Phenotypic Diversity and Mineral Contents of Field Pea (*Pisum sativum* L.) Accessions from North Wollo and South Tigray, and Improved / Introduction Varieties

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GRADUATE PROGRAMMES

This is to certify that the Thesis prepared by Blen Wondimageghu Woldesemayat, entitled*: Phenotypic Diversity and Mineral Contents of Field Pea (Pisum sativum* L.*) Accessions from North Wollo and South Tigray, and Improved / Introduction Varieties* and Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Plant Biology and Biodiversity Management complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

Phenotypic Diversity and Mineral Contents of Field Pea (*Pisum sativum* L.) Accessions from North Wollo and South Tigray, and Improved / Introduction Varieties

Blen Wondimageghu, MSc Thesis

Addis Ababa University, June 2017

Among legumes, the field pea has multiple purpose of fixing atmospheric nitrogen and providing protein. This study was undertaken to identify the phenotypic diversity of field pea (Pisum sativum L.) landrace accessions, improved and introduced varieties. It was planted in two locations namely Holeta and Debrezeit agricultural research centers using Randomized Complete Block Design (RCBD) with 3 replications during the 2016-2017 cropping season. Standard morphological measurements and scores were taken and the harvested grains were analyzed for their mineral contents including Iron, Zinc, Calcium, Copper, Potassium, Magnesium, Phosphorus and Selenium. The morphological and mineral content data were analyzed with descriptive and inferential statistics. The genotypes showed morphological diversity as observed in the field trails. The results showed that significant differences exist among samples, within blocks and across locations. Cluster analysis for average performances grouped the genotypes into two different classes where cluster 1 had short maturity period whereas cluster 2 had high grain production and total biomass production even though they are late maturing. In the correlation analysis, days to maturity was highly correlated to total biomass production and grain yield to which breeders draw much attention. All the nine minerals that were analyzed, was there but varied from sample to sample. The amounts of Ca, K, Mg and P were relatively higher in the landraces than in the other samples. It had high Ca, Fe and P compared to lentil and faba bean. There was strong positive correlation between the research sites in Holeta and Debrezeit. Diseases like ascochyta blight and powdery mildew with scales of 1-9 were present. From 77 samples RAYA 1, DEKOKO 41 and DEKOKO 15 were resistant for both diseases. The early genotypes (the DEKOKO varieties) can be used in drought prone areas or in double cropping while those lines shown to be resistant to ascochyta blight and powdery mildew could be taken up in breeding programs.

Key words: Chemical composition, correlation, cluster, morphological diversity, RCBD, *Pisum sativum*

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List of Acronyms

EMA	Ethiopian Metrological Agency
HARC	Holeta Agricultural Research Center
DZARC	Debrezeit Agricultural Research Center
ICARDA	International Center for Agricultural Research in Dry Areas
ANOVA	Analysis of Variance
PCA	Principal Component Analysis
KARC	Kulumsa Agricultural Research Center
DAP	Di-Ammonium Phosphate
SAS	Statistical Analysis Software
DTE	Days to Emergence
DTF	Days to 50% Flowering
DTM	Days to 90 % Mature
GF	Grain Filling Period
PPP	Number of Pods per Plant
SPP	Number of Seeds per Pod
BPP	Shoot Biomass per Plant
TBPP	Above ground Total Biomass per Plant
Ha	Hectares
Hi	Harvest Index
GPE	Grain Production Efficiency
BPR	Biomass Production Rate
EGR	Economic Growth Rate
WT	Thousand Seed Weight
GYP	Grain Yield

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Field pea is one of the few oldest crops of the world. The first cultivation of the crop took place about 9000 years ago alongside cereals like barley and wheat (Saxesena *et al*., 2013). It is an annual herbaceous legume adapted to cool moist climate with moderate temperatures found in various regions of Ethiopia (Yasin Goa and Mathewos Ashamo, 2014). The crop is the third legume crop in Ethiopia, headed only by faba bean (*Vicia faba*) and chickpea (*Cicer aritienum*) in terms of both area coverage and total national production (Gemechu Keneni *et al*., 2013). According to Thulin (1989) and Haddis Yirga *et al.* (2013), there are two botanical varieties of *Pisum sativum* L known to grow in Ethiopia, namely *P. sativum* var *sativum* and *P. sativum* var *abyssinicum*, while much of the production in our country is on *P. sativum* var *sativum*.

Field pea is known to fix more nitrogen than chickpea and lentil but less than faba bean (Gemechu Keneni *et al*., 2013). The crop has important cultural, ecological and economic advantages in the highlands of Ethiopia. It plays a significant role in soil fertility restoration and also serve as a break crop suitable for rotation to minimize the negative impact of cereal based mono-cropping (Seboka Habtamu and Fikre selassie, 2013). The crop uses can differ from place to place. It is used primarily for making cultural 'shiro wot', an Ethiopian stew, which is sometimes served as a main dish to be eaten with "injera" and also as feed, silage and green manure (Westphal, 1974 and Haddis Yirga *et al.*, 2013). The crop is valuable and cheap source of protein having essential amino acids (arginine, leucine, lysine, aspar-tic acid and glutamic acid) that have high nutritional values for resource poor households (Holt and Sosulski, 1979). Another key point on field pea is that, it has crude protein, calcium, potassium, magnesium and phosphorus and low fat (Khalil *et al*., 1988 and Ates, 2012).

From local field pea varieties DEKOKO has significant nutritious value especially in the northern parts of the country. Farmers and consumers call it as the “Dero-Wot of the poor” (chicken stew of the poor) to mention its nutritional value (Haddis Yirga and Dargie Tsegay, 2013).

As said by Amarakoo *et al*. (2012) legume seeds are rich in nutrients like Fe, Zn, Ca, and Mg. Micronutrient malnutrition, which is also known as hidden hunger, can affects more than half of the world’s population, with most being women and preschool children in Asia and Africa. Though the nutrients are there due to anti nutrient property the availability will be low.

In a plant breeding program, estimates of genetic relations among parental lines may be useful for determining which material should be combined in crosses to maximize genetic gain. Low or lack of genetic diversity led to the epidemic, to a plateau in genetic improvements of yield in common bean and obstacle in breeding plans. (Tar’an *et al*., 2004). However, diverse genetic background among parental lines provides an ample supply of allelic variation that can be used to create new favorable gene combinations. Through this high yielding and resistant to diseases field pea varieties can be selected.

This study particularly focuses on identifying the diversity of the collected *P.sativum* var *sativum* and *P. sativum* var *abyssinicum* and also difference on minerals can be revaled.

Thus, the findings of this study will be significant for identifying and documenting the diversity of the crop, to select resistance among them and help breeders to select one that can help local farmer.

1.2. Statement of the Problem, Research Questions, Hypotheses and Objectives

1.2.1 Statement of the Problem

Field pea is an important source of protein in developing countries, because it is hard to buy and eat animal products in unindustrialized world. The needed of protein and fat content is replaced by the pulse crops and on the other hand it is a major feed in the developed world (Abel Teshome *et al*., 2014).

Subsistence farmers produce the highest portion of field pea to use as supplementary protein sources and maintain soil fertility. Field pea have value such as good protein source, used as rotation crop, supplement many minerals, green manure and good source of feed specially for beef and poultry production. Although this is true, yield is very low. It is mainly limited by soil fertility as mostly legumes are cultivated in poor soils, often without fertilization in order to restore the soil (Yemane and Skjelvag, 2003). Despite its high nutritional and economic value, DEKOKO is the most neglected pulse crop in the research area. Hence, its productivity is low because of lack of improved varieties, low soil fertility and little or no application of fertilizers. DEKOKO is usually sown without fertilizer and as a result its yield under farmer's condition is often below optimal even though it is nutritious (Engels *et al*., 1991).

Nevertheless field pea and specially DEKOKO have different importance for humans, there is no documented information about the different accession of DEKOKO and other hybrid field peas and the mineral difference. Data on phenotypic diversity was found to be rather limited. Therefore, this study will contribute by documenting and assessing the landrace diversity of field pea in Ethiopia central highlands and the mineral analysis among different samples so that the farmers will be benefited and get more improved varieties against disease and yield.

