian occupation of Ethiopia in 1935/36
- To discuss Imperial government's obsession to granting land to its favorites, soldiers and exiles after 1941 and the concomitant increase in scarcity of land and eventually the relegation of the peasants to the status of servitude
- To explore the intensification of land measurement, and augmentation of tax which became a burden to the toiling masses
- To discuss how appointed officials in Hararghe were dishonest and nonchalant to the plight of the peasants
- To discuss how eviction, land scarcity and burden of taxation compelled the peasants in the region to move to Bale and Arsi
- To briefly explain peasant revolt, measures of the Degue against revolt leaders and the land reforms taken by the Dergue.

Methodology and source

Since historical methodology requires exhaustive investigation of source materials, this work is heavily dwelt on both primary and secondary sources, published and unpublished documents, books, articles, journals, and manuscripts. Particularly, corpses of manuscripts collection of the former Minister of Interior found at the Wolde-Meskel Archival Center of the Institute of Ethiopian studies is a rich mine of manuscript collections on issues related to land tenure and other environmental issues that one can explore. Oral informants, who are eyewitness accounts during the period under the study, are consulted and used by crosschecking the information they have rendered with other sources in properly and seriously controlled way.

Menelik's Conquest of Harar

The evacuation of the Egyptian forces from Harar in 1885 gave emperor Menelik an opportune moment to carry out his campaign for the conquest of Harar, a rich province which he had been coveting for. After launching the most protracted and the deadliest campaign against Arsi Oromo, Menelik turned his attention to Harar. Thus, the battle of Chelenqo that took place on 6 January 1887 marked a milestone in the long saga of the region. Menelik triumphantly entered the city of Harar, the loci of Islamic learning and busy trade, bringing the region into the Ethiopian Empire. The people of Harari, the Oromo, and the Somalis had no other option but to surrender to strange rulers who treated the local people with their heavy hand.[1] The conquest of Harar was very crucial in that it brought Menelik into the most prosperous province which its proximity to the sea enabled him to import enormous weapons he used to fend off the Italians at Adowa. Though wild looting and wanton killings were the hallmarks of his southern conquest the Hararis to a certain extent spared such ominous act presumably because of the assurance that they gave to Menelik to pay indemnity both in cash and kind. Notwithstanding, however, the Emperor had confiscated the Amir's property, and some of those who had fought against the Shewan forces at Chelenqo. He used these properties to prop up Christian clergy and the garrison. Despite his somewhat magnanimous gesture towards the Hararis, however, the Oromos and the Somali were ruthlessly treated. Menelik's soldiers, particularly, the Gondaris who were reputed for raiding and plundering the local people, dispatched to the countryside. In the words of Richard Caulk, they took the whole thing "down to dogs and doves." Every attempt at uprisings by the local people was coldheartedly put down by the occupying army.[2]

Menelik appointed *Dejazmach* Mekonnen, later *Ras*, as governor of Harar and set off for Entoto on 7 February. Following Menelik's return to Shewa the Gondari soldiers hastened their raids, lootings and plundering the local population. Captives were turned to slaves. The Gondaris resumed to raiding and looting the countryside. Thus, the damage they brought to the Oromo was incalculable as the Oromos had no guarantee to their property and their lives.[3]

The Establishment of the *Neftagna-Gebbar* system

Since the forces of Menelik was thinly stretched over the Danakil and the Ogaden regions owning to their hostile climates, it was in the highland Oromo settled areas of Hararghe that the *neftagna-gebbar* established its hold firmly.[4] Two French travelers, Borelli and Rimbaud witnessed that several outposts were established at Gelemso and Boroma in

Chercher in May 1887. Rimbaud estimated the number of settlers who at the beginning flocked down to the province at 12,000 of whom 4000 men were armed with firearms. In the eastern highland regions Menelik's soldiers too founded garrison in areas like Babile, Jarso and the Giri areas near Jijiga.[5]

In the early 1890, *Deja* Mekonnen was promoted to *Ras* and additional forces were recruited from Tigre, Gondar, Lasta, and Gojjam and also from Shewa, all came along with their families. Hayla Giorgis, Mekonnen's biographer, candidly illuminates about these forces that "Their number was so great that the people of Shewa said: The whole world has followed him.[6]

At the outset the local people endeavored to put stiff resistance but put down and they were no longer capable of offering further resistance.[7] In the years that followed the battle of Chelenqo many garrison towns were established in Ittu, Afran Qallo and Anniya areas serving as centers of *neftagna* administration. Particularly, it was in such highland areas as Garamulata, Kombolcha, Wobberra, Qulubi, Kersa, Gursum, Chalenqo, Quni, Jarso, Harar, Jijiga, Ania, Gelemso, and Boroma in Chercher that *Ras* Mekonnen's officials, governors and soldiers moved and settled in different parts of Hararghe. With the outbreak of the great famine of 1888 to 1892[8] even additional settlers from the north and Shewa arrived in Harerghe. With the coming of a large number of settlers who were indiscriminately dubbed "Amharas" land scarcity became heightened creating strain on the local people [9]. As a consequence each major garrison area or *awaraja* had to host a number of settlers ranging from 3000 to 6000 and less than this figure in other smaller districts.[10]

These garrison towns were Christian Islands amidst of the "pagan" and Muslims for whom they thought should be under their ruthless firepower. These areas were socially secluded from the local people different in many respects among the people whom these new settlers demeaned and labeled them as "savage" and "infidels" deemed to be looted. Though the peasants in Hararghe opposed to the new *neftagna–gebbar* system, the *neftagnas* who had firearms responded ruthlessly and the local peoples were no longer capable of putting further resistance. At the same time the scourge of famine that attended the conquest greatly reduced the number of population. Added to this was the administration of the *neftagnas* which included the whole landowning class created by the Egyptian and as well as those emerging land owning class outside the realm of Egyptian control in the province of Chercher.[11]

The traditional leadership hierarchy of *damin* (chief of a whole tribe), *garad* (chief of a village), *malaq* (chief of sub-village) which was consolidated under the Egyptian, was acknowledged by *Ras* Mekonnen. Ostensibly, this administrative system seems to have been Adal's heritage. During the times of amirs, the city was divided into five gates each under officials bearing the preceding titles. This system was later extended to farming regions for the purpose of taxation and supervision of land under amir's control. At the higher echelons of power were the *dogins* who were always Harari. The Oromos who were usually titled *garad* and *damin* retained part of the taxes they collected and this increased their wealth and linked them to the Harari both politically and economically.[12] Hence, this traditional titleholders continued to entertain the rights attached to these positions after the conquest of the region.

Under Menelik, this traditional position which was consolidated by the Egyptians remained undisturbed.[13] The *damin* chiefs and their subordinates, *garads* and *malaqas* were granted land as the southern chiefs were permitted to retain some degree of authority over their regions. The size of the land granted corresponds to their title or status while in Chercher province where Egyptian control did not extend; the *Abba* Burkas were allowed a *gasha* of land each. As a conquered regions were alienated from their lands the state retained vast portions of lands in Hararghe which the emperor distributed among his generals, officials, soldiers and settlers. Of course, land appropriation was carried out by Menelik's generals and their officials with the backing of the local *balabats*.[14]

After the conquest, the whole Hararghe highlands was claimed by the state as crown domain and the state used this claim as a legal right to curve and distribute land to whom it wished. *Ras* Mekonnen extended the office of *Damin*, *Garad* and *Malaq* to other areas outside Egyptian control and this traditional titleholders facilitated the exploitation of the local people by Menelik's governors, officials, soldiers and settlers.[15]

The indigenous peasants living in the vicinity of the major garrisons were assigned to the *neftagnas* as *gebbars* or serfs of the governors, officials, soldiers and settlers.[16] Since money was scarce and the tax was paid in kind, the newcomers continued quartering on the farming population of the conquered regions. At the same time, land distribution was conducted parallel with assigning *gebbars* to soldiers of the garrison towns. The number of *gebbars* allocated to each person commensurate with their rank, and status. Governors (*Rases*, *Dejazmaches*) may receive 1000 *gebbars* each, a *Fitawrari* up to 300 *gebbars*, a *Qagnazmatch* up to 150 *gebbars* and ordinary soldiers between 10 and 20 *gebbars*.[17]
The land was distributed and allocated to the governors; the rank and file of garrison soldiers, settlers like the clergy, the indigenous chiefs and the rest was designated government land.[18] The priests were also granted from three to five *gashas* of measured land in Hararghe. *Semon* land was granted to the Churches: Egziabher Ab (Asebe Teferi), Sellassie (Herna), Mikael (Doba), Qullubi Gabriel, Quni Giorgis. Priests from Gojjam, Gonder and Menz (from northern Shewa) came along with their *tabots*, sistra, praying stick and made conquest and blatant occupation of any land they found appropriate and established Churches. Prominent officials were also ordered the establishment of Churches in their realm. At the beginning some priests were given *qelab* or provisions as a salary for their services.[19]

By the year 1894 *Ras* Mekonnen employed various steps to make available more lands to the growing number of settlers to appropriate it to his large soldiers and civilian administrators. One of the measures taken was the introduction of *qalad* system (the instrument used to measure the land was a piece of rope called *qalad,* its size varied from 40 to 80 hectares) which was previously began with the conquest of Shewan Oromo in 1879 [20] and this helped to parcel out

unmeasured land into plots. In the surrounding areas of Harar where demographic pressure was high one *gasha* out of the excess holdings of eighty *garads* was appropriated and designated government land to be distributed to persons whom the state wished to favor. In Garamulata and eastern Chercher where population density was somewhat low one *gasha* was curved out of the holdings of ten *garads* and then registered as government land.[21] Not to impinge on the size of the land holdings of the peasants, the extent of *qalad* in Harar was fixed at a reduced size than that of Shewa. When *qalad* was available, soldiers and civil servants were given *maderya* land in lieu of salary. Some immigrants were allocated land as *rist* on account of settlement and long term use. The *qalad* system which was introduced by *Ras* Mekonnen enabled the appropriation of vast areas of land for its own purposes or to reward institutions and individuals who facilitated the conquest. Essentially, land measurement was relatively intensified in Chercher province of today's west Harerghe than in the eastern parts, where *quter gebbar* or unmeasured land was not uncommon. In the surrounding region of Harar where the highland population was concentrated land shortage became very high.[22] With the appointment of more and more *Malkagnas* (the term *malkagna* originally meant commander of 1,000 men. In Harar it applies to all ranks of *neftagna* who owned *gebbars*) over most of the districts in the vicinity of Harar particularly after the death of *Ras* Mekonnen in 1906 those with small plots constituting the poorer *garads* were even reduced to near serfdom.[23] The state continued to curve out land by taking different measures in the guise of excess holdings.

