Landrace (Farmers' Varieties) Diversity of Field Pea (*Pisum sativum* L., Fabaceae) in Arsi Zone of Oromia Region and Kefa Zone of SNNPR, Ethiopia

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June 2017

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A Thesis Submitted to

The Department of Plant Biology and Biodiversity Management
Presented in Partial Fulfillment of the Requirements for the Degree of Master of Science (Plant Biology and Biodiversity Management)

Addis Ababa University
Addis Ababa, Ethiopia
June 2017

ADDIS ABABA UNIVERSITY
GRADUATE PROGRAMMES

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Abstract

Landrace (Farmers‟ Varieties) Diversity of Field Pea (*Pisum sativum* L., Fabaceae) in Arsi Zone of Oromia Region and Kefa Zone of SNNPR, Ethiopia

Mulugeta Berhanu Woimebo, MSc Thesis
Addis Ababa University, June 2017

This study was undertaken to identify and document the landrace (farmers' varieties) diversity along with description of the morphological variability and ethnobotanical uses of field pea (Pisum sativum L.) in Arsi and Kefa zones, Ethiopia. From each of these two study zones, three kebeles (lowest administrative unit) were randomly selected within each stratum. The strata were first determined based on purposively sampled agroecological zones and ethnic groups or cultural zones. A total of 144 randomly selected general informants and 24 purposively selected key informants were interviewed using a set of structured questionnaire and semi-structured interview guide, market survey and field observations. Voucher specimens and seed samples were collected for documentation and further agromorphological investigation. The resulting data were analyzed using descriptive statistics, Shannon-Wiener diversity index, ANOVA, Chi-square test, Student's T-Test, Paired T-Test, Wilcox Sum Rank Test, Tukey test and Mann-Whitney U Test. Thirty accessions were collected and classified under seven farmer-named varieties and one varietal admixture (a composite of two varieties). High varietal occurrence was observed in Arsi zone (7) than Kefa (4). The Tepid moist mid-highland (M3) agroecologic zone of Arsi had high varietal diversity (H'=1.5) while the Tepid sub-humid mid-highland (SH3) zone of Kefa came up with the least varietal diversity (H'=0.9). Famers grow field pea on farm sizes ranging from 0.0125-0.5 ha. All the farmers interviewed preferred field pea, which the community mainly use for food and for income generation, and farmers in H3-Arsi (100%), M3-Arsi (97%), SH3-Kefa (75%) and H3-Kefa (17%) had preferences for field pea claiming that this crop is of high fodder quality. The farmers in H3-Kefa extensively (69%) used the crop as honeybee forage and medicine for humans and livestock (67%) compared to other study strata. Field pea was an important food item mainly consumed in the form of SHIRO (sauce made of roasted and finely ground grains), KIKI (sauce made of split grains), NIFRO (boiled grains), KOLLO (roasted grains) and ESHAT (green grains). Of the farmers interviewed in each stratum,100% in SH3-Kefa, 89% in H3-Arsi, 56% in M3-Arsi and 44% in H3-Kefa grow field pea as a sole crop, whereas, 56% and 31% of farmers in H3-Kefa and M3-Arsi intercrop field pea with faba bean. This study has shown the essential role which traditional farmers play in the development and maintenance of field pea landraces. Observations and discussions showed that improved varieties have high market values and yield potentials than the local farmers' varieties. The seven farmers' varieties were grouped into three clusters based on squared Euclidean distance (D^2) values for which the maximum distance was found between clusters two and three. The final germination percentages of all collected field pea varieties were high (> 95%). The germplasm conservation, awareness raising of local farmers, and further research on improvement on yield of the low yielding varieties are needed in order to maintain the landrace diversity of field pea.

Key words: Agroecological zones, cluster analysis, ethnicity, ethnobotany, field pea, landrace,

strata

Acknowledgements

First and for most, I would like to thank, „**Almighty God'** who made it possible, not only to begin and finish this work successfully, also for his protection and favor in my entire life.

I would like to express my deep and heartfelt gratitude to Ann Lemo Woreda Education Office which sponsored my study for M.Sc. degree, with full salary; the Department of Plant Biology and Biodiversity Management of the Addis Ababa University (AAU) and the McKnight Foundation-supported Legume Diversity Project for their financial, material and training support. My warmest thanks go to my advisors, Prof. Zemede Asfaw and Prof. Zerihun Woldu of AAU and co-advisors D.r Berhanu Amsalu (National Pulse, Oil and Fiber Crops program Coordinator) for their excellent advice, guidance, valuable suggestions from beginning of proposal development to thesis writing. I also thank Dr. Morgan Ruelle for his continued support and guidance on statistical data analysis and Mr. Demeke Nigussie (GIS expert from EIAR) who made the maps of the study area.

I thank all farmers, local people, zonal and district agricultural and rural development offices and development agents of the study area for their support in finding districts and kebeles which produce mainly the field pea and supportive letter which facilitated easy movement in the rural kebeles and to obtain cooperation from local leaders, people and development workers. . My special gratitude goes to Kulimsa Agricultural Research Center to do my on-station trial and office staff members.

Finally, my gratitude goes to my friends especially Berhanu Abute, Mekibib Fekadu, Teshale Mencha, Degu Selassei, Amanuel Eramo and all my family for helping me in different materials and advice during my study.

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Acronyms

AEZ:	Agroecological zones
ANOVA:	Analysis of Variance
CRBD:	Completely randomized block design
CSA:	Central Statistical Agency
DA:	Development Agents
DNA:	Deoxyribonucleic Acid
EBI:	Ethiopian Biodiversity Institute
EIAR:	Ethiopian Institute of Agricultural Research
ETB:	Ethiopian Birr
FAO:	Food and Agricultural Organization of the United Nations
GP:	Germination Percentage
GPS:	Geographic Positioning system
ICARDA:	International Center for Agricultural Research in the Dry Areas
MoARD:	Ministry of Agriculture and Rural Development
SNNPR:	Southern Nations, Nationalities and Peoples Region

CHAPTER ONE

1.1. Introduction

1.1.1. Background of the study

Field pea is known for having high intraspecific diversity within Ethiopia and most of the diversity is maintained by farmers. Field pea is a valuable cool-season pulse crop grown worldwide for its seed and soil fertility benefits (McPhee, 2003). In Ethiopia, more than 15 cultivars of field pea, with superior yield potentials, seed size and seed color and disease resistance have been released for different agroecological conditions (MoARD, 2008). Some of these varieties were obtained from local collections while others were obtained through hybridization of landraces with introduced germplasm. Land races are the genetic wealth that a crop acquires over many years of its existence and have considerable breeding values as they contain valuable adaptive genes to different circumstances (Messiaen *et al*., 2006). The existing field pea germplasm in the country has phenotypic diversity and tolerance/resistance to diseases (Gemechu Keneni *et al*., 2007; Berhane Gebreslassie & Berhanu Abraha, 2016). There are two recognized subspecies, *Pisum sativum* var. *sativum* and *Pisum sativum* var. *abyssinicum* and the latter is endemic to Ethiopia (Thulin, 1989; Haddis Yirga *et al*., 2013). Both subspecies are found in Ethiopia being grown in the highlands from 1800 – 3200 m a.s.l. According to Thulin, (1989), it is stated that both *Pisum sativum* var. *sativum* and *Pisum sativum* var. *abyssinicum* are grown in the highlands of all regions of Ethiopia, occupying different parts of the landscape and having variations in their vegetative and reproductive structures. *Pisum sativum* var. *sativum* is widespread across the Middle East and has affinity to the wild *Pisum sativum* var. *elatius* while *Pisum sativum* var. *abyssinicum* is restricted to highland regions (mainly in Tigray Upland and

Wello Upland, but known also from Shewa Upland, Arsi, Bale and Harerge) of Ethiopia (Thulin, 1989; Haddis Yirga *et al*., 2013). However, according to Haddis Yirga *et al*. (2013), *Pisum sativum* var. *abyssinicum* is known as DEKOKO (meaning minute seeded) in Tigrigna and YAGERE ATER (pea of my country) or TINISHU ATER (the small pea) in Amharic, which is capable of producing seed yield of up to 1.95 t/ha under phosphorus fertilization and is known for its high market price (more than twice as much as the other pulses) and for being much preferred for food. Cultivated *Pisum* is dominated with *Pisum sativum* sub group, but *Pisum sativum* var. *abyssinicum* (DEKOKO) is a unique subgroup developed and cultivated in Ethiopia (Haddis Yirga *et al*., 2013). The highlanders use the two varieties of field pea for various purposes. They use the seeds for food and to generate income. The residue is used as fodder in some areas (Baranger *et al*., 2004). Farmers also use field pea to restore their soil fertility.

1.1.2. Statement of the problem, research questions, hypotheses and research objectives

1.1.2.1. Statement of the problem

In general as identified by different researchers, farmers in Ethiopia cultivated two sub families of field pea namely sub family *Pisum sativum* var. *sativum* and *Pisum sativum* var. *abyssinicum* (Thulin, 1989 and Habtamu Seboka and Fikreselassie Million 2013). Also there are different genetic diversity studies on field pea germplasm in Ethiopia. According to Abel Teshome *et al*., (2015) there is high genetic diversity within field gene pool in Ethiopia by significant differentiation among accessions, regional and altitudinal groups. The level of genetic differentiation is higher among regions within Ethiopia than altitudinal groups. This could be a consequence of seed exchange among farmers resulting in low differentiation in allele

distributions and due to the presence of significant number of private and rare alleles as well as differences in allele frequencies among accessions. Gemechu Keneni *et al*., (2005) studied that no definite relationship between geo- graphic diversity and genetic diversity as overlapping was encountered in clustering pattern among accessions from different parts of the country. Hajjar *et al.,* (2008) have argued that a consequence of decrease in genetic diversity of landrace availability causes genes will not be available for breeders to develop improved varieties and meet: changing consumer demands; changing environmental conditions; exploit new markets or environments; provide food security, cultivars grown by farmers become increasingly genetically homogenous; agroecosystem functioning and its provision of services (e.g., pest and disease control, pollination, soil processes, biomass cover, carbon sequestration, prevention of soil erosion, etc.), as well as potential innovation in sustainable agriculture are each likely to be seriously impacted. However, there are no studies that describe and identify field pea varieties considering farmers‟ nomenclature and identification as well as the diverse local uses and management systems and relating them to formal science. Thus, the main purpose of this study is to assess, identify, document and analyze the diversity of field pea landraces (farmers‟ varieties) in Ethiopia focusing on farmers‟ criteria by applying the methods of science. The results will contribute to enhance farmers‟ access to a wide range of varieties of field pea while the research programs also make effective use of the wide genetic material of field pea found with farmers.

1.1.2.2. Research questions

The research is focused towards answering the following main questions:

- Which field pea farmers‟ varieties are found in Arsi and Kefa zones?
- Which stratum contains diverse landraces (farmers‟ varieties) of field pea?
- Are there any differences among landraces in terms of their morphological traits and germination rate?
- Which agroecological zones in the study areas are very important for the growth and productivity of *Pisum sativum?*
- What are the main production constraints (pests, diseases, others) faced by farmers in cultivation of *Pisum sativum* in the study area?
- Which varieties of field pea have the highest values for specific purposes (nutrition, economic values, soil fertility enhancement, and climate change adaptation)?
- What conservation and management measures should be undertaken for cultivation of field pea?
- Is there any difference in market price values and yield among *Pisum sativum* farmers‟ varieties in the study area?
- What are the seed exchange systems among the farmers in the study area?
- Is there any relationship between diversity and distribution of the variety with soil color?

1.1.2.3. Hypotheses

Among other things, this research attempted to test the following research hypotheses:

- Arsi has high diversity of field pea farmers‟ variety than Kefa.
- Low-income farmers grow fewer varieties of field pea than mid-high income farmers.
- There is a statistically significant difference in price value of field pea between Arsi and Kefa zones.
- The variation in agroecological zones affects the number of field pea landraces.
- Seed selection criteria and ways of traditional seed storage have differences among the zones of the study area.
- Conservation and management measures taken for cultivation of field pea are different among the two study zones.
- There is a significant difference in the use value of field pea among the two study zones.
- The study zones show significant differences in cropping season, crop rotation, benefits of crop rotation, intercropping practice, intercropping system, benefits of intercropping and place of field pea
- The percentage of germinating seeds of the different landraces under laboratory condition is different.
- Soil color has no influence on landrace distribution and diversity of field pea.
- Unique properties, amount of production, amount of household consumption and market values of field pea are different among the zones of the study area.

1.1.2.4. Research objectives

1.1.2.4.1. General objective

The general objective of this study is to identify and document the landrace (farmers‟ varieties) diversity, morphological variability and ethnobotanical uses of field pea (*Pisum sativum* L.) in Arsi and Kefa zones.

1.1.2.4.2. Specific objectives

- To identify and document the landrace diversity those are cultivated by farmers in Arsi and Kefa zones.
- To gather, record and document indigenous knowledge of the people on the ethnobotanical uses and management system in Arsi and Kefa zones.
- To identify potentially useful farmers‟ varieties based on farmers‟ preferences for future use.
- To identify the effect of agroecological differences in the number and types of farmers‟ varieties in Arsi and Kefa zones.

CHAPTER TWO

2.1. Literature review

2.1.1. Origin and domestication of field pea

The center of origin for field pea is believed to stretch from the Mediterranean to Central Asia as well as in the high elevation of Ethiopia (Davies 1976; Hagedom 1984). However, the exclusive origin and primary source of diversity of the crop is not well known (Davies 1976). Four centers of diversity, based on genetic assessment were listed by Vavilov (1926), namely central Asia, the Near East, Abyssinia and the Mediterranean. Blixt (1970) indicated that the principal center of genetic diversity is the Mediterranean gene center with secondary centers in the Near East and Ethiopia. Ethiopia and western Asia as centers of diversity, with secondary centers as southern Asia, and south and east Mediterranean regions (Gemachu Keneni *et al*., 2007; Haddis Yirga and Dargie Tsegay, 2013; Berhane Gebreslassie & Berhanu Abraha, 2016). The crop is known to grow in Ethiopia since antiquity (Dawit Tadesse *et al*., 1994) and the country is considered one of the centers of diversity for this crop (Hagedom, 1984; Hailu Mekibeb *et al*., 1991). The species *Pisum sativum* L. is known to dominate the production system in Ethiopia (Hagedom, 1984; Gemachu Keneni *et al*., 2007; Amare Ghizaw and Adamu Molla, 1994).

2.1.2. Taxonomy of field pea

According to Upadhyaya *et al.,* (2011) the family Fabaceae which is commonly known as the pea or bean family consists of 700 genera and more than 20,000 species. Fabaceae is the hub for most domesticated crops in comparison to all other families (Harlan, 1992). Fabaceae consists of three sub-families: Mimosoideae, Caesalpinioideae and Faboideae (Papilionoideae).

The subfamily Faboideae (Papilionoideae) comprises most of the important edible legumes like broad beans (*Vicia faba* L.), chickpea (*Cicer arietinum* L.), field pea (*Pisum sativum* L.), pea nuts (*Arachis hypogaea* L.) and soybean (*Glycine max* L.) (Smartt, 1980). Each sub-family is identified by its flower. Edible legume crops are mainly found in the sub-family Papilionoideae (Allaire and Taylor, 2007). Legumes are grown agriculturally, primarily for their grain seed called pulse, for livestock forage and silage, and as soil-enhancing green manure (Wang *et al*., 2010). Legumes are a very healthy food because of their low fat and high protein content (Ayeh *et al*., 2009). Legumes are also very high in fiber and other nutrients (Allaire and Taylor, 2007; Hoover *et al*., 2010). According to Clark (2007), legumes are notable in that most of them have symbiotic nitrogen-fixing bacteria in structures called root nodules. For that reason, they play a key role in improving soil fertility after crop rotation. A legume fruit is a simple dry fruit that develops from a simple carpel and usually dehisces (opens along a seam) on two sides. A common name for this type of fruit is a pod, although the term "pod" is also applied to a few other fruit types, such as that of vanilla capsule and radish siliqoe (Allaire and Taylor, 2007). Well-known legumes include alfalfa (*Medicago spp*.), clover (*Trifolium spp*.), pea, and bean (*Vicia faba, Phaseolus vulgaris*), lentil (*Lens culinaris*), lupin (*Lupinus spp*.), mesquite (*Prosopis juliflora*), carob, soybeans (*Glycine max*), peanuts (*Arachis hypogaea*) and tamarind (*Tamarindus indica*). Soybean, chickpea (*Cicer aritienum*), bean, and pea, are the edible legumes that are grouped under sub-family Papilionoideae (Allaire and Taylor, 2007). Ethiopia is one of the major Vavilovian centers of diversity for several grain legume crops including lupin, field pea and wild ancestors of cow pea (Vtg).

The earliest archaeological evidences on cultivated pea are as old as 8000 BC from the Fertile Crescent (Messiaen *et al.*, 2006). According to Linnaeus (1753), the genus *Pisum is* classified

into four species: *P. sativum* (garden pea), *P. arvense* (field pea), *Pisum ochrus* and *Pisum maritinum*. On the other hand, Boissier (1872), only recognized a single species of *Pisum i.e. Pisum sativum* L. with three wild relatives (*Pisum elatius*, *Pisum humile* and *Pisum fulvum*). Davis, (1970) stated only two species in this genus *Pisum*. For example, *Pisum sativum* and *Pisum fulvum* and the others were placed at the subspecies level under *P. sativum*. However, according to Kosterin & Bogdanova (2015) and Maxted & Ambrose (2001), species in this genus are classified in to *Pisum sativum*, *Pisum fulvum* and *Pisum sativum* var. *abyssinicum* depending on their taxonomic status.

2.1.3. Botanical description of field pea

Field pea is an annual vine that is smooth and has a bluish-green waxy appearance. According to Inga, H. & Sue E. (1969) in volume three of flora of Ethiopia considers, field pea (*Pisum sativum*) is an herb about 2 m long plant. Its stipules are larger than the leaflets, up to 10 cm long. Racemes are 1-2 (1-3) flowered. Corolla is 15- 35 mm long and it has white to purple. Its pod is 3.5-9.5cm long and 1-1.8 cm wide, by containing 2-9 seeds. The seeds are 5-8 mm in diameter and it can be small, smooth or wrinkled, and globose or angled. Elzebroek and Wind (2008) stated that Vines can be up to 3 meter long. However, modern cultivars have shorter vines, about 0.67 meters long. The stem is hollow, and the taller cultivars cannot climb without support. The pinnately compound leaves are arranged alternately along the stem, each leaf comprising up to 4 pairs of leaflets and ending in a tendril which is usually branched. The stipules (appendages at the base of the leaf) are leaf-like and are up to 10cm long (usually 1.5-8 cm), on round, slender, and glabrous stems. The petiole (the part of the leaf which connects to the stem) is up to 7 cm long. Leaves consist of one or more pairs of opposite leaflets borne on petioles together with several pairs of tendrils (which are essentially modified leaves) and these

modified terminal leaflets form a single or compound terminal branched tendril. This plant climbs using the tendrils produced at the apex of a compound leaf. Inflorescences occur in the leaf axils, and consist of racemes with one to four flowers. Flowers have five green fused sepals and five white, purple or pink petals of different sizes. The top petal is called the „standard", the two small petals in the middle are fused together and called the „keel" (because of their boat-like appearance), and the bottom two petals taper toward the base and are called the „wings" (Elzebroek and Wind, 2008). Within the keel there are ten stamens; nine form a tube that surrounds the pistil, and there is one loose stamen. The ovary contains up to 15 ovules, and the fruit is a closed pod, 1 to 4 inches long that often has a rough inner membrane (L.S.Pavek, 2012). Ripe seeds are round, smooth or wrinkled, and can be green, yellow, beige, brown, red-orange, blue- red, dark violet to almost black, or spotted. The flowers are primarily self-pollinating, which enables breeders to create true breeding lines**.** The plant is a diploid (2n = 14) chromosomes (Ben Ze'ev & Zohary, 1973).

2.1.4. Distribution of field pea in Ethiopia

In Ethiopia, field pea is a cool season legume crop which is widely grown in mid to high altitude and the country is considered as one of the centers of diversity (Hagedorn, D.J., 1991). *Pisum sativum* var. *sativum* grows in the highlands of all regions of Ethiopia. *Pisum sativum* Var. *abyssinicum* is an Abyssinian pea which is native to Ethiopia (Haddis Yirga and Dargie Tsegay 2013 and Habtamu soboka and Fikreselassie Million 2013), and it has very low genetic diversity and possesses a distinct set of phenotypic characteristics (early flowering, an adaptation useful for avoiding drought periods; unipinnate and strongly serrate leaflets), as well as unique alleles at particular loci (Petr *et al*., 2015). According to report of MoARD, (2008) mainly there are five agroecological zones where field pea is widely cultivated in Ethiopia (Table 1).

Table 1. The main field pea production agroecological zones of Ethiopia.

	AEZ	Altitude ranges (m)	Length of growing period (days)	Regions
1	H3 - Tepid humid mid-highlands	2000 - 3000	241-300	SNNP, Oromia
2	SH3 - Tepid sub-humid mid-highlands	2000 - 2800	181-240	SNNP
3	M3 - Tepid moist mid-highlands	1400 - 2200	121-180	Oromia
4	SM3 - Tepid sub-moist mid-highlands	1000 - 2000	61-120	Amhara, Tigray
5	SM4 - Cool sub-moist mid-highlands	1000 - 2000	61-120	Amhara, Tigray

2.1.5. Adaptability of field pea

Field pea is an annual cool-season grain legume (pulse) crop. According to Cherinet Alem and Tazebachew Asres (2015) and Humplik *et al*., (2015), field pea requires cool, moist growing conditions and can withstand heavy frost once established. It does not grow well in hot weather and its germination can occur at temperatures as low as 40°F, although optimal temperatures for germination and growth are between 60 and 70°F (LPavek, 2012) but generally grows best between 10^0C and 20^0C (Velykis and Satkus, 2012). Field pea grows well on a wide range of soils; though water logged soils and temporary flooding are not tolerated. Field pea is not shade-tolerant and shows little salinity tolerance (Ortiz, R., 2013). This poorer performance may be due in part to field pea‟s low tolerance for water logged soils or its susceptibility to water-associated root diseases. Field pea seed will germinate at a soil temperature of 40^0F. According to Velykis and Satkus, (2012), field pea has hypogeal emergence in which the cotyledons remain below the

soil surface and the emergence normally takes 10 to 14 days. Flowering usually begins 40 to 50 days after planting. Flowering is normally two to four weeks, depending on the flowering habit and weather during flowering (Pallavi *et al*., 2013).

According to Berhane Gebreslassie & Berhanu Abraha (2016) Ethiopian pea is highly suitable for cultivating on the soils with rather low fertility, such as those in northern Ethiopia, where it achieves better results on field pea and other cool season legumes. Figure 2 showed that In Ethiopia from total of 112482728 hectare of land in Ethiopia 86470280 hectare is on suitable land for cultivation of field pea. However, 2835080 hectare of land is marginally suitable, 21395268 hectare of land is moderately suitable and 1782100 hectare of land is highly suitable for cultivation of field pea.

2.1.6. Farmers' field pea seed exchange system

Diversity of crops and varieties are created and maintained through seed exchange among farmers, and the scales and strengths of these pathways have enormous influence on agricultural biodiversity (Dennis and Ilyasov, 2007). In order to understand patterns of diversity, it is therefore useful to explore the patterns of farmer seed exchange that influence farmers‟ use of and access to agricultural biodiversity, and the ways in which cultural, demographic, and agricultural changes have the potential to enhance or erode that diversity. Generally, seed exchange takes place within communities, long distance exchanges may be more common than previously thought, and traditional agricultural systems are not isolated with respect to the flow of genetic material (Perales and Brush, 2003). Farmers in traditional agricultural systems acquire traditional seed from different primary sources: their own saved seed, gifts or exchanges with other farmers and purchase in local markets. Benefits from the use of saved seed include

adaptation to local conditions, known seed quality, and reduced financial and social costs (Badstue and Bellon, 2007).