1.2.2 Research Questions

The research has answered the following questions:

- What are the field pea (*P. sativum* L.) landraces found in the central highlands of Ethiopia and which one is the best in the study areas?
- Is there morphological variability between the landraces of field pea collected from central highlands of Ethiopia and other genotypes?
- Is there any difference on the collected samples grown in the two experimental sites?
- How is the resistance ability to ascochyta blight (*Ascochyta pisi*) and powdery mildew (*Erysiphe polygoni*), across the two experimental locations?
- Are their differences in the mineral contents of different samples?

1.2.3 Hypotheses

- There are diverse field pea varieties in central highlands of Ethiopia.
- The field pea samples are morphologically variable.
- Two experimental locations have different result on the trait examined.
- Some samples are resist to diseases like powdery mildew and ascochyta blight.

- Mineral concentration show dissimilarity between samples.

1.2.4 Objectives

General objective

- The general objective of this study is to describe and document the phenotypic diversity of field pea (*P. sativum* L.) from various sources.

Specific objectives

- To describe the phenotypic diversity of the field pea accessions grown in the central highlands of Ethiopia, some varieties from research centers and Australia based on morphological characters;
- To assess the extent of morphological variation in field pea samples;
- To identify the key traits contributing to the overall diversity of field pea samples;
- To determine mineral content of collected accessions, released and introduced;
- To evaluate disease resistance performance among the collected field pea samples on each sites;

CHAPTER TWO

2. LITERATURE REVIEW

2.1 The Field Pea Crop

Cherinet Alem and Tazebachew Asres (2015) describe legumes as high rank grain for the purpose of fixing atmospheric nitrogen and high protein in world agriculture. Pulse crops production in Ethiopia is 13.24 % (1,652,844.19 ha) of the total area of production (CSA, 2015). Land covered by Field pea crop is 221,415.67 ha (CSA, 2015). It is the fourth most important staple legume among the highland pulses in rural Ethiopia (Fisseha Negash and Tewodros Mulualem, 2014). To put it differently, the crop is the major food legumes with a valuable and low-cost source of protein for resource poor households (Cherinet Alem and Tazebachew Asres, 2015). The crop is the cheapest source of protein for cash source to many people who live in different parts of the country.

2.1.1 Taxonomy

Field pea is a plant in the Fabaceae (Leguminosae) family and genus *Pisum*. There are three species like *P. fulvum, P. abyssinicum* and *P. sativumm* (Martin-Sanz *et al.*, 2011). However according to Thulin (1989) flora volume 3, the species have two varieties that is distributed from Mediterranean region to West Asia. Namely they are *P. sativum* var *sativum* and *P. sativum* var *abyssinicum*.

2.1.2 Botanical Description

Based on Daisy (1979) field pea is an annual plant that is climbing and herbaceous. It shows variation form and habit. The stems ranges from dwarf, medium and tall which are 15-90 cm, 90-150 cm and 150-300 cm respectively. Stems angular-terete, slender, with no or few basal branches; internodes hollow and sometimes purple at base.

Leaves are alternate and pinnately compound. The leaflets are ovate, entire, 1.5 – 6 cm long and 1-4cm broad. Leaflets opposite or sub-opposite, short-petioluled, ovate or obovate, sometimes more or less rhomboid and asymmetrical. Leaflets are essentially sessile. The stipules are large, up to 10cm long (usually 1.5-8 cm), on round, slender, and glabrous stems. The midrib of the leaf rachis can be slightly winged. This plant climbs using the tendrils produced at the apex of a compound leaf. These modified terminal leaflets form a branched tendril (Westphal, 1974).

The inflorescence is axillary, solitary, or in 2-3 flowering racemes. The flower are large, butterfly like, usually white but may also be pink or purple and mostly the flowers are self-pollinated. Flowers have 5 sepals, 5 zygomorphic petals (bilaterally symmetrical), 10 stamens in two groups (9 fused + 1 free) and a single superior carpel. The standard petal is obovate, 1.6-3cm long and the glabrous ovary is nearly sessile (Daisy, 1979).

Pod is oblong. The color of the pod may vary from yellowish-green to dark- green. Seeds are smooth or slightly wrinkled, 6-8 mm in diameter, white with an orange tinge, green, orange-brown to brown, dark violet, green or brown with violet spots, or with mosaic pattern. Hilum small, elliptic, light colored, sometimes black. Cotyledons light yellow (Westphal, 1974). Nevertheless DEKOKO differ markedly from field pea. It has leaves with on pair of leaflet and reddish-purple flower and sweeter seeds with black hilum (Daisy, 1979).

Of course peas mature in 3-5 months, but DEKOKO need only 3-4 months and yield between 500 and 1500 kg/ha. DEKOKO is capable of producing seed yield of up to 1.95 t/ha under phosphorus fertilization and is known for its high market price (Haddis Yirga *et al*., 2013).

2.2. Origin, Geographic Distribution

As described in Gixhari *et al.* (2014) the existence of pea back to 9000- 10,000 B.C in Near East and Central Asia. It is one of the world's oldest domesticated crops. Pea and other grain legumes with cereals were important nutritional source of early civilizations in Middle East and Mediterranean. Vavilov suggested four centers of origin for field pea, based on genetic diversity. They are Central Asia, the near East, Abyssinia (Ethiopia) and the Mediterranean.

DEKOKO or Abyssinian pea found in Northern part of Ethiopia (South Tigray and North Wollo) and Southern Yemen (Westphal, 1974). Abyssinian pea is also found along the road to Asella. *P. sativum* var *abyssinicum* is the one that is mostly cultivated in the northern parts is locally known as DEKOKO (minute seeded) and Yagere Ater (pea of my country) or Tinishu Ater (the smallest pea) in Amharic (Westphal, 1974 and Haddis Yirga *et al*., 2013).

2.3 Use and Economic Importance of Field Pea

Field pea have different importance across the world and in Ethiopia. Other than the value of getting cash for the farmer and foreign currency for the country, it has essential amino acid and nutritious value for poor farmers. Protein concentration of field peas range from 9.7 to 15.53 % (Benti, 2014). Based on Harmankaya *et al*. (2010) the crop also contains nutrients such as Mg (Magnesium), K (potassium), P (phosphorus), S (sulfur) and Ca (calcium).

In certain part of the world young leaves and fresh green seeds are cooked and eaten as a vegetable (Westphal, 1974). The green pod is fairly sweet and edible. Mostly in Ethiopia, pea is usually finely ground to make 'shero wot' and 'kek wot'. Canned peas is also consumed in large number of population (Westphal, 1974).

Field pea is used for the crop rotation purpose in order to increase the nitrogen concentration for the soil by fixing nitrogen, to break pest cycle, by providing a moisture for the next crop and due to short growing period (Beck *et al*., 2015).

Anderson and Ilse (2011) said that field peas are very palatable and digestible for animals. It is sources for energy and protein in livestock production. Now a days peas have been used in production of feed for aquaculture.

In particular, DEKOKO has high nutritional value. The dry seeds are decorticated and split before boiling. Sometimes they are boiled without decortications and consumed as soup (Haddis Yirga and Dargie Tsegay, 2013).

2.4. Field pea breeding in Ethiopia

Field pea breeding in Ethiopia started since 1960's by having aim on enhancing productivity through generation of productive and tolerant cultivars under different agro-ecologies of the country (Tamene *et al*., 2013). The struggle continued and varieties have been suggested for cultivation in different environmental areas. Presently the productivity improving actions are in progress (Teshome Legese, 2011).

Research institutes like Holleta Agricultural Research Center, Kulumsa Agricultural Research Center and Sinnana Agricultural Research Center are doing their best to find suitable varieties for the country. Varieties like MOHANDERFER, G22 763-2C, GUME, TEGEGNECH, WOLMERA , HASSABE, ADI, ADET-1, SEFINESH, HOLETA, BIRKITU, BILALO, AGRIT , LATU, WEYITU, DADIMOS, TULLUSHENEN, URJI and MILKIY were released in the meantime (Tadele Tadesse and Edosa Fikru (2009), Mulusew Fikere *et al*.(2010), Cherinet Alem and Tazebachew Asres (2015) and Awol Mohammed *et al*. (2016)).

On the other hand, semi-leafless pea are a mutant gene that converts normal leaflets to tendrils. These increase inter-plant binding and mutual support so that erect plant stands are produced, reducing lodging and harvesting problems. The semi-leafless type has yielded well in evaluation trials, particularly under dry land conditions where its yields have been significantly better than conventional cultivars .They are important for using limited water supplies more efficiently than conventional peas (Wilson *et al*., 1981).