When *Ras* Teferi Mekonnen (later Emperor Haile Sellassie) became the governor of Harar in 1910, he set on to increase government land by restricting the maximum ceiling of holdings a *garad* or *malaq* supposed to own. In view of that extensive land survey which necessitated the introduction of a measurement unit which referred to as *Jarib* was initiated in 1912. Land was measured and the maximum holdings of a *garad* and *malaq* was circumscribed at 600 *Jaribs* (77.52 ha) and 300 *Jaribs* (38.76 ha), respectively. *Ras* Teferi sent first *Qagnazmatch* Habte Wold and later *Blambaras* Jire to Garamulata, Wobberra and Midhaga Lola to measure the land and distribute among *garads* and *malaqas* according to the maximum ceiling of holdings lay down for them. A vast land was measured and excess lands of the *garads* were coined out as government lands. The land which was acquired in this way was sold to the original occupiers given that they had the wherewithal to afford it. The remaining was divided and allotted to new settlers, government officials and soldiers as *maderya* land or offered to notable chiefs and favorites as *rist* or permanent holdings.[24]

In 1919 the government reduced the amount of land tax, which had been heavy and onerous under the Egyptian rule, with the view to increase the number of taxpaying tenants and also to lure new settlers. In the scarcely populated parts of Wobberra and Metta lands and as well in Chercher new *garads* were designated and tenants were made to settle on their land. The tenants enjoyed usufructuary rights and the right to inherit their property to their children as far as they paid land tax. The hereditability of land consequently led to the fragmentation of land in size as the young men marry up to four wives who given birth many children to a single father. In some families the number of children who laid claim to the land on the death of their father was as many as eighteen. Due to the large number of inheritors the land was further divided and reduced to small plots. In the year 1930s there was a sheer dearth of cultivable land in the highland regions of Hararghe given that there were about 300,000 settlers in 1939.[25]

Many tenants had small plots of *Shebata* (a unit of land measurement which its size varies from individual to individual or from ordinary farmer to the chiefs usually ranging from 0.24 to 16.22 hectares, the average holding being 4.29 hectares) land with the least having two hectares and the maximum 8 hectares. When they divided it among their families the size of their land diminished and eventually becoming fragmented plots which could not meet their sustenance. Most families left their premises and moved to other places vying for *qalad* (measured) land to work simply as tenants of the grantee offering *erbo* (1/4th) or *sisso* (1/3rd) of their produce. Some of the *gebbars* who had 15 or 39 hectares paid to *garads* a customary gift called *bercha* (usually in cattle) as a guarantee for continued tenure and for not incurring the disfavor of the *garads* or any other grantee.[26]

During the Egyptian occupation of Harar, the ceiling of the holdings of individual peasant was not defined and the tax exacted from them was back-breaking as it failed to consider the size and the quality of their plots. This problem persisted even after the conquest of Harar by Menelik since the category of the peasants' land and the ceiling of their holdings was not clearly defined. A *garad* who had settled a large number of *gebbars* on his land (600 *Jaribs*) had to collect more taxes commensurate with their number than one who had settled few *gebbars* on the same size of land. The tax payment would become heavier the more the number of *gebbars* settled on a *garad* land and its size become progressively diminished even when it was divided among each family. This trend was ubiquitous in Metta, Qulubi and right up to the Burka country and no overt efforts were made by the state to ease this problem though land measurement was recurrent and granted to its officials and the local chiefs.[27]

In Harar *Ras* Emru had tried to dispose the *malkagnas* the right to seek labor from *gebbars* except that those who had settled on their personal land *hudad* in their *malkagninet*. His efforts were to restrain the *malkagnas* from looking for corvee labor, the construction of their houses and repairing their fences. In 1922-23 Tekla Hawariat who was the more radical person in the Chercher sub-province of western Harar endeavored to remove *malkagninet* in general by assigning state pensionaries with uncultivated land as free hold. Nevertheless, his attempt to tax the owners of this and other *gult* holders earned him accusation of being a Bolshevik relating him to the Russian revolution.[28]

In 1923 Tekle Hawariat established the whole Chercher areas as Tafari's *gult* (absolute property) and conducting extensive land measurement. The land holding of a *garad* in eastern Chercher remained the same size as that of a *garad* in Harer with a length of 9 ropes and 6 in width (30.37 ha). On the other hand, the Burka system of the western Chercher

was somewhat larger and it was fixed at 11 ropes in length and 7 in width (43.30ha). Instead of the *Abba* Burkas who played intermediary role the tenants were made unswervingly accountable to the government. Since the area was reputed for its coffee production Tekle Hawariat levied land-use taxes six times greater than the one paid in Harar highlands and in due course making the region an area of unpleasant destination for those farmers who were coming from Harar highlands and yearning for land.[29]

In the Chercher sub-province of Masla and Hawaracha districts which were reputed for coffee production new *garads* were appointed and Tekle Hawariat put heavy taxes. The *gebbars* in the area were forced to pay 150 *birr* per plots of their land. The tenants continued periodic appeals though favorable response did not come.[30] However, Tekle Hawariat made some reforms in the collection of *Zakat*, a local variant of the tithe which he planned to eventually abolish. He also levied tax on khat with the view to disgruntle the planting of khat (inebriating plant). The revenue collected showed a dramatic increase from less than 100 to 200,000 Eth. *Birr* of which the greatest amount went to the state treasury to prop military organization.[31]

In 1930 *Ras* Teferi Mekonnen assumed the throne and carried out several measures to solve land shortage in Harar highlands. By September 1930 he passed a decree which declared the measurement of all lands in Harerghe by *qalad*. In April 1931 *Dejazmach* Emeru Haile Sellassie, the governor of the province, carried out land measurement in Harerghe and the *garads* and the *malaqas* were left with their 600 and 300 *Jaribs,* respectively. Excess land was measured in *qalad* and earmarked as government land to be distributed to new settlers with the support of a *malkagna*, a member of the gentry who was granted land for his service to the government. The granting of land was not given merely as wages (*maderya*) but also to settlers from the north who were granted *metoriya* land (in lieu of pension) for their service to the government.[32]

In the early 1930s the Ethiopian state was earnestly coveting to increase its revenue from the land taxation as the highest proportion of revenue was expropriated by different intermediary tiers who estranged the state from taxpaying cultivators of the land. The government also came to realize the burden that the peasants shouldered as the land holders imposed multiple exactions on them without contributing anything to the state treasury. During this period the government's intention was to abolish the intermediary levels that constituted different groups whom it granted landholding rights and the right to collect tribute. In the early 1930s, the government made initial endeavor albeit their implementation was interrupted by the Italian invasion in 1935.[33]

Intensified land measurement, classification, grant and the concomitant augmentation of tax: their repercussion on the peasants in Hararghe, 1941-1974

During the Italian occupation in Ethiopia the *gebbar* system was abolished although the Italians required regular quotas of recruited force for road and public works.[34] With the restoration of the government in 1941 the government sought to eliminate intermediary tiers to increase its revenue by way of converting tribute to tax. The first tax proclamation in this regard was made in 1942 and the tax rate on both measured and unmeasured land was fixed at half the rate of 1935. Accordingly, the tax rate for forty hectares (*gasha*) was set at 15 Eth. *Birr* for cultivated land (*lam*), 10 for semi-cultivated (*lam-taf*), and 5 for uncultivated land (*taf*). In 1944 another decree was issued and the tax was increased on measured land to Eth. *Birr* 50, 40 and 15 per *gasha* of *lam*, *lam-taf*, and *taf,* respectively. Hararghe was also one of the many regions in Ethiopia which was subjected to this rate on its measured lands.[35]

In Hararghe much of the revenue from land taxation had come from the highland regions. The land was divided into measured and unmeasured (*quter gebbar*). The measured land was categorized into cultivated, semi-cultivated and uncultivated lands. The tax was also imposed based on this classification. In Chercher *awaraja* the size of a *gasha* (*qalad*) land was fixed at about 433, 125 square meters while in Harar and other *awarajas* it was decided at about 303, 750 square meters. In Chercher the number of *gebbars* who settled on a *gasha* land invariably range from about six to as many as twelve, while in other *awarajas* of Hararghe the size and the fertility of land as well as the number *of gebbars* who were supposed to settle on a *gasha* land was not defined. By virtue of being *gebbars* all the peasants were obliged to pay uniform tax regardless of the size and fertility of their lands. In Chercher, with the exception of those peasants in Masla and Hawaracha districts, most of the lands in the rest regions were somewhat measured and the land tax was made to be paid according to the size and quality of their land. In the upper Chercher the peasants were somewhat paying taxes based on the new tax regulation though Masla and Hawaracha districts were under onerous tax.[36]

The process of land measurement in Masla and Hawaracha had been started before the Italian invasion, but its classification and implementation for taxation purpose was interrupted by the Italian occupation of Ethiopia. The peasants in these two districts, which were noted for their fertility of soil and coffee production, had to pay land-use tax incongruent with the new tax decree since they paid as set before 1935 which was imposed on them by the ex-governor of the *awaraja*, Takala Hawariat. This created a great burden to the toiling masses. In these two districts the land tax for the first quality measured land was fixed at 65 *Birr* per *gasha* and even in some areas they were forced to pay 150 *Birr* per plots. Contrary to these two districts of Chercher, the peasants in other areas of Chercher and Harar regions were more or less paying 26 *Birr* per their holdings. The tax system in these two districts neither considered the size of the peasants' holdings nor the quality of their lands. In these districts the number of *gebbars* which had to settle on a *gasha* land was neither defined like that of the rest of Chercher areas. Nor could maximum ceilings of holdings were initiated like that of Harar regions where *garads* and *malaqas* were granted 600 and 300 *Jaribs,* respectively. Thus, the peasants in the same

Governorate General of Hararge were under different tax systems and this distressed the peasants since their request did not secure hearings from the officials who were nonchalant to the peasants' misery. Neither the state was much concerned though its decrees were recurrent with a semblance that it was committed to ameliorate peasants' misery.[37]

In 1944, the government sent workers to east of Chercher in the highland regions of Harar and the neighboring *awarajas* to carry out land classification to be conducted with the auspices of *garad*, *malaqas* and *chiqa shum* so as to carry out the new tax regulation which was fixed by the decree. In the previous time (pre-1935) the *malkagnas* in Hararge imposed numerous exactions from the peasants by accruing the fruits of their toil in the form of tribute, the peasants were offering various services like grinding grains, providing mutton during holidays, giving corvee labor on their *hudad*, offering transportation services to the *malkagnas* which took much of their labor time. The new tax regulation was meant to ease these entire manifold burdens on the peasants. Notwithstanding, however, this new tax decree *per se* did not solve peasants' problems in Hararghe since the peasants were compelled to pay uniform tax despite the different size and varied quality of their land.[38]

The government's intention to send its officials to Harar in 1943/44 was for classification and assessment of taxes and as well as registration of land held by the local *balabats* and peasant cultivators. This measure was undertaken not to respond favorably and sympathetically in favor of the peasants request but to find out excess land. These officials discovered that some of the *garads* concealed their large holdings on accounts of being encroached by their rivals. As a consequence, the Office of the Governorate General of Hararghe sent to each *awaraja* a copy of registration book bearing lists of *gebbars* who were registered earlier in 1919. This was done to verify lest the *garads* concealed and not registering the land under their disposal and to know the number of peasants who settled on their lands. Notwithstanding, however, the peasants who settled on excess land chiefly in Wobberra and Garamulata, where the *garads* and *malaqas* were allotted land in *Jaribs*, were reduced to become tenant. Earlier the local *balabats* curved and took the best land for themselves and they permitted from one up to twenty or more *gebbars* settling on their land. The remainder was earmarked as government land which was kept under the disposal of the state to reward its officials and favorites with grants of such land. The *garads* and *malaqas* hence helped in assigning and registering tenants on *malkagna,* and government lands and as well as his lands, and overseeing tax payment by the tenants. When the *qalad tay* (those who measure the land) were sent to Wobberra and Garamulata they measured the holdings of a *garad* and *malaq* and what was left of the maximum ceiling allotted to them was confiscated as surplus land of the *garad* and *malaq* and designated government land. The *qalad tay* discovered several *garads* possessing excess land on which many *gebbars* as many as twenty were settled. These *gebbars* who had already settled on these excess lands were reduced to become the tenants of the grantee. [39] The *gebbars* were not even granted a fixed size of land.