2.1.7. Landrace diversity

The term landrace refers to a dynamic population of a cultivated plant that has historical origin, distinct identity, and lacks formal crop improvement, as well as often being genetically diverse, locally adapted, and associated with traditional farming systems (Camacho Villa *et al*., 2005). Landraces have been selected by farmers for adaptation to specific sets of field conditions as well as particular uses within the food system. They are often highly variable in appearance, but they can be identified and almost always have distinct local names. They have particular characteristics (e.g. early or late maturing), a reputation for adaptation to local climatic conditions, cultural practices, and resistance or tolerance to diseases and pests (Harlan, 1992). Major advantages of landraces are adaptation to their specific agro-systems and low input requirements, and ethnic reasons are also present in traditional agriculture practices. Therefore, landraces generally provide high yield stability and intermediate average yields under a low input agricultural system (Zeven, 1996). The genetic diversity of landraces is very important for global biodiversity conservation for future world production (Wood & Lenné, 1997). Diversity is expressed as genetic differences between species, subspecies, varieties, populations or individuals. Diversity can be measured at the morphological level, the physiological level, diversity in a plant‟s resistance to pest and disease or in its degree of tolerance to drought and in terms of differences in biochemical, protein and molecular (DNA) properties within and between plant populations.

2.1.8. Genetic erosion

From the beginning of agriculture, farmers have domesticated hundreds of plant species and due to migration, natural mutations and crosses, and unconscious or conscious selection, genetic variability has increased within species gradually (Teshome Hunduma 2014). Continuous expansion of genetic diversity within crops went on for several millennia, until scientific principles and techniques influenced the development of agriculture (Scarascia-Mugnozza and Perrino, 2002). With growing technology, population, production and consumption rates, the impact of humans upon biodiversity has gradually increased (Scarascia-Mugnozza and Perrino, 2002). Also due to the question for increasing food production and the resulting success achieved in several crops has begun to replace landraces by improved varieties.

The concept of genetic erosion emerged forcefully between 1965 and 1970, in a period when crop improvement had clearly demonstrated its power to transform local crop populations in industrialized countries and in certain less developed regions (Brush, 1999) and the term gene erosion was coined (Bennett, 1968). Brush (1999) defined genetic erosion in crops as the loss of variability from crop populations. Variability refers to heterogeneity of alleles and genotypes with their attendant morphotypes and phenotypes (Teshome Hunduma 2014). Genetic erosion is the main threat to landraces. It is the loss of a crop, variety or allele diversity; the reduction in richness and evenness *(*Maxted and Guarino, 2006). According to Gemachu Keneni *et al*., (2007), genetic erosion implies that the normal addition and disappearance of genetic variability in a population is altered so that the net change in diversity is negative.

There are numerous factors that negatively impact plant species and their populations which will result in taxonomic (species, subspecies, and varieties) and erosion of genetic diversity, and

eventual extinction (Nabhan, 2007). According to Hammer and Laghetti (2005), the main factors that contribute to the genetic erosion of landrace diversity are changes in agricultural practices and land use; use of pesticides and herbicides; replacement of traditional varieties with modern, uniform cultivars which lead to a genetic bottleneck. Once landraces have been replaced by modern cultivars, unless the landrace is conserved *ex situ*, the unique combination of genetic diversity is unavailable to breeders; as a consequence, the total number of different varieties grown is reduced and/or cultivars grown by farmers become increasingly similar to each other; research program that ignore landraces and their associated knowledge and uses; ageing of farmers and the unsuccessful passage of landrace and associated knowledge from one generation to the next; lack of education of the unique value of landraces as a local, national and global resource.

Several approaches have been employed to estimate the degree of genetic erosion that a particular taxon faces in a certain region over a given time. Methods usually rely on either the analysis of molecular data (Provan *et al.*, 1999; Akimoto *et al.*, 1999), or comparison between the number of species/landraces still in use by farmers at present time to those found in previous time (Hammer *et al.*, 1996).The most widely used figures in estimating genetic erosion are indirect, i.e., the diffusion of modern crop varieties released from crop breeding programs.

2.1.9. Cropping systems and agronomy of field pea

Field pea often is planted in mixtures with cereal grains and faba bean. The cereal protects the soil during winter, when field pea growth is slow, and provides a support for vines to climb, keeping the field pea off the ground where it is more likely to rot. *Pisum sativum* is planted both as sole and mixed cropping systems in Ethiopia (Zentner *et al*., 2002), predominant sole

cropping of pure varieties. In highlands, sole cropping is the common practice, while intercropping with either barley or faba bean is more familiar in some areas (Strydhorst *et al*., 2008). Field pea offers natural soil maintenance benefits through nitrogen-fixing, which improves yields of cereals through crop rotation, and can also result in savings for smallholder farmers from less fertilizer use (Angaw Tsigie and Asnakew Woldeab, 1994).

According to Underwood *et al*., (2013), crop rotation is the practice of growing a series of dissimilar types of crops in the same area in sequential seasons (as opposed to monoculture). Rotations may include from two to six or more crop types, and ideally should include a balance of crops from different crop groups (cereals, legumes, root crops and broad-leaved arable crops). No one crop group (e.g. Cereals) should occupy more than half of the rotation**.**

2.1.10. Uses of field pea

Field pea is grown for different purpose such as edible seed or seed pods, silage and green fodder (Pavek 2012 & Santalla *et al.*, 2001, Cousin *et al*., 1985), desirable in crop rotations because of conserve soil water and economic advantages, green manures (Biederbeck *et al*., 1995 and Endres *et al*., 2009)**.** Field peas may also be used as cover crop to prevent soil erosion, soil moisture retention and soil fertility restoration as suitable rotation crop that fixes atmospheric nitrogen (Angaw Tsigie and Asnakew Woldeab, 1994). Field pea does not escape to become a weed. Field pea often is planted in mixtures with cereal grains and faba bean.

Filed pea flour mixed with various spices is popularly used as SHIRO or the pea may be split as KIKI for the preparation of wot in Ethiopia or curry in other international cousins. Field pea supplies 344 calories, 20.1 g protein and 64 carbohydrates / 100 g edible portion and it has no

anti-nutritional factors (Asfaw Telaye *et al.*, 1993)**.** Pea protein is deficient in Sulphur containing amino acids (cysteine and methionine) but contains relatively high levels of lysine making it a good dietary complement to cereals (McPhee, 2003). It provides balanced diet in combination with wheat, rice and other cereals (Santalla *et al.,* 2001).

2.1.11. Management of field pea

The conservation and management of germplasm, like that of other components of natural resources, is very crucial not only for food security but also for sustainable agriculture and environmental health. For legumes, 80% of the yield gap can be taken back to agronomic management (Gemachu Keneni *et al*., 2007). Field pea often is planted in mixtures with cereal grains and faba bean. Its production and productivity is affected by different agronomic management practices. According to Fisseha Negash and Tewodros Mulualem (2014), low yield might be due to several factors among which low input and poor agronomic managements are important. Weeding, Ploughing and fertilizer rate have positive effect on growth and yields of field pea. Therefore, exploring the available improved practices, including sowing dates, sowing rate, disease and pest control, fertilizer application (timing and amount), intercropping are the main management system that are practiced by farmers for the productivity of field pea. Insect-resistant varieties can be used as alternatives to chemical insecticides or in combination with other pest management methods. In addition to this Esayas Mendesil (2015) the adverse effects due to the current high dependency on chemical insecticides, such as development of insecticide resistance coupled with increasing public awareness about the effects of pesticides on human health and the environment, have provided the impetus for integrated pest management like, cultural control, biological control, host plant resistance, and chemical control with insecticides.

2.1.12. Productivity and production constraints of field pea

The main field pea producing countries include Canada, Russia, China, India, France and Ethiopia, while Ethiopia ranks first in Africa and number six in the world in field pea production (FAOSTAT, 2012). Getachew Tesfaye (2000) said that field pea is grown twice per year (the short rain and the main growing seasons) in Ethiopia. Field pea is the second major pulse cultivated in Ethiopia next to faba bean (*Vicia faba* L.). Field pea serves as food for millions of people in Ethiopia (CSA, 2011) and also used as a source of income for the farmers and foreign currency for the country (Girma, 2003). Having all these multiple benefits in the economic lives of the farming communities, however, the average yield of the crop is only 1.24 t / ha in Ethiopia (CSA, 2011 and FAOSTAT, 2012), which is far below the potential 40 to 50 t / ha sometimes achieved in Europe (Netherlands, France and Belgium) and the worldwide average yield of 1.7 t / ha (Petr *et al*., 2012). The crop is popular among farmers due to its high return value even when grown in degraded soil, and it requires less management input than cereals to give good yield. Its symbiotic nitrogen fixing capacity (Esayas Mendesil, 2015 and Messiaen *et al*., 2006) makes the crop popular among famers as a break crop in between two to three years of cereal cropping for crop rotation. Unfortunately the increase in production is not due to increase in yield/hectare but rather due to an increase in acreage (FAOSTAT, 2015).

The productivity has been constrained by several yield limiting factors. Among them, the important ones are the inherent low yielding potential of the indigenous cultivars (Asfaw Telaye *et al*., 1994), fungal diseases like Ascochyta blight (*Mycosphaerella pinodes*) and powdery mildew (*Erysiphe polygoni*), Dereje Gorfu and Testate Bashir (1994), poor soil fertility, unimproved cultural practice such as poor seed bed preparation and lack of fertilizer use

(Amare and Adamu, 1994). Lack of improved high yielder varieties resistance to diseases, insects and abiotic calamities for specific location with appropriate agronomic recommendations can be cited as a major reason for this low productivity.

CHAPTER THREE

3.1. Materials and Methods

3.1.1. Description of the study area

The study was conducted in two regional states (Oromia and SNNPR) of Ethiopia, by selecting two major field pea growing Zones (Arsi from Oromia and Kefa from SNNPR) depending on production and economic and cultural roles of the crop. Two agroecological zones were selected from each study zones (H3 - Tepid humid mid-highlands and M3 - Tepid moist mid-highlands from Arsi zone and H3 - Tepid humid mid-highlands and SH3 - Tepid sub-humid mid-highlands from Kefa zone) were selected randomly. Finally, a total of twelve kebeles, three from each agroecological zones of the two study zones were randomly selected for this research. Figure 1 shows the sampling sites and Figure 2 demarcates areas in Ethiopia considered suitable for cultivation of field be based on the requirements of the crop.

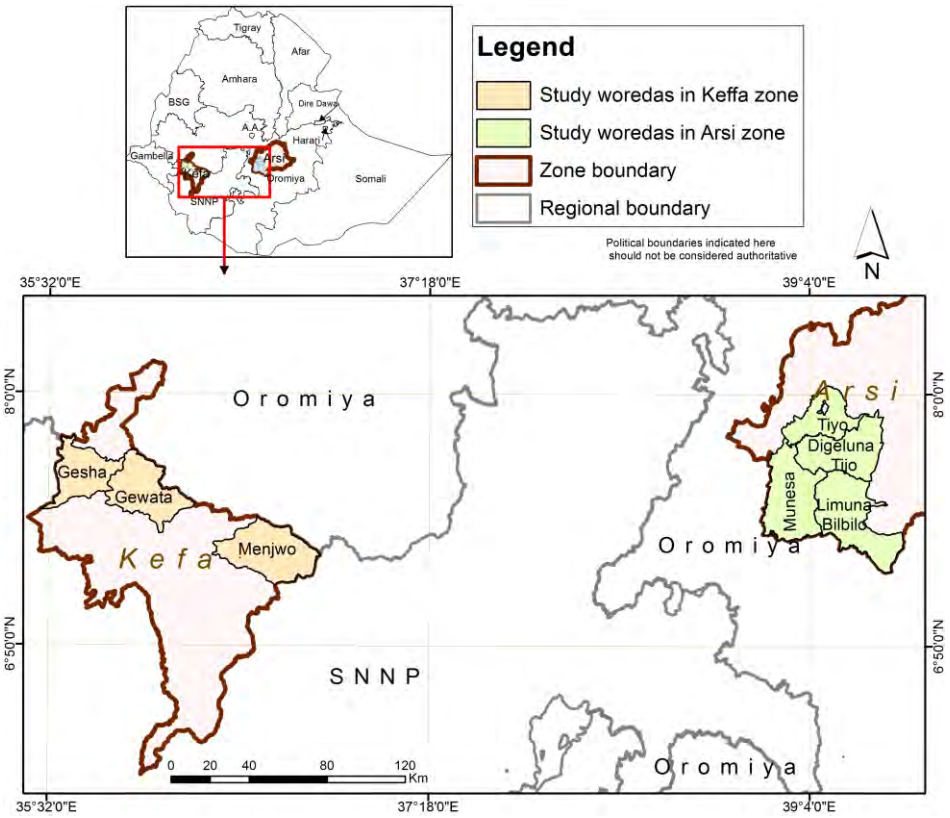


Figure 1. Map of Ethiopia showing the study zones

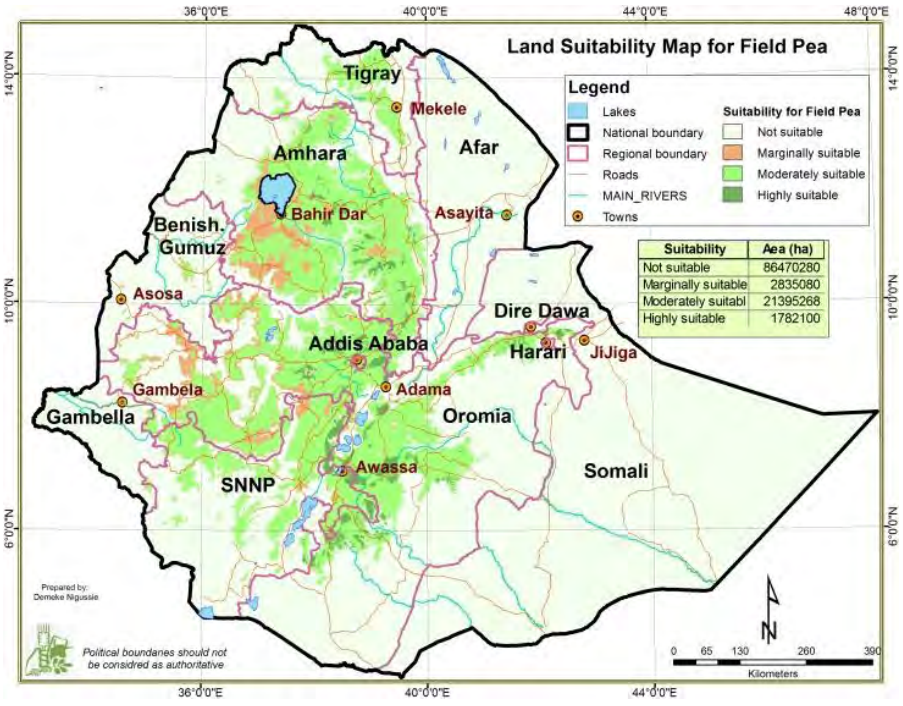


Figure 2. Land suitability map of field pea in Ethiopia

3.1.2. Climate

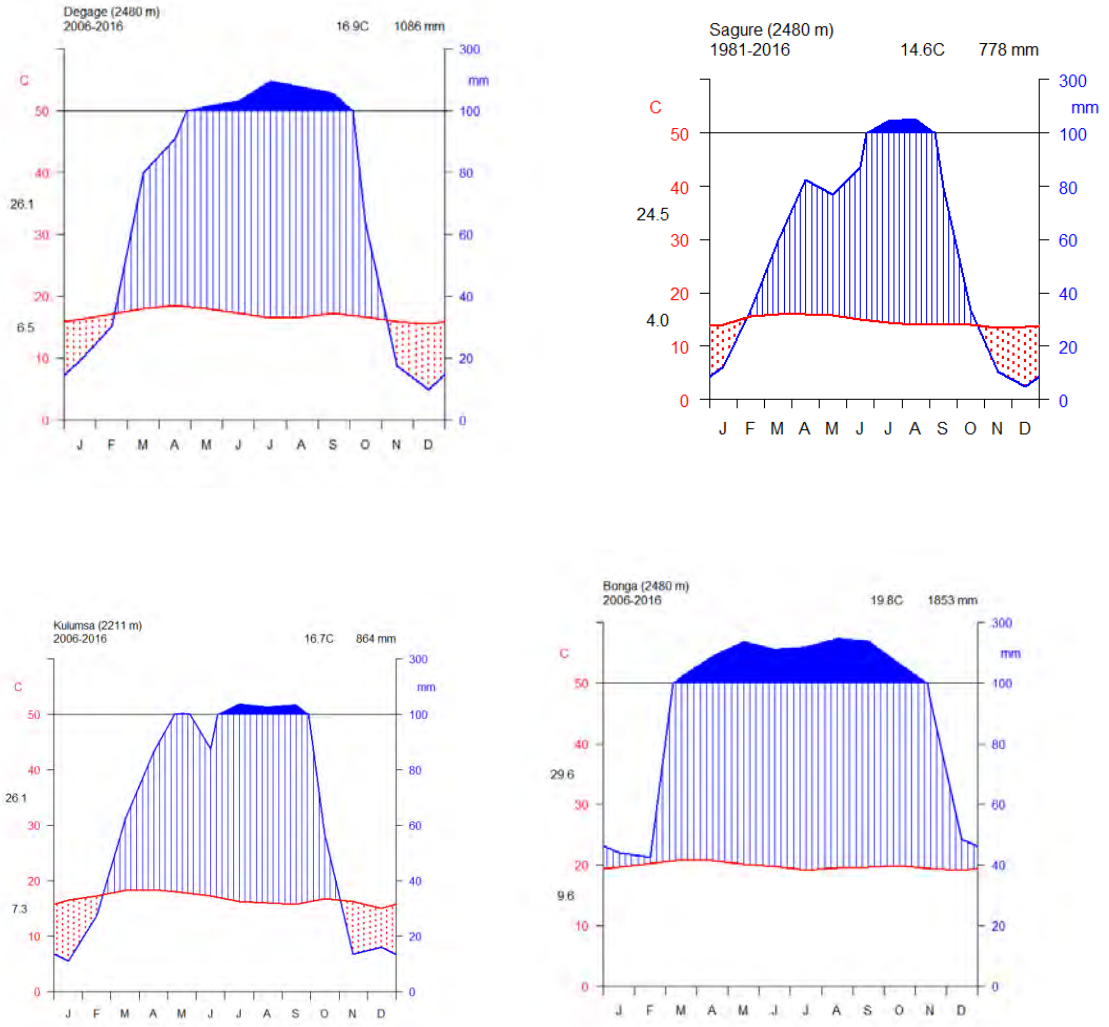


Figure 3. Climate diagram of the study sites in Arsi and Kefa Zones

The climate of the study sites has been represented using the rainfall, maximum and minimum temperature based on the data obtained from National Meteorological Service Agency (NMSA) for the last ten years. The mean annual maximum temperature of the study areas for the last ten years ranged between 14.6–19.8 ^{0}c. The average annual rainfall of the study areas ranged between 778-1853 mm. All the study areas have a slightly bimodal rainfall for Kulumsa and Sagure and unimodal rainfall pattern in Bonga and Degage. The climate conditions of study

woredas (only those woredas where climate stations are available) are depicted in climate diagrams (Figure 3).

3.1.3. Materials used

Materials used to conduct this research were: GPS to collect longitude, latitude and elevation of study area; Digital camera to take picture of plants and landscapes; Plant press, secateurs for herbarium specimen collection, Petri-dish and filter paper for germination test; paper bags/envelops- for seed sample collection and other supportive materials needed to conduct the research.

3.1.4.Methods

3.1.4.1. Site selection

Study sites were selected purposively to get areas that show greater diversity and production potential. This was done by referring to different literature sources, studying the collection areas of the crop in national herbarium of Addis Ababa University, referring to the survey made by CSA (2015), on area and production of major crops and by using the suitability map of field pea made depending on data obtained from FAO (1984), on the crops‟ ecological requirements. Three agroecological zones (Tepid humid mid highlands (1600 - 2400 m a.s.l,), Tepid moist mid highlands (1600 - 2400 m a.s.l.) and Tepid sub-humid mid highlands (1600 - 2400 m a.s.l) with growth period 241-300 days, 121-180 days and 181-240 days respectively) from the two selected administrative zones were purposively selected (EIAR, 2011) depending on their elevation, rainfall and growing season of the crop, by using Google earth GIS software. Three kebeles were selected from each stratum randomly.

3.1.4.2. Informant selection

The survey included twelve randomly selected farmers by considering the wealth status and gender of the farmers (6 low-income and 6 middle/high-income households (3 women from high-income households, 3 men from high-income households, 3 women from low-income households and 3 men from low-income households) from each kebeles. A total of 144 general informants (12 informants x 3 kebeles x 4 strata = 144 general informants) having different ethnicity, relative wealth states, age and sex categories were interviewed. One man and one woman who are knowledgeable about the field pea were selected from each kebeles as key informants. These key informants were selected among the farmers who have already responded to the structured interview (by ODK), or based on the recommendations made during those interviews, or based on information from other village members. The total number of key informants was 24 (4 strata x 3 kebeles x 2 key informants). Figure 4 shows the flow diagram of the sampling frame.