2.5. Genetic variability and diversity in field pea

According to Westphal (1974) and Gemechu Keneni *et al*. (2005) field pea (*P. sativum* L.) is assumed native in south-western Asia and cultivated from Mediterranean to the Central Asia as well as in the highlands of Ethiopia.

Genetic diversity is mandatory in order to produce better cultivars and sustain food security. A large genetic diversity has been found in *P. sativum* collections from both Africa (e.g. Ethiopia) and Asia. High to medium field pea genetic diversity in Ethiopia was observed in collections from Shoa, Gojam, Gondar, Wollo, and Tigray, while low to trace genetic diversity was observed in collections from Arsi, Gamo-gofa, Wellega, Illubabur and Kafa (Haddis Yirga *et al*., 2013). Landraces have valuable adaptive genes to different circumstances (Gemechu Keneni *et al*., 2005). In addition, continual selfpollination and increasing homozygosity of pea varieties may also have contributed to a loss of genetic integrity (Ahmad *et al*., 2012).

2.6. Genetic progress from breeding in field pea

In general different activities has been done in pea breeding. As Burstin (2009) said, researches are making ways to improve yield, defend against weed and disease infestation, enhancing seed quality and size and increase nodulation of pea root with wanted bacteria.

In Ethiopia, the yield of field pea incurred by many problems such as disease, insect pests, frost, poor cultivars and poor management practices. Even though there is diverse agro-ecological conditions, field pea productivity is in its point without changing (Cherinet Alem and Tazebachew Asres, 2015).

Researchers are doing eagerly however, farmers are also a barrier for production. They sow field pea without enough ploughing and adding of fertilizer. The assumption is mostly legumes can fertilize the soil and they don't give it much attention. The crop will decrease the yield due to low level of phosphorus (Fisseha Negash and Tewodros Mulualem, 2014).

2.7 Nutrition value of field pea:

Although pea is rich in mineral elements, it also has anti-nutrient properties which determine the dietary bioavailability of nutrients. They decrease the accessibility of major minerals, particularly of Ca Fe and Zn.one is phytates (inositol hexaphosphate) which form complexes with iron and zinc may cause deficiency of elements in human diet. They are synthesized during seeds maturation and constitute from 60 to 90% of total phosphorus. Even if they cause phosphorus accumulation in plant tissues, they also reduce risk of ischaemic heart disease, atherosclerosis and diabetes development as well as show antioxidative properties (Amarakoo *et al*., 2012) and (Wozniak *et al*., 2014). Nowadays nutrient malnutrition is worldwide health problem. Specifically Fe, Zn, Mg, Ca and K are the most prevalent one (Thavarajah *et al.*, 2016). To solve hidden hunger nutritionists form biofortification. It is a process that increase the nutritional quality of foods through traditional plant breeding and modern biotechnology (Amarakoo *et al*., 2012). It can minimize micronutrient malnutrition through supplementation and food fortification, to increase human micronutrient intake through diet (Thavarajah *et al.*, 2009). Thermal treatment, fermentation and processing food after germination mostly for lentils and pea can diminish the activity of anti-nutrients as well as detoxify it (Bora, 2014).

Even if anti-nutritional factors have problem like blocking the absorption of nutrients or act as toxins, they have useful values such as promoting beneficial bacteria in gastrointestinal track.

On the words of (Kumar, (2011) and Jacquie, (2015)) some anti –nutrients in legumes are:

Tannins are phenolic compounds of high molecular weight. They are responsible for the astringent taste of some leaves, fruits, and wines and found in plant leaves, bark, fruit, wood, and roots. They have been closely linked with plant defense mechanisms against ruminant animals, birds, and insects. They act as anti-nutritional factors when included in the diet of animals. Digestive proteins can bind with dietary tannins, making the proteins unavailable to the animal. Diets high in tannin content have been found to reduce growth rate of animals.

Protease inhibitors are small protein molecules that have the ability to interfere with the action of the proteolytic enzymes involved in breaking down protein into amino acid components. The typical animal response to an intake of protease inhibitors is to increase enzyme secretions, which results in increased size of the pancreas.

Phytate is the principal storage form of phosphorus in many plant tissues. Phytate has been shown to block the absorption of not only phosphorus but also other minerals, particularly calcium, magnesium, iron, and zinc. Animals do not produce the enzyme phytase needed to break down phytate. As a result, diets with high levels of phytate have reduced nutrient availability. Phytate is found in many grains and legumes. The level of phytate will depend on the feedstuff and the conditions under which it was grown. Cooler temperatures during the growing season produces lentils with a reduced phytate content. But now a days Breeders are also looking to produce low-phytate grains and phytase, which can help breakdown of phytate

Lectins are proteins that have the unique property of binding carbohydrate-containing molecules which cause the agglutination of red blood cells. Agglutination causes the atrophy of the microvilli, reduces the viability of the epithelial cells, and increases the weight of the small intestine caused by hyperplasia of crypt cells. Moist heat treatment will destroy much of the lectin present in grain legumes. Lectins, however, are quite resistant to inactivation by dry heat treatment.

Cyanogens can be hydrolysed by enzymes to release HCN which is volatile gas. Damage to the plant results in the enzymes and glycoside coming together and producing HCN. The hydrolytic reaction can take place in the rumen by microbial activity. As a result ruminants are more susceptible to HCN toxicity than non-ruminants. The HCN absorbed detoxified in the liver by the enzyme rhodanese which converts HCN to thiocyanate. Excess cyanide ion inhibits the cytochrome oxidase that can stop ATP formation, tissues suffer for energy deprivation and death follows rapidly.

2.8 Diseases in field pea:

As stated in Zaumeyek (1962), Hagedorn (1991) and Seid (2015) peas are subject to a number of diseases, several of which may cause serious injury or loss. Annual losses from diseases vary from year to year, depending often on local weather conditions. Major diseases of pea include Ascochyta blight, Fusarium wilt, downy mildew, rust and powdery mildew. The fungi and bacteria causing diseases of peas may be carried one plant to other plant by insects, infected seed, drainage water, refuse and stable manure, farm animals and implements, and wind .

Ascochyta diseases:

There are three types of ascochyta diseases namely *Mycosphaerella blight*, ascochyta foot rot and ascochyta leaf and pod.

Ascochyta foot rot**:** small purple to blue black lesion up to 1cm in length along the stem. It is apparent on the lowest leaves and stipules and on the lowest stem and upper root. These lesion run together, girdling the stem and give it blue black look. The causal organisms are carried by the seed and infect the seedlings when they emerge. Rains after germination splash the spores to surrounding plants, and eventually many of the plants in a field may become infected.

Powdery mildew:

The disease is caused by a fungus parasite (*Erysiphe pisi*),which is characterized by the formation of a white, powdery, dust like coating on the surface of the leaves and less frequently on the petioles of the leaves, stems, and pods. The leaves are yellowed, dwarfed, and sometimes considerably malformed. The first symptom occurs on the upper foliage. The absence of rain and presence even slight dew favor disease development. Rain can control the disease by washing away off spores.

CHAPTER THREE

3. MATERIAL AND METHODS

3.1 Description of study Area

The field trial was done at Debrezeit agricultural research center (DZARC) and Holeta agricultural research center (HARC) in the station research site. DZARC is located 47 Km to east and HARC 38Km to west direction away from Addis Ababa .HARC and DZARC are centers in Oromia region, working under Ethiopian Agricultural Research Institute.