The maximum land ceiling a *gebbar* should possess was not determined. Whenever a *garad's* land was measured it was not uncommon to discover excess land and those *gebbars* who settled on them were reduced to become tenants of the grantee. The remaining *gebbars* of a *garad* had to shoulder the tax burden. This was frequent after 1942. Though the ceiling of landholdings of *garads* and *malaqas* were decided, those of the *gebbar*s were not defined. In Wobberra and Garamulata, and Fadis, and Midhaga Lola sub-districts were the regions where land was measured and excess land was transferred to the hands of the government. While in Gursum and Harar *awarajas* where there were relatively vast lands, a *gasha* was carved from 10 *garads* and in Nole where land was scarce a *gasha* land was carved as government land from 80 *garads*. In the previous times, at least at the outset, *gebbars* who were dispossessed of their land and become landless in this way had to be provisioned in grains or fed by *garads*. If they received provisions for their up keep from *garads* they were required to pay tax. Later they refused to take ration and paying taxes.[40] But in the post-liberation period those *gebbars* who were alienated from their land due to land measurement refused to pay land-use tax since their land was granted to others. In Nole most of the *garads* own less than 600 *Jaribs* and others had large and still some others small. Though they own varying proportion they were subjected to the same tax rate which they opposed it. On the other hand those peasants who had lost their land by *qalad* were once exempted from tax but they were later obliged to pay the tax.[41] There was no regulation as to the size of land a *gebbar* should receive in *Jaribs* and the number of *gebbar* a *garad* should administer. In Nole and Gursum where *garads* and *malaqas* had not been granted lands in *Jaribs* those *gebbars* who lost their land through land measurement were exempted from tax. But in Wobberra and Garamulata since excess land was taken away from them the remaining *gebbars* had to shoulder tax burden and those *gebbars* who settled on these excess lands were transformed to become the tenants. Though the land held by the peasants was not precisely defined in most parts of Hararghe, in Chercher from 6 up to 12 *gebbars* settled on a *gasha* land and a *gebbar's* holdings range from 27 to 55 *Jaribs*. Similarly peasants in Hararge held from 10 up to 15 *Jaribs* and in some areas from 100 to 200 *Jaribs*. As already discussed above the size of land held by the *gebbars* varied in size, some small and others had large and this made taxation unfair and put the peasant in misery. The province of Hararghe decided to ease the matter by limiting the holdings of *gebbar* at 50 *Jaribs* which was 1296x50=64,800 m^2 or six hectares and 4.800 m^2. The tenants who held more than the size allowed (50 *Jaribs*) were subjected to pay tax commensurate with the size of land or those who held less than 50 *Jaribs* pay a reduced tax but were not compensated by other plots. If *garads* and *malaqas* held a vast land beyond what was allowed for them, excess land was carved as government land.[42]

In some hot areas and lowlands of Gursum and Harar *awarajas,* peasants had large size of more than 50 *Jaribs* of land although their land was poor. However, they were obliged to pay 8, 12 and 6 *Birr* for the tithe, tax and education, respectively, which altogether totaled 26 *Birr*. This became a heavy burden and many of them left for other areas to

escape the burden of tax as they were compelled to pay high tax rate on poor land. This tax rate was equal with those having fertile land. The land in these areas was not measured and classified and hence this made tax system unwarranted in view of the fact that it was incompatible with the category of their land. Some of the peasants whom the burden of tax forced to leave their homestead were either forced to search for what was vaguely called government land to make it cultivable by occupation or conquest of the land.[43]

Land classification and the inherent problems

In Chercher *awaraja* many peasants who had worked as tenants on the *rist-gult* land preferred to move to the different districts of the region by making conquest and occupation of what was then coined out as government land. They cleared the land and made it cultivable and lived on it with their families for many years. But when the government granted these lands to its favorites peasants who had the wherewithal to afford were either allowed to purchase at least a third of their holdings or forced to become tenants of the grantee. However, the governors and officials were indifferent to handle and embark upon problems meted out to the tenants who had labored in toiling the land for a long period of time. Apart from this there was another problem which was faced by the tenants pertaining to tax assessment and category of the land. The government sent officials for the purpose of land category in 1945 [44] and their task was characterized by chaotic registration and inaccurate classification. The poor land was categorized and registered as semi-fertile while semi-fertile land was registered as fertile. Though the regulation laid down underscored that the *gebbars* should appeal within twenty days from the time of classification, this did not seem to have been so either due to lack of awareness on the part of the peasants or the officials intentionally denied them hearings so as to stifle and discourage further complaints. Again in 1950 officials were assigned to classify and make land assessment. By this time the peasants vehemently requested the officials to correct chaotic classification which ignored the quality of their land. The response of the officials to the peasants was even infuriating to the extent that they came to upgrade its category, and register poor land under semi-fertile and semi-fertile as fertile and augment the tax accordingly. This made taxation unjust and put the peasants in despondency as the landlords were retaining much and delivering some portions of what they had collected from the tenants and the government was earnest to siphon off much revenue from tenants and channel it to its treasury. The peasants attempt to secure hearings from *awaraja* governors or finance offices did not fell on receptive ears. Though *awaraja* and *woreda* governors and their respective finance offices were supposed to supervise and oversee and as well as scrutinize fair classification of the peasants land they were not keen to have it quickly enforced. The peasants' matters were even left to the *rist-gult* owners.[45]

In Chercher *awaraja* there were *rist-gult* owners who held the position of *woreda* governorship. They had employed their faithful men in the *woreda* judge and their own security forces who were subordinate and paid allegiance to them. They exercise outright power over any matter and presided over issues arising in their respective areas. There were no appointed government officials to oversee and monitor matters arising from their regions. As consequence there is no doubt that the tenants had not been protected from multiple obligations imposed on them and the state *per se* did not seem to have secured the revenue which it claimed it should deserve. Though the government did not remove owners of *rist-gult* from their position it appointed its own judge and clerks to their courts, a *naib* (representative of *qadi*) and a secretary to *qadi* and police force for security. The owners of *rist-gult* were urged to channel salaries of these workers to government treasury.[46]

In Gursum *awaraja* where the tenants were evicted from *rist-gult* land the government claimed its outright power to assign *gebbar* or either left the matter to the *rist-gult* owners themselves. There also happened conflict among *rist-gult* owners when one of them persuaded each other's tenants to leave another's land and to work on one's land. There was no regulation as to *rist-gult* administration that monitor the relationship between and among *rist –gult* owners on the one hand and the tenants on the other. As a consequence the tenants were under double jeopardy, harassment, severe treatment and had no legal protection from the state since they were exposed to marauders who stripped the tenants of all their human quality while at the same time extracting the fruits of their toil for their sustenance.[47]

The traditional chiefs also played a conspicuous role as a liaison between the local people and the government as well as the officials executing government orders, collecting taxes and keeping peace and order and being obedient to the government. In return for the services rendered they were granted *sisso* land and collect annual tribute in the area under their jurisdiction. In the post-liberation period the administration of the governor general of Hararge sought to buttress the *balabats* to tip them with special offerings and *per diem* besides what was traditionally allowed them so that they would become loyal conduits. Unlike those *balabats* in the low land areas who were supported and provided with rations by the government, the *balabats* in Harerge highlands were liken with *gebbars* paying taxes like them. In the general meeting of the province of Harerge the issue was discussed simply not to mitigate peasants' grievances by letting the *balabats* enforce better and fair treatment of the peasants rather they showed some tendency to be sympathetic to the *balabats* who would better facilitate for squeezing and reaping the fruits of the peasants' toil. Thus, they were permitted to retain two percent out of the total amount of taxes collected from the peasants.[48]

In Harerge province land measurement and classification was inconsistent since all the peasants possessing large or small size of plots were subjected to a uniform tax. Different measurement units were employed and hence there is no doubt that the peasants were under severe and precarious life as they were obliged to pay whatever amounts levied on them. In relation to this, land measurement units and classification of the quality of land was incoherent in Masla and

Hawaracha districts of Chercher awaraja. In the upper Chercher it was apparent that the *Abba* Burkas took the best chunk of land for themselves and settle *gebbars* on the remaining land and transfer other *gebbars* to another place when the space was not enough to accommodate them. However, implicit in the discussion of the evidence at my disposal is the pervasiveness of uniform tax regardless of the size and quality of the peasants land in Hararghe. Problems related to the assignment of *gebbars*, land measurement and classification of the quality of land had adverse effect that debilitated peasants' efforts at productivity and put them in despondency. However, when the issue of remeasurement and redistribution of land was raised, the general council meeting of the province admittedly regretted, for its impracticality on the ground that this would adversely affect the administration of the province but had no courage to implement them.[49]

Even worse still to the peasant lots in Hararge in the post liberation period was the conversion of *Maderya* land (which was earlier given in lieu of salary to those in government services and land which was revocable on termination of their term of office), to free hold by the government to its favorites. Added to this, the government intensified its grants from its large reserve, which was held under the blurred term of government land to its patriots, exiles, soldiers and civil servants.[50]

In Hararge the government granted vast lands to its officials and soldiers in different *awarajas* of the province. Some of them had many *maderya* lands in two or three *awarajas* albeit the regulation outlawed possession of *maderya* land in more than one area.[51] According to the proclamation on November 5, 1952/53 the government intensified land grant to its favorite as *maderya* lands in Chercher, Wobberra, Harar, Garamulata, and Dire Dawa which were made convertible to freehold. The main beneficiaries of this proclamation were civil servants, the police, the imperial bodyguard, the clergies, *Nech lebash* and the nobility. The government sustained its extensive grants of land to soldiers, civil servants in Hararge in the post-liberation period. In Chercher 1947 alone there were about 670 soldiers who stationed in Asabe Tafari under a military officer, *Shaleqa* Ejigu Hailu, each with grants of *maderya* land in the province. Later about 400 soldiers were transferred to Harar headed by the same officer.[52]

As a report from the office of Governorate General of Hararge to the Ministry of Interior made clear, there is no doubt that a vast portions of land was granted as permanent hold to its favorites in various *awarajas*, *woredas* and *mikitil woredas* of the province. The report reveals that most of *maderya* lands in Hararghe province were granted as *hudad*. For instance, in Wobberra and Dire Dawa *awarajas* alone there were about 184 grantees who received *maderya* land as *hudad*. Extensive grant of *maderya* land as a permanent hold was widespread in Kombolcha, Fadis, and Jarso districts of Harar *awaraja*, in Meta, and Chelenqo districts of Wobberra sub-province, and Kersa, Water, Yebeta, Lange, Warabile, Bululo, Dulo and many other areas of Dire Dawa *awaraja*. Thus, the conversion of *maderya* land (which was earlier revocable, but now held permanently) was made convertible to *rist* or permanent hold. Thus, privatization process of land in Hararge was intensified and this had its own ramification in the region in that most of the peasants on these lands were relegated to the status of tenants and hence tenancy became the most wide spread phenomena in the province.[53]

In Chercher most of the lands in the region were somewhat measured and distributed to the Amharas. Chercher hosts a large number of settlers. The nobility, notable men and women and the clergy had large *rist* holdings. For instance, large *rist* holdings of Asfawossen found in Boroma, Tekle Hawariat's in Herna and Wolde Tsadiq's in Asabe Teferi. The region of Chercher had the highest concentration of tenants serving the Amharas.[54] The landlords took half of the tenants produce. Until the *malkagnas* were called before threshing, the tenants were not allowed to touch their harvests. Neither could they collect coffee from their field without prior knowledge of the *Malkagnas*. As regards to coffee, the *malkagnas* took half of the tenants' coffee production in *farasula* (1 farasula=17k.g). Besides, the tenants were obliged to transport his produce to the house of the *Malkagnas* who often lived in towns. In the absence of the landlords their *wokil* (representatives) acted on their behalf to supervise everything the tenants make towards the improvement of his production. In return the *wokils* were compensated by grants of a portion of *malkagnas's* land for his up keep. Since Chercher was reputed for its fertility of soil and coffee production, particularly, Boke in Gelemso, most coffee lands were owned by the Amharas. Ahmed. Apart from offering the fruits of their produce the tenants worked on *malkagnas's* personal holdings twice a week, work during special occasions like weeding and public holidays, clearing animal dung, grinding grains, mending fences and others. There were *atbia dagnas* (village judges) who were responsible for handling cases related to issues in case the tenants concealed parts of their produce and lest the tenants lay a hand on *eshet* (unripe crop). With the intensification of land grant to officials and fragmentation of family plots most tenants moved to the sparsely populated areas of Hararghe. They moved to Daro Labu, Ardi, and Anchar regions neighboring Arba Gugu in Arsi.[55] The burden of taxation and all sorts of exaction demanded from tenants compelled and pushed them to search for cultivable land in pastoralist areas or in scarcely populated areas of the province and beyond`.[56] This might have also been the case in most of the regions as land measurement was persistent throughout the province.

The state sustained its grant to civil and military officials in Herna and it was customarily granted to officials as many as 1 0 or 15 *gashas*. Men like *Fitawrari* Ergate and *Qagnazmatch* Shifa owned such large size. Large portion were owned by some prominent men. In Herna for instance, *Dejazmatch* Wolde Sellassie, owned vast areas of coffee land whom the tenants satirically yelled saying that do all these vast portions of land belong solely to *Deja.* Wolde Sellassie?' With the allotment of land burning and clearing forests became common phenomena in areas of Nole Oromo (Goro Gadi). In Herna land measurement was recurrent in Guagur, Chafe, Bante and Wagur. Those who undertook land measurement were not honest and often free from being bribed by different gifts and they were slaughtered mutton in return for the

favor they had done to the grantees or claimants. Along with land measurement litigation was also a day today phenomena. The overwhelming court cases were related to disputes over land issues of claim and counter claim, and over boundaries of their plots. Murdering was not uncommon among litigants.[57] Despite this the state continued to allocating land without regard for the implication it had on the peasants. Not only granting land as permanent hold or as *hudad* by the state but the government also continued to grant land to its favorites by assigning *kuter gebbar* land.