Methodological framework

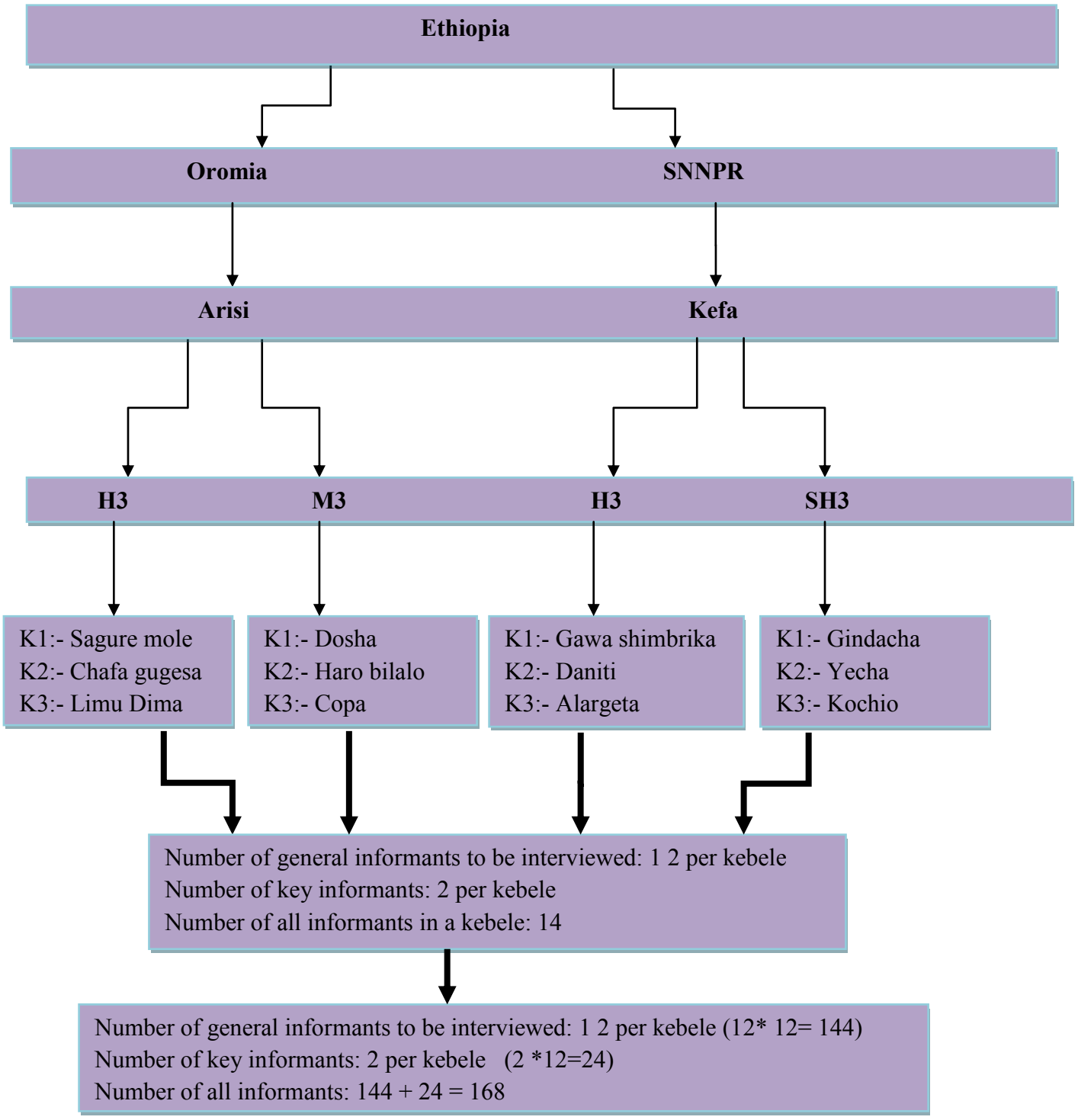


Figure 4. Flow diagram of the methodological framework of the study

3.1.4.3. Methods of data collection

3.1.4.3.1. Field data collection

The field study was conducted from October – December, 2016. Botanical and ethnobotanical data of field pea and its landrace varieties were acquired using primary and secondary data sources. Primary source of data was obtained from the farmers‟ fields (on-farm data collection), threshing ground, home gardens, store and market places. Additional data was sourced from farmer informants and researchers as well as secondary data were collected from both governmental and non-governmental organizations.

3.1.4.3.2. Informed consent

Ethical considerations pertinent to ethnobotanical research were made from the beginning of the study as this is crucial in such an undertaking (Alexia des 1996, Cunningham 1996). Therefore, the purpose of the study was explained to the informants before the study was conducted **(appendix 1).** Prior informed consent was obtained from the informants before the study was conducted. Only those farmers who consented took part in the study.

3.1.4.3.3. Ethnobotanical data collection

Ethnobotanical data was collected in order to understand the indigenous knowledge of farmers on field pea. Different qualitative and quantitative ethnobotanical data collection methods, procedures and techniques recommended by Alexiades (1996) were followed in order to get ethnobotanical information on the crop from the informants.

3.1.4.3.3.1. Interview method

The checklist of the structured survey was applied with general informants using ODK software (open data kit) in cell phone which is presented in Appendix 2 and semi-structured questions presented in Appendix 3 was employed for discussion and interviewing the key informants who have better knowledge about the issue and to record and collect required information based on the objectives of the research. Group discussion was conducted with individual local resource users and informants to record their general impressions about field pea cultivation, utilization and management.

3.1.4.3.3.2. Field observation and guided field walk

Field observation was supported by local guides, language translators and participating informants to obtain the necessary data in the study area. The necessary information on how field pea is cultivated intercropped, used and market value was systematically recorded by applying both etic and emic perspectives of categorization. The local perspectives on vegetation type, dominant crops produced, landscapes and soil type of the study area were identified by the researcher through personal observation and discussion with local experts.

3.1.4.3.3.3. Market survey

During the study, market survey was undertaken to record the field pea landrace varieties that are sold in the market together with information on market values of field pea were gathered (Appendix 4). This method is good especially to identify the market values of the landraces and conserve landrace varieties of field pea that have high economic value. Therefore, local markets in the study areas were visited and semi-structured interview was conducted with field pea producers and/or sellers at the market.

3.1.4.3.4. Soil data collection

Top soil from 30 cm depth was collected from the fields of each varieties of field pea and brought to Addis Ababa University and using dry and wet soil it was checked with the Mussel soil colour chart.

3.1.4.3.5. Seed collection

The seed samples were collected from farmers‟ traditional seed storage containers, from local markets or from farmers‟ fields by using the seed collecting format of EBI protocol, (Appendix 5). This is for seed collection for germination test, morphological diversity study and germplasm preservation using suitable conservation strategies.

3.1.4.3.6. Voucher specimen collection and identification

The voucher specimens collected from the study areas were identified in the National Herbarium of Ethiopia, Addis Ababa University using taxonomic keys in the Flora of Ethiopia and Eritrea and by comparison with already identified herbarium specimens. Finally, the identified specimens were deposited at National Herbarium of Ethiopia, Addis Ababa University for further educational and research purposes.

3.1.4.3.7. Morphological data collection

For on-farm agronomic data collection, five randomly selected individuals of the variety from the field of two randomly selected farmers that grow a particular variety. The qualitative agronomic traits and average of quantitative information of the variety was taken. The collected quantitative agronomic traits were: number of branches, Number of nodes, number of pod per peduncle, peduncle length, pod number per plant, seed number per pod, length of the plant,

length of primary branch and others as listed in Appendix 6. For all quantitative descriptors (metric traits), the average of five field pea plants were recorded and most of the observations was made at maximum vegetative growth stage (at 50% flowering), unless and otherwise specified. On the other hand, qualitative agronomic traits were: stem pigmentation, seed color, pod color, flower color, flower vein color, leaflet broadest, petiole thickness, stiple flecking density, pod parchment, pod curvature, seed shape and seed eye color.

3.1.4.3.8. Germination data collection

The collected seeds of the farmers‟ varieties of field pea were subjected to germination testing and evaluated based on Germination Percentage (GP) parameters. From the collected seeds of varieties of field pea, representative seed samples from each of the three agroecological zones found in the two study zones were subjected to germination testing. The experiment was conducted at Addis Ababa University plant physiology laboratory by following the procedure provided by Amador and Dieguez (2000). Each landrace was replicated three times by sowing twenty five seeds per Petri dish. Completely randomized design (CRD) was used to layout the treatments. All seeds are allocated randomly and all exogenous factors were assumed constant. In order to ensure accuracy of the results of the study, the experiment was repeated twice and data analysis was carried out using the average data of the experiments. The following procedure was followed in testing the germination rates of landraces:

- ✓ All the Petri dishes were sterilized by alcohol and washed with distilled water.
- ✓ The Petri dishes were arranged randomly on the table.
- ✓ Tissue paper was placed on each Petri dish.
- ✓ Seeds from each variety were placed on each Petri dish.
- ✓ Distilled water was applied equivalently on each Petri dish

- ✓ Germination counts were carried out for eight respective days starting from the next day after placing of seeds on petri dish.
- ✓ Germination for each treatment was calculated as germination percentage (GP), considering the number of germinated seeds as a percentage of the total number of tested seeds. GP= Germinated seed/Total tested seed × 100%.

These landraces were planted at Kulumsa research station; all germinated and have been observed up to flowering stage.

3.1.4.4. Methods of data analysis

3.1.4.4.1. Descriptive statistics

By following the relevant approaches of Martin (1995) and Cotton (1996), both qualitative and quantitative analytical tools of ethnobotany were used for data analysis. To identify the most widely used field pea farmers variety in the study area, ethnobotanical data was analyzed by entering the data in to the excel spreadsheet and summarized using descriptive statistics. Calculating the mean values, standard deviations, ranges and other tools to identify the most commonly and widely used field pea landraces using R software. To determine proportions of different farmers varieties, ability to resist pest, ease of harvesting, test, yield in drought and source of seed, are analyzed by using various ethnobotanical scoring and ranking methods, percentage frequency methods and inferential statistics were employed in order to test the consistency of respondents‟ information and to obtain scientifically more reliable results. Then the results were presented with graphs, charts and in texts.

3.1.4.4.2. Analysis of variance (ANOVA)

One way analysis of variance was computed to explore the differences in area coverage of field pea landraces among study strata, farmers‟ wealth status and study zones. It was also used to understand the difference of the price of varieties among the study zones, agroecological zones. Shapiro-Wilk Test for normality test was used to test the normality of the distribution of data on farm land size where field pea was cultivated per mid-high and low income farmers. Two ways ANOVA was used to test the difference of the yield of farmers‟ varieties in two consecutive years (2015, 2016) as well as to test the difference in morphological characteristics of the farmers‟ varieties.

3.1.4.4.3. Direct matrix ranking

Direct matrix ranking was made following Martin (1995) in order to answer the question, which landrace is best for which properties. Landraces and properties that were commonly reported by informants were selected. Then, each informant was asked to rank the landraces for each properties listed. The values of each landraces were summed up and ranked for each informant, and then for the total informants.

3.1.4.4.4. Diversity analysis

The number of varieties per farmer, number varieties per agroecology and number of varieties per administrative zone of the study areas were subjected to Shannon-wiener diversity analysis.

$$H = -\sum_{i=1}^{s} pi \ln (pi)$$ Where: S is the number of landraces and pi is the relative proportion of the total number of entries (N) in the class.

Whittaker (1960) divided diversity into various components. The best known are diversity in one spot that he called **alpha diversity**, and the diversity along gradients that he called **beta diversity**. The basic diversity indices are indices of alpha diversity. Beta diversity should be studied with respect to gradients (Whittaker, 1960), but almost everybody understands that as a measure of general heterogeneity (Tuomisto, 2010a): how many more species/variety do you have in a collection of sites compared to an average site. The best known index of beta diversity is based on the ratio of total number of species/landraces in a collection of sites S and the average richness per one site:

(Tuomisto, 2010): $ß = S/\bar{\alpha} - 1$ ---------- (1)

Subtraction of one means that ß = 0 when there are no excess species or no heterogeneity between sites. The index of eq. 1 is problematic because S increases with the number of sites even when sites are all subsets of the same community. Whittaker (1960) noticed this, and suggested the index to be found from pairwise comparison of sites. If the number of shared species in two sites is a, and the numbers of species unique to each site are b and c, then $\bar{\alpha} = \frac{(2a + b + c)}{2}$ and S = a + b + c, and index 1 can be expressed as: $ß = \frac{a + b + c}{(2a + b + c)/2} - 1 = \frac{b+c}{2a+b+c}$

Gamma diversity: - the total number of landraces within a region or among farmers of a certain ethnic group.

Alpha diversity: - is the average number of landraces listed by each farmer.

Beta diversity: - is gamma diversity divided by alpha diversity. This indicates the degree to which farmers within the same ethnic group or region share the same landraces.

3.1.4.4.5. Clustering and estimation of distance of the varieties

The grouping of varieties in different clusters based on dissimilarity matrix was calculated using the R software. Thus, the analysis was computed based on dissimilarity analysis using Gower‟s formula (Gower, J. C. 1971) because of the presence of both quantitative and qualitative data. Based on on-farm phenotypic data clustering of varieties was done using Ward‟s method.

$$d\,(q,p) = \sqrt{(q1-p1)^2 + (q2-p2)^2 + \cdots + (qn-pn)^2}$$

d - Squared Euclidean distance between varieties

q- Variety one

p- Variety two

n- The value of each parameter for every variety

3.1.4.4.6. Chi-square test, Tukey test, Mann Whitney u test and Wilcox test

The chi-square test assumes that each cell has an expected frequency of five or more. Chi-square test is used if no more than 20% of the expected frequencies are less than 5 and none is less than 1. Tukey test: is used to assess differences among the study strata, agroecological zones with wealth status of the farmers or between the two regions on total number of respondents per zone/region. In general, Tukey test is used to determine the significant differences among mean values of the treatments. Mann Whitney u test was used to analyses two categorical data like seed source of the varieties and Wilcox test was used to analyze two paired data.

CHAPTER FOUR

4.1. Results

4.1.1. Distribution, diversity and richness of field pea

4.1.1.1. Diversity of field pea when seen with other legume crops in the study area

Field pea is grown with faba bean in Arsi and with both faba bean and common bean in Kefa Zone (Figure 5). In Arsi, 100% and 89% of farmers plant only the two legumes, field pea and faba bean respectively. In Kefa, 100% and 99% of the farmers planted both field pea and faba bean respectively. However, there were a few farmers (5%) who plant common bean in the study area.

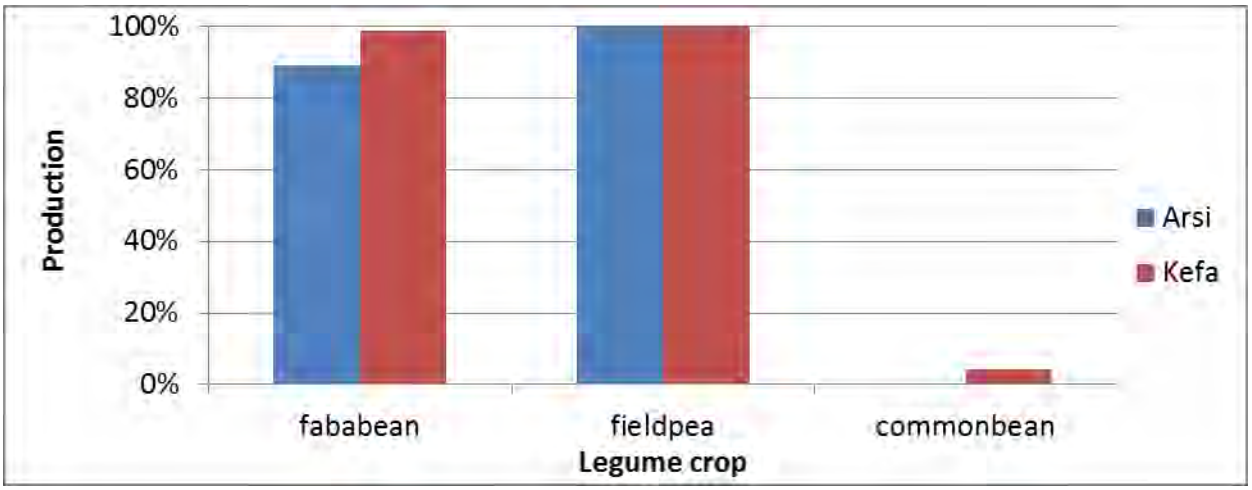


Figure 5. Field pea seen against other legumes (interspecific diversity) in Arsi and Kefa zones

4.1.1.2. Field pea farmers' varieties distribution, diversity and richness

A total of 30 accessions were collected from different kebeles of the study areas. Based on the names and descriptions given by farmers these accessions were categorized in to seven farmers" varieties and one varietal admixture (Table 2). These landraces were varied in maturity, yield

potential, stress tolerance, end-use qualities and other agronomic traits as listed in Table 2. The naming and descriptions of the landraces reflect key quantitative, qualitative traits and end-use qualities as well as other information such as planting time or origins.

Table 2. Diversity of landraces (farmers‟ varieties) in the study area

No	Local name of the variety	Picture of the seeds	Meaning of landrace name	The name derived from	Farmers' identifying criteria					Improved or Local variety	Collection Woreda/District
					Seed color	Seed eye color	Seed shape	seed size	Flower color		
1.	AA‟O ATERO (Kefino)		Black seeded field pea	Morphological traits	Black (Dark Grey)	White	wrinkled	Medium	Purple	Local	Daniti, Gawa shimbrika Gindacha, Kochio and Yecha **(SNNPR, Kefa)**
	DANGALO or (GONDARE) (Afan Oromo)		Cannot grow upright Or that came from Gonder in Amhara Region	Morphological traits or source/origin of seed	Black (Dark Grey)	White	wrinkled	Medium	Purple	Local	Dosha, Sagure molle and Copa **(Arsi, Oromia)**
2	BONO ATERO (Kefino)		White seeded	Morphological traits	White	White	Smooth	Medium	White	Local	Gawa shimbrika, Kochio and Yecha **(SNNPR, Kefa)**

No	Local name of the variety	Picture of the seeds	Meaning of landrace name	The name derived from	Farmers' identifying criteria					Improved or Local variety	Collection Woreda/District
					Seed color	Seed eye color	Seed shape	seed size	Flower color		
	ADII (Afan Oromo)		Look like the Milk	Morphological traits	White	White	Smooth	Small	White	Local	Sagure molle, Haro bilalo and Dosha (Arsi, **Oromia**)
3	AKURI ATER (Afan Oromo and kafino)		Its seed is look like a soybean seed	Morphological traits	White	Black	Smooth	Larger	White	Improved	Daniti **(from SNNPR, Kefa),** and Dosha, Haro bilalo, Limu dima and Chafa gugesa **(from Arsi, Oromia)**
4	TAGAGNECH (Afan Oromo)		Producing high yield	Because of providing high yield	White	Black	Smooth	Small	White	Improved	Dosha, Copa, Sagure molle, Haro bilalo **(Arsi, Oromia)**

No	Local name of the variety	Picture of the seeds	Meaning of landrace name	The name derived from	Farmers' identifying criteria					Improved or Local variety	Collection Woreda/District
					Seed color	Seed eye color	Seed shape	seed size	Flower color		
5	MARKOS (Afan Oromo			Morphological traits	White	Black	Smooth	Largest	White	Improved	Haro bilalo **(Arsi, Oromia)**
6	BURKITU (Afan Oromo)			Morphological traits	White	White	Smooth	Large	White	Improved	Sagure molle, and Haro bilalo **(Oromia)**
7	BILALO (Afan Oromo)		Comes from bilalo	Morphological traits	White	Black	wrinkled	medium	White	Improved	Haro bilalo **(Oromia)**
8	SERGAGNA *(*kafino*)*		A mix of black and white seeded field pea	Looking the mixed seeds	It is not an actual variety but the farmers considered it as a variety when both aa"o and bono are sown together at the same field.					Local	Kochio, Gindacha and Yecha **(Kefa)**

4.1.1.2.1. Distribution of farmers' varieties

A total of seven field pea farmers" varieties were observed in Arsi and Kefa (Figure 6). Of these, (AA"O ATERO *(*DANGALO*)*, BONO ATERO *(*ADII*)* and AKURI ATER *(*GUME*))* are cultivated in both Kefa and Arsi. However, four varieties *(*BILALO, BURKITU, MARKOS, and TAGAGNECH) are from Arsi only. SARGAGNA is not actually a single variety but the farmers in Kefa call it SARGAGNA when both AA"O ATERO and BONO ATERO are mixed together in one field. The result of the study indicates that the farmers in Arsi grow more number of varieties than the farmers in Kefa (Figure 6). Not only the types of varieties are different, but also those varieties grown in the two zones differ in the intensity of cultivation. More than 70% of the farmers plant BONO ATERO *(*ADII*)* in Kefa and AKURI ATER (GUME) in Arsi dominantly. A few farmers (3%) only in Arsi grow a variety known as BILALO.

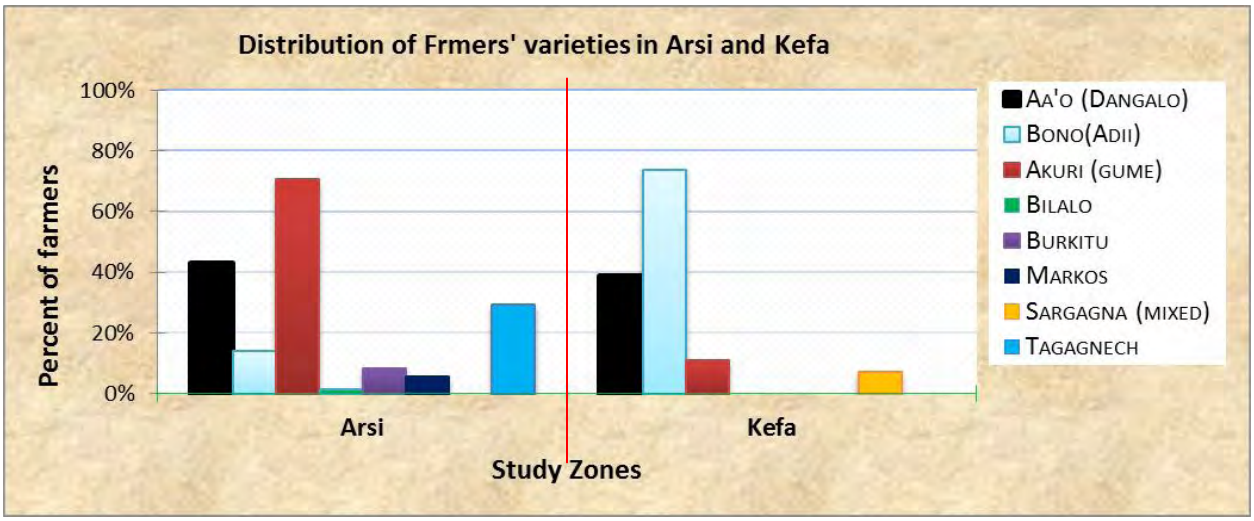


Figure 6. Distribution of farmers" varieties of field pea in the study area

4.1.1.2.2. Landraces diversity and richness

The result of the study reveals that the diversity of farmers" varieties is different among the farmers (Figure 7a) study zones (Figure 6) and study strata (Figure 7b). The total number of

varieties (gamma diversity) is higher in Arsi (7) than Kefa (4) (Figure 6). The average number of varieties per household (alpha diversity) (Table 2) is high in H3-Arsi (1.8) and low in both H3 and SH3 - Kefa (1.3). The total number of varieties (gamma diversity) is higher in M3-Arsi (7) followed by H3-Arsi (5), however the two agroecological zones (H3 and SH3) of Kefa have low gamma diversity (3). In terms of the Shannon Wiener Diversity Index, the four study strata (Figure 7b), H3-Arsi have the highest varietal diversity (H‟=1.5), followed by M3-Arsi (H‟ = 1.35). The lowest diversity index (H‟ =1.02) and (H‟ =0.85) was computed for H3-Kefa and SH3-Kefa respectively (Figure 7b and Table 3).

Table 3. Diversity of the farmers‟ varieties within each stratum

Strata	Variety listed	Alpha diversity	Gamma diversity	Beta diversity	H‟
H3 – Arsi	64	1.8	5	2.8	1.5
H3 – Kefa	47	1.3	3	2.3	1.0
M3 – Arsi	60	1.7	7	4.2	1.3
SH3 – Kefa	47	1.3	3	2.3	0.9

Some of the key informants reported that the field pea landraces diversity could be related to factors such as low supply of improved varieties; lack of ability to cross-fertilize and create new varieties by farmers by themselves and low access to find some improved varieties from research centers and from some non-governmental organizations. The result on Figure 7a indicates that the Shannon-Wiener Diversity Index for each household, based on the area in ha cultivated with each variety is low with most farmers. About 120 (83%) farmers out of 144 total respondents grow less number of landraces (H‟ =0 – 0.5), and there were about 20 (14%) farmers who had a

medium diversity (H‟=0.5 – 1.0) however, there were a few farmers (3%) show highest diversity index (H‟=1.0 -1.5) who have high landraces (farmers‟ varieties) (Figure 7a).