The geographic location of DZARC is 38^0 58' E longitude and 8^0 44' N latitude with an elevation of 1900 meter above sea level. The HARC is situated in 38^0 30'E longitude and 09^0 00' N latitude with elevation of 2400 meter above sea level. The temperature of DZARC range from 8.6^0C to 29.2^0 C and its sum annual rain fall is 939mm. The temperature of HARC range from 2^0C to 25^0C with sum annual rain fall 1143mm (EMA, 2017). The climadiagrams of the two experimental sites are shown with minimum and maximum temperature and monthly rainfall in Figure 1**.**

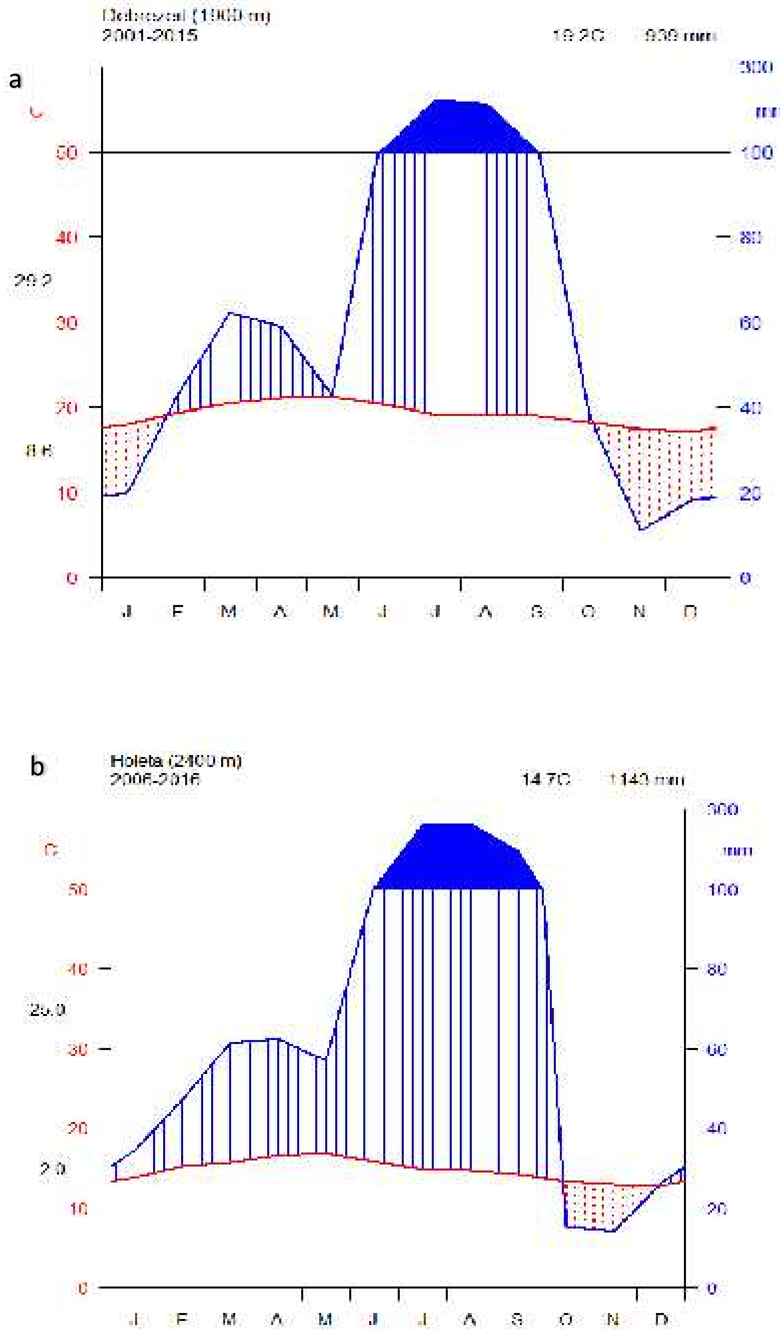


Figure 1. Climadiagram of the study area at Debrezeit Agricultural Research Center (a) and Holeta Agricultural Research Center (b) (Data source EMA)

3.2 Experimental materials

Seventy seven materials had been used for evaluation over the two location during 2016/17growing season. The description of the cultivars is given in table 1. In general, 43 landrace accessions were from Kulumsa Agricultural Research Center (KARC) which was collected from northern Ethiopia (North Wollo and South Tigray) (Figure 2). From International Center for Agricultural Research in the Dry Areas (ICARDA) 18 varieties was used and from Holeta Agricultural Research Center (HARC) 16 varieties was used.

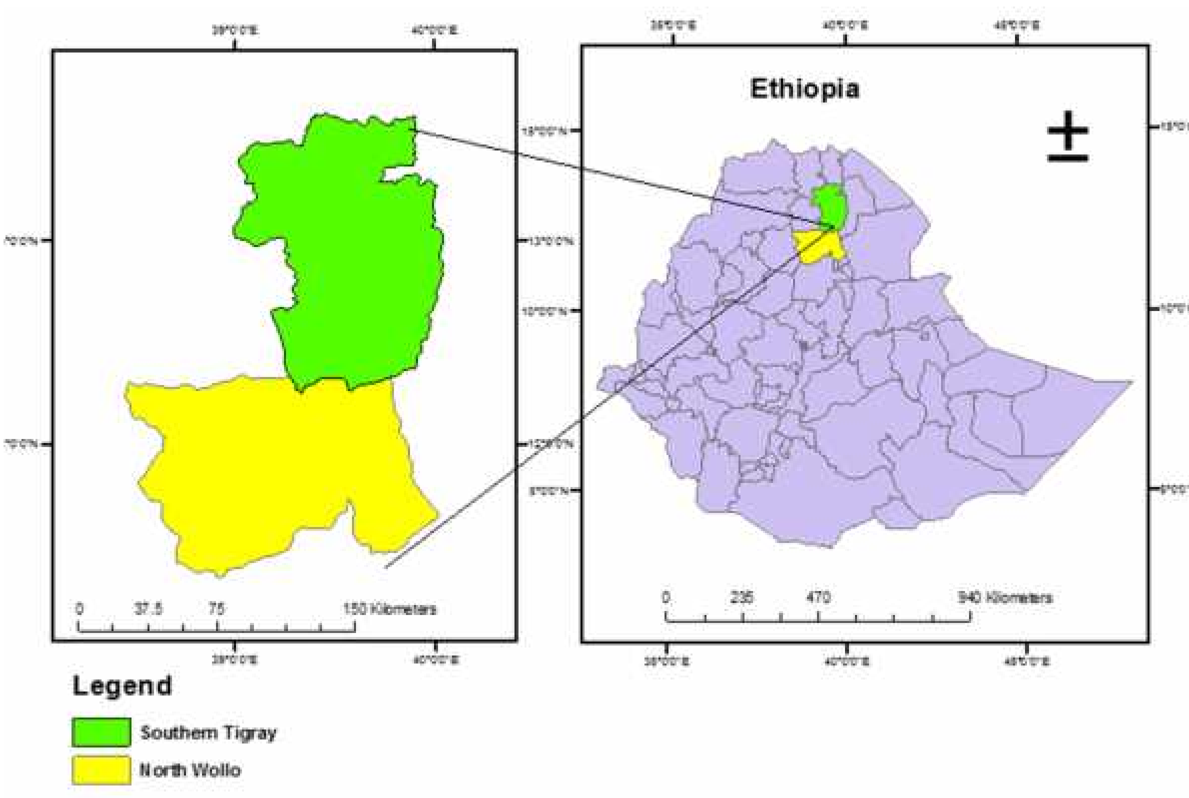


Figure 2 Map showing the two location where the samples were collected

Table 1. List of field pea samples used in the study

No	Sample Name	Accessions name or pedigree	Maintaining center	Origin
1	Gume	Tegegnech X PSI210713	HARC	Holeta
2	Dekoko 26	Tkcoll-5/07	KARC	South Tigray, Askiti
3	P313-010	P313-010	ICARDA	Australia
4	Ek08023-1	EK08023-1	HARC	Holeta
5	Dekoko 9	Mcoll-9/07	KARC	North Wollo
6	Dekoko 7	Mcoll-7/07	KARC	North Wollo, Dikowuha
7	P313-027	P313-027	ICARDA	Australia
8	Dekoko 40	Mcoll-6/07	KARC	South Tigray, Mekan
9	Dekoko 31	Tkcoll-10/07	KARC	South Tigray, Kidana
10	Dekoko 2	Mcoll-2/07	KARC	North Wollo, Melatera
11	Adi	G22763-2C x 305PS210813-2	HARC	Holeta
12	Wolmera	FpEx Dz X 305PS210822-1	HARC	Holeta
13	Milkiy	NEP634 x 180-1	HARC	Holeta
14	Dekoko 30	Tkcoll-9/07	KARC	South Tigray, Kidana
15	Mohanderfer	Not known	HARC	India
16	P313-082	P313-082	ICARDA	Australia
17	Dekoko 8	Mcoll-8/07	KARC	North Wollo, Dikowuha
18	P313-067	P313-067	ICARDA	Australia
19	Latu	Not known	HARC	Holeta