In 1952 many officers were sent to Gursum to assign *kuter gebbar* (unmeasured land). Some of the officers were fraudulent in assigning the land to the officials and civil servants of the government. One of the officers sent to Gursum *awaraja* to carry out the task was *metoaleqa* Tsegaye Desta (from ministry of defense) and his secretary Wolde Mikael Worku (sent from the Ministry of Finance). According to the report from the Governorate General of Harar, the officer was a pathological fraudulent in assigning land to the grantees.[58] On several occasions the Office of the Governorate General of Hararghe and its *Bajirondi* (treasurer) urged the Minister of Interior to send back the officer to Harar to let him make clear his task to the province. The ministry did not favorably responded to their request in sending the officer even though a series of letters were dispatched by the Governorate General of Harar in Hidar 29, 1952 E.C. This vividly depicts that the ministry and the officials were disorganized in their task given that they were not much concerned to the large section of the peasants who were under numerous obligation and unfair category of their land.[59] There was no guarantee to the peasants' right to ownership of their land since the government evicted them from their land at any time as it saw fit. This case was true in Bate Mikitil woreda of Haramaya district where the state ordered the *daminas* to evict the peasants from their land.

In Bate sub-district, Abdo Yuya and Shanko Gala, who were the *daminas* over the areas of today's premises of Haramaya University, compelled the local people to put their thumbnail mark on a paper as an approval of their willingness to acknowledge relocation and leave their ancestral land. According to one informant the size of the land was about 25 *gashas*. Another informant claims that the size of the land was about 33 *gashas*.[60] Instead of compensating the peasants with some plots of land somewhere else in the area, the government dispossessed, and expelled the peasants from their ancestral land through its conduits. The peasants were simply ordered to search for *mankut* land (confiscated land for tax failure) and most of them moved to Jarso and Kombolcha but had to fight with other peasants and ended up their life in the fight over land. Some lucky peasants were able to secure *mankut* land in Adelle, Garahubata and Baldhata.[61] Still some others had no any other option other than working as daily laborers for their sustenance in what was then called the Imperial College of Agriculture. In Bate there was a sizeable *rist* land to the north west of the university, which belonged to Princess Sara, wife of prince Mekonnen. Some portion of the land was occupied by the peasants and the rest was swampy areas reserved as grazing land. Its fodder was sold to the local people and the revenue went to the state treasury. The local people were charged some 2 to 6 *Birr* to feed their cattle. This grazing land was called *aflama* (compensation). In Bate peasants moved to Wobberra and Chercher either for tax failure or fragmentation of family plots.[62]

In Hararghe, there were duplicity in assigning the land and arbitrary eviction, and also many claimants entered to litigation on what was called the government land whether it was occupied by peasants or not. In Kurfa Chale *Woreda* of Garamulata *awaraja* where Haji-Adem Seido and Haileleul were *damin* and *garad,* respectively, it was reported that there was more than two *gashas* of land which *garad* Haileleul was suspected of concealing the land. Many claimants such as Haileluel W/Tensay, Lulseged Girma, *Ato* Francois Gebreyes, *Ato* Alemayehu Molla, *Weizero* Ayelech Menhale and Ato Seyoum Feleke were people who laid claim to this land. There were several areas where *gashas* of land were asked in the guise of government land. In Dagu *mikitil woreda* of Garamulata specifically in Derbale kebele under Usman Adem *daminship* and Suleyman Tuse *garadship* similar issues emerged. The land between Wobberra and Garamulata *awarajas* in the districts of Metta and Bedenno to the left and right of Woldiya Lamesa River there was an estimated 10,000 *gashas* of land. The Minister of Interior urged the governor to clarify its size in *gasha*, previous holders, reasons for withdrawal or eviction, its current status, whether it had claimant or not.[63]

In 1955 in Garamulata a *gasha* land which was estimated at about 3,333 1/2 *gasha* land existed and the government ordered Ato Hailemariam Seifu to carry out land measurement. The report underlines the financial arrangements for those who would assign *Kuter gebbar* land, the *qalad tay*. The governorate general asked the Ministry of finance to allow their budget for the *qalad* tay. This clearly depicts that the government was preoccupied with intensified land measurement and to reap much more from the peasants through tax which became a burden to them.[64]

In Wobberra *awaraja* there were problems related to the land tax from the year 1947-1956. The office of *Bajirondi* (treasury) of the governorate general of Harar estimated that the total land tax arrears at about 17 9,356.31 *Birr* for the specified period in Wobberra *awaraja*. The *woreda* and *mikitil woreda* governors were called on by the *awaraja* governor to make clear *raison d'être* for failure to collect taxes. The meeting which was held in June 1957 was chaired by Deputy *Endarase Shambel* Aemiro Sellassie and attended by officials of other departments in the governorate general of Harar. The land tax arrears of Meta, Dedar and Goro Gutu districts were calculated at 22,853.94; 28,430.37 and 8251.35 *Birr*, respectively. A close examination of the evidence at our disposal unearths many defects in the tax collection from the tenants. There was no proper mechanism of controlling the tax collected in the *awaraja*. The duty of properly documenting and recording statistically the tax collected from the tenants was lacking. Even the *woreda* and *mikitil woreda* governors did not immediately deliver the taxes collected to the state treasury. The peasants in the *awaraja* were on some occasions obliged to pay twice. Those who were unable to pay the tax were coerced by the police and thrown into prison

without any charge from the court. The tax collectors had found nothing to confiscate or sell tenants' property when they failed to pay the tax. In most cases tenants were forced to leave their homestead on failure to pay the tax due. Though the *woreda* governors were blamed for not collecting the tax overdue before the end of each year the governors of Goro Gutu, Dedar and Meta such as Shawul Degafa, Tilahun Wolde Hiwot and Seyoum Dinbaru respectively were fined a one month salary. Notwithstanding, however, the governorate general of the province never took any meaningful and pragmatic measure to relieve the peasants of their grievances. The Office of *Bajirondi* (treasury) of the province of Hararghe *per se* had no proper statistical record of tax collected from different *awarajas*. The figure which it estimated regarding tax arrears in the *awaraja* itself was quite high transcending the figure literally recognized by the governors.[65]
In the Ogaden sub-province of Hararghe similar tax overdue was reported from the year 1950-1955. Different measures were suggested by the province to take back the tax arrears. But it was difficult to get the cultivators to force them pay the tax since they were pastoralists and mobile. In Jijiga district similar tax arrears was also reported.[66]

An overview of Taxation in Hararghe by Sub-province

In Hararghe province agricultural tax was collected from the peasants and as well from the nomads by levying on their cattle. It was the largest province in size and ranks third in the contribution of the tax to the state surpassed only by Shewa and Wello provinces. According to the 1960 statistics, Hararghe contributed 9.2 percent, out of the tax which was supposed to be collected (25.7 million) from the 13th provinces. In terms of tax default for 13 years (1947-1960) Hararghe's share was 2 percent of the total unpaid tax of the whole country which put the province seventh among the debtors. The total tax revenue of the province for 16 years (1947-1962) was increased by 44.8 percent.[67] This increase was achieved through additional taxes of education and health on the land. Moreover, the size of land put under cultivation increased resulting in increase in the total revenue from land tax. The increase was the highest in Jijiga, Adal-Isa and Chercher. In Hararghe in 1962 there were 421, 258 hectares of measured land and 71, 502 units of *kuter gebbar*. About 2,810,311 *Birr* were expected to be collected from the region. The tax paid by *kuter gebbar* land owners was the highest accounting for 83.6 percent of the total collectable tax. It was estimated that forty hectares were equal to 10 to 15 *kuter gebbar* land units. In Hararghe the land tax payment per *gasha* of fertile, semi-fertile and poor land was fixed at 80 or 73.5, 64 and 24, respectively. With regard to *kuter gebbar*, the land was categorized into five classes in order of their fertility fixed at 32, 27, 24, 16 and 8, respectively. [68]

Analysis of tax payment of both measured and *kuter gebbar* land in Hararghe province shows that about 83.6% of the possible collectible tax annually is paid by the *kuter gebbar* owners. It is assumed that 10 *kuter gebbar* land units make one gasha or 40 hectares. On the basis of this an owner of 10 kuter gebbar land units pays at least four times more than the *gasha* holder. It is obvious that there was inconsistencies in tax payment between measured and *kuter gebbar* land owners. There was also disparity even among *maderyaa, rist-gult* and *sisso-gult* holdings. For instance, *maderya* owners were exempted from tax. *Rist-gult* and *sisso gult* did not pay the full rate of 15, 10 and 5 of land tax on different fertility of per *gasha* but a reduced rate of 3.5 across varied fertility of *gasha*. For land tax, tithe, health and education taxes, owners of *rist-gult* and *sisso gult* paid 68.5 or 62, 57.5 and 22.5 of fertile, semi fertile and poor land, respectively, instead of the full rate of 80 or 73.5, 64 and 24, respectively. In 1947 the Ministry of Finance estimated that $ 12,399.9 amounts were not collected from both measured and *kuter gebbar* lands because of tax exemption to owners of these lands. From this total, the *kuter gebbar* make up 50.8% or about $ 6, 294.2 excluding *maderya* or Church lands. The above estimate was very meager in view of the fact that most of the *rist-gult* owners were reluctant to have their lands registered in the early 1947 tax book. Yet the registration of *rist-gult* land had to be postponed four times from 1949 to 1952. It is obvious that owners of this land were not paying the tax due until their land was registered in tax book.[69]

Had all the *rist- gult* been registered and taxes were paid accurately the government would have secured $6.6 million. When we look at *maderya* land owners they were exempted from land tax except tithe, education and health since the owners did not have ownership rights until 1955. For the last 16 years about $268, 000 was lost by the government from this land tax alone. In 1955 the government gave full ownership right to owners of *maderya* land and the total number of *maderya* land decreased greatly. On the other hand, since the Coptic Church retained the land taxes from its holding nothing went to the Ministry of Finance. It was only in 1959 that the Church allowed the Ministry of Finance to collect its tax on account that the tax collectors were abusing tax receipts. The Church decided that the Ministry of Finance was to take over the tax collection. In return the Church allowed the Ministry of Finance a 2% for service. In the 16 years period from 1947- 1963 the Church had collected about $1.6 million of land tax. The granting of tax exemption to *maderya* and *rist-gult* made the government to lose over $740,000. Had the Church land, *rist-gult* and *maderya* land were not granted tax exemption the government would have collected about $8.4 million from 1947-1963.[70]

In general, when we compare the various sub-provinces of Hararghe the total contribution of tax illuminate that Harar accounted for 37.3%, Chercher 18.9%, Garamulata 13.5%, Jijiga 6.2%, Dire Dawa 5.1%, and Adal-Isa 2.1%. However, when we see the total yearly average imbursement from 1960-63, Dire Dawa paid 86%, Chercher and Wobberra each 81%, and Harar and Garamulata 78% each , and Adal-Isa 32.9%. Out of the total $2.8 million yearly assessment from the recorded taxable of 421, 258 hectares and 71, 502 *kuter gebbar* lands, an average total of 68.5% was collected. In Hararghe only 25.2% of the total measured land and 74.2% of the total *kuter gebbar* land was recorded in tax books. Indeed the burden of taxation fell on the shoulders of the peasant masses in the region who responded to this problem differently while the government remained nonchalant to their plight. The majority of the peasants in Hararghe were

relegated to the status of tenants, who were subjected to different demands of the landlords. In 1968, a government survey of Hararghe province the distribution of holdings by type of land tenure shows that 46% of the holdings were owned, 49% rented, and 5% partly owned and partly rented from other. Renting shows the existence of tenancy. Hararghe is a vast area and ecologically varied and the disparity in percentage of tenancy is considerable. In Chercher the richest agricultural area 89% of land holdings were occupied by tenancy, while in the district of Harar *zuria awaraja* 89% of the holdings were by owners most of them Harari. According to Bahru, tenancy was the most widespread in Hararghe (75%) followed by Shewa (67%) and Kafa (62%).[71]

Tenancy Agreement

When we see the agreement between the tenants and landlords, in most cases it was oral and for indefinite time. The common duration of time of tenancy for poor and fertile lands varied from three to one year, respectively. The rental agreement was either in cash or kind. The tenancy agreement ended when the landlords evicted the tenants either for failure to give rent payment, or the landlords want the land in case they get better rentals. On the other hand, the tenants terminated when their land is getting poorer and the landlords increased the rentals and as well as when the landlords demanded from them several services or when the tenants' health get deteriorated. If the tenants got better land and in case of disagreement with the landlord and inability to pay fees were some of the cases of ceasing agreement.[72]