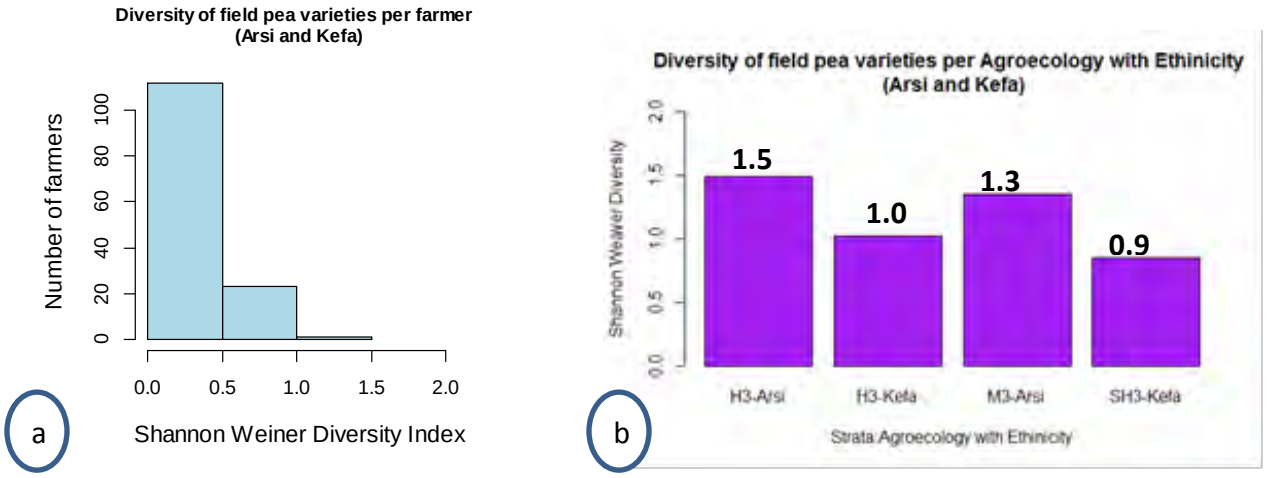


Figure 7. Diversity of field pea landraces per farmers and per strata (a) Diversity of field pea landraces (farmers‟ varieties) per farmers‟ varieties. (b) Diversity of field pea landraces (farmers‟ varieties) based on agroecological zones.

4.1.2. Area of the farms covered by field pea per farmer

The farmers in Arsi and Kefa grow field pea in different size of land. As indicated in Figure 8a, 0.25 hectare is the average farm size of the crop per year. 50% of the farmers grow the crop between 0.25 and 0.5 hectare farm size (Figure 8a). The largest area coverage of the crop was 1 hectare. The result of the study showed that the farmers grow from 0 - 0.8 hectare land size of field pea within one year, but there are few farmers that grow about 1 hectare of field pea in one year (Figure 8a). However, 50% of the farmers grow the crop between 0.25 and 0.5 hectare of land. As shown in (Figure 8b) there were a small number of farmers that grow field pea in 0.0 - 0.2 hectare of land. Starting from 0.2 hectare the number of farmers decreases continuously when the area coverage of field pea increases (Figure 8b).

Table 4. ANOVA test for cultivated land size of field pea by agroecology, administrative zone and wealth status of farmers

	Degree of freedom	Sum Square	Mean Square	F value	P-value
Agroecology	2	0.774	0.3870	7.984	0.000519 ***
Wealth	1	1.416	1.4157	36.859	$1.16x10^{-8}$ ***
Administrative zone	1	0.016	0.01552	0.29	0.591

Statistically there was highly significant ($P< 0.01$) variation in the area coverage of field pea by farmers‟ wealth status and agroecological zones (Table 4). Most of the high-mid income farmers grow 0.25 up to 0.75 hectare area of field pea whereas most of the low income farmers grow about 0.15 to 0.50 hectare of field pea in one year (Figure 9a). However there was no significant difference ($P > 0.05$) on the area coverage of field pea among the two study zones (Table 4). There is similar mean value on the area of field pea in SH3 (Tepid sub-humid mid highlands) and M3 (Tepid moist mid highlands) agroecological zones. The farmers‟ farm land size that they grow field pea is not significantly different in two study zones. However the result of Tukey test also indicated that the hectarage of farm size that farmers cultivate field pea has a significant difference among the study strata (Figure 9b). 50% of the farmers grow field pea on farm size 0.375-0.75 ha in SH3 Kefa, 0.25-0.5ha in H3 and M3- Arsi and 0.125-0.5 ha in H3-Kefa. Most the farmers from tepid humid mid-high land agroecological zones of the two zones grow field pea with in small lead size than tepid sub-humid mid-highland of Kefa and Tepid most mid-high land of Arsi.

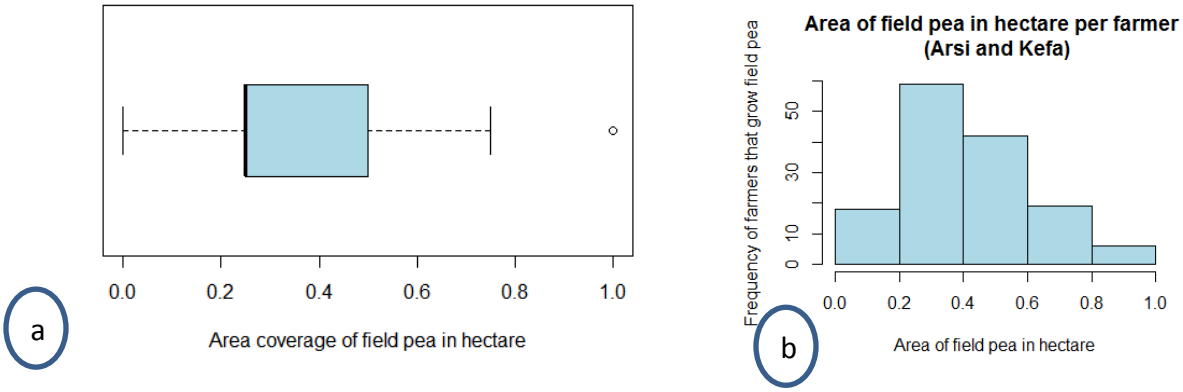


Figure 8. Size of farm land that the farmer grow field pea (a) the total farm size in which field pea was cultivated in the study area (b) histogram showing the farm land size of field pea cultivation per farmers

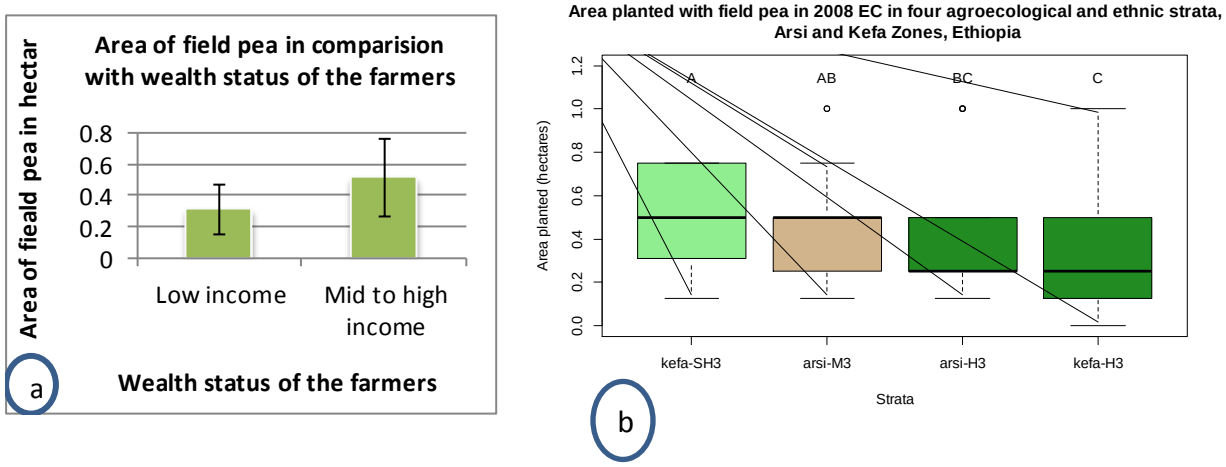


Figure 9. Size of farm land where the farmer cultivate field pea by wealth status of farmers and study strata (a) Area coverd by field pea in comparision with wealth status of the farmers.
(b) Area of farmers planted area of field pea with in different agroecological zones.

4.1.3. Use value of field pea in each strata

The farmers in Arsi and Kefa used field pea for different purposes (Figure 10). The crop is used for Marketing (100%) and as food (100%) in all selected agroecological zones of the study area. About 100% of the farmers in H3 agroecological zones and 97% of the farmers in M3 agroecological zones of Arsi used the crop for fodder. However, 75% of the farmers in SH3 agroecological zones of Kefa zone and a few farmers (17%) of the farmers in SH3 agroecological zones of Kefa zone used the crop as a fodder for their livestock. The key informants of the area indicated that the fodder from field pea is very important for their livestock especially during autumn (March, April and May).

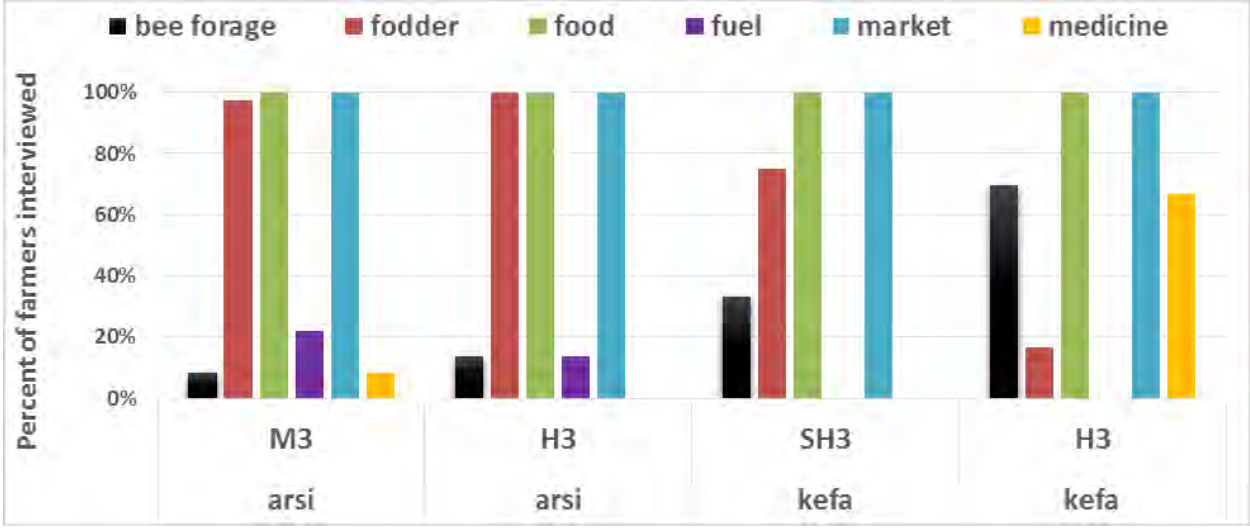


Figure 10. Use value of field pea in the study area

The farmers in Arsi mentioned that the fodder from field pea is not good for pregnant livestock because it may cause abortion. In addition, 22% and 14% of farmers in M3 and H3 agroecological zones of Arsi used the crop as a fuel respectively. Using the crop as bee forage is more common in Kefa than Arsi. About 69% of farmers in H3 and 33% of in SH3 agroecological zones of Kefa used the crop as bee forage, whereas only 14% and 8% of farmers in H3 and M3

agroecological zones of Arsi zone used it for bee forage. Sixty seven percent of the respondents in H3 agroecological zones of Kefa and a few respondents (8%) M3 agroecological zones of Arsi mentioned that the crop had a medicinal value for both human and livestock.

Different types of foods are prepared from field pea such as sauces (KIKI WOT and SHIRO), boiled grains (NIFRO), roasted (KOLLO) and raw green (ESHAT) are the major food types that farmers prepared from seed of field pea (Table 5). The result from key informants in Table 4 indicated that AKURI, BONO (ADII), TAGAGNECH, MARKOS and BURKITU are mostly preferred to prepare KIKI , BILALO and AAʺO (DANGALO) are mostly preferred for SHIRO. However, all varieties are equally preferred for NIFRO, KOLLO and ESHAT.

Table 5. The type of food prepared from field pea varieties

Name of food in Amharic	Common English name	Parts used	Mostly Preferred variety	Zone	The reason why this variety was preferred
KIKI	Stew of split grain	Seed	AKURI, BONO (ADII), TAGAGNECH, MARKOS AND BURKITU	Kefa & Arsi	✓ Because good test and color, ✓ Food quality and ✓ Ease of preparation (simple for grinding)
SHIRO	Stew fine ground grain	Seed	AA"O (DANGALO) and BILALO AND AA"O (DANGALO)	Kefa & Arsi	✓ Because its flour have the ability to hold more water than the other varieties ✓ Good test
NIFRO	Boiled grain	Seed	BONO (ADII) and AA"O (DANGALO), AKURI, TAGAGNECH, MARKOS, BILALO, and BURKITU	Kefa & Arsi	✓ Ease of preparation and ✓ good test
KOLLO	Roasted grain	Seed	BONO (ADII) and AA"O (DANGALO), AKURI, TAGAGNECH, MARKOS, BILALO, and BURKITU	Kefa & Arsi	✓ Ease of preparation and ✓ good test
ESHAT	Spike (green) grain	Seed	BONO (ADII) and AA"O (DANGALO), AKURI, TAGAGNECH, MARKOS, BILALO, and BURKITU	Kefa & Arsi	

4.1.4. Cultivation and management systems of field pea

4.1.4.1. Gender roles in production and management of field pea

This study showed that local farmers played a great role in maintaining the landraces of field pea by applying traditional farming systems, seed selection and seed storage practices. The traditional farming systems that field pea growing farmers used in all the study areas were the same as all Ethiopian farmers. However, farming practices for field pea were easier as the field of field pea is not ploughed for sowing or ploughed only once or two times.

Planting, harvesting, storage, marketing, seed selecting, food preparation and fodder collection are practices related to field pea in which different gender and age groups participate in all of the study strata (Figure 11, 12, 13, and 14). Fertilizer application in field pea farms is practiced only in Arsi. Weeding is not the commonly practiced in field pea farms. However, key informants mentioned that some farmers manage weeds with herbicides which are applied before sowing the crop. They also mentioned that a few farmers weed the farm by using hand weeding method. A few farmers in H3 collect the fodder from field pea of Kefa, a practice with is not common in the other strata a (Figure 13).

Plowing, planting and adding fertilizers are the activities that involve only males (adults and elders) in all study strata that the practices are exercised. Male and female adults in H3 and M3 agroecological zones of Arsi and male (adults and elders) and female adults participated in storing the crop yields. This activity requires carrying (transporting) of the yield from threshing field to the storage. Due to the high for strength, children, elders and women did not participate in this activity. Male and female adults and elders participated in marketing of the crop in all study strata (except female elders in Arsi). Seed selection for sowing purpose is the activity

which is done by adults and elders of both sex, but the result of the study in Figure, 11, 12, 13 and 14 indicates that the practices is predominantly done by male adults and elders. Harvesting of the crop and fodder collection activities is very easy as compared to other pulse and cereal crops of the area. Because of this these two activities of the crop involves the children, adults and elders of the any gender group in all study strata (Figure, 11, 12, 13 and 14) except female elders on both activities in H3 and M3 Arsi and only in fodder collection in H3 of Kefa. However food preparation involves only females in all study strata.

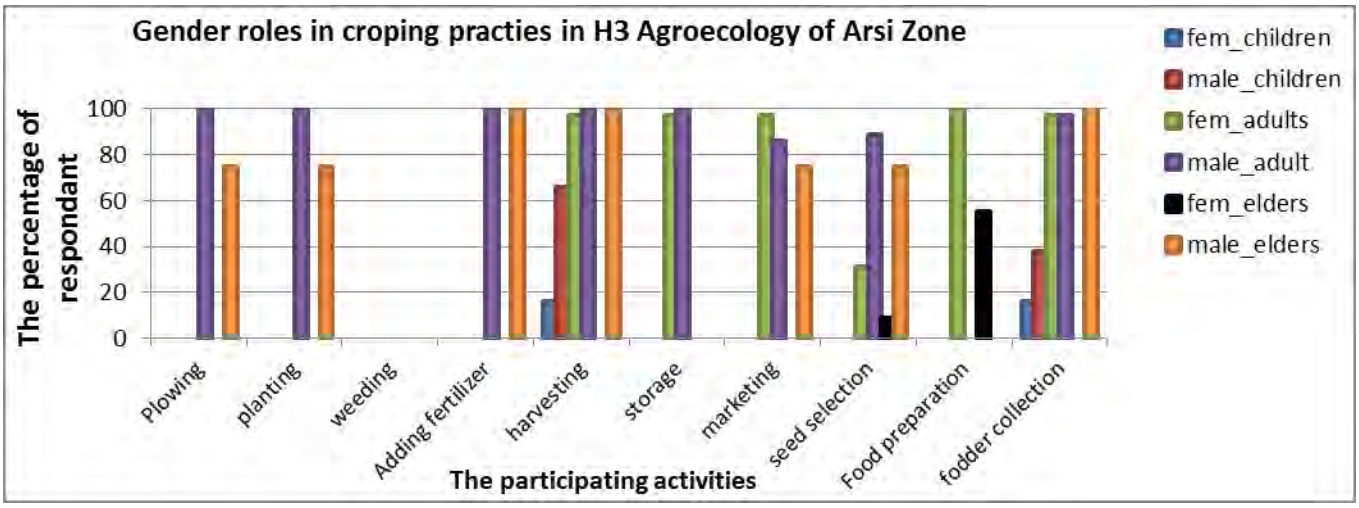


Figure 11. Gender roles in cropping practies in H3 agroecology of Arsi zone

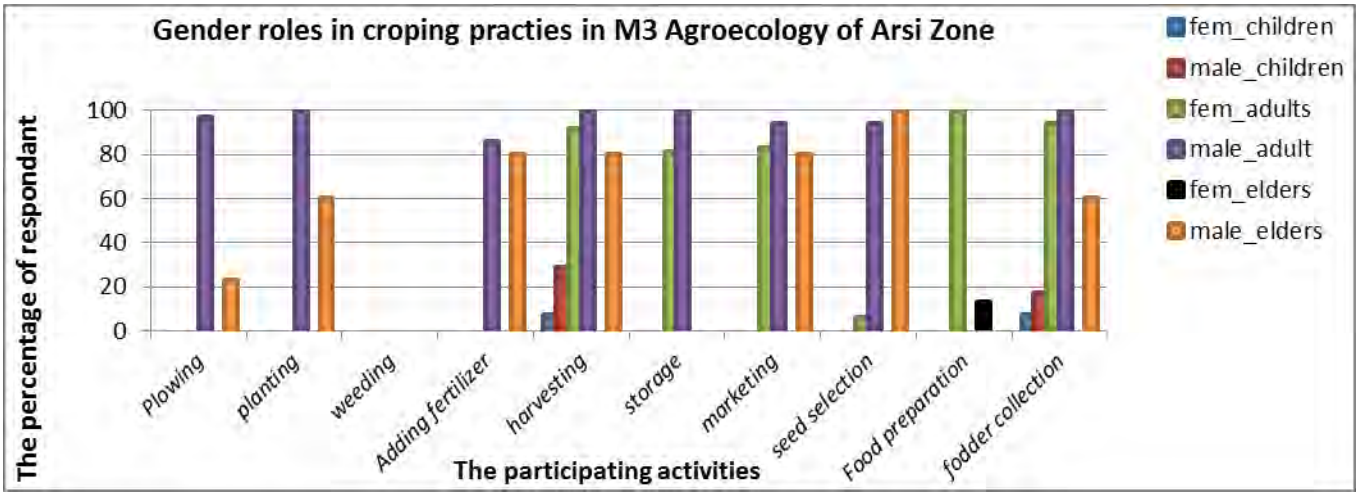


Figure 12. Gender roles in cropping practices in M3 agroecology of Arsi zone

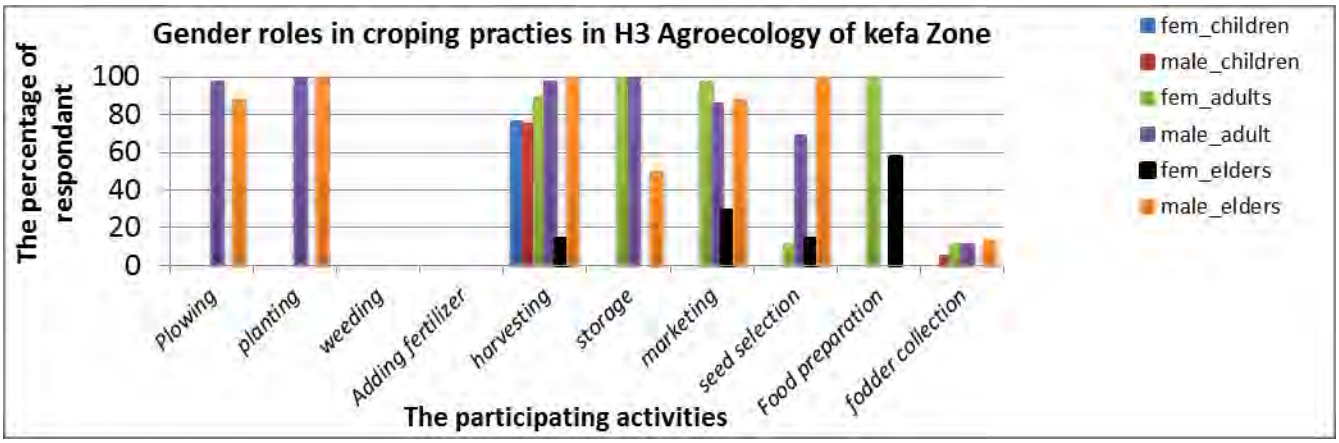


Figure 13. Gender roles in cropping practies in H3 agroecology of Kefa zone

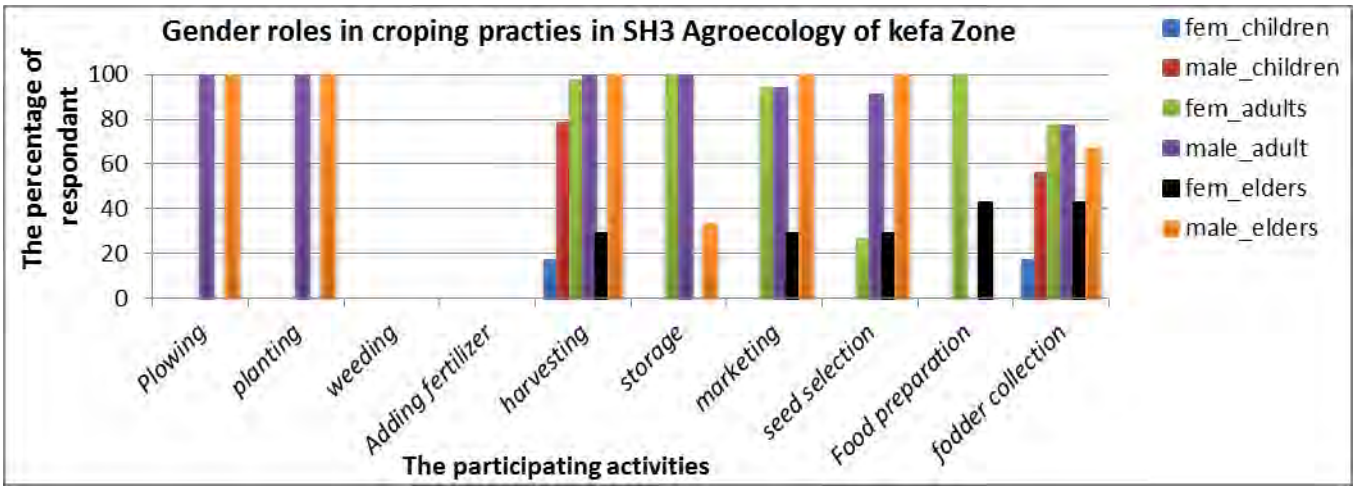


Figure 14. Gender roles in cropping practies in SH3 agroecology of Kefa zone

4.1.4.2. Planting time (cropping season) of field pea

Farmers in Arsi and Kefa plant field pea only once in a year but the planting (sowing) months and harvesting months could be differ in different agroecological zones of the study areas. In H3 agroecological zones of Arsi the sowing seasons (time) for field pea was completed from let June to let July (Figure16). The time between let June and let July is the most suitable sowing season for the varieties AAʺO (DANGALO), BURKITU and TAGAGNECH. However, for BONO (ADII) and AKURI *mid*-July is the most suitable sowing season than the other seasons. In M3 agroecological zones of Arsi the sowing seasons (time) for field pea extended from let-June to mid-July, besides of

this there were a few farmers who plant only one variety at early-August (Figure 17). In M3 agroecological zones of Arsi early-July was the most suitable sowing season for the varieties AKURI and TAGAGNECH and mid-July was for the varieties BILALO, BONO (ADII) and BURKITU. AA"O (DANGALO) and MARKOS were mostly planted in both early-Julys to mid-July (Figure 17). Sowing season of the field pea in H3 agroecological zones of Kefa was included from let-June to let-august (Figure 18). In this agroecological zones of Kefa most farmers choose mid to let-July and early-August are best sowing season for the variety BONO (ADII), let-July and early-August for AA"O (DANGALO) as well as mid-August and early-September is the best season for planting AKURI. Sowing season of the field pea in SH3 agroecological zones of Kefa was included from early-July to let-august (Figure 19). The farmers in SH3 agroecological zones of Kefa choose let-July as a best season for sowing of the varieties AA"O (DANGALO), BONO (ADII) and SARGAGNA followed by early-August.