20	DEKOKO 34	Tkcoll-13/07	KARC	South Tigray, Kidana
21	DEKOKO 25	Tkcoll-4/07	KARC	South Tigray, Tekulesh
22	DEKOKO 4	Mcoll-4/07	KARC	North Wollo
23	P313-086	P313-086	ICARDA	Australia
24	G22 763-2c	G22 763-2C	HARC	Holeta
25	DEKOKO 5	Mcoll-5/07	KARC	North Wollo
26	DEKOKO 13	Awcoll-2/07	KARC	South Tigray
27	P313-090	P313-090	ICARDA	Australia
28	BURSA	Not known	HARC	Holeta
29	DEKOKO 14	Awcoll-3/07	KARC	South Tigray, Luchuberet
30	RAYA 1	Not Known	KARC	Alamata
31	MARKOS	DMR-4	HARC	Holeta
32	MEGERI	Not known	HARC	Holeta
33	DEKOKO 41	Mc coll-7/07	KARC	South Tigray, Ajira
34	DEKOKO 6	Mcoll-6/07	KARC	North Wollo
35	DEKOKO 19	Kcoll-4/07	KARC	North Wollo
36	DEKOKO 21	Kcoll-6/07	KARC	North Wollo
37	DEKOKO 18	Kcoll-3/07	KARC	North Wollo, Tekulsh
38	P313-068	P313-068	ICARDA	Australia
39	TEGENECH	Not known	HARC	Burundi
40	DEKOKO 3	Mcoll-3/07	KARC	North Wollo, Melatera

41	DEKOKO 43	KR coll-2/07	KARC	North Wollo
42	HOLETA	Holeta Local-90	HARC	Holeta
43	DEKOKO 42	KR coll-1/07	KARC	North Wollo
44	RAYA 2	Not known	KARC	Alamata
45	DEKOKO 36	Mc coll-2/07	KARC	South Tigray, Endamihoni
46	P313-045	P313-045	ICARDA	Australia
47	DEKOKO 12	Awcoll-1/07	KARC	South Tigray, Jemedo mariam
48	P313-070	P313-070	ICARDA	Australia
49	DEKOKO 23	Tkcoll-2/07	KARC	South Tigray, wanberet
50	DEKOKO 11	Wcoll-1/07	KARC	South Tigray
51	P313-071	P313-071	ICARDA	Australia
52	DEKOKO 15	Awcoll-4/07	KARC	South Tigray, Jemedo mariam
53	DEKOKO 24	Tkcoll-3/07	KARC	South Tigray, Kidana
54	DEKOKO 16	Kcoll-1/07	KARC	North Wollo, Herbat
55	DEKOKO 33	Tkcoll-12/07	KARC	South Tigray, Daguyat
56	BILALOL	Not known	HARC	Holeta
57	DEKOKO 1	Mcoll-1/07	KARC	North Wollo, Melatera
58	DEKOKO 27	Tkcoll-6/07	KARC	South Tigray, Kidana
59	DEKOKO 22	Tkcoll-1/07	KARC	South Tigray, Kidana

60	P313-042	P313-042	ICARDA	Australia
61	DEKOKO 29	Tkcoll-8/07	KARC	North Wollo, Kidana
62	DEKOKO 10	Mcoll-10/07	KARC	North Wollo, Dikowuha
63	DEKOKO 20	Kcoll-5/07	KARC	North Wollo, Lasta
64	DEKOKO 17	Kcoll-2/07	KARC	North Wollo, Tekulesh
65	P313-053	P313-053	ICARDA	Australia
66	DEKOKO 37	Mc coll-3/07	KARC	South Tigray, Endamihoni
67	DEKOKO 39	Mc coll-5/07	KARC	South Tigray, Mekan
68	BIRKITU	Not known	HARC	Holeta
69	DEKOKO 32	Tkcoll-11/07	KARC	South Tigray, Daguyat
70	DEKOKO 35	Mc coll-1/07	KARC	South Tigray Hiziba
71	P313-059	P313-059	ICARDA	Australia
72	P313-046	P313-046	ICARDA	Australia
73	P313-003	P313-003	ICARDA	Australia
74	P313-061	P313-061	ICARDA	Australia
75	P313-026	P313-026	ICARDA	Australia
76	HASABE	Not known	HARC	Holeta
77	P313-089	P313-089	ICARDA	Australia

HARC=Holeta Agricultural Research Center. ICARDA= International Center for Agricultural Research in the Dry Areas. KARC= Kulumsa Agricultural Research Center.

3.3 Experimental design

The samples used for the study represent DEKOKO (*P. sativum* var *abyssinicum*) and others were released and introduced ATER (*P. sativum* var *sativum*) varieties. The experiment has been conducted using Random Complete Block Design (RCBD) with three replications. The 60seeds per plot were planted in 3 m^2 area of plot with 3 m row length. The plot had a spacing of 20 cm and 5 cm between rows and plants, respectively (Figure 3, 4 and 5). The samples were assigned randomly to avoid bias. Planting were take place on 30th June, 2016 in Debrezeit and 7th July, 2016 in Holeta.

Band application of DAP (Di-ammonium phosphate) was applied at the rate of 18 kg N and 46 kg P/ha for each area. Weed was controlled by manual weeding as needed. With the intention of controlling insects like (aphids) Danitol was used at the rate of 25 ml per ha^{-1} .The disease occurred, for instance ascochyta blight and powdery mildew was scaled up on 1-9 scale (Little and Hills, 1978).

Figure 3. Field in Debrezeit

Figure 4. Field in Holeta

Figure 5. Field visit by Prof. Zemede in Holeta

3.4 Data collection

Five plants were randomly selected from each row and those plants were used for data analysis (Figure 6).

Figure 6. Selection of Five Plant in Field

Data collected from field across plot was:-

Days to emergence (DTE): Number of days from planting to when emerges above the ground.

Days to 50% flowering (DTF): Number of days from planting to when 50% of plants in a plot had at least one flower.

Days to 90 % mature (DTM): Number of days from planting when 90% of the plot is ready for harvest, foliage color becomes yellowish and on the lower stem start shedding, pods and seeds harden.

Grain Filling Period (GF): The number of days from days to 50% flowering to days to 90% physiological maturity.

Number of pods per plant (PPP): The average number of pods counted from sample of five plant taken randomly from each plot.

Number of seeds per pod (SPP): The average number of seeds per pod counted from five plant taken randomly from each plot.

Shoot biomass per plant (BPP): The mean weight of above ground parts sun dried of five plants taken from each plot.

Above ground total biomass per plant (TBPP): The mean weight of above ground parts sun dried of five plants taken from each plot plus the mean weight of seed taken from the representatives which is the five plant.

Harvest index (HI): ratio of grain yield which is oven dried over total biomass of oven dried.

$$\mathbf{HI}=\frac{GY}{(\mathrm{TB/P})}$$

Grain production efficiency (GPE): Ratio of grain filling duration and duration of vegetative period (Days to 50% flowering) and multiplied by grain yield.

$$\mathbf{GPE}=\frac{GFP}{\mathrm{DTF}}*\mathbf{100}$$

Biomass production rate (BPR): It is the ratio of above ground total biomass weight divided by days to 90% physiological maturity and then multiplied by 100.

$$BPR=\frac{(\mathrm{TB/P})}{\mathrm{DTM}}*\mathbf{100}$$

Economic growth rate (EGR): Grain yield divided by grain fill duration and then multiplied by 100.

$$EGR = \frac{GY}{GFP} * 100$$

Thousand Seed weight (WT): The weight of thousand seeds taken randomly from the harvested seed lot of each plot.

Grain yield (GYP): Weight of seed from the randomly taken five plant and adjusted to its recommended (12%) moisture content.

Ascochyta blight and powdery mildew data were recorded to evaluate disease severity. Based on Little and Hills (1978) 1-9 scale where, 1 stands for immune, 2 for highly resistant, 3 for resistant, 4 for moderately resistant, 5 and 6 for moderately susceptible, 7 for susceptible, 8 and 9 highly susceptible. After the pea was harvested, it was threshed on an open field (Figure 7).

Figure 7. Threshing of harvested field pea

3.5 Laboratory analysis

3.5.1 Drying of samples

Moisture removed from the grain by putting it in oven on 72^0c for 24 hours. Weighing the seed sample was carried on both before and after oven.

3.5.2 Mineral analysis

The samples for the mineral analysis were only from Debrezeit. It was done in USA, South Carolina in Clemson University on collaboration. Chemical standards, reagents and high purity solvents used for mineral digestion, phytic acid extraction and analytical determinations were purchased from Alfa Aesar, Water, distilled and deionized (ddH_2O) to a resistance of 18.2 MΩ was used for sample and reagent preparation.