The tenants were expected to give labor services like cultivating virgin land, building irrigations, planting trees and making cattle sheds and fences and others. Tenants were not compensated for their relentless part of their improvements on termination of their agreements. Farm expenses were covered by the tenant with few exceptions w here landlords help with labor or seed in times of tenants' poor harvests. The most appropriate time for termination of tenancy was either by the landlords or tenants was right after harvests or sometimes before the next seeding period which was in the month of January to February.[73]

The implication of the government's land policy in Hararghe

The land policies of the Ethiopians in Hararghe had two implications for agricultural production. First land became concentrated in the hands of state that had an insatiable appetite for more land. Officials of the Ethiopian state and its supporters came to posses large tracts of land and restricted the indigenous cultivators to their ancestral lands which diminished in size as population increased. Second the ruling elite possessed the right of allocation and therefore, controlled right to use all lands. Land hungry farmers were discouraged from migrating to new lands, thus increasing population concentration on lineage lands and diminishing the size of land owned and worked by farming families. In the long run the difficulty of acquiring land led to increased fragmentation as tenant holdings were broken up as a consequence of expropriation, population growth and inheritance by multiple heirs. Cultivators at first responded to the problem of land scarcity by moving from densely populated *garads* to thinly populated areas. Some tenants settled on the lands of *garads* who admitted them for the customary *bercha* a payment in sheep or cattle. Others became sharecroppers working for other tenants who owned large tracts of land. Still some others migrated from Wobberra, Harar and Garamulata to Chercher, Bale, Ardi, and Anchar, neighboring Arba Gugu of Arsi to work on *qalad* land and even to the uninhabited areas of Chercher in Ramis valley and reverted to pastoralism. These processes, migration, sharecropping and to a limited extent, reversion to pastoralism continued.[74]

Peasant Revolt

Owing to onerous taxation, multiple obligations and evictions from their land the peasants in Hararghe restored to revolt in the late 1960s and early 1970 inspired by the peasant revolt in Bale. Particularly it was started in Gara Mullata and from there spread to Chercher province of western Hararghe like Habro, Mechara, Michata and several other places. In Gara Mullata the revolt was started by men like Jarra Abba Gada and Hasan Ibrahim (Elemo Kiultu). In Chercher Mohammed Jilo was responsible for organizing the revolt in Gub Koricha, Habro, Mechara, and Xumuga (near Arsi). Mohammed Gildi and Aliyi Nuru also organized and led a revolt in Mechara. They evoked terror on many landlords who escaped to other areas like Gololcha. But most of the revolt leaders were decimated by the Derg on grounds of having subterranean relations with the then emerging Oromo nationalist organization. Among these were Mohammed Jilo (killed at Kuba Koricha), Elemo Kiltu (Habro, Wacu), Mohammed Gildi (at Mechara), and Aliyi Nuru (at Michata).[75]

Revolution and Reform

With the coming to power of the Derg, Proclamation for Public ownership of rural lands was made in April 1975 which irrevocably changed the political economy of Ethiopia including Hararghe. Further Proclamation of Government ownership of urban lands and extra houses proclamation of July, 1975 reduced disparities in the distribution of wealth. Eliminated extensive holdings and absentee landlordism and the privilege of Harar versus Oromo, ended. Some Harari served the *malkagnas* system under the *damin* and in many Oromo areas as middlemen now became the forces of resentment. Harari themselves emerged from an understratum background, albeit a comparatively comfortable urban one. They had succeeded in adjusting to the rule of outsiders by providing essential clerical services and they had gained some property by using these positions wisely. Yet they shared with the Oromo the loss of political independence and control of their political destiny. The Oromos were reduced to servitude because of the widespread tenancy under the

empire, the Harari disenfranchisement came as a result of much needed reforms in Ethiopia. In 1975 having lost their farms and urban properties, the Harari in the old city view themselves victims. [76]

Conclusion

Hararghe was brought to the Ethiopian empire state after the bloody battle of Cheleqo. As the region that resisted the conquest fiercely the people in the region faced the wrath of Menelik and his soldiers who confiscated the property of those who participated in the battle and distributed the booty among his soldiers, settlers and the clergies. Different garrison centers were established and people living close to these centers were assigned, to mention Mohammed Hassan's word, to be eaten by governors, officials, clergies and settlers who quartered on farming population. The people in the region were obliged to provide whatever they needed. To strengthen the conquest settlers were encouraged and large number of them flocked down to the province. The effect was to create land shortage in the region and strain and stress on the farming population. Large portions of land which were curved under what was vaguely called state domain, government land whether the peasants settled on them or not, the state allocated to those whom it wished to reward without any regard for the peasant masses in the region. After 1941 the state declared its successive reform proclamation with a pretext to ameliorate the burden that fell on the shoulders of the peasants but to siphon off much revenue from land tax to its treasury. It intensified land measurement and grant to the patriots, exiles, soldiers and its favorites until 1970s which ultimately led to eviction, burden of tax and widespread tenancy in Hararghe. The peasants responded to the problem by moving from densely populated garads to thinly populated areas. Even a good number of them were resorted to pastoralism in the lowland areas of the region and many other moved to Bale and Arsi to work on qalad as tenant. But, the Derg eliminated tenant and landlordism though the leaders of peasant revolt did not spare the heavy hand off them.

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6. Extension Activities

6.1 Pre-extension Demonstration of Two High Yielding Common Bean Varieties (Haramaya and Chercher) in Habro and Boke Districts, West Hararghe Zone

Teklemariam Keneni, Moges Dereje, and Bulti Teso

Abstract: Common bean is becoming increasingly important in eastern Ethiopia because of the recurrent late onset and early termination of rainfall. It is an important crop under various intercropping systems and used for soil fertility management, and as emergency and security crop. However, its productivity is below 13.2 qts/ha, especially in eastern Ethiopia due to soil depletion, low technology intervention and farmers' lack of awareness of improved common bean varieties that have a yield potential of 17-40 qts/ha on research stations and 13-21qts/ha on-farmers' field. The major emphasis of this project was to demonstrate the two released common bean varieties (Haramaya, food type and chercher, canning type) in Habro and Boke districts of West Hararghe Zone during Belg and Meher seasons. Its specific objectives were to demonstrate the two improved common bean varieties with the local checks; to evaluate their performances and identify a variety that meets farmers' choice in Belg and Meher seasons. Four kebeles were identified from the two districts based on their common bean production potential from which 12 target farmers were selected based on their willingness to demonstrate the technology. Training was given to the target farmers including the district and kebele extension agents on the modern common bean production. Farmers' days were organized at the maturity and harvesting time during the two seasons. Chercher variety was selected first, Haramaya second and the local common bean third based on their maturity dates, color and market demand. Farmers preferred Chercher variety for use during Belg season and Haramaya variety during rainy season to fully fetch its yield potential. The data shows that an average yield for Chercher, Haramaya and the local varieties across the two districts during Belg to be 17.9, 13.5, and 7.9 qts/ha, respectively. The corresponding yield during the Meher seasons was 20.1, 21.2, and 10.2 qts/ha, respectively. This result shows that target farmers were able to increase common bean yield from the previous 13.2 qts/ha to around 21.2 qts/ha because of the interventions conducted through demonstration of the technologies together with associated trainings.

Keywords: Improved Common beans; Technology; Demonstration; Belg; Meher

Introduction

Common bean is becoming increasingly important in eastern Ethiopia because of the recurrent late onset and early termination of rainfall, which force the farmers to use short duration corps. It is an important component of crop production in Hararghe under various intercropping systems. It is used as soil fertility management, as emergency and security crop and as a supplemental animal feed (Chemeda and Bulti, 2006; Tana and Chemeda, 2006). The major problems of common bean production in Eastern Ethiopia are: inaccessibility to improved common bean varieties, low extension intervention, and inferior performance of local varieties.

To address these constraints, Harmaya University (HU) developed six improved common been varieties along with its improved practices for the last 10-15 years, of which five are food beans (Gofta, Ayenew, Haramaya, Dursitu and Kufanzik) and one navy (white) variety (Checher). The merits of the new varieties include high yield (17-40 qts/ha on research stations and 13-21qts/ha on-farmers' field), tolerant to major diseases, excellent growth habit, early maturing (82-114 days) and adaptive to wider agro ecology of 1300-2000 m.a.s.l. (Chemeda and Bulti, 2004).

Most of the technologies developed were not demonstrated and transferred to the end users through appropriate extension methods to complement the work conducted on research stations, and to provide more realistic evaluation of the new technology under farmers' condition. The process also provides an excellent opportunity for farmers to learn, evaluate, and participate in the recommendations drawn on the specific technology. Furthermore, it can encourage and strengthen researchers-extension–farmers- stakeholders and policy makers' dialogue and provide opportunity to jointly identify research thematic area, participatory technology generation, transfer and utilization. Hence, the objective of this project was to demonstrate the two recently released common bean varieties (Haramaya and Chercher) with the local one in Habro and Boke districts during Belg and Maher to select the variety (ies) that meet farmers' criteria and thereby increase target farmers common bean production from 10.5- 21 qts/ha.

Methodology

Description of the Study area

Western Hararghe Districts (Boke and Habro) are situated at altitude of 1357-2800 m.a.s.l. Their annual rainfall ranges from 500 to 1200 mm. They have bimodal rainfall distribution, the small rainy season which occurs in February and the main rainy season that occur between June and September. The major crops grown in the districts are sorghum, maize, teef and haricot beans, groundnut, coffee and chat. Western Hararghe farmers grow common bean twice per year (during *Belg* and *Maher especially in Habro)*. The Belg production is sol and larger, whereas Maher is mostly intercropping with various major crops. They usually sow teff after the harvest of Belg on the common bean fields in Habro.

Sampling technique

Habro and Boke districts were identified from western Hararghe Zone using purposive sampling technique based on common bean production potential. Two kebeles were identified from each districts. Three model farmers were selected from each kebele depending on common bean production potential, full interest to participate in the project during the two seasons (Belg & or Maher), ability to allocate the required land for the three common bean varieties (two improved and one local varieties). The name of the target farmers, their respective districts and peasanbt associations (PAs) is indicted in Tables 6.3 and 6.4.

Training

Training is one of the important extension methods to enhance and integrate the farmers' indigenous knowledge and skill with improved practices. Accordingly, training need assessment before and after technology demonstration was made. Six development agents (4 in Habro and 2 in Boke districts), 2 district extension experts one from each district, and 12 target farmers (6 from Habro and 6 from Boke districts) attended the trainings on the common beans agronomic practices before sowing (Tables 6.1 and 6.2). Each target farmer provided 10mx20m of land for the two improved common beans and one local common bean varieties demonstration in Belg and Maher. Neccessary packages were distributed together with the varieties. The varieties were sown in April, 2009 for Belg and in late July, 2009 for Maher because of the late onset of rainfall in both seasons. Field days were organized in June, 2009 for Belg and September 2009 for the Maher seasons. The performance of each improved common bean varieties were evaluated against the local check in each kebele in terms of their yield performances, diseases tolerance, maturity dates and market demand (Tables 6.3, 6.4, 6.5 and 6.6).

Results

Table 6.1 showed that target farmers' knowledge and skill on improved common bean agronomic practices was very low but increased after training.

Table 6.1. Training needs assessments before and after training on the target farmers

		Before Training				Assessment After Training			
		Farmer' No.				Farmer' No.			
No.	Questions	M	F	Total	%	M	F	Total	%
1	Land preparation	3	-	12	25	11	-	12	91.6
2	Row planting	-	-	12	0	10	-	12	83.4
3	Spacing	-	-	12	0	10	-	12	83.4
4	Weed control	6	-	12	50	12	-	12	100
5	Disease control	-	-	12	0	11	-	12	83.4
6	Harvesting	4	-	12	33.3	12	-	12	100
7	Post Harvesting Mgt.	-	-	12	0	9	-	12	75
8	Crop rotation	6	-	12	50	12	-	12	100
9	Soil fertility	6	-	12	50	12	-	12	100

Table 6.2 showed that development agents' knowledge and skill on improved common bean agronomic practices to be quite low before the training, which was greatly improved after undertaking the training.