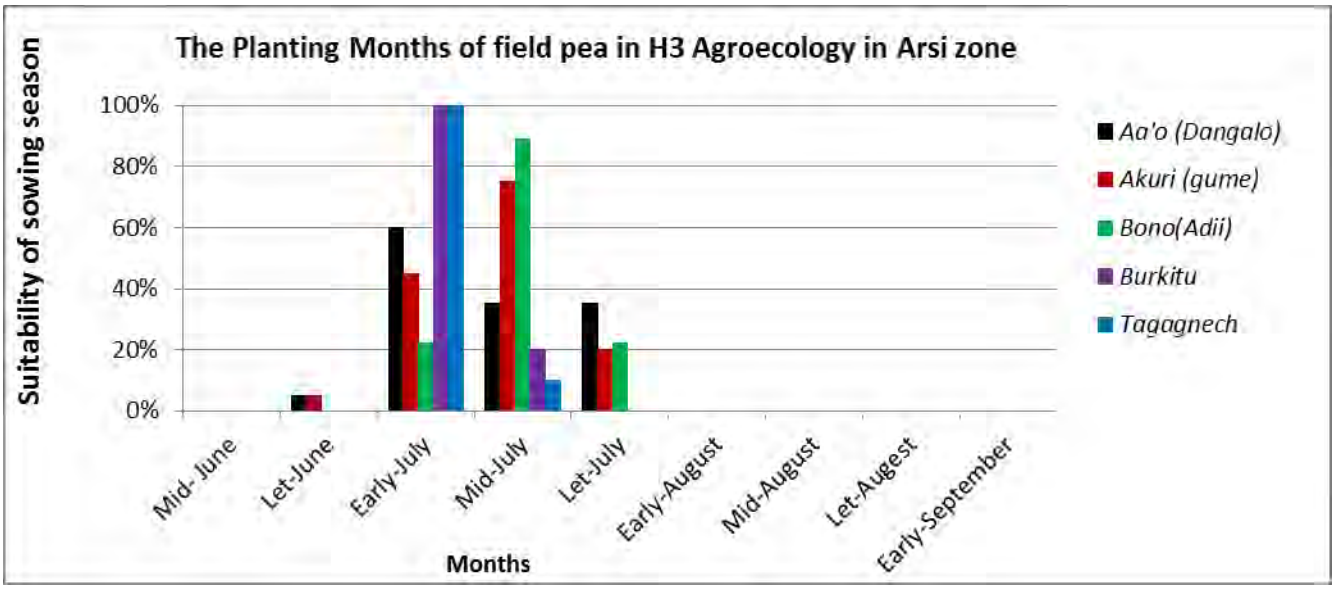


Figure 15. Sowing season of field pea in H3 agroecological zones of Arsi

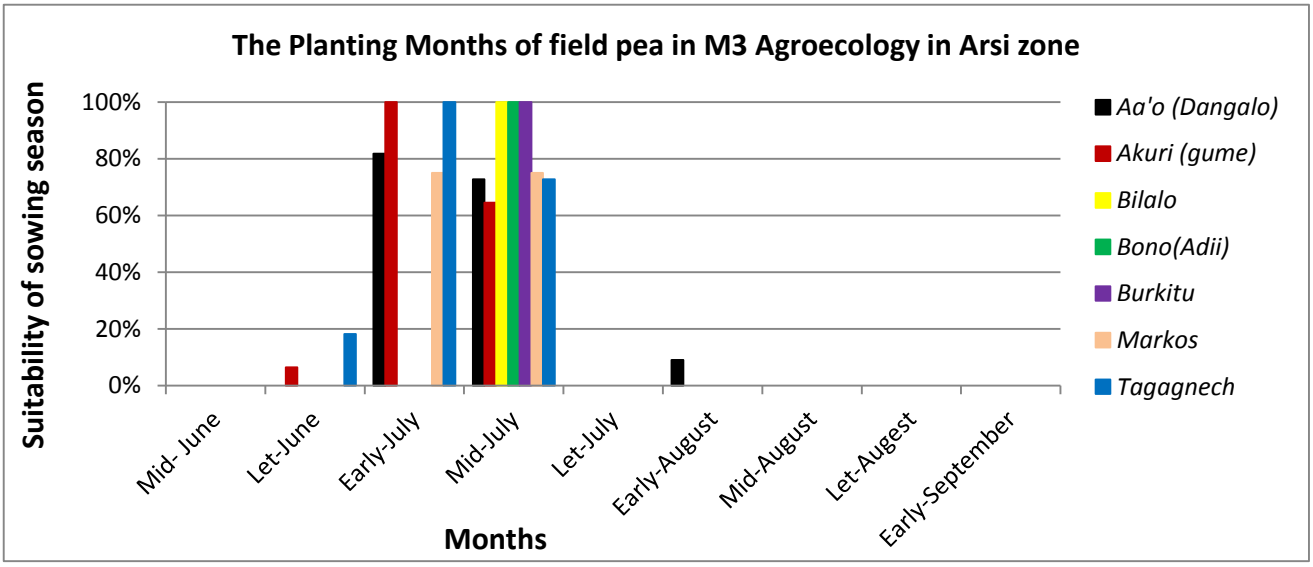


Figure 16. Sowing season of field pea in M3 agroecological zones of Arsi

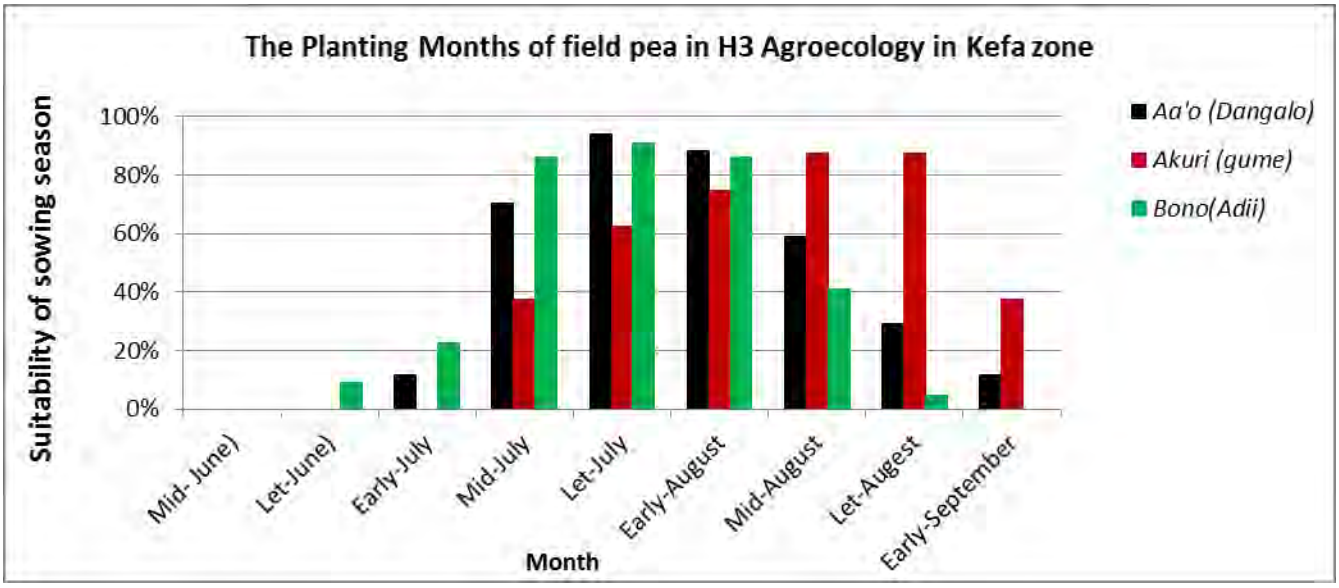


Figure 17. Sowing season of field pea in H3 agroecological zones of Kefa

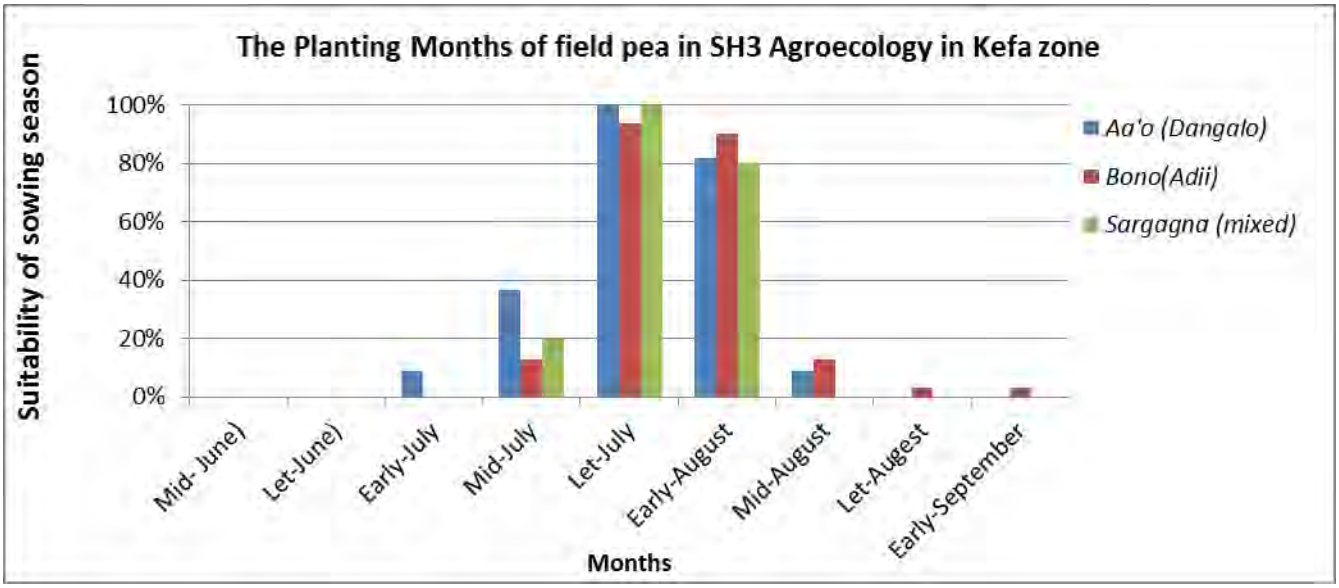
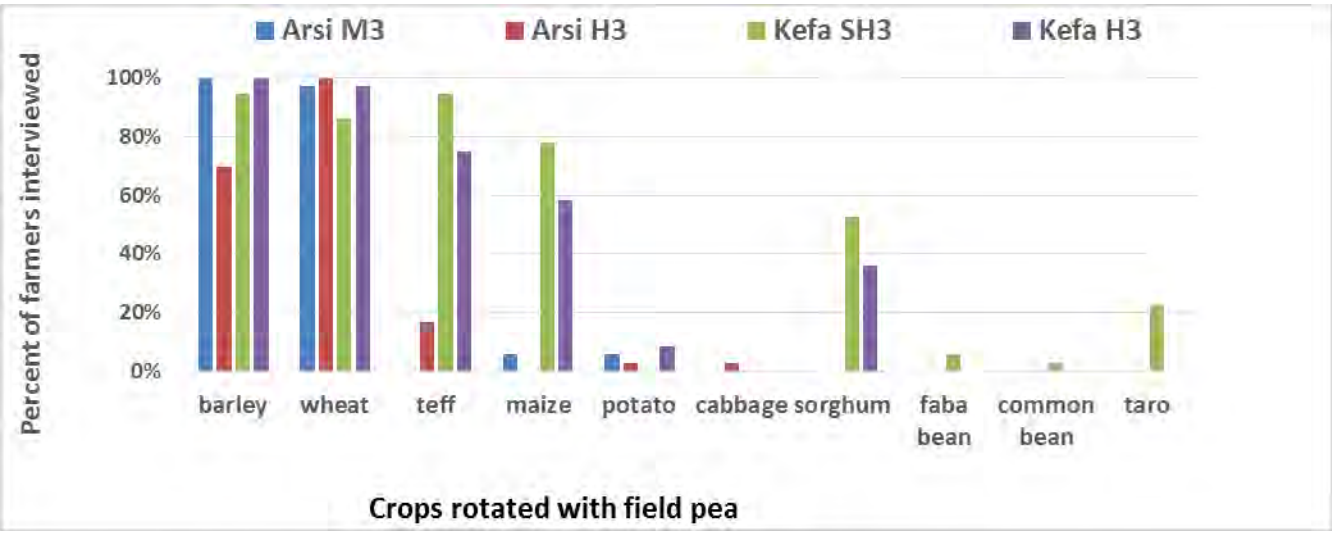


Figure 18. Sowing season of field pea in SH3 agroecological zones of Kefa

4.1.4.3. Crop Rotation

The result of the study in Figure 20 reveals that majority of the farmers (91%) in all zones of the study areas used crop rotation program. Different crops were grown after field pea harvested in the next season (Figure 20). Majority of farmers in M3 agroecology of Arsi, in H3 agroecology of Arsi, in SH3 agroecology of Kefa and in H3 agroecology of Kefa cultivated barley (100%, 70%, 95% and 100%) respectively and wheat (97%, 100%, 86% and 97%) respectively. 94%, 75% and 15% of the farmers cultivated teff after field pea harvested in SH3 agroecology of Kefa, in H3 agroecology of Kefa and in H3 agroecology of Arsi respectively. Also about 76%, 56% and 5% of the farmers cultivated maize after field pea harvested in SH3 agroecology of Kefa, in H3 agroecology of Kefa and in M3 agroecology of Arsi respectively. About 52%, and 35% of farmers from SH3 agroecology of Kefa, and H3 agroecology of Kefa cultivated sorghum after harvesting of field pea. However, a few farmers 5% from M3 agroecology of Arsi,3% from H3 agroecology of Arsi and 7% from H3 agroecology of Kefa cultivated potato after harvesting of field pea, and 3% of farmers from H3 agroecology of Arsi grew cabbage. About 21%, 5% and

3% of farmers from SH3 agroecology of Kefa grew taro, faba bean and common bean respectively after harvesting of field pea.



Fugure 19. Crop rotation system in Arsi and Kefa with field pea

4.1.4.4. Intercropping system of field pea

Most of the farmers in the study area were plant field pea by sole cropping system (Figure 21). Out of 36 respondents from each stratum 36 from SH3 agroecology of Kefa, 32 from H3 agroecology of Arsi, 20 from M3 agroecology of Arsi and 16 from H3 agroecology of Kefa said that they plant field pea by sole cropping system. However, about 20 respondents from H3 agroecology of Kefa, 11 from M3 agroecology of Arsi 3 intercrop field pea with faba bean, 6 respondents from M3 agroecology of Arsi intercrop with barley, 4 respondents intercrop with maize. 4 peoples from M3 agroecology of Arsi and 1 person from H3 agroecology of Arsi intercrop field pea with potato.

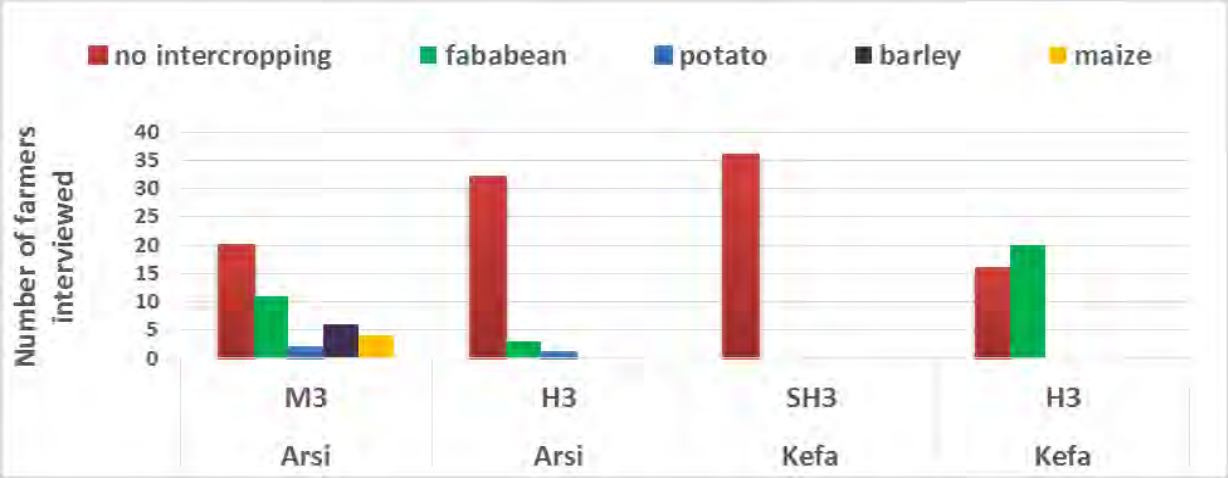


Figure 20. Intercropping system of field pea in Arsi and Kefa

4.1.5. Farmers seed exchange, selection and storage of field pea

4.1.5.1. Farmers traditional seed storage systems

Farmers in the study areas used different traditional storing materials but majorly used the modern sacks woven from plastic locally called MADABERIA because it is better for air easy circulation than the other traditional storing materials and GOTARA (Figure 15) which is considered good for storing the crop for longer period of time without human and animal contact.

Figure 21. Photo of traditional Seed storage containers (a) GOTARA in Manjio Woreda of Kefa, (b) GOTARA in Tiyo woreda of Arsi

4.1.5.2. Seed source of the varieties

Farmers obtain the seeds of field pea varieties from different sources (Figure, 22). Fifty one per cent of the farmers obtained the seed of the traditional varieties from market for the first time and 30% from their family members like their fathers, uncles, bothers and 6% obtained seed from their neighbors and 1% of them obtained the seeds of the traditional varieties from rural agriculture extension workers (D.A). About 31% of the farmers got improved variety from the market for the first time, 14% obtained seeds from rural development agents (D.A), 13% were obtained from neighbors, 3% of them found from research centers and a few farmers (1%) obtained the seed of new varieties from family.

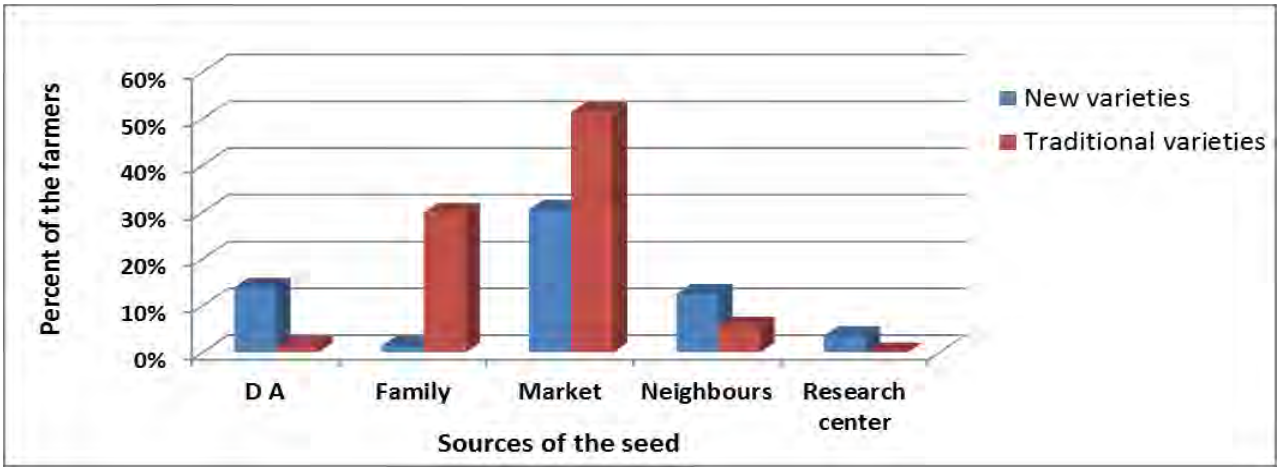


Figure 22. Seed source for field pea farmers varieties

4.1.6. Ranking of landraces (farmers' varieties)

Seven farmers" varieties of *Pisum sativum* var. *sativum* were collected from the study area (Table 1). In these study farmers were asked to rank the landraces of field pea for selected properties (Figure 23 a, b, c and d). Two varieties BILALO and BURKITU are not included in this ranking because of the limited knowledge of farmers about these recently introduced varieties.

The result of the study in Figure 23a shows that AKURI ATER (GUME) and TAGAGNECH are the varieties that are very easy to harvest than the others due to their better growing habit. Farmers ranked AA'O (DANGALO) followed by BONO (ADII) based on test in Figure 23b. Farmers were also asked to rank the varieties by yield that during time of drought (Figure 23d). The ranking result revealed all varieties do not produce high yield at times of drought. However, the varieties MARKOS, TAGAGNECH and AKURI produced relatively better yield than local varieties at times of drought. Comparison based on resistance to pest showed that SARGAGNA ranked the best (Figure 23c).