Minerals were determined by inductively coupled argon plasma emission spectroscopy (ICP) using a Thermo 6500 Duo instrument after HNO_3-H_2O_2 digestion. 500mg freeze dried samples were digested with 6 mL of 70% HNO_3 overnight at room temperature. The digested sample were then heated to 90^0c for 1hr after which 3 mL of 30% hydrogen per oxide (H_2O_2) were added. When the organic matter was digested, the solution was diluted with millipore water to 25 mL. Mineral concentrations were determined by inductively couple plasma emission spectrometry.

The solution detection limit was 5 μg $L^{-1}$for Mn, Cu, Se, Fe and Zn, 30 μg$L^{-1}$for K, Ca and Mg, 80μg$L^{-1}$for P. Analytical quality assurance was accomplished using authentic calibration standards.

3.5 Data analysis

Analysis of variance (ANOVA) across location and among the samples used, cluster analysis, dendrogram, principal component analysis (PCA), and correlation were done by SAS software 9.0 version (Evans, 1999).

Before performing the analysis of variance for each trait, normality test was done using PROC UNIVARIATE procedure of SAS computer program. Separate and pooled analyses of variance (ANOVA) were computed to quantify the total variation among samples. Means were separated by Tukey Grouping (Evans, 1999).

CHAPTER FOUR

4. RESULTS

4.1 Phenotypic diversity

The results of the analyses of variance (ANOVA) for 14 traits of field pea studied on individual locations (Debrezeit & Holeta) and showed significant difference among location and among accessions (Table 2 and 3). For all quantitative characters analysis of variance showed significant difference ($p < 0.05$, $p<0.01$ and $p<0.001$) among locations and samples. Result of all traits was grouped by Tukey (Appendix 2 and 3).The result showed distinction between the Ethiopian DEKOKO, released and introduced samples.

Table 2. ANOVA Results of 14 Quantitative Traits of 77 Accessions Grown At Debrezeit and Holeta, in 2017 G.C

	Mean squares													
SOV	DTE	DTF	DTM	GF	PPP	SPP	BPP	TBPP	HI	GPE	BPR	EGR	WT	GYP
L	0.0010***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***
B	<.0001***	0.2539ns	0.0882ns	0.3014ns	0.0002**	0.028*	0.7903ns	0.306ns	0.3494ns	0.497ns	0.392ns	0.6749ns	0.390ns	0.2972ns
S	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***
S*L	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***

NB: *=significant at α = 0.05, ** = very significant at α=0.01 probability level, ***= extremely significant at α=0.001 and ns =Non significant , Source of variation (SOV), Days to emergence (DTE), Days to flowering (DTE), Days to maturity (DTM), Grain filling period (GF), Pod per plant (PPP), Seed per pod (SPP), Biomass per plant (BPP), Total biomass per plant (TBPP), Harvesting index (HI), Growth production efficiency (GPE), Biomass production rate (BPR), Economic growth rate (EGR), Thousand Seed weight (WT), Grain yield per plant (GYP), Location(L), Block(B) and Accession (A).

Table 3 Analyses of variance for 14 traits of 77 field pea varieties in both location.

Description	Holeta	Debrezeit
DTE	8.26a	8.12b
DTF	54.53a	52.67b
DTM	113.10a	106.65b
GF	58.58a	53.97b
PPP	18.62a	7.59b
SPP	3.83a	3.42b
BPP	40.18a	32.88b
TBPP	65.00a	64.10b
HI	36.07a	25.04b
GPE	24.61a	19.68b
BPR	61.71a	55.03b
EGR	43.66a	28.02b

As shown below in table 4, Days to emergence (DTE) mean value ranged from 7-9 days, Days to flowering (DTF) stretched from 42 to 72 days, Grain filling period (GF) from 44-71, Pod per plant (ppp) from 3 to 30 and Seed per pod from 2-6 per plot .Days to maturity (DTM) ranged from 85-134.5(Figure 8).

Table 4 Standard deviation with maximum and minimum value of trait.

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM
DTE	8.192	0.3789	7.2	9.3
DTF	53.57	11.49	42.5	72
DTM	109.2	20.68	85	134.5
GF	56.26	9.5	44.5	70.9
PPP	13.12	3	8.5	26
SPP	3.61	0.48	2.5	5
BPP	36.33	9.99	12.1	56.7
TBPP	64.38	18.25	39.8	102.6
HI	30.6	6.04	16.7	45
GPE	22.45	8.38	11.3	42.7
BPR	58.33	7.59	43.9	77.1
EGR	35.29	10.67	7.8	59.4
WT	105.35	38.69	61	184.1
GYP5	20.9	8.92	6.4	40

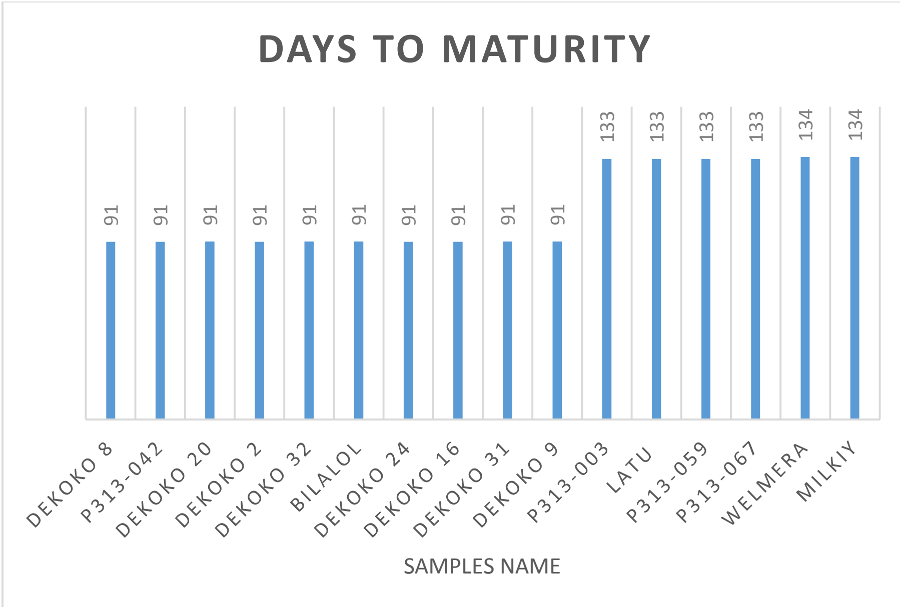


Figure 8. Graph that shows maturity date based on location mean

Grain yield of the evaluated samples location one ranged from 40.7 to 4.66 and in location two from 44.02 to 7.92. Their overall mean value ranged from 40.03 to 6.42 (Figure 9).

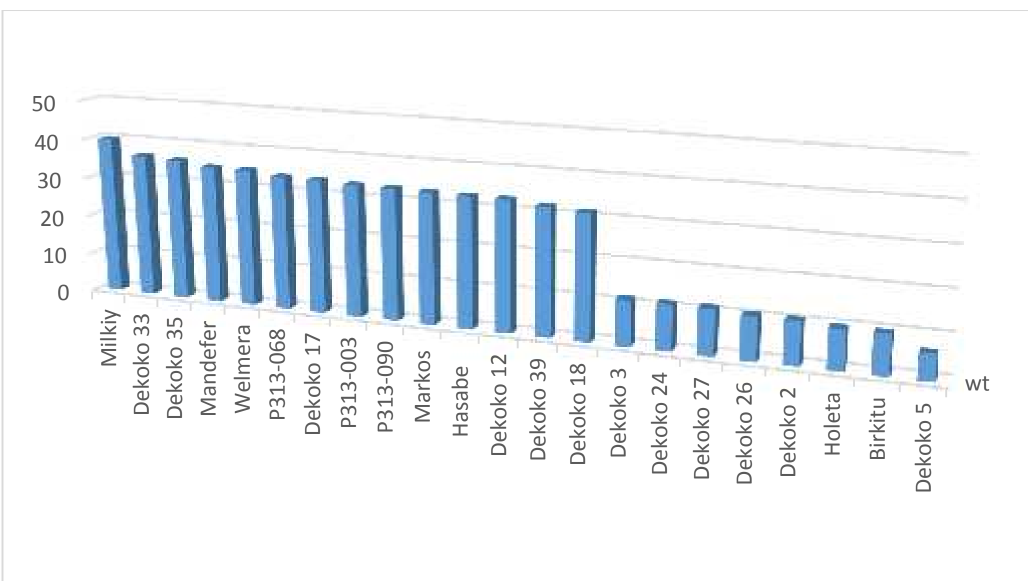


Figure 9. Yield production sequence

Leaves of DEKOKO type peas had alternate, pinnate, with one pair of leaflets, and also tendril (Figure 10). The edge of the leaf had toothed structure. When compared to the other leaves their size was smaller. The improved ones had alternate, pinnate, and 1-3 pair of leaflets. The edge of the leaf was smooth in structure. Some had more tendrils than leaves throughout.