Table 6.2. Training needs assessments before and after training for development agents

No.	Questions	Assessment Before Training Number of DAs				Assessment After Training Number of DAs			
		M	F	Total	%	M	F	Total	%
1	Land preparation	3	-	6	50	6	-	6	100
2	Row planting	2	-	6	33.3	6	-	6	100
3	Spacing	3	-	6	50	6	-	6	100
4	Weed control	4	-	6	66.7	6	-	6	100
5	Disease control	3	-	6	50	6	-	6	100
6	Harvesting	1	-	6	16,7	6	-	6	100
7	Post Harvesting Mgt.	1	-	6	16.7	6	-	6	100
8	Crop rotation	4	-	6	66.7	6	-	6	100
9	Soil fertility	4	-	6	66.7	6	-	6	100

Farmers' Days

Farmers' days were conducted at flowering stage and and at harvesting stage. At flowering stage, crops resistances to different diseases and drought tolerance ability were evaluated. At harvesting stage, the yield performances were evaluated (Figure 6.1.). During the Belg season, a total of twelve target farmers, 4 development agents, 2 district extension experts and 55 follower farmers were participated in Habro and Boke districts

Figure 6.1. Improved common beans evaluation

Evaluation at harvest

During the Maher season, a total of twelve other target farmers, 2 development agents, 2 districts' extension experts, 63 follower farmers participated at both districts. The common beans were compared and prioritized based on participants' criteria as follows:

Haramaya improved common bean variety was selected first for its grain and biomass yield and Chercher for maturity date and drought resistances during summer in Habro district. But Chercher was rated first and Haramya second in Boke district in both seasons based on yield performances and earliness in maturity. There was serious rain shortage in Boke district, consequently Haramaya variety need more time to mature.

The target farmers and participants decided to share the available seed they harvested to other follower farmers and also decided to grow the two improved common bean varieties. But, they decided to grow Haramaya common bean only during the main rainy season as it need extended period of rain to fetch its full production potential.

Table 6.3. Name of target farmers, and grain yield of common bean varieties during Belg season in Habro and Boke districts

No.	Name of Farmers	District	PAs	Yield/plot (200m²) in qt.			Yield qt /ha.		
				Chercher	Hara	Local	Chercher	Hara	Local
1	Ahemed Sali	Habro	Waachu	0.30	0.28	0.14	15.00	14.00	7 .00
2	Abdalla Usman	"	"	0.36	0.20	0.12	18.00	10.00	6.00
3	TeshagerTeshome	"	"	0.42	0.33	0.90	21.00	16.50	4.50
4	Demisie Belachaw	"	Badada	0.22	0.18	0.13	11.00	9.00	6.50
	Toatal			1.30	0.99	0.48	0.65	49.5	24.00
	Mean			32.5	24.75	12.00	16.3	12.40	6.00
5*	*Mohamed Amin	"	"	0.00	0.00	0.00	0.00	0 .00	0.00
6*	*Eshetu Kinfe	"	"	0.00	0.00	0.00	0.00	0.00	0.00
7	Abrahim Amed	Boke	Dhera Jamb	0.55	0.45	0.24	27.5	22.5	12.00
8	Ahemed Hasen	'	'	0.30	0.16	0.15	15.00	8.00	7.50
9	Miftiha shekrashid	"	"	0.50	0.34	0.18	25.00	17.00	12.50
10	Miftha Haji	'	:"	0.37	0.22	0.13	18.50	11.00	6.50
11	Alemayehu Kebede	"	Kersa	0.22	0.17	0.11	11.00	8.5.00	5.50
12	Debebe Makeshe	"	"	0.75	0.40	0.28	37.50	20.00	14.00
	Total			2.34	1.74	1.09	117.0	87.00	58.00
	Mean			0.39	0.29	0.18	19.50	14.50	9.70

*****Indicted that the common bean demonstrations on the two farmers' plots were affected by drought and there were no yield.

Table 6.3 shows that the highest mean yield/ha was recorded in Boke during the Belg season by Chrcher improved common bean (19.5qt/ha) which was followed by Haramaya (14.5qt/ha) and the local variety (9.7qt/ha), respectively and the order was similar in Habro district, but there was yield difference between the districts.

Table 6.4. Name of target farmers, and yield performances of bean varieties in Maher season in Habro and Boke districts

No.	Name of Farmers	District	PAs	Yield /plot(200m²) in qt.			Yield qts /ha.		
				Chercher	Hara	Local	Chercher	Hara	Local
1	Tasfa Demeke	Habro	Luugoo	0.30	0.35	0.17	15.00	17.50	7.50
2	Hashum Usmael	"	"	0.60	0.80	0.32	30.00	40.00	16.00
3	Mohamed Abrahim	"	"	0.50	0.50	0.28	25.00	25.00	14.00
4	Worku Endrias	"	Efa Gamachu	0.40	0.65	0.24	20.00	32.50	10.00
5	Saniyo Ahimed	"	"	0.34	0.60	0.18	17.00	30.00	8.50
6*	*bdella Saniyo	"	Kufa Kas	0.00	0.00	0.00	0.00	0.00	0.00
	Total			2.14	2.90	1.19	107.0	145.0	60.00
	Mean			0 .43	0 .58	0 .24	21.40	29.00	12.00
1	Megarsa Husien	Boke	Dhera Jamb	0.25	0.25	0.13	12.50	12.50	6.50
2	Hayati Ahimed	'	'	0.40	0.25	0.18	20.00	12.50	9.00
3	Jafar Sirajo	"	"	0.23	0.21	0.14	11.50	10.50	7.00
4	Shifaraw tadasa	"	"	0.42	0.28	0.13	21.00	14.00	6.50
5	Amadin Yusf	"	Kersa	0.00	0.00	0.00	0.00	0.00	0.00
6	Debebe Makeshe	'	'	0.60	0.35	0.25	30.00	17.50	12.50
	Total			1.90	1.34	0.83	95.00	67.00	41.50
	Mean			0.38	0.27	0.17	19.00	13.40	8.30

*****Indicted that the farmer' demonstration field was attacked by drought

Table 6.4 shows that the highest mean yield/ha was recorded in Habro during the Maher season by Haramaya variety (29 qt/ha) which was followed by Chercher variety (21.4 qt/ha) and the local variety (12 qt/ha). But, the highest mean yield/ha was obtained from Chercher variety (19 qt/ha) in Boke district which was followed by Haramaya (13.40 qt/ha) and the local variety (8.3 qt/ha) during the same season. The mean yield differences were due to the inconsistency in rainfall in both districts during the growing seasons.

Table 6.5. Summary of agronomic data of common bean varieties in the two districts during Belg season

No.	Agronomic Data	Common beans Varieties			Remark
		Chercher	Haramaya	Local	
1	Date of planting	Late April	Late April	same	rainfall delay
2	Maturity date	End of June	End of June	End of June	
3	Resistance to diseases	high	average	low	
4	Resistance to drought	High	average	low	
5	Harvesting Date	End June	Early July	Early July	
6	Color	white	brown	mixed	
7	Market Demand	High	Average	low	
8	Average yield	17.9	13.5	7.9	

Table 6.6. Summary of agronomic data of common bean varieties in the two districts during Maher Season

No.	Agronomic Data	Common beans varieties			Remark
		Chercher	Haramaya	Local	
1	Date of planting	Late July	Same	Same	Rainfall delay
2	Maturity date	Mid Oct.	End Oct.	Late Oct.	
3	Resistance to diseases	High	Average	Low	
4	Resistance to drought	High	Average	Low	
5	Harvesting Date	End Oct	Early Nov.	Early Nov.	
6	Color	White	Brown	Mixed	
7	Market Demand	High	Average	Low	
8	Average yield	20.2	21.2	10.2	

Table 6.7. Farmers' selection criteria and responses' to the packages

	Farmers' Selection criteria	Improved common bean cultivars vs local			
No.		Haramaya	Chercher	Local	Remark
1	Yield	High	V. high	Low	
2	Date of Maturity	Late	Early	Medium	
3	Drought Résistance	Medium	High	Low	
4	Diseases Resistance	High	V. high	V.low	
5	Colors	V.good	Excellent	Mixed	
6	Market demand	High	V. high	Low	
7	Farmers' Rank	2	1	3	

Farmers' decision: target farmers have decided to grow the two improved common bean varieties and share the available seed to other follower farmers who eagerly follow the demonstration activities.

Discussion

The two improved common bean varieties were compared with the local and both improved common bean varieties (Chercher and Haramaya) met the farmers' criteria. The variety that can be suitable for Belg and Maher seasons were also identified. Cherecher variety is suitable for Belg season since it is early maturing and Haramaya variety for the Maher as it is relatively late maturing. Depending on rainfall requirement, yield potential and other quality attributes, however, Chercher variety was selected first by farmers'. This variety has high market demand, shorter maturity date and it is drought tolerant. It was learnt that demonstration of new technology using appropriate extension methods such as training and farmers' days are among the best approaches in technology transfer. Experiences were shared among target farmers, followers, researchers, agricultural development agents, and other stakeholders through group discussion on the specific improved practices during the farmers' days.

In general, participants' capability and skill on the improved common bean production technologies increased and thereby their common bean production increased from 8.0 qts/ha to 20.70 qts/ha as a result of the demonstration made on the two common beans technologies along with training and farmers days. The ground for further popularization and dissemination of the two improved common bean technologies was established.

Possible Suggestions

1. Optimum use of rainfall through land preparation before the arival of rainfall and use of early maturing varieties.

2. Researchers' should be involved in pre-extension demonstration activities after technology generation to facilitate the timely dissemination of the same to the wider community.
3. Motivation system should be developed to encourage researchers.
4. Districts and Kebele level extension agents' should give priority for the technology transfer activities.
5. Enough skilled manpower, vehicles and budget should be assigned for the research and extension department so that the office can fully achieve the activities of technology transfer.

6.2 Scaling-up of Improved Faba Bean Variety (*Gachena*) and Improved Field Pea Variety (*Meti*) in Meta, Deder and Goro-Gutu Districts, East Hararghe Zone

Teklemariam Keneni, Moges Dereje and Kindie Tesfaye

Abstract: Faba bean and field pea are the most important legumes in Ethiopia. These crops are used as a source of food, feed, and cash to farmers. Moreover, they play an important role in sustaining the productivity of framing systems through the fixation of atmospheric nitrogen. Despite their great role and availability of high yielding varieties (18-30 qt/ha and 15-25 qts/ha on research stations and 15-25 qts/ha and 13-22 qts/ha on farmers' field for faba bean and field pea, respectively) in the country, their production in eastern part of Ethiopia, particularly in East Harahghe zone is very low (7.5-9.8 qts/ha and 6-8 qts/ha for faba beana and field pea, respectively). This is attributed to the severe diseases to the local faba bean and field pea crops, farmers' inaccessibility to the production technologies, and lack of improved agronomic practices. To address these constraints, the demonstrations of improved varieties were conducted on 12 target farmers in Goro-Gutu, Dedar and Meta districts of East Hararghe Zone during 2009/10. Farmers involved in the technology demonstration obtained an average yield of 29.3 qts/ha of faba bean and 22.7 qts/ha of field pea across the three districts. As a result, the target farmers and the followers have shown high interest to use these technologies to improve their production sustainably starting in 2010/11 cropping season. Hence, this work was designed to scale up faba bean and field pea technologies in Goro-Gutu, Dedar and Meta districts during 20010/11 to achieve the wider dissemination of the same in the 3 districts and its adjacent districts. A total of 180 farmers for field pea and 90 farmers for faba bean were selected based on their interest to the packages across the 3 districts. Training was given and a total of 18 qts of the two technologies of which 9 qts field pea and 9 qts faba bean seed were distributed to the respective kebeles and the recommended agronomic practices was followed. Farmers' field days were also organized. As a result farmers' field pea and faba bean production increased from 8 to 20.2 qt/ha and from 9 to19.4 qts/ha, respectively, and the wider distribution of the technologies were achieved.

Keywords: Faba bean, field pea technologies, technology scaling up

Introduction

Highland crops such as faba bean and field pea are produced in the highland and semi highland regions of Ethiopia with altitude ranges from 1800-3000 m.a.s.l. These are crops used as a source of food, feed, and cash to farmers. Moreover, they play an important role in sustaining the productivity of farming systems through the fixation of atmospheric nitrogen. The area under faba bean cultivation is estimated to be 474,892 ha, leading the pulse category in area coverage. The total faba bean production reached about 4.47 million qts with an average yield of 9.4 qt/ha. The two crops contribute about 30% of the total pulses produced and cover about 33% of the total area under pulse (EEPAPDMRD, 2004).Whereas the area under field pea is 175,000 ha and it's annual production is 1.5 million qts with an average yield of 8.4 qt/ha. (MoARDCDDCVR no. 8, 2005).