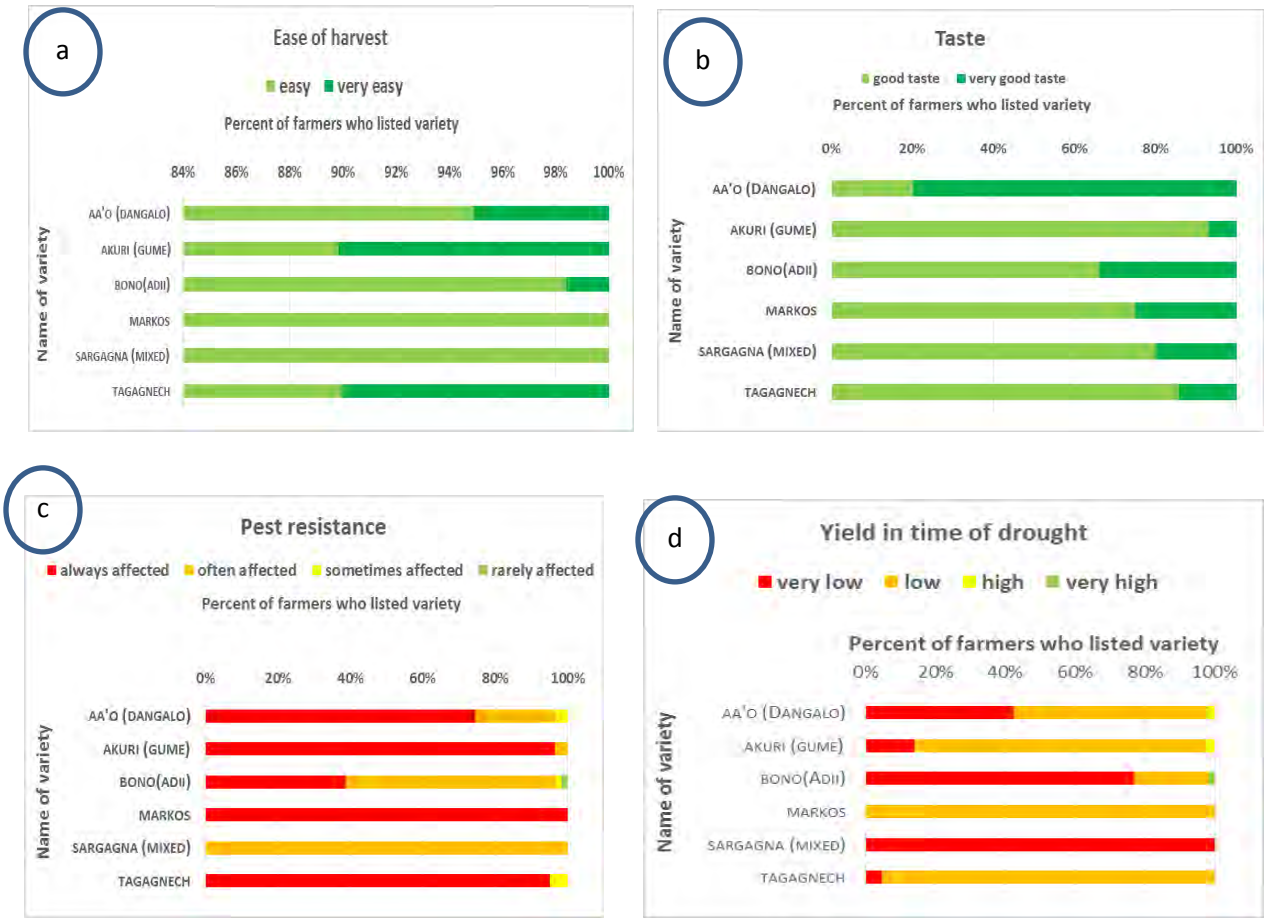


Figure 23. Ranking of varieties (a), Ranking of the varieties by ease of harvesting (b), Ranking of field pea varieties by their test (c), Ranking of varieties by the ability to resist biotic stress (pest) (d), Ranking of varieties by resistance of abiotic factor (drought)

4.1.7. Market value of the varieties and traditional measuring materials

4.1.7.1. Materials used for measuring landraces in the market

People in the study are used different measuring devices or units (house hold utensils) to measure crop in the market (Figure 24). GACHA, KUBAYA, QUCHIBALU and JOGI are some of the measuring devices used by the community.

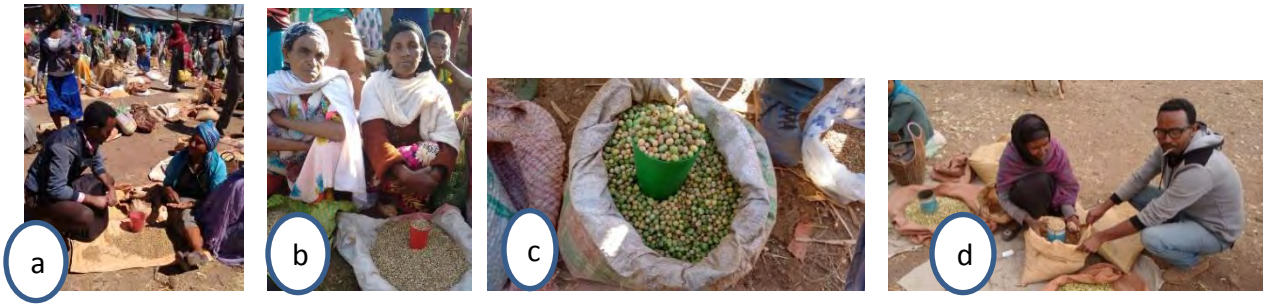


Figure 24. Photo of measuring material of seed (a) JOGI from Digaluna tijo woreda of Arsi zone *(b)* KUBAYA from Manjio woreda of Kefa zone *(c)* GACHA from Gawata woreda of Kefa zone *(d)* QUCHIBELU from Manjio woreda of Kefa zone.

4.1.7.2. Price value of the varieties

The market values of landraces in the study zones and study strata (agroecological zones) were significantly different ($p < 0.001$) (Table 6). The market price of farmers‟ varieties of field pea varies from variety to variety (Figure 25).

Table 6. ANOVA test on price value of field pea

	Degree of freedom	Sum Square	Mean Square	F value	P-value
Zone	1	451.9	451.9	110.0	$2_x\ 10^{-16}$ ***
Agroecology	2	240.4	120.2	23.5	$5.72_x\ 10^{-10}$ ***
Varieties	5	94.0	18.8	4.3	0.00104 **

The result of Tukey test on price value of farmers‟ varieties of field pea in Figure 25 indicated that the market price of TAGAGNECH is significantly different from the local varieties. Accordingly TAGAGNECH is expensive (20 ETB/kg or 0.95 us dollars) on their market value, followed by AKURI and MARKOS (19 ETB /kg 0.90 us dollars). However, AA‟O (DANGALO), BONO (ADII) (18 ETB /kg 0.86 us dollars) and SARGAGNA (17 ETB /kg 0.81 us dollars) were the cheapest varieties in the study areas.

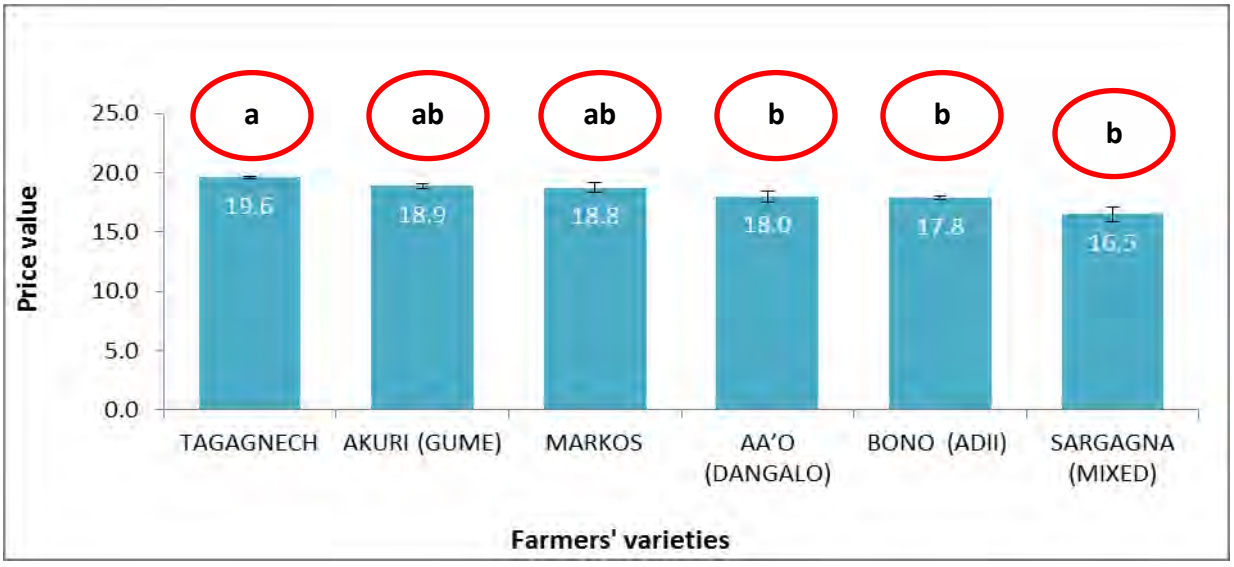
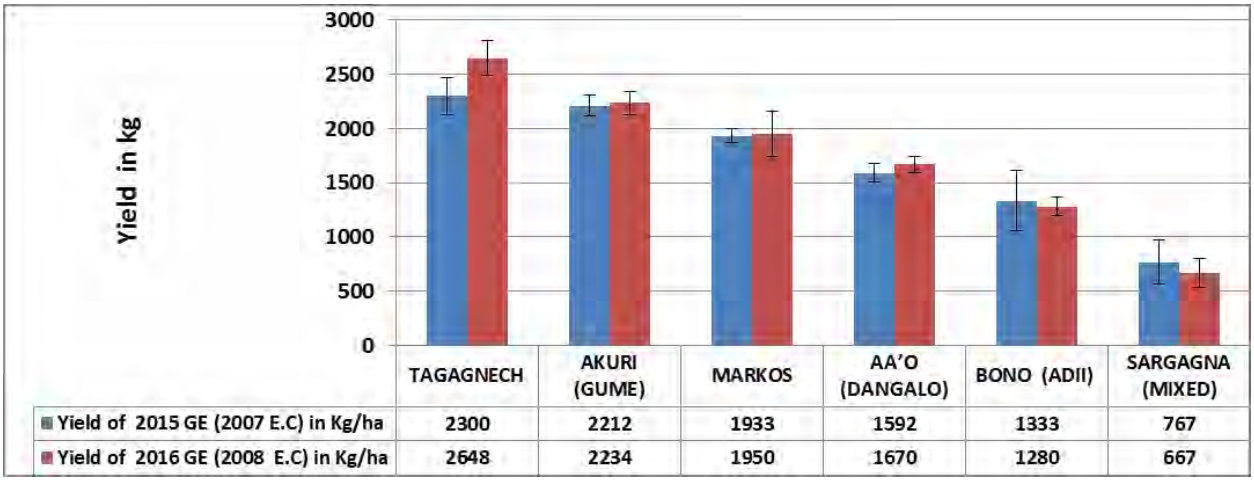


Figure 25. Price value of field pea varieties in Arsi and Kefa

4.1.8. Yield of the varieties

The farmers varieties in the study area were different from each other by their yield potential Figure 26). The result of the two respective years (2015 and 2016) yield indicates that the highest yield was recorded for TAGAGNECH (2474 kg/ha), followed by AKURI *(*2223 kg/ha). The other varieties MARKOS (1942 kg/ha), AA'O *or* DANGALO (1631 kg/ha) and BONO *or* ADII (1306 kg/ha), however the lowest yield was recorded for SARGAGNA *or (*MIXED *(*717 kg/ha).



	TAGAGNECH	AKURI (GUME)	MARKOS	AA'O (DANGALO)	BONO (ADII)	SARGAGNA (MIXED)
Yield of 2015 GE (2007 E.C) in Kg/ha	2300	2212	1933	1592	1333	767
Yield of 2016 GE (2008 E.C) in Kg/ha	2648	2234	1950	1670	1280	667

Figure 26. The 2015 and 2016 or (2007 and 2008 E.C) average yield of the farmers" varieties

The combined result of the two years average yield and price showed highly significant difference ($p < 0.001$) among the varieties (Figure 27). Figure 27 shows that TAGAGNECH had the highest value in the average yield and price whereas SARGAGNA (MIXED) had the lowest value in the average yield and price value. In general the local varieties had lower yield and price than the improved varieties.

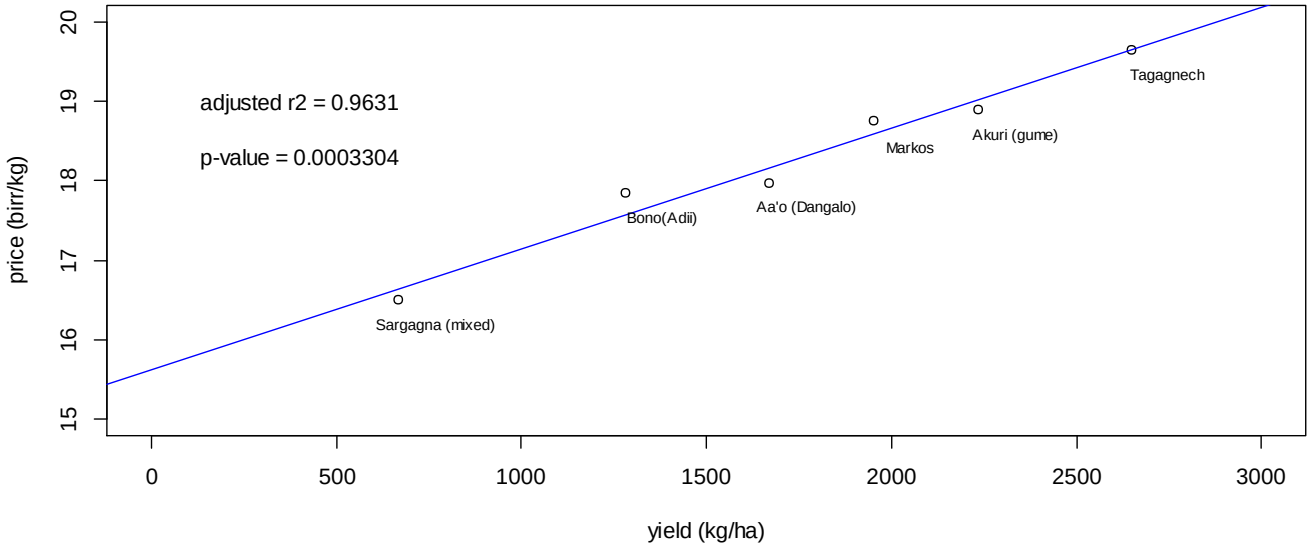


Figure 27. The combined result of two years average yield and price of farmers varieties

4.1.9. Cluster analysis

The seven landraces (farmers‟ varieties) of field pea were grouped in to three distinct clusters (Figure 28) by applying hierarchical clustering based on Ward‟s method based on on-farm quantitative attributes (Appendix 6). The dissimilarity values among varieties (Table 7) are the basis for the clustering and drawing the dendrogram. Accordingly, Clusters I which is the largest cluster contained three varieties (57%), Cluster II contain two varieties s(29%), and Cluster III (14%) was the least with only one variety comprised of varieties form two administrative zones of Ethiopia as indicated in the Table 7.

Table 7. Dissimilarity Matrix between the farmers‟ varieties of field pea

Varieties	AA'O (DANGALO)	TAGAGNECH	MARKOS	BURKITU	AKURI (GUME)	BONO (ADII)	BILALO
AA'O (DANGALO)	0						
TAGAGNECH	0.619359	0					
MARKOS	0.398489	0.397688	0				
BURKITU	0.578196	0.31613	0.351263	0			
AKURI (GUME)	0.480498	0.369336	0.315551	0.389779	0		
BONO (ADII)	0.321228	0.46016	0.289477	0.420499	0.29331	0	
BILALO	0.426974	0.368884	0.216397	0.284443	0.207021	0.284908	0

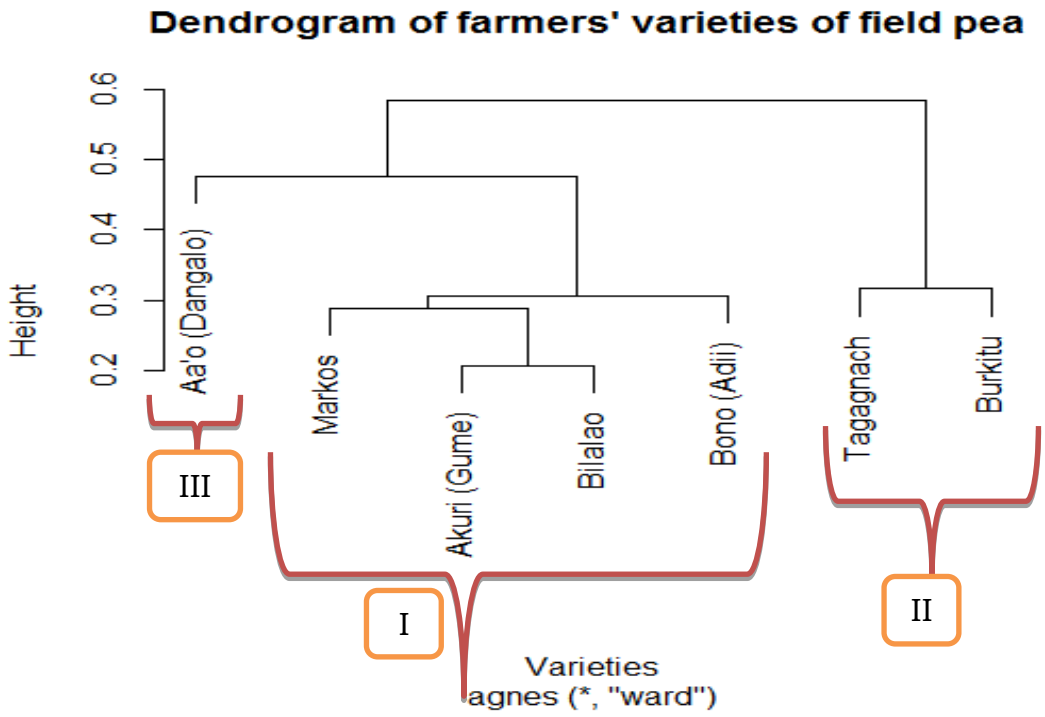


Figure 28. Dendrogram of seven field pea landrace (farmers‟ varieties) based on quantitative and qualitative on-farm morphological data using Ward‟s method.

4.1.10. Germination percentage

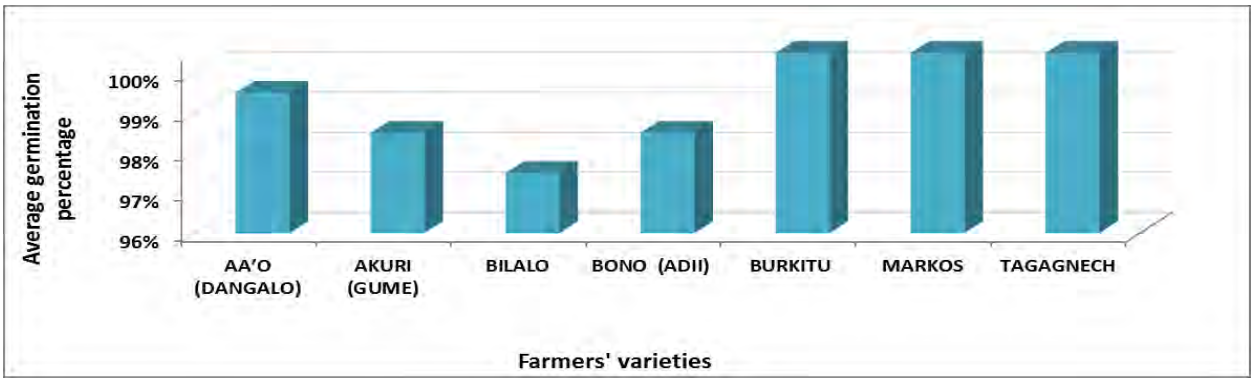


Figure 29. Germination percentage of the varieties in laboratory test

The result in Figure 29 reveals that the mean germination percentage of all farmers‟ varieties ranged from 97-100%. BURKITU, MARKOS and TAGAGNECH had the highest germination percentage, AKURI and BONO (ADII) germinated up 98%, whereas BILALO had the lowest germination percentage (97%), Statistically there was no significant difference ($p>0.05$) on germination percentages among the farmers varieties of field pea.

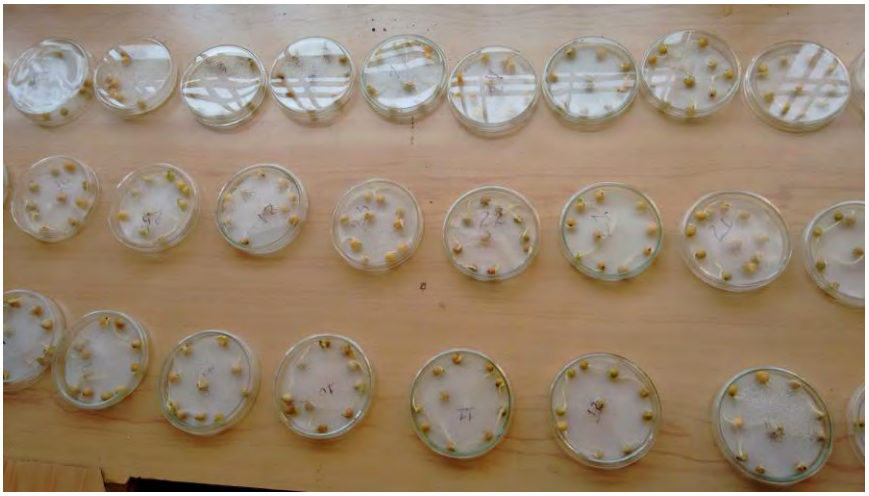


Figure 30. Photo of germination trials

4.1.11. Soil color and varietal distribution

There was only a slight of soil color on varietal distribution in field pea. The varieties of field pea were grown on different soil color (figure 31). BONO (ADII), AAʻO (DANGALO) and AKURI (GUME) are the varieties that grown on diverse soil color (15, 12, and 10 soil color respectively) whereas BURKITU and BILALO grown on few soil colors (3 and 2 soil color respectively). 75% BILALO was grown on 2.5 YR 3/3 soil color and 25% grown on the soil color 2.5 YR 4/4. 50 % of BURKITU grown in soil color 5YR4/4, about 25% grown on 7.5 R 3/2 and about 25% grown in 10 YR 3/4 soil color. 23% of MARKOS grown in soil color 10R 3/4 and 23% grown in 10 YR 3/2 soil color whereas it equally adaptive to all the rest four soil color that it grew. The variety SERGAGNA is equally adaptive to all coil color. 25%, 23% and 15% of TAGAGNECH was grown in soil color 2.5YR 3/4, 10YR 7.5R 3/2 respectively. 22%, 20% and 16% of the variety AKURI (GUME) grew on the soil color 10YR 3/4, 5YR 3/4, and 7.5YR 3/4 respectively. AAʻO (DANGALO) grew 25%, 20% and 15% in the soil color 7.5YR 3/4, 2.5YR 4/4 and 10YR 3/4 respectively. 25% of BONO (ADII) grown in soil color 10YR 3/4 followed by 10% that grown in 5YR 3/4 soil color.