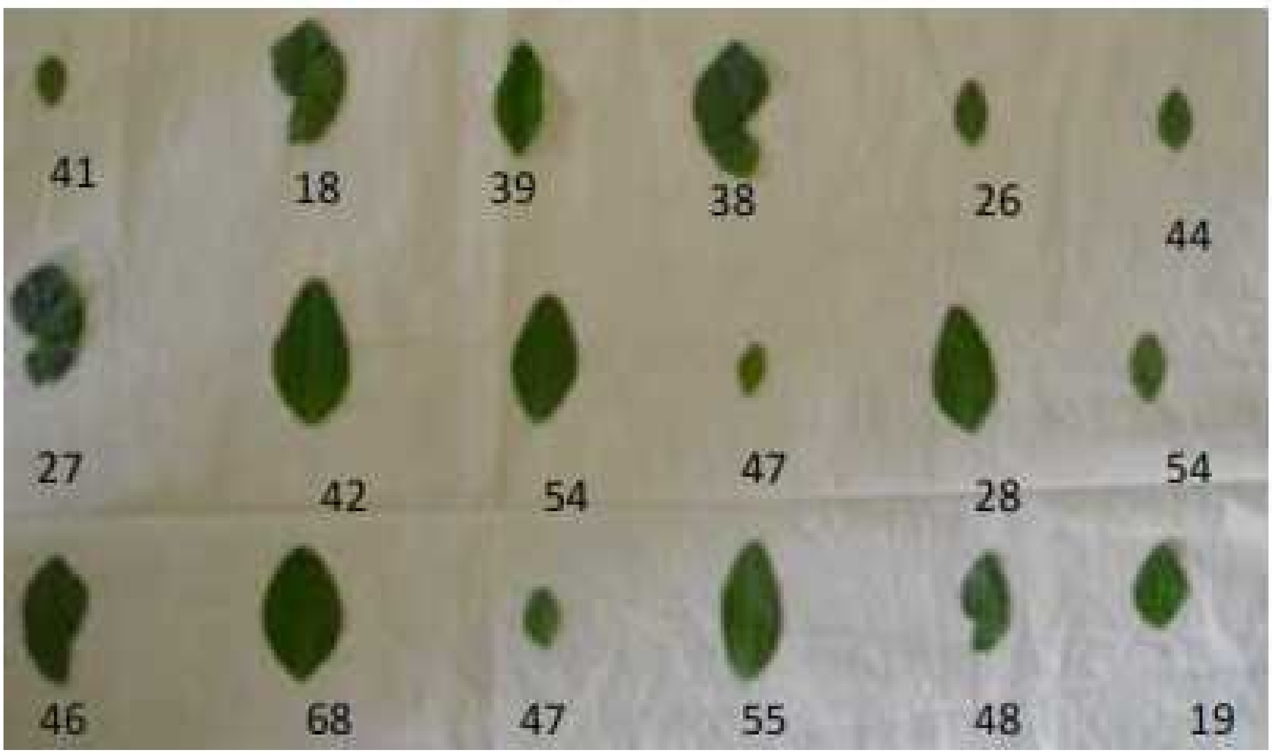


Figure 10. Partial view of leaf samples showing phenotypic diversity in leaf shape and size among the test field pea accessions (for names of the samples refer to table1).

As shown in the below figures by visual observation, it could be concluded that there were dissimilarity on plant ideotype, flower color, seed shape and seed color, leaf shape and size (Figure 11 and 12).

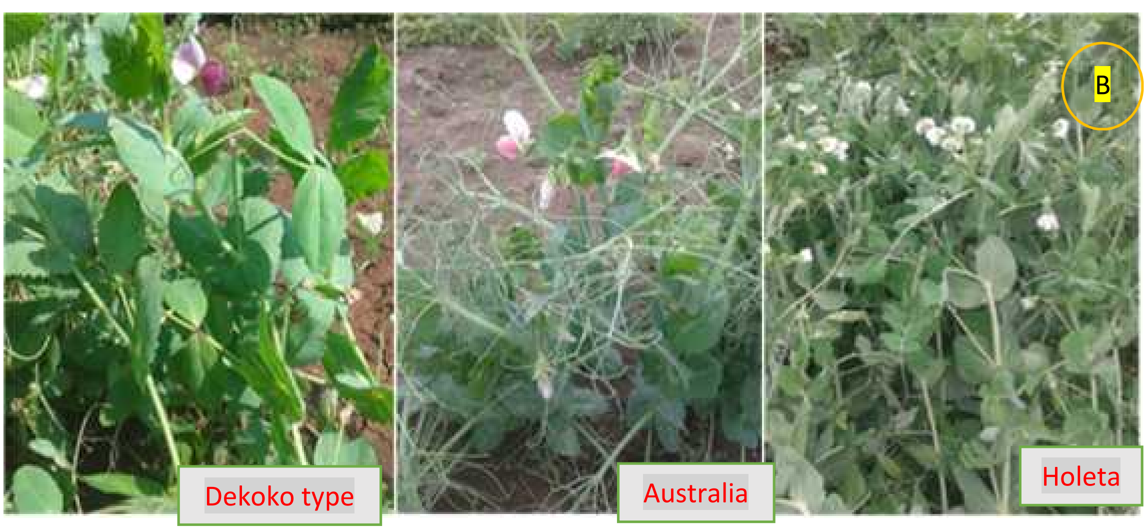
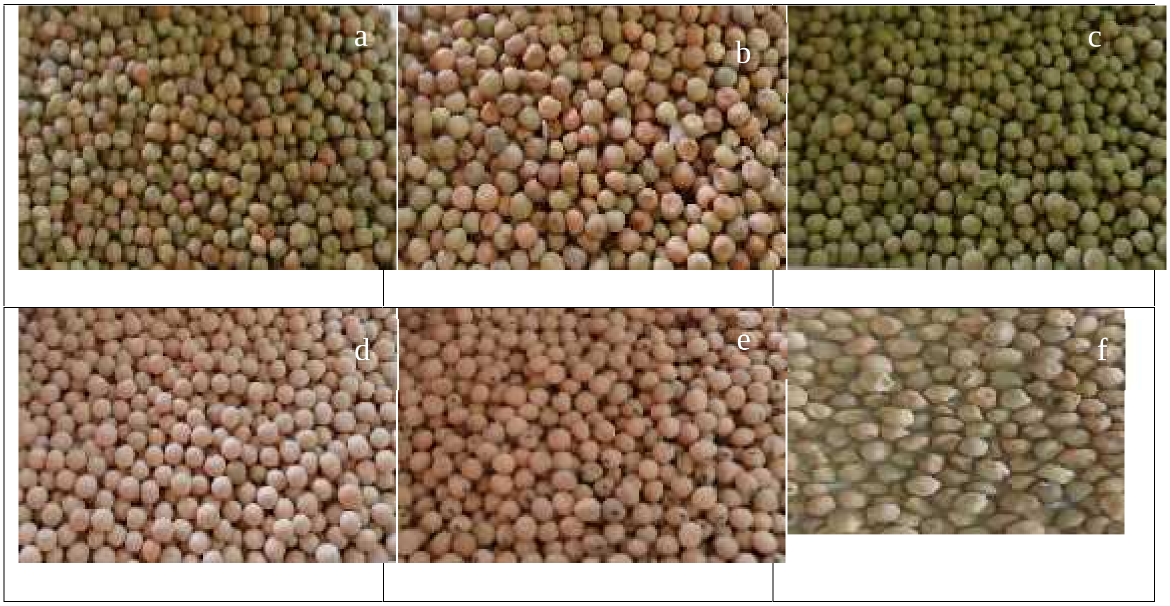


Figure 11. Partial view of flower samples showing phenotypic diversity in (A) flower color and size and (B) plant ideotype among the test field pea samples.



NB A. BURSA B. LATU C. MEGERI D. ADI E. GUME F. DEKOKO.