The production of faba bean and field pea in the eastern parts of the country, especially in East Hararghe Zone, has faced very low level of production. Yields were only 7.5-9 qts/ha and 6-8 qts/ha, respectively. These is due to sever diseases attack of the local faba bean and field pea crops, farmers' inaccessibility to improved faba bean and field pea technologies, weak technologies intervention, and lack of improved agronomic practices (EHARDO, 2008).

To address these constraints demonstrations of the recently developed improved faba bean and field pea varieties for the eastern part of Ethiopia by Haramaya University (HU) have been conducted. This varieties have a yield potential of 18-30 qt/ha for faba bean and 15-25 qts/ha for field pea on research stations and 15-25 qts/ha and 13-22 qts/ha on farmers' field. The demonstration involved 12 target farmers in Goro-Gutu, Dedar and Meta districts of East Hararghe Zone during 2009/10. The result revealed that farmers involved in the demonstration obtained an average yield of 29.3-qts/ha from faba bean and 22.7 qts./ha from field pea across the three districts. As a result, the target farmers and the followers' have shown high interest to use these technologies to improve their faba bean and field pea productions sustainably starting from 2010/11 cropping season. Hence, the principal objective of the project was scaling up of the

demonstrated faba bean and field pea technologies in Goro-Gutu, Dedar and Meta districts during 20010/11. Its specific objectives were to improve farmers' faba bean and field pea productivity and to achieve the wider dissemination of the same in the 3 districts and its adjacent districts.

Methodology

Sampling technique, technology distribution

Using purposive sampling technique Meta, Goro-Gutu and Deder districts were identified based on their highland pulse production potential and awareness to the faba bean and field pea technologies. Three peasant associations (PAs) were identified from each districts based on their awareness to the faba bean and field pea technologies during the demonstration season. The PAs were Kulubbi-slama, Burka–Jalala, Chafe-anneni from Meta district; Warji-Jalala, Biftu–Diramu, Hora-Waligala from Goro-Gutu district, and Chafee-Gurmu,Walta'a-guddina and Cheka-gemachu PAs from Dedar district. A total of 180 farmers for field pea and 90 farmers for faba bean were selected based on their interest to the packages. In terms of distribution, 60 farmers for field pea and 30 farmers for faba bean were selected from each district.

Farmers selected for the field pea technology provided about 500-1230 m^2 of land and those farmers who were selected for faba bean technology provided about 750-850 m^2. Training on the improved production practices of the two technologies was given to the selected farmers and the development agents before sowing the crops. About 5-13 kg of field pea and from 10-12 kg of Faba bean seed were distributed to each farmer in mid June 2011. In total, 18 qts of the two crop varieties (9 qts each) were distributed to the respective Kebeles' in early June 2011. The farmers sow the seeds with the recommended agronomic practices, that is spacing of 20x5 cm and 40x10cm; seeding rate of 106 kg/ha and 134 kg/ha for field pea and faba bean, respectively under the supervision of the respective development agents of the Kebeles.

Farmers' days

Field day (Figure 6.2) was conducted at dough stages of the crops at Kulubi-salama PA in Meta district and evaluated diseases tolerance, maturity dates and field stand of the crops. More than 20 researchers, 14 GOs, 7 NGOs, 37 farmers (7 female and 30 male), 12 districts experts, 6 DAs attended the farmers' day. Discussion was made among stakeholders and experiences were shared on the technologies of the two crop varieties. Farmers' day participants', farmers who didn't get the technology, and stakeholders who participated on the farmers' day from different districts and organizations were highly motivated and requested the University to access the varieties and production technologies inorder to improve faba bean and field pea productions using these technologies and to disseminate to the wider community.

Faba-bean Field Pea

Figure 6.2. Field evaluation during the farmers' day

Data collected: Date of planting, disease occurrences, harvesting date and yield performance, participants' responses and other related data were collected and documented.

Data type, collection & analysis: Both primary and secondary data were collected through group discussion, interview and observation and analyzed by descriptive statistics and interpretive data analysis methods.

Results and discussion

Farmers that participated in the technology scaling up after awareness creation about the technologies through demonstration, training and farmers' days were found to enhance the process of technology promotion and

dissemination to the wider community. A total of 270 farmers participated in the technology scaling up process in the three districts, of which 180 participated on field pea and 90 farmers on faba bean technologies. As a result of the technology scaling-up process and trainings, yields of field pea and faba bean increased from 8-20.2 qt/ha and from 9-19.4 qts/ha, respectively. Different stakeholders appreciated the process of technology scaling-up during farmers' day and suggested to be used as one approach for a wide dissemination of the different types of technologies. However, the above processes need strict follow-up by the districts' and Kebeles' extension agents including the principal extension team and end user.

Table 6.8 reveals that the highest mean yield/ha recorded in field pea was 21.6 in Deder and followed by Meta and Goro-Gutu with 20.0 and 18.7 qt/ha, respectively. The table also shows that about 5-13 kg improved field pea seed was distributed to the sample farmers and produced from 100 kg–214 kg with an average mean yield of 20.1 qts/ha from 500 m^2 - 1230 m^2 in the six PAs across the three districts. In general, the grand mean of field pea across the three districts was about 20.2 qts/ ha.

Table 6.8. Field pea yield performance at sample farmers' in the three districts during 2011

No	Districts	Name of PAs	No of farmers	Seed/PA in kg	Plot in m^2/ farmers'	Seed/fa-rmers	Average yield/plot (kg)	Average yield (qt)/ha
1	Meta	Chafe -annani	6	30	500	5	100	20.0
	Total		6	30	500	5	100	20.0
2	Gorogutu	H/waligala	5	42	600-1200	6-12	148	15.9
		B/diramu	5	50	1000	10	212	21.5
	Total		10	92			360	37.4
	Mean						180	18.7
3	Dedar	C/Gurmu	5	25	200-500	5	100	21.0
		Gemachu	5	44	625-1230	6-13	214	24.2
		Leman-walta	5	25	500	5	103	19.6
	Total		15	94			417	64.8
	Mean						139	21.6
	Grand Total	6PAs		216			877	
	Mean Across Districts						146.2	20.1

Table 6.9 indicates that the highest mean yield/ha in faba bean was observed in Deder district with 21.6 qt/ha followed by Goro-Gutu and Metta districts with mean yield of 20.7 and 16.2 qt/ha, respectively. The table also reveals that the farmers produced from 59 kg–175 kg and the average mean yield was 19.4 qts/ha from 350m^2 - 850 m^2 in the eight PAs across the three districts. Generally, the grand mean of faba bean across the three districts was by far better than the local production.

Table 6.9. Faba bean yield performance at sample farmers' in the three districts during 2011

No	Districts	Name of PAs	No of farmers	Seed/PA (kg)	Plot in m^2/ farmers'	Seed/farmers (kg)	Average yield/ plot (kg)	Average yield /ha (qt)
1	Meta	Muti	5	50	800	10	155.00	19.60
		c/Annani	5	50	800	10	123.00	16.90
		Salama	5	50	500	5	59.00	12.12
	Total	3	15	150			337.00	48.62
	Mean						112.30	16.20
2	Gorogutu	H/waligala	4	48	850	12	156.30	19.90
		B/diramu	2	20	850	10	175.00	21.50
	Total		6	68			331.30	41.40
	Mean						165.7	20.70
3	Deder	C/Gurmu	5	40	350-750	5-10	140.00	24.60
		Gemachu	3	30	750	10	141.70	20.20
		L/walta'a	7	70	750	10	150.70	19.90
	Total		15	94			432.40	64.70
	Mean						144.10	21.60
	Grand Total	8PAs	36	312			1100.40	154.70
	Grand mean						137.60	19.40

Source: Field data

Conclusion

Technology scaling up through extension is found to be one of the effective steps in the process of technology transfer and technology diffusion to the wider community after demonstration, training and farmers days in which farmers, researchers and different stakeholders participated. In general, wider distributions of the field pea and faba bean technologies were enhanced using scaling-up extension method. Yield increase of field pea and faba bean by participant farmers was observed in this study and a fertile ground for further dissemination of the technologies was established.

Challenges

Districts and Keble development agents' give less attention to such type of project. Some farmers have still unable to grow the crop varieties according to the package/recommendation. So, capacity building is necessary through further training and demonstration till the farmers develop the capability to adopt the technologies. Heavy rainfall at the early stage of crop growth and shortage at flowering stage is another problem.

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6.3 Scaling-up of Improved Groundnut Seed along with Management of Rootrot through Seed Revolving Strategy in Dire Dawa and Harari Region and Gursum and Babile Districts of East Hararghe Zone of Oromia Region, Ethiopia

Teklemariam Keneni, Moges Dereje, and Adamu Tefera

Abstract: Due to numerous diseases and insect pests of groundnut to a much larger extent than many other crops, there is less domestic production of groundnut. Per capita consumption of edible oil in 1995 in urban and rural areas was 3.55 and 0.55 kg/annum, respectively, which is by far less than the recommendation of 6.9 kg/capita/year made by Ethiopian Nutrition and Health Institute for adequate nutrition. Pre-extension demonstration on groundnut root rot disease management has been made for the last two years using seed treatment with and without mancozeb. Improved groundnut seed along with the management of root rot through seed revolving strategy by using model farmers has been made in Babile and Gursum districts, Harari region, and Dire Dawa administrative council with the objective of scaling-up the technology. A total of 150 farmers were selected from the indicated study areas based on farmers' interest to use the package, trend in groundnut production, and accessibility for continuous follow up. Practical training on the application of the package was given to the farmers. A total of 30 quintals of improved groundnut seed were distributed along with 12 kg mancozeb fungicide. Trials of seed treatment with mancozeb fungicide and pure seed had shown more than 58% yield increment and the farmers' interest has increased to use the packages. Generally, the result revealed that the technology reduced the groundnut production failure due to root rot; farmers' knowledge and skill increased on the adoption of the technology and groundnut production increased from 11.5 qt/ha to 17.6 qt/ha.

Keywords: Groundnut Rootrot Management; Improved Groundnut Seed; Seed Revolving Strategy

Introduction

Groundnut (*Arachis hypogea* L.) is one of the world's principal oil seeds. It is grown in countries having warm climates at altitudes ranging 500-1700 m.a.s.l. throughout the world where other crops can't be produced due to drought (Freeman *et al*., 1999). It is the 6th important oilseeds in the world. It is grown on 26.4 million ha worldwide with a total production of 37.1 million metric tons and an average productivity of 1.4 ton/ha. Its production is largely concentrated in Africa and Asia, accounting for 40% and 56% of the global area and 25% and 68% of the global production, respectively (**N**igum *et al*., 2004). In Ethiopia groundnut is the 2nd economically important oilseed crop after noug and largely produced in the eastern part of the country (Getnet and Nigussie, 1992). It serves as a source of cash, food with high protein, carbohydrate and fat contents for many small scale farmers. The estimated total land under groundnut in the country is 41,578.7 ha. Among the 16 high yielding groundnut varieties developed in Ethiopia, 9 were suitable for the eastern part of the country. Despite this fact, its productivity remained very low, which is only about 7.5-11.1 qt/ha of dry pods compared to 18-25 qt/ha yield potential of the improved varieties.

The major factors for the low productivity groundnut are low level of technology interventions, less accessibility to groundnut packages, groundnut root rot disease and drought. The study conducted by Tarekegn *et al.* (2007) at different sites of Babile district found that soil born fungi were mainly responsible for root rot of groundnut and seed treatment with mancozeb at the rate of 4 gms/kg seed was very effective in reducing the diseases and improving the yield. Efforts were made by HU in demonstrating and promoting these recommended packages during the years 2008, 2009 and 2010 in Babile and Gursum districts; Harai Region and Dire Dawa Administrative Council. Plots planted with mancozeb treated seeds had higher plant stand and resulted in higher yields and the farmers' showed interest to use the technology. The objective of this project was to scale up the groundnut packages through seed revolving strategy in Babile, Gursum, Dire Dawa and Harai region to minimize groundnut root rot disease risk and thereby increase the groundnut productivity from about 8-11qt/ha to 14-22 qt/ha during 2010/11.