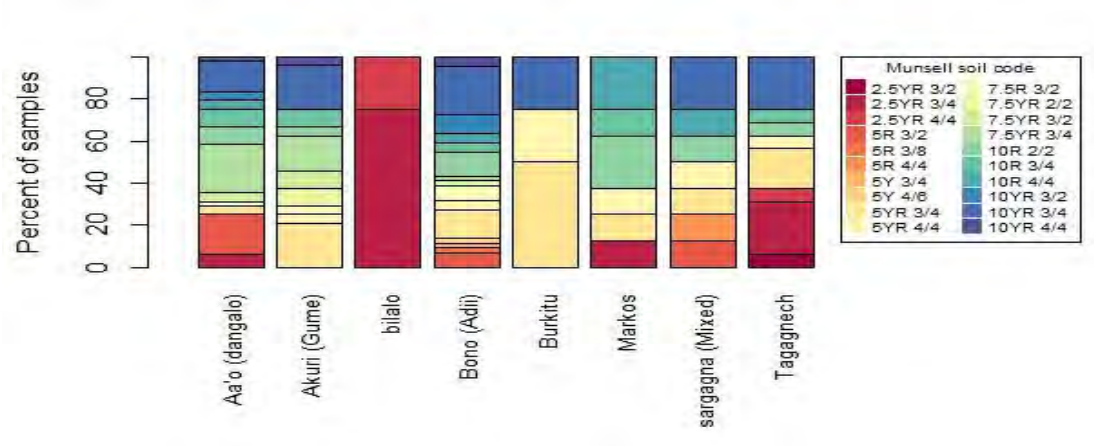


Figure 31. Soil color and varietal distribution

CHAPTER FIVE

5.1. Discussion, Conclusion and Recommendations

5.1.1. Discussion

5.1.1.1. Interspecific diversity of legumes and the place of field pea among the legumes

Field pea, faba bean, and common bean are widely cultivated in Kefa while in Arsi the major legumes are field pea and faba bean. Thus in both study zones field pea is a major legume cultivated by farmers. Farmers in the highlands of Arsi and Kefa cultivate faba bean and field pea mainly for food and income generation in rotation with other cereals.

5.1.1.2. The area covered by field pea

Farmers cultivate field pea on farm size ranging from 0.0125-1 hectare. Most of the farmers cultivate field pea in farm size of 0.25-0.5 ha in the study area. This indicates the farmers grow field pea in addition to other cereals and pulse crops. Farmers plan the site of field to grow field pea for the next year (season) depending on the fertility of the land by adjusting the total land allotted for different crops. In general there was a significant difference between the farm size of field pea cultivated by low income and mid-high income farmers. The farm size of pea was significantly less that in humid agro-ecological zone (H3) of the two study zones as compared to sub-humid zone in Kefa (SH3) and moist high lands of Arsi (M3) due to the dominance of other crops cereals (wheat and barley) in Arsi and coffee in addition to other cereals in Kefa zone.

5.1.1.3. Landrace distribution and diversity

5.1.1.3.1. Distribution of varieties

The 30 accessions collected from the study areas had distinct names in the area of cultivation and constitute a landrace or a farmers‟ variety. Based on names and descriptions given by farmers these accessions were categorized into seven major landrace groups and one varietal admixture. As indicated in Table 1 most of the name category that farmers used to name their variety was used for landrace identification; particularly morphological traits were used for identification of landraces, such as seed color, seed size, shape, flower color and habit of growth. Some farmers give name to their variety based on their use and source of seed. For example, the variety called AA‟O ATERO and BONO ATERO was named based on its seed color meaning black seed and white seed respectively in Keficho (the language of Kefa). However, the same variety (AA‟O ATERO) was given another name in different areas of Oromia ethnicity as DANGALO and GONDARE based on growth habit and the origin of seed meaning the variety which does not grow upright without support and one which came from Gonder. BONO ATERO has also the other name in Oromia ethnicity as ADII which means its seed is look like a milk because of the white color of the seed. Similar study which was conducted by Yemane Tsehaye *et al.* (2009) also indicated that the name of a farmer‟s variety may be related to the original source of the materials, morphology and uses.

Of the seven varieties of field pea, (AA‟O ATERO *(*DANGALO*),* BONO ATERO (ADII*)* and AKURI ATER *(*GUME*))* are cultivated in both Kefa and Arsi. However, four varieties *(*BILALO, BURKITU, MARKOS, and TAGAGNECH) are from Arsi only. SARGAGNA is not actually a variety but it is varietal admixture of both AA‟O ATERO and BONO ATERO grown mixed in one field. Farmers cultivate this varietal

admixture as a strategy of risk aversion during times of attack by pest. Out of the eight varieties (seven varieties and one varietal admixture) three are local varieties (AA"O ATERO (DANGALO*),* BONO ATERO (ADII) *and* SARGAGNA (MIXED*)* and five are improved varieties (AKURI ATER (GUME*)*, BILALO, BURKITU, MARKOS, and TAGAGNECH)). The information obtained from key informants of the study area indicates that there is low occurrence of improved varieties of the crop in general. A similar result is reported by Yemane Tsehaye *et al*., (2009) in that BONO ATERO is the most dominant variety because of its ability to resist disease and its high yield. AA"O ATERO is the second dominant variety in the area but SARGAGNA and AKURI are less dominant varieties in Kefa because of their less adaptability and recent introduction. Even though, AKURI ATER is a common variety in both study zones, it is the dominant variety in Arsi because of its high yield and adaptability. TAGAGNECH and DANGALO are varieties preferred in Arsi next to AKURI ATER. However, BURKITU, MARKOS, ADII, GONDARE and BILALO are preferred less in Arsi due to their low yield and their recent introduction.

5.1.1.3.2. Varietal diversity and richness

A total number of farmers" varieties of field pea is higher in Arsi zone that in Kefa zone due to the presence of the Kulimsa Research Center (Federal Research Center) which conducts research on improving of varieties and applies the research on farmers" fields. The research center supports the farmers by providing the improved varieties of field pea. This is the main reason why improved varieties of field pea are highly distributed in Arisi than Kefa. Hence there is higher gamma diversity in Arsi that in Kefa.

Except sergagna the two local varieties (AA"O ATERO (DANGALO) and BONO ATERO (ADII) are common in the two study zones because of the long time since their introduction as well as their higher

adaptability and higher yield. The improved variety (AKURI OR GUME) is common in the two zones because of high adaptability and high yield. AKURI ATER (GUME*)* in Arsi and BONO ATERO (ADII*)* in Kefa are the most dominant varieties due to their better yield, higher resistance to pest attack than AKURI ATER less shattering for BONO ATERO (ADII*)* as compared to AA"O ATERO (DANGALO*)*. However AA"O ATERO (DANGALO*)* is the second dominant farmers" variety in both study zones. Specially, the farmers in Arsi and Kefa prefer it because of its use for food quality especially of sauce (SHIRO) due to more water holding capacity of its flour and for its very good test.

In general the varietal diversity of the crops is very low in the study area (strata) and among the farmers as indicated in Figure 7a & b, because of low occurrence of field pea varieties and the presence of low number of improved varieties. Due to the shortage of land and the need for high yielding variety most of the farmers grow a few varieties. However the few farmers that have enough land grow many varieties based on food quality, productivity and market value. Average number of landraces listed by each farmer was highest for H3-Arsi followed by M3- Arsi, whereas H3-Kefa and SH3-Kefa was the lowest. Beta diversity was highest for M3- Arsi and this shows different farmers grow different landraces in this strata while in H3-Kefa and SH3-Kefa beta diversity is the lowest and farmers plant almost similar landraces. The result on varietal diversity showed that, H3-Arsi has a higher variety richness and evenness followed by M3-Arsi as compared to the two strata, H3-kefa and SH3-Kefa. A high diversity index at H3-Arsi suggests that the area is not dominated by one or two landraces rather by a number of successful landraces. A lowest value for the index diversity at SH3-Kefa, suggests that there were only a few successful landraces or that that the strata is dominated by a limited number of landraces.

5.1.1.4.Use value of field pea in each strata

Farmers also mainly use field pea as food. Various sauces (KIKI and SHIRO), boiled grains (NIFRO), roasted (KOLLO) and raw green and tender stage ESHAT are the major foods that the farmers used from seed of field pea because the seeds are a major source of plant proteins and vitamins for humans. Farmers in Arsi and Kefa prefer AKURI, BONO (ADII), TAGAGNECH, MARKOS and BURKITU are mostly to prepare KIKI. BILALO and AA"O (DANGALO) are mostly preferred for SHIRO. However, for NIFRO, KOLLO and ESHAT all varieties are preferred equally. Many farmers in H3 agroecological zones, M3 agroecological zones of Arsi and a reasonable number of farmers at H3 agroecological zone of Kefa used the crop for fodder. The farmers of the area mentioned that the fodder from field pea is very important for their livestock especially in autumn season (March, April and May) when there is shortage of animal feed. However, pregnant animals are not feed with the fodder from field pea residues because the farmers believe that it may cause abortion. Sometimes farmers give to their livestock the seed coat which the residue of KIKI or SHIRO soaked with salt water. The farmers in SH3 agroecological zones of Kefa did not know the use of field pea residues as animal feed but use it mostly for mulching of their coffee (*Coffee arabica*) and Enset (*Ensete ventrcosom*) farms. The farmers in Arsi used field pea residues as fuel for as a fuel baking *injera*. SHIRO (the floor of roasted and hauled field pea) is used as bee forage by mixing it with water and sugar especially during the season when flowers are scarce. Most farmers in Kefa and a few farmers in Arsi mentioned that the crop had a medicinal value for both human and livestock. The grain of field pea is used for treating fracture. The people with broken bones are fed with farmers used boiled (NIFRO*)* and roasted *(*KOLLO*)*. Horses with equine influenza are treated with the smoke of burning field to discharge the mucus through the horse"s nose.

5.1.1.5. Cultivation and management systems of field pea

5.1.1.5.1. Gender roles in production and management of field pea

The farmers in Arsi and Kefa practiced different activities during managing and harvesting field pea such as like Plowing, planting, harvesting, storage, marketing, seed selecting, food preparation and fodder collection. Application of fertilizers in field pea farms is practiced only in Arsi while adding fertilizers is the practice which is applied only in Arsi. As the information from the key informants of the two strata of Kefa the farmers didn‟t use fertilizers, because of the high cost of the fertilizer and the presence of enough fertility for the crop on their lands. Weeding is not the common cropping practices for the crop. However, sometimes farmers manage weeds with chemicals (herbicides), which are applied before sowing the crop if the field is known to contain high abundance of weeds that would affect the crop during its emergency and growth. In addition to this they may weed by using hand weeding method. Most farmers in H3 of Kefa does not collect the fodder of the crop as stated in Figure 13 rather they left it at the threshing field either they burn it or it becomes to be decayed there.

In the study areas most of the management practices/agronomic practices in the cropping of field pea were mostly done by both men and women adults except plowing, planting and adding fertilizers which were only done by male. Both of them participate in seed selection, harvesting carrying, threshing, grain storage, marketing and fodder collection. However, women were exclusively involved in food preparation of field pea for home consumption in the form of local recipes. Children also participate in the activities like harvesting, threshing and fodder collection to support their parents, including in harvesting and threshing.

5.1.1.5.2. Crop rotation

Field pea played a great role in the life of farmers by adding a positive impact on their farm fields. As mentioned by key informants, it helped them to increase and restore soil fertility because field pea plant is efficient symbiotic nitrogen fixers, and by the ability of holding water in the soil for the next crops that is sown after it. In addition to increase crop yield and profit rotating field pea with other crop is used by farmers for better control of weeds by breaking the life cycle and suppresses the growth of weeds. Because of this quite a number of farmers included field pea in their crop rotation sequences for the same purposes. As shown in Figure 20 cereals and legume crops were included in most of the farmers‟ crop rotation sequences; barley and wheat were mostly grown after field pea. The farmers in Kefa used teff and maize next to barley and wheat to rotate with field pea. Farmers rotate field pea with other crops by carful observation of their land fertility. The period of crop rotation with field pea and other crops is varies from two up to four years by depending with the farm land fertility and the house hold need for other crops. As it plays a significant role in soil fertility restoration and also serves as a break crop suitable for rotation to minimize the negative impact of cereal based mono-cropping. The same result is found on the study studied by Angaw Tsigie and Asnakew Woldeab, (1994).

5.1.1.5.3. Intercropping and sole cropping of field pea

Field pea is predominantly grown as a sole crop because of its main advantage on restoring of soil fertility for the productivity of next crop which is sown after harvest of field pea and for the use of grasses and weeds from the field after the harvest of field pea as a fodder for their cattle. Traditional cropping systems reported by farmers showed that field pea is also intercropped with faba bean, barley, maize and potato as similarly reported by Willey, R. W. (1979) except SH3 agroecological zone of Kefa which has no intercropping practices. In agreement with Amare Ghizaw (1996) the intercropping combination of field pea with faba bean is the predominant inter cropping combination on the study area. Because of the climbing character of the field pea, morphological difference of the crops and land use efficiency of the farmers. Intercropping is also an important with proven capacity to restrict disease and pest incidence and bring soil fertility benefits as studied by Abel Teshome *et al*., (2015)

5.1.1.5.4. Cropping and harvesting season of field pea

There were only one cropping season (mainly from June to August) for field pea production in both Arsi and Kefa zones. From Mid-July to early-August was the main cropping season for field pea in Arsi however form mid-July to Let-August was the main cropping season for Kefa. Therefore, Arsi farmers sow earlier than the Kefa farmers at the same season due to the shortage of late rain in Arsi and the presence of enough rain through all season in Kefa.

The varieties AAʺO ATERO (DANGALO), BURKITU *and* TAGAGNECH were sown earlier than BONO (ADII) and AKURI (GUME) in H3-Arsi. Due to let maturity property, AKURI, MARKOS, and TAGAGNECH are sown earlier than AAʺO (DANGALO), BONO (ADII), BILALO and BURKITU in M3-Arsi. The locale varieties AAʺO (DANGALO) and BONO (ADII) were sown earlier than the improved variety AKURI in H3-kefa because

of its less susceptible for the disease than the local varieties. However, in SH3-kefa all varieties were sown at the same time.

Harvesting time was extended from October to December in both Arsi and Kefa. In both zone field pea was sown earlier before sowing other dominant cereal crops of the area (wheat, barley). As indicated on section 5.5.1 harvesting activities of field pea was done by peoples by involving both male and females including elders and children from both sexes because of easiness of the crop to harvest as compared with other crops of the area. The early matured varieties (AA'O (DANGALO), BONO (ADII), BILALO *and* SARGAGNA (MIXED)) were harvested earlier than the rest varieties of the areas.

5.1.1.6. Farmers` seed exchange, selection and storage of field pea

5.1.1.6.1. Seed source of the varieties for the first time

Farmers obtain seeds of field pea varieties from different sources. Market is the Main sources for both traditional (local) varieties and improved (New) varieties. This is because of the availability of the seeds in the market. Also the seeds of both improved and traditional varieties are mainly used for income generation of farmers. Most of the farmers obtained the seeds of traditional varieties of field pea from family next to market. This implies there is a genetic /gene/ transferee of traditional varieties from generation to generation. The farmers also have a seed sharing habit with their neighbors for the transfer of genetic materials within each other for both traditional and improved varieties. In addition to the above sources, improved varieties are provided by development agents of the kebele and by research centers. Separately Kulimsa research center play a great role in providing the seed of improved varieties for the farmers. The farmers in Arsi

have an experience to share the seed of high yielding varieties with each other that is why the Arsi zone has higher gamma diversity than Kefa zone.

5.1.1.6.2. Farmers traditional seed storage systems

For seed storage farmers in the study areas used different traditional storing materials but majorly the modern sack locally called MADABERIA because it is better for air flow than the other traditional storing materials and GOTARA because it is better for a long period of time without human and animal contacts.

5.1.1.7. Ranking of farmers' varieties

Farmers‟ varieties tends to possess significant phenotypic variability some have developed tolerance to particular biotic and abiotic stresses and some are lauded for their yield stability while the others are not (Cleveland et. al., 2000). In this study from the identified seven landraces (farmers‟ varieties) and one varietal admixture, the five varieties and a varietal admixture are included on farmer ranking. Two varieties are not ranked because of the limited information about them due to their recent introducing time. The landraces exhibited differences based on different properties.

In general all varieties of field pea are not drought tolerant however MARKOS, TAGAGNECH and AKURI produce a relatively better yield than the other varieties in time of drought because of their batter low water demands and due to high water demand the varieties SARGAGNA, BONO and AA‟O are highly affected by drought and give a very low yield in drought time as compared to improved varieties. Pests and disease are the major production constraints of the area as similarly studied by Esayas Mendesil (2015) and Teshome Hunduma (2014) farmers ranking of varieties on ability of pest resistance, even though all varieties are susceptible for pest, SARGAGNA have

relatively more ability to resist pests due to the presence of two different varieties by mixture. Next to SERGAGNA, BONO ATERO (ADII) is also relatively pest resistance variety die to its early Maturity.

The harvesting activity of field pea is easy as compare with other crops ion the study area. Because of this all age group and all gender groups were participated on this activity. On the other hand, as similarly studied by Banniza *et al*., (2005) the improved varieties, AKURI and TAGAGNECH are the varieties that are very easy for harvesting as their non-sheltering character and having high biomass than the others. Because of providing a very good test for the food called sauce by the presence of best flavor AAʺO (DANGALO) have very good test.

5.1.1.8. Market survey

The price of the crop becomes low during harvesting time of the new field pea and high after harvesting period. The result from market survey indicated that TAGAGNECH had the highest demand from the buyers because of this their price value could be higher than the others. As indicated in combined result of average yield and price (Figure 27) the production of high yield, increases the demand of the farmers for TAGAGNECH. This is why its price is becomes to highest. Also the sellers said that SERGAGNA is a mixture of both BONO (ADII) and AAʺO (DANGALO) because of this the buyers demand to this variety was very low due to this its price value could be low. According to the responses of the respondents as a result of having high yielding characters, improved varieties have high market value. This price value also increases during the planting time because of the requirement by many farmers for sowing due to their high yield, and high biomass for fodder. TAGAGNECH is a fastest distributing variety in Arsi zone due to the above factors. Local varieties have low Market value than the improved varieties. As indicated by key

informants the local varieties have low yield amount and their biproducts is very smaller than the improved due to the presence of low biomass. Peoples in the study area buy and sell the yield of field pea both by using traditional materials, like GACHE, KUCHJIBELU, KUNA, KUBAYA and JOGI and by using a kilogram for the merchants who have a depositary. There is no any variety which is restricted to measure with traditional measurement or with kilogram. GACHA = 0.5 kg, QUCHIBALU = 0.67kg, KUNA = 7.5kg, KUBAYA = 0.33kg and JOGI = 1kg. SERGAGNA has low market value than the others varieties because of the mixing of two varieties together, having low yield and having low nutritional value. As indicated by key informants most of the low income farmers sow it because of its low market price to purchase and ability to resist disease.

5.1.1.9. Yield of the varieties

The varieties of field pea are varying by their yields. The farmers in the study area grow field pea mainly for market in addition to food conception. This is because of high price value of field pea when it compared with other crops in equal measure. Varieties of field pea are differing by their yield amount. Less distributed varieties burkitu and bilalo are not included in ranking of varieties by their yield amount they produce because of limited information that were collected about their yields. The results of the two respective years (2015 and 2016 GE; or 2007 and 2008 EC) yield indicates that because having high number of pod per plant and high number of seed per pod and high adaptability TAGAGNECH is high yielding variety than the other varieties followed by AKURI (GUME) and MARKOS respectively. The varieties produce low yield due to low adaptability, for different environmental factors and variations in seasons this is in line with Esayas Mendesil (2015). SARGAGNA has low yield. Also the combined result of the average yield and price shows this variety has a lowest value. Even though its yield and price values are very low farmers still grow the variety because the farmers considered that, if one variety is attacked by disease they

saves the other varieties and because of it low price value the formers with low wealth status found it at the local market easily by small amount of price than the other varieties. In general local varieties have low yield amount than the improved varieties. Because of this famers give more emphasis for varieties that produces high yield. Therefore, the genetic erosion of local varieties is the main problem of the area. In addition to selecting the variety that have high yield and high price as an information from key informants, the varieties that could not resist the overtime changing weather condition is rejected by most farmers.

5.1.1.10. Cluster analysis

The observed farmers‟ varieties of field pea were clustered in to three distinct groups based on on-farm qualitative and quantitative traits (appendix 6) collected from farmers‟ field. The clustering is based on Euclidean distance (Table 8) by applying Ward‟s method of hierarchical clustering technique of clustering was used as illustrated by Gower, J. C. (1971) using R-software and produced a more understandable portrayal of the seven field pea farmers‟ varieties by grouping them into three clusters as indicated in Figure 28, whereby different members within a cluster being assumed to be more closely related in terms of their on-farm phenotyphic trait under consideration with each other than those members in different clusters as similarly studied on clustering the genotypes of field pea by Fikreselassie Million (2012). This means the varieties MARKOS, AKURI, BILALO and BONO (ADII) (cluster I) are highly related varieties by their on-farm phenotypic characters. Also TAGAGNECH and BURKITU (cluster II) are the related varieties by their phenotypic traits. The maximum phenotypic distance was observed between cluster two and three.

5.1.1.11. Germination percentage

BILALO has the lowest germination percentage as compared to the rest farmers‟ varieties of field pea that were collected from the study area. The final germination percentages of all collected field pea varieties were high (> 95%). Therefore, there was no germination problem of all landraces under study.

5.1.1.12. Soil color and varietal distribution

Color is one of the most obvious features of the soil profile. Soils are complex mixtures of minerals, water, air and organic matter (both dead and alive), forming at the surface of land." The varying levels of minerals, water, etc. can affect the color of soil. Understanding the changes in color is tells us a lot about the history of the soil, particularly the seasonal abundance of water. Soil particles take on colors that are different when saturated with water or not. There for soil scientist used soil color to interpret drainage classes. Soil drainage is determined by nothing the depth that greys mottles or matrix from the top of the mineral soil. The color of soil helps agronomists understand soil composition and classify it so that farmers can produce optimum crops. Soil color tells agronomists if soil is lacking essential nutrients such as nitrogen, phosphorus and potassium. Munsell soil color chart is an affordable way to evaluate the type of soil that is present with in a given area. The result of soil analysis by Munsell color chart reveals that soil color is vary by farmers‟ varieties. This indicates that different varieties of field pea are adaptable for different soil types that have different s colors.

There was only a slight of soil color on varietal distribution in field pea. As similarly studied by Elzebroek and Wind, (2008) on the point peas are adapted to many soil types, but grow best on fertile, light-textured, well-drained soils, this study also the adaptability of farmers‟ varieties to

many soil colors. For instance, BONO (ADII) grew in about fifteen types of soil color but it is largely associated with soil color 10YR 3/4, and 5YR 3/4. AAʻʻO (DANGALO) grew in about twelve soil color in the study area however; it is highly adaptive on the soil color 7.5YR 3/4, 2.5YR 4/4 and 10YR 3/4. AKURI (GUME) grew in ten types of soil color however it is largely associated with a particular soil colors like 10YR 3/4, 5YR 3/4 and 7.5YR 3/4. The variety TAGAGNECH was also highly adaptive for the soil color 2.5YR 3/4, 10YR 3/4 and 7.5YR 3/2. SARGAGNA is the only variety that is equally associated with all soil colors. Unlike the others, BURKITU and BILALO are grown in less diverse soil color. However BURKITU is highly associated with soil color 5YR 4/4 and BILALO is highly associated with a soil color 2.5YR3/4. Generally it was seen that landrace is associated largely with red soils that are well drained.

5.1.2. Conclusion

A total of 30 accessions from different kebeles of the study area were collected and categorized into seven landraces (farmers‟ varieties) by depending on farmers‟ identification. Most of the farmers‟ varieties were named by their morphological traits, uses, source of seed, and productivity. In general, Arsi Zone has high varietal diversity, richness and evenness than Kefa Zone. Also, the total number of varieties and average number of varieties is high in Arsi Zone than Kefa. This means the Arsi Zone was not only dominated by one or two landraces rather by a number of successful landraces of field pea. Low income farmers grow limited number of varieties because of the problem of having low income to buy the seeds and being holders of small land size. This implies that the diversity of field pea varieties was affected by wealth status of the farmers. AKURI ATER (GUME) in Arsi Zone and BONO ATERO (ADII) in Kefa Zone are the most dominant varieties of the area. However, BILALO in Arsi and SERGAGNA in Kefa are the least dominant varieties as a result of low yielding capacity (productivity) for SARGAGNA and being of recent introduction for BILALO. The land size on which farmers grow field pea is not significantly different in the two study zones. However, most the farmers from tepid humid mid-highland agroecological zones of the two zones grow field pea within small land size than tepid sub-humid mid-highland of Kefa and Tepid moist mid-highland of Arsi. Field pea is mainly used for food and income generation and fodder in Arsi Zone. However, using it as fodder is not a common habit for most farmers in H3-Kefa. Rather, the farmers in H3-Kefa use the fodder for mulching of coffee and Enset farms. Field pea seed is used as medicine for healing broken bone of humans and its byproduct (stem and leaves) to heal the equine influenza.