Methodology

Sampling, training and package distribution

A total of 150 farmers, 30 from Dire Dawa, 40 from Harari regions, 40 from Babile, and 40 farmers from Gursum districts were selected based on their interest to use the packages, potential for groundnut production, and accessibility for continuous follow up. Practical training was given to the framers and respective development agents on the application and care to be taken in the use of the chemical. The dressing was done in the presence of development agents and the farmers just during sowing time. Four types of improved groundnut varieties were used. These are *Roba, W-961, Sedi* and *Sulamith*. The seeding rate used were 110, 70, 60, and 100 kg/ha, respectively. A total of 30 qt of groundnut and 12 kg of mancozeb were distributed to the four locations. A field day was organized and different stakeholders participated, and discussion was made regarding to the package. Most of the participants and followers

showed interest to get these technologies from the university/district or through organizing themselves. The farmers mentioned the seriousness of the groundnut root rot and the necessity of the use of the chemical in the future.

Data collection and analysis

Response of farmers and field day participants on the package was gathered; farmers' field were observed to evaluate the crop stands. The entire farmers' groundnut dry pod yield data were collected and analyzed using descriptive statistics.

Results and discussion

Farmers involved in groundnut seed multiplication using the package through revolving seed strategy increased their groundnut production on average from 8 qt/ha to 17.6 qt/ha (Table 6.10). The result shows that using the integrated groundnut technology (mancozeb and improved seed together) minimized crop failure due to groundnut root-rot and increased groundnut production by 58%. The table also shows that there are yield differences among the four varieties, and Roba stood 1st, Shulamith 2nd, w-961 3rd and Sedi last. This was also true for market demand as the respondents said during the first demonstration. However, their maturity date is the reveres, and Sedi is the earliest (85days), followed by W-961 (95 days), and Shulamith (130 days). Farmers selected the varieties during previous demonstrations based on maturity date, market demand, yield performance, seed size and color, nature of vegetative growth (erect or runners, usually they prefer the erected one because of the ease of work).

Table 6.10. Results of scaling-up of improved groundnut varieties over locations

No.	Region/ District	PA	No of farme-rs	Variety	Average plot size in ha	seed/Farm-er in kg	Average yield/plot (qt)	Average yield/ha (qt)
1.	Babile	Ab/kadir	20	w-961	0.22	15	4.10	18.20
		Tulla	20	Roba,	0.22	15	4.60	21.80
2.	Gursum	K/Oromia	8	Wrere-961	0.25	15	4.40	17.50
		Awdal	8	Wrere-961	0.25	15	4.25	17.00
		Elalami	7	Wrere-961	0.25	15	4.10	16.20
		Odaoromia	4	Wrere-961	0.25	15	4.40	17.80
			3	Shulamith	0.19	15	3.60	19.20
3.	Harari	Kile	30	Roba	0.19	15	4.20	22.40
		Waldaya	10	Roba	0.19	15	3.30	16.50
4.	D/Dawa	Awale	40	Sedi	0.25	15	2.00	13.50
Total			150	4		22.50 qts		
Grand means (over location)								17.60

Conclusion

Using integrated groundnut root-rot management through seed dressing with mancozeb fungicide and improved seed showed to be an effective method of minimizing the challenge from groundnut root-rot**.** A seed multiplication through revolving seed strategy is found to be one of the best way of extension methods in the scaling-up of the groundnut technology to the wider community, which has lead to increase in groundnut productivity from 8 qts/ha to 14-22 qt/ha, thereby improving seed shortage of the area. That means, participating farmers in seed multiplication served as an ambassador in disseminating the technology to adjacent kebeles. Field day is also another effective extension method that helped as additional tool for disseminating the technology.

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6.4 Scaling-up of improved Teff variety (Kuncho-RIL-355) through Seed Revolving Strategy in Gurawa and Tullo Districts, East and West Hararghe Zones

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Abstract: Teff is endemic to Ethiopia and it is adapted well to the changing environment resulting to lower risk to the farmers. In some environments where farmers may face complete crop failure due to moister stress, teff is the crop of choice to be harvested. It is estimated that teff contributes 4 to 5 billion Birr to the gross domestic product of the country annually. The major limitation of teff production in the eastern part of the country is its low grain yield due to low teff technology intervention and less accessibility to improved seed. To address these constraints, Haramaya University extension team had conducted pre-extension demonstration in Gurawa district of East Hararghe Zone and Tullo and Habro districts of Western Hararghe Zone during 2010. The target farmers got better yield as a result of the intervention and the follower farmers have shown high interest to use this technology to improve their teff production. The main objective of this project was to scale up improved teff variety (Kuncho-RIL-355) through seed revolving strategy in Tullo and Gurawa districts during 2011 and thereby improve teff productivity and reduce seed shortage. The project areas were identified based on suitability of the agro-ecologies, accessibility for continuous follow up, and district's willingness to seed revolving strategy. Selection of number of peasant associations per district and number of target farmers per PA was decided in consultation with districts agricultural and rural development offices. Target farmers were selected based on their willingness to transfer the amount of seed they received to follower farmers at harvest, to follow appropriate agronomic practices during the implementation process, and to give full information about the technology to the researchers when required. A total of 250 target farmers were selected from the two districts (150 from Gurawa and 100 from Tullo). Refreshment training was given to farmers and Kebele development agents. About 13 qts of Kuncho teff variety was distributed to a total of 250 farmers. Teff productivity of participant farmers has increased from 9 qts to 15.2 qts/ha on average (more than 60% yield increment). The same amount of seed was collected from the first receivers and transferred to the followers during 2012 through the respective districts and Kebele extension agents. The method is considered as one of the extension approaches to transfer and scale-up improved technologies, especially of teff to the wider community if the districts, Kebele level extension agents, and other concerned stakeholders give the necessary attention for its effective implementation.

Keywords: Teff-technology; Scaling-up; Revolving Seed Approach

Introduction

Teff (*Eragrostis tef*) is one of the ancient and most important indigenous staple cereal crops grown in Ethiopia. Teff has paramount importance in alleviating food deficiency, as it is one of the principal cereals grown in the country. Teff occupies the largest acreages 2.21 million hectares covering 28% of the total land area under cereals with annual production of 2.29 millions tons in the country (CSA, 2005). The principal use of teff grain is for making *Injera*, a major staple food in Ethiopia. Teff is highly nutritious and ranked second by FAO next to peanut in terms of kilo caloric compared to all other crops (FANTA, 2004); and it provides about two-third of human nutrition in Ethiopia (Uraga, 1997).

Economically, both the grain and the straw of teff fetch higher domestic market prices than other cereals and also internationally exported. According to Staliknechet *et al.* (1993) teff grain has already found a niche as grain and flour in the healthy food market of the United States. Teff is adapted to diverse agro-ecologies from sea level up to 2800 m.a.s.l in Ethiopia, and grows well under stress environment better than other cereal crops known worldwide. To date, 4395 teff germplasm have been preserved by the Institute of Biodiversity Conservation of Ethiopia (Demissie, 2000). Twenty improved teff varieties that give from 14-25 qt /ha on farmers' field and 18-35 qt/ha on research stations have been developed and recommended for the different agro-ecologies since 1970 (Ashok *et al.*, 2005; MoARD, 2006). A number of extension activities have also been conducted in disseminating teff technologies in different parts of the country (Teklu *et al.*, 2001; HU, 2010). In spite of huge efforts made in developing and transferring tef technologies in the country, its productivity still ranges from 7.40-9.80 qt/ha in the eastern part of Ethiopia, especially in East and west Hararghe Zones, due to less accessibility to improved teff technology and weak extension efforts (EHZARD and WHZARD, 2009).

To this end, efforts were made by Haramaya University in demonstrating teff variety (Kuncho- RIL-355) technology in Gurawa district of East Hararghe Zone and Tullo and Habro districts of West Hararghe Zone using 12 target farmers' during the year 2010 and the farmers obtained better yield (17.2 qt/ha on average). As a result, the follower farmers

showed high interest to use this technology to improve their teff production. Therefore, the objective of this project was to scale-up Kuncho teff variety with its production package through seed revolving strategy in Tullo and Gurawa districts during 2011 to improve teff productivity and thereby alleviate improved teff seed shortage of the areas.

Methodology

The project areas were selected based on the suitability for Teff production, accessibility for continuous follow up and districts' agreement to implement the project. The selection of the number of peasant associations per district and number of target farmers per PA was decided in consultation with the respective districts agricultural and rural development offices. A total of six Kebeles, three from each district, were selected based on its teff production potential and inclination of farmers towards production of Teff. Target farmers were selected based on their agreement and willingness to share the amount of seed they received for the nearby follower farmers after harvest, and allot about 2000 m^2 plots of land for technology promotion (on the basis of 5 kg seed/farmer), willingness to follow appropriate agronomic practices during the implementation process, give full information about the technology to the researchers and other farmers when required.

A total of 250 target farmers in equal proportion were selected from the two districts. Agreement was signed between the districts, the target farmers and Haramaya University (HU) to transfer the amount of seed they received to the follower farmers' at harvest. Refreshment training was given to the farmers and the respective Kebeles development agents about the technology. About 12.5 qt of improved teff seed was distributed to 250 farmers in June 2011. Field supervisions were made by HU extension team at appropriate time for the seed quality control. Farmers' day was organized at vegetative stage of the crop. Experience sharing was made among different stakeholders such as 25 researchers, 35 follower farmers, 9 government bodies, and 4 NGOs. As to the extension methods, training, field days and group and individual extension methods were used. All the necessary data such as response of the stakeholders, grain yield performance of the variety on each farmer's plot and other relevant comments were recorded during the project preparation as well as implementation periods.

Results and discussion

Distribution of seed through seed revolving strategy was found to be one of the best approaches in scaling-up technologies and thereby improving seed supply of the area. That means, participating farmers in seed multiplication using such strategy helps to enhance the process of technology promotion and dissemination to the wider community. Farmer's knowledge and skill increased through adoption of the seed revolving strategy/approach. Farmers teff production was increased from 9 to 15.2 qt/ha (by more than 60%). Different stakeholders appreciated the revolving seed strategy during farmers' day and suggested to be used as an approach in disseminating similar types of technologies for other crops like potato, wheat, and field pea as such type of crops don't easily cross bred. The strategy can also address many farmers in a short time and less cost. But it needs carful follow up by the districts and Kebeles extension agents including HU extension team in the implementation process to control seed quality. The same amount of seed was collected from the first receivers and transferred to 250 follower farmers to be grown during 2012.

Table 6.11 shows that better teff grain yield performance was recorded in Gurawa district especially in Rasa Janata Kebele (17.5 qt/ha) and the least yield in Tullo district in Kirakufis Kebel (12.9 qt/ha). According to the respondents, "un-even yield performance was because of irregular rainfall distribution". The average yield of teff in Gurawa district was 16.7 qt/ha and that of Tullo was 13.7 qt/ha. The overall grand mean of teff yield across the two districts was about 15.2 qt/ha, which is far better than the yield of traditional teff production system (7.40- 9.80 qt/ha) of the areas.

Table 6.11. Participants' teff yield performance in the two district during 2011 (n= 250 farmers)

No	Districts	Name of PAs	No of farmers	Seed/PA (qt)	Seed/farmers (kg)	Average yield/plot (qt)	Average yield/ha (qt)
1.	Gurawa	L/ilatatesa	80	4	5	3.10	15.80
		L/somolo	40	2	5	3.40	16.70
		R/janata	30	1.5	5	3.50	17.50
	Sub Total	3	150	7.5			50.00
	Mean						16.70
2.	Tullo/Hirna	K/kufis	30	1.5	5	2.60	12.90
		R/fura	40	2	5	2.70	13.70
		O/nagaya	30	1.5	5	2.90	14.50
	Sub Total	3	100	5			41.10
	Mean						13.70
	Grand total	6	250	12.5			91.10
	Grand mean						15.20

Source: Field data, Average area (plot) used per farmers was 0.2 ha

Conclusions

Distribution of seed through seed revolving strategy was found to be one of the best approaches in scaling up of teff technologies and thereby improving seed shortage constraints in the area. Field days was also found to be another effective extension method that can help as additional tool for disseminating the technology, since many stakeholders gather and make discussions on the issue for its applicability in the context of technology scaling-up. Farmers' teff production on average increased from 9 to 15.2 qt/ha as a result of utilizing teff technology. From the result of scaling-up project, we can conclude that using improved technology improves productivity and food security. It was believed that at least about 750 farmers will be reached through the revolving seed strategy at the end of 2013 if its implementation process is properly followed.

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