The fields where field pea is sown were either plowed once after sowing or plowed twice one before sowing and the other after sowing at different times. Fertilizer was not used in Kefa

whereas DAP is the only type of fertilizer which was moderately used by Arsi farmers. Except plowing, which was done by males and food preparation which was done mainly by females, all the other agronomic and management practices of field pea involves both males and females. Most of the farmers obtained the seeds of both traditional and improved varieties for the first time from the market. Next to market, family sharing of seeds also plays a great role as source of seeds for traditional varieties regarding from where the farmers obtained the seeds for the first time.

In general, harvesting of field pea is an easy practice, whereas the varieties AKURI and TAGAGNECH are very easy for harvesting. AAʺO (DANGALO) has a very good taste as compared to other varieties. Even though pests are the major production constraint of the area for all varieties, SARGAGNA and BONO (ADII) are not always affected varieties. Even though all varieties have low ability to resist drought, local varieties (AAʺO (DANGALO), BONO (ADII) and SARGAGNA) have very low ability to resist drought. Improved varieties of the area have high price value and yield amount than the traditional varieties. Phenotypically, AKURI, MARKOS and BILALO are highly related varieties with each other that are found in the same cluster. TAGAGNECH and BURKITU are also the related varieties with each other. However, the maximum phenotypic distance is obtained between cluster two (TAGAGNECH and BURKITU) and cluster four (AAʺO (DANGALO)). All varieties had high (> 95%) germination percentage.

5.1.3. Recommendations

- This study documented that only landraces of *P. sativum* var. *sativum* were cultivated and that the crop is a good source of income, which has increased over time making strengthening trade linkages of farmers and merchants highly important. Thus conservation and utilization of the field pea landraces found in cultivation, research and development centers must be given due attention.
- Further ethnobotanical studies with seed collection of landraces, their characterization and evaluation must be conducted particularly in areas not covered by this study in order to have a complete country-level account on this crop.
- Efforts towards distribution of field pea seeds to areas of the country where the landrace diversity is low need to be given due consideration in view of the importance of the crop and the preferences shown by farmers.
- Further study on the varietal distribution with soil color in relation to soil minerals is highly recommended.
- It would also be interesting to check the nutritional compositions of the landraces studied particularly taking the different food types (SHIRO, KIKI, NIFRO, KOLLO, and ESHAT).

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Appendices

Appendix 1:- Informed oral consent

"Before I begin my interview, I want to introduce myself, explain my research activities, I want to answer any questions you may have, and make sure I have your permission to continue. My name is Mulugeta Berhanu and I am a student at Addis Ababa University studying in Plant Biology and Biodiversity Management department. This is my colleague [name], who is assisting me as a local guide and translator. We are conducting a study of field pea (*Pisum sativum)* as part of my education at the university." The purpose of this study is to identify different types of field pea and to understand their use and management by farmers. With your permission, I would like to ask you questions about field pea. Of course, your participation is entirely voluntary. These interviews require less than one hour. I do not anticipate that the interview will pose any risks to you. Because I am a student, I cannot pay you. I hope that our research will benefit farmers in Ethiopia by promoting the diversity of field pea. If you agree to an interview, you do not have to answer all of my questions, and you can tell me at any time if you would like to stop. I would record your answers to my questions using my cell phone and my notebook. I would include this information in my thesis, and it would be shared with other researchers who are interested in field pea. Do you have any questions? In case you have any questions in the future after I leave, here is my contact information Mulugeta Berhanu my phone number is 0949140479 or 0961011587. Before we continue, I need to make sure I have your permission. Do you consent to your participation in this research? "Do you grow field pea?" ☐ Yes ☐ No

Appendix 2: Structured interview

Section 1: Basic information

Date of interview:	
Name of interviewer:	
Region:	Zone:
Woreda/District:	Kebele/Sub-District:
Latitude (in decimal degrees):	*Longitude (in decimal degrees):*
Altitude (in meters):	
Agroecological classification	
Random number of household from farmers" association list:	
Relative wealth on farmers" association list: ☐ Low income ☐ Middle/High income	

Section 2: General information about informant

Name of informant:
Language spoken by informant during interview: ☐ Amharic ☐ Other (specify): _____
Age (**observed**): ☐ 18 to 30 ☐ 30 to 45 ☐ 45 to 60 ☐ 60+
Gender (**observed**): ☐ Male ☐ Female
Is the informant the household head? ☐ Yes ☐ No
If no, household-head gender: ☐ Female-headed ☐ Male-headed

Section 3: Market access

How far is the **closest** market from your home? In minutes on foot

Do you go to any other **larger** market? ☐ Yes ☐ No
If yes, how far is this **larger** market from your home? In minutes (on foot)
How far is the nearest **road with vehicle transport** from your home? In minutes (on foot)

Section 4: Interspecific diversity of legume crops

Are you growing any legumes this year? ☐ Yes ☐ No If *yes, how many hectares.*
Which legumes did you **plant** in 2008 (Meskerem to Pagume)?
For each of the legumes you listed, how many hectares of land did you **plant** in 2008 (Meskerem to Pagume) including any areas under intercropping? *Convert any local units to hectares* (e.g. 1 timad or qurt = 0.25 hectare).

Section 5: Use of field pea (*Pisum sativum* L.*)*

How do you use field pea? ☐ Food ☐ Spice ☐ Medicine ☐ Fodder/Forage ☐ Fuel ☐ Market ☐ Bee forage ☐ Other (specify): _____

Section 6: Cropping practices

Do you rotate field pea with other crops? ☐ Yes ☐ No
If yes, with which crops do you rotate with field pea?
If yes, how often do you plant field pea within the crop sequence?
Do you intercrop field pea with other crops? ☐ Yes ☐ No
If yes, with which crops do you plant field pea in the same field?

Section 7: Intraspecific diversity of field pea

Note: Be sure to include all varieties, including landraces and released/improved types.

What varieties of field pea have you grown in the past three years (for the 2007, 2008, and 2009 harvests)?
Are there any other varieties that you have grown in the past, prior to 2007?
Are there any other varieties of field pea grown by other farmers in your community, but not by yourself?
Are there any other varieties of field pea that you remember from a long time ago, or have heard about from Elders, that are no longer grown by your community?
If you run out of a particular variety, whom would you ask to replenish your seeds? (*Record name as a potential key informant*).

Section 8: Key attributes of varieties

Instructions: At the top of each column, write the names of all varieties harvested in 2007, 2008, and 2009. Use additional sheets if necessary

Question	Variety 1	Variety 2	Variety 3	Variety 4
Local vernacular name of variety				
Is this a **traditional** or a **new** variety?				
Where did you first obtain this variety? (e.g. family, neighbors*, DA, market, food aid, research center)				
For **how many years** have you planted this variety?				
Where do you plant this variety? (e.g. main fields, field margins, home gardens, fence lines, other places)				
Are the places where you grow this variety **rainfed, irrigated, or both**?				
Do you plant this variety on **soils with low, moderate, and/or high fertility**?				
How many **times per year** do you sow this variety?				
When do you usually **sow** this variety?				
When do you usually **harvest** this variety?				
Is this variety grown mainly for **home use** or mainly for the **market**?				
How many hectares of these varieties did you harvest in 2008 and 2007, including area under intercropping? *Make sure you convert any local units to hectares* (e.g. 1 timad or qert = 0.25 hectare).	2008: 2007:	2008: 2007:	2008: 2007:	2008: 2007:
How much of this variety did you harvest in 2008 and 2007? *Record with local units to be converted later. Be sure to include the name of the units. Later, go to a local market to determine the conversion factor from local units to kilograms.*	2008: 2007:	2008: 2007:	2008: 2007:	2008: 2007:
Based on your experience, was the yield for this variety in 2008 and 2007 a very high yield, a high yield, a medium yield, a low yield, or a very low yield?	2008: 2007:	2008: 2007:	2008: 2007:	2008: 2007:
What is the current **price** of this variety at your local market? (use farmer units)				

* If a particular variety came from friends or family, ask for the name of the individual who provided it as a potential key informant. Record that person‟s name in your notebook.

Section 9: Rating of attributes for varieties of field pea.

Ask the informant to rate the varieties of field pea planted for the 2007, 2008, and 2009 harvests. This is **NOT** a ranking activity, so multiple varieties may receive the same score.

Rating criteria and scale	Var. 1	Var. 2	Var. 3	Var. 4	Var. 5
Local name (copied from previous pages)					
Best yield this variety has ever given you (5=very high, 4=high, 3=medium, 2=low, 1=very low)					
Yield under drought conditions (5=very high, 4=high, 3=average, 2=low, 1=very low)					
Yield when excessive rain causing water logging (5=very high, 4=high, 3=average, 2=low, 1=very low)					
Yield when rainy season begins late (5=very high, 4=high, 3=average, 2=low, 1=very low)					
Yield when rainy season ends early (5=very high, 4=high, 3=average, 2=low, 1=very low)					
Resistance to frost (5=never affected by frost, 4=rarely affected by frost, 3=sometimes affected by frost, 2=often affected by frost, 1=always affected by frost)					
Resistance to common diseases (5=never affected by diseases, 4=rarely affected, 3=sometimes affected, 2=often affected, 1=always affected by diseases)					
Tolerance to common insect pests (5=never affected by insect pests, 4=rarely affected, 3=sometimes affected, 2=often affected, 1=always affected)					
Tendency for seeds to detach/shatter (5=seeds never detach/shatter 4=rarely detach/shatter, 3=detach/shatter about half the time, 2=often detach/shatter, 1=always detach/shatter)					
Importance as food for the household (5=extremely important, 4=very important, 3=somewhat important, 2=not so important, 1=not at all important)					
Importance as a source of income (5=extremely important, 4=very important, 3=somewhat important, 2=not so important, 1=not at all important)					
Importance as fodder for livestock (5=extremely important, 4=very important, 3=somewhat important, 2=not so important, 1=not at all important)					

Effect on soil fertility (5=very positive effect on soil fertility, 4=some positive effect, 3=no effect, 2=some negative effect, 1=very negative effect on soil fertility)					
Ease of harvesting (5=Very easy to harvest, 4=easy, 3=neither easy nor difficult, 2=somewhat difficult, 1=very difficult to harvest)					
Ease of preparing as food (5=very easy to harvest, 4=easy, 3=neither easy nor difficult, 2=somewhat difficult, 1=very difficult to harvest)					
Taste (5=very good taste, 4=good taste, 3=neither good nor bad taste, 2=bad taste, 1=very bad taste)					

Section 10: Gender roles in production and management of field pea (*Pisum sativum* L.*)*

Which gender and age groups live in your household (including the respondent)?	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No

When it comes to field pea, who within the family usually participates in the following activities? Check any that apply.

Activity	Gender and age groups*			Is this true for all varieties?*
Ploughing with animals (mares)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No
Preparing the soil by hand with a hoe (mekofer)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No
Leveling soil and removing uprooted weeds (gulgualo)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No
Sowing (zer mezerat)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No
Weeding (marem) and cultivation (kutkuato)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No
Fertilizer application (madaberia, fig, kompost…)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No
Harvesting (mached ena mesebseb)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No
Threshing (mewkat)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No
Storage (makemachet)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No
Marketing (meshet)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No
Seed selection (zer memret)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No

Food preparation (megib mazegajet)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No
Collection of fodder for animals (meno mesebsebe)	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No
Other activity (specify):	☐ M-children ☐ F-children	☐ M-adults ☐ F-adults	☐ M-Elders ☐ F-Elders	☐ Yes ☐ No

* Note: For this classification only, **children** are individuals 14 and younger, **adults** are ages 15 to 59, and **Elders** are 60 or older.

** Take detailed notes of any exceptions for particular varieties.

Section 11: Closing and follow-up questions

We are looking for both men and women who have a lot of knowledge about different varieties of field pea. Is there anyone from your community who you recommend? (*Ask this if I haven't recorded any names of potential key informants in my notebook)*	
Thank you very much for answering my questions. Do you have any comments and/or questions **you would like to raise** at this time? (Record farmers‟ questions in my notebook, if relevant.)	
At any point during the interview, did the informant indicate that s/he had gained some new knowledge? ☐ Yes ☐ No	
If yes, what knowledge did he/she report to have gained as a result of the interview (Record farmers‟ statements in your notebook.)	
Time interview was completed:	*Duration of interview (minutes):*

Appendix 3: Semi-structured interview with key informant

Note: You must take additional notes in your notebook. Informants will raise their own points during the interview – not necessarily as responses to questions - and these must be recorded. Second, interviewers must dig deeper by asking additional questions whenever she or he senses interesting information or ideas. This approach generates a richer, more complete understanding.

Section 1: Basic information about Key Informant

Date of interview:	
Name of interviewer:	
Region:	Zone:
Woreda/District:	Kebele/Sub-District:
Language spoken during interview: ☐ Amharic ☐ Other (specify): _____	
Name of informant:	
Age (**observed**): ☐ 18 to 30 ☐ 30 to 45 ☐ 45 to 60 ☐ 60+	
Gender (**observed**): ☐ Male ☐ Female	

Section 2: Knowledge of varieties listed within the same kebele

Compile a list of all of the varieties that have been mentioned by the general informants within the same kebele. For each variety, ask the following questions of the key informant. Remember to note if the key informant says that two or more local names refer to the same variety.

Are there any other varieties that you know that we can add to our list? You may include any that you remember or have heard about from a long time ago, but are no longer planted in the kebele.

Names of varieties (from ODK survey)	Have you heard of this variety?	Is this variety planted in this kebele?	Have you planted this variety yourself?
1.	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
2.	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
3.	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
4.	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No

Section 3: Attributes/characteristics of varieties

Instructions: Ask the key informants the following questions about each of the varieties with which s/he is familiar. Record the information in your notebook. The following table is intended to keep track of the questions you have asked.

Question	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
What is the **meaning** of the local name? (e.g. color, shape, nutritional quality, origin, etc.)										
Are there **alternative names** for this variety?										
How do you **recognize** this variety? How does it **differ** from similar varieties? (By appearance or other features?)										
What are the **ideal growing conditions** for this variety (e.g. amount and timing of rainfall, sunlight, temperature)?										
Characterize the **soil types** on which the variety is planted.										
What **fraction of the farmers** in your community plants this variety? (e.g. almost all, half, one out of ten)										
Over the past 5 years, has this variety become **more commonly planted or less commonly planted** in your community?										
If applicable…What is the **main reason** that this variety is becoming more or less common?										

Section 4: Use of field pea (*Pisum sativum* L.) as food

What foods do you prepare using field pea?

Note: Add a note if foods are of special cultural value. You may include foods that the key informant does not prepare her/himself.

Name of food	Which parts are used?	Which variety is preferred?	Why is this variety preferred?*

*For example, color, taste, ease of preparation, etc.

Section 5: Nutritional value of foods prepared with field pea (*Pisum sativum* L.)

Do any of the foods you prepare with field pea have any special health benefits?

Name of food	Health benefit	Specific group who use it or for whom it is recommended*?	Which variety is preferred?	Why is this variety preferred?

*For example: children, elderly, pregnant women, lactating women, sick people, people with broken bones, people who have lost a lot of blood.

Section 6: Use of field pea as medicine

Do you use field pea as medicine?

Name of ailment treated with field pea	Which parts are used?	Which variety is preferred?	Why is this variety preferred?*

Section 7: Use of field pea as fodder

Do your animals consume field pea?

Which animals consume field pea?	Which part(s) do they consume?	When (in which season) do they consume field pea?

Section 8: Other specific uses of field pea.

Do you use field pea for any other purpose?

Description of use	Which parts do you use?	Which variety do you prefer?	Why do you prefer this variety?

Section 9: Crop Management

1. Do the people in your community apply fertilizers to field pea (*Pisum sativum* L.*)*? Which fertilizers are used (including manure, compost, crop residues)?
2. Do people in your community use pesticides or herbicides on field pea (*Pisum sativum* L.*)*?
3. What else do people in your community do to prevent and control pests, weeds, and diseases affecting field pea (*Pisum sativum* L.*)*?
4. Are there any varieties of field pea (*Pisum sativum* L.*)* that produce more residues (stems, leaves, etc.) than others?
5. What do people in your community do with the residues from field pea (*Pisum sativum* L.*)* after the harvest?
6. Does anyone in your community ever use inoculants for field pea (*Pisum sativum* L.*)*?
7. How do people in your community store field pea (*Pisum sativum* L.*)*?
8. What are the major production constraints for field pea (*Pisum sativum* L.*)* in your community (e.g. weeds, pests, diseases, drought, low fertility).

Section 10: Closing and follow-up questions

I have asked all of the questions I had for you. Thank you very much for spending this time with me and sharing your knowledge. Do you have any comments and/or questions **you would like to raise** at this time? (Record farmers‟ questions below)	
(During the interview, did the informant indicate s/he had gained some new knowledge? ☐ Yes ☐ No)	
If yes, what knowledge did he/she report to have gained as a result of the interview?	
Time interview was completed:	Duration of interview (in minutes):

Additional notes:

Appendix 4: Interview data collection format for market survey

Date _____

Seller Name_____Age_____ Sex _____

Market name_____

Location of market place: Region _____Zone _____ Woreda _____ Kebele _____

Altitude _____Latitude _____ Longitude _____

1. Name all the farmers‟ varieties you sell, the meaning of their names and their price per kilogram.

Name of the landraces	Meaning of the name	Price per kilogram
1.		
2.		

2. How do you differentiate between them?

Name of the landraces	Unique characters used for differentiating
1.	
2.	

3. Which variety is most dominant in market? Why? _____
4. Which variety is most needed? Why? _____
5. Which one is the most expensive? Why? _____
6. Is the supply of field pea dwindling or increasing? _____
7. Is field pea available all year around? _____
8. If not, in which season is it available? _____
9. In which season is the price of field pea become high? Why?_____
10. Do you gather field pea by yourself or do you purchase it for resale from someone else? _____

Appendix 5: Field Pea Seed Passport Descriptors

Ethiopian Biodiversity Institute Accession No _____

Collection Record Sheet

Collection No _____ Crop_____
Date_____ Genus_____
Country_____ Species_____
Region _____ Local/Vernacular Name_____
Zone_____ Ethnic Group_____
Woreda_____ Language_____
Kebele_____
Village /Site_____
Farmer"s Name_____
Latitude_____Longitude _____ Altitude_____ (M)

Topography

1. Swampy
2. Flood plain
3. Plain level
4. Undulated
5. Hilly
6. Hilly dissected
7. Steeply dissected
8. Mountaineer
9. Other (specify)

Sample

1. Single line
2. Pure line/clone
3. Population/mixture
4. Other (specify

Site : 1. Level
2. Sloppy
3. Summit
4. Depression

Soil Texture

1. Sand
2. Sandy loam
3. Loam
4. Clay loam
5. Clay
6. Silt
7. Highly organic
8. Other (specify)

Herbarium Specimen Yes,☐ No☐

Photographs Yes, ☐ No ☐

Soil Color

1. Black
2. Brown

Genetic Status

1. Wild
2. Weed
3. Primitive cultivar/Landrace
4. Breeding line
5. Advanced cultivars

Source of Collection

1. Field
2. Backyard
3. Farm store/Threshing place
4. Agricultural Institute
5. Natural vegetation
6. Other (specify)

Nature of Samples

1. Seed
2. Spikes
3. Pods
4. Cherry
5. Tuber
6. Rhizomes

Sowing Month:

1 2 3 4 5 6 7 8 9 10 11 12
Early/Mid/Late

3. Orange
4. Red
5. Yellow
6. Other (specify)

Stoniness

1. None
2. Low
3. Medium
4. Rocky

Drainage

1. Poor
2. Moderate
3. Well drained

Shade Yes No

Harvesting Month

1 2 3 4 5 6 7 8 9 10 11 12
Early/Mid/Late

Origin of Seed

1. Local
2. Elsewhere

Usage (specify) _____

Disease & Pests_____

Note (Associated wild weedy species, crop, local flora, disturbance factor) _____

Remark_____

Collectors Name (s):_____

Appendix 6. On-farm phenotypic data of the varieties

Varieties	AA'O (DANGALO)	TAGAGNECH	MARKOS	BURKITU	AKURI (GUME)	BONO (ADII)	BILALO
Plant length in cm	178	194	190	145	195	189	192
Primary branch length in cm	44	90	84	85	63	45	76
Maximum number of leaflets	4	6	6	6	6	6	6
Number of nodes	22	24	22	22	27	28	26
Number nodes after 1st pod	8	12	7	8	9	10	9
Number nodes to 1st podding node	14	12	15	14	16	18	17
Number branches	1.5	4	2.5	3	3	2	2.5
Number peduncles per branch	2	3	3	3	3	2	3
Number pods per peduncle	1	2	1	2	1.3	1	1.2
Number pods per branch	2	6	3	6	4	2	4
Number of seeds per pod	5	6	6	6	7	6	6
Total number of seeds per branch	10	36	24	36	28	12	24
Petiole length last tendril in cm	27	27	24	25	28	26	25
Petiole length to 1st tendril in cm	7.5	7.5	6.5	5.5	7	7	7.5
Stipule length to axil tip in cm	7.5	8.5	6	6.5	7.2	7.3	6.5
Stipule width in cm	4	4.5	3	3.5	4	5	3
Stipule length axil tip2 in cm	6	7	4.6	5	5.6	5.3	5.2
Peduncle length b/n 1st & 2nd pods	4	6	5	4.5	4	3	5
Peduncle length without spur in cm	2	2	1	2	2.3	2	2
Peduncle length including spur	15.5	12	15	9	14.3	12	15
Number of bracts per peduncle	5	5	5	5	5	5	5
Number of peduncles	13	24	16	19	17	15	16
Number of pods per peduncle	1.153	2	1.18	2	1.4	1.3	1.5
Number pods per plant	15	40	25	38	24	20	25
Pod length in cm	6	7	6.5	6	9	6.6	6.3
Pod width in cm	1.3	1.8	1.5	1.8	2.2	1.5	1.5
Number of seeds per pod	6	7	6	6	7	6	6
Seed yield per plant in number	90	280	150	228	168	120	150
Seed length in cm	0.71	0.83	0.7	0.84	0.7	0.6	0.7
Maximum flowers number per node	2	2	2	2	2	2	2
Minimum number flowers per node	1	2	1	2	1	1	2
Seed shape	cylindrical and wrinkled	elipsoid and smooth	elipsoid and smooth	elipsoid and smooth	elipsoid and smooth	elipsoid and smooth	cylindrical and wrinkled
Seed color	grey	White	white	white	white	white	white
Seed eye color	white	Black	black	white	black	white	black
Flower color	pink	White	white	white	white	white	white

Declaration

I, the undersigned declare that this Thesis is my original work and it has not been presented in other universities, colleges or institutes for a degree or other purpose. All sources of the materials used have been duly acknowledged.

Name: _____ Signature: _____ Date: _____

This work has been done under my supervision.

Name: _____ Signature: _____ Date:_____

_____ Signature: _____ Date: _____