Figure 12. Showing phenotypic diversity based on seed color and size

4.2 Clustering of samples

4.2.1 Cluster based on traits

Phenotypic diversity of the 77 tested samples were distinguished in to 2 different groups based on behavior physiological traits (Days to emergence, Days to flowering, Days to maturity, Grain filling period, Pod per plant, Seed per pod, Biomass per plant, Total biomass per plant, Harvesting index, Growth production efficiency, Biomass production rate, Economic growth rate, Thousand Seed weight, Grain yield per plant) as shown in figure 13. Cluster C_1 was 56% from the total materials used and where most of them were landrace. Cluster C_2 was collection of released varieties and semi-leafless types, it accounted 46%. Across origin most of cluster C_1 was from South Tigray and North Wollo, which were the farmer's varieties (Table 5). Cluster C_2 was group of Holeta and Australia origin except few landraces.

Table 5. Grouping of 77 field pea samples into different diversity classes.

Cluster	Number of samples	Name of the samples in the cluster	Origin
C_1	43	2,8,9,14,20,21,26,29,33, 49,52,53, 58, 66, 69	South Tigray
		5,6,10,17,22,25, 34,35,36, 40,43, 54, 57, 61,62,63	North Wollo
		46, 48,51, 60, 65, 72	Introduced
		39, 42,56, 68	Holeta
		30,44	Alamata
C_2	34	1, 4, 11,12,13, 19, 24, 28,31,32, 15, 76	Holeta
		3, 7, 16,18, 23, 27, 38, 71, 73,74,75, 77,	Introduced
		45, 47, 50, 55,59, 67, 70,	South Tigray
		37, 41,64	North Wollo

As can be seen on table 6, Cluster C_1 had used short period of time for flowering and to be matured when compared to cluster C_2. Pod per plant and seed per pod was somehow relatively same. In this case, cluster C_2 plant biomass was higher and larger when it was compared to cluster C_1. On WT and GYP cluster C_2 was a collection of superior varieties.

Table 6. Cluster mean for fourteen characters in field pea samples.

	C_1	C_2	Grand Mean
DTE	8.1	8.3	8.2
DTF	43.5	66.3	54.9
DTM	91.6	131.5	111.5
GF	48.0	66.7	57.4
PPP	12.1	14.4	13.3
SPP	3.8	3.4	3.6
BPP	29.0	45.6	37.3
TBPP	49.7	83.0	66.3
HI	26.0	36.4	31.2
GPE	15.9	30.7	23.3
BPR	55.0	62.5	58.8
EGR	27.8	44.8	36.3
WT	73.5	145.6	109.6
GYP	13.6	30.1	21.9

Days to emergence (DTE), Days to flowering (DTE), Days to maturity (DTM), Grain filling period (GF), Pod per plant (PPP), Seed per pod (SPP), Biomass per plant (BPP), Total biomass per plant (TBPP), Harvesting index (HI), Growth production efficiency (GPE), Biomass production rate (BPR), Economic growth rate (EGR), Thousand Seed weight (WT) and Grain yield per plant (GYP).

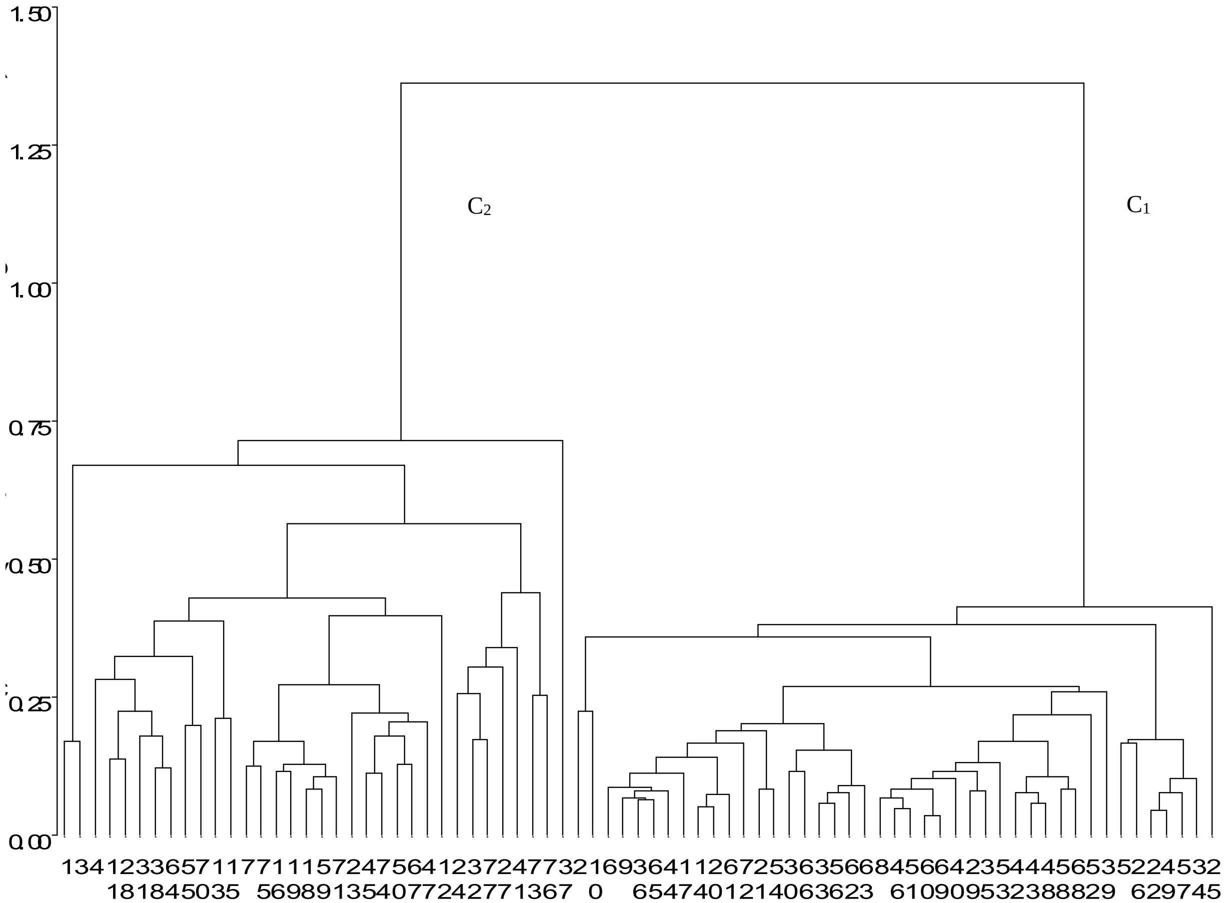


Figure 13. Dendrogram of forty three DEKOKO accessions and thirty four field pea genotypes based on examined traits

4.2.2 Distribution of clusters against samples

Cluster 1 consisted about 76% of the materials selected. It was group of 33 landrace varieties, 4 released and 6 semi-leaf less type, while cluster 2 contained 10 landrace varieties, 12 released and 12 semi-leaf less type (Table 7).10 landraces materials presented in C_2.

Table 7. Clustering pattern of field pea samples from different origins over two clusters

Origin	Number of samples	Number of samples in each cluster	
		C_1	C_2
Introduced	18	6	12
Burundi	1	1	0
India	1	0	1
Ethiopia, Holeta	14	4	10
Ethiopia, North Wollo	19	16	3
Ethiopia, South Tigray	22	15	7
Ethiopia, Alamata	2	2	0

4.3 Principle Component Analysis (PCA)

Principal component analysis (PCA) grouped the samples into two different classes alike to Cluster analysis (Appendix 2). It showed that both PCA_1 and PCA_2 accounts 77% from fourteen principal components. From the two Principal components, the first vector covered 68% PCA2, PCA3, PCA4, PCA5, PCA6 and PCA7 accounted for 8%, 6%, 5%, 4%, 2% and 1% sequentially. The other 7 vectors covered below one percent.

DTF, DTM, GF, BPP, TBPP, GPE, WT GYP had strong positive relation in PCA_1. For PCA_2 strong relation was on DTE, PPP, SPP and BPR. In PCA_1 EGR, HI, BPR, PPP, DTE and SPP were least contributors, where as in PCA_2, GF, BPP, DTM, HI, WT, DTF, EGR, TBPP and GYP successively smallest to higher (Table 8).

Table 8. Cumulative variances and eigenvectors on the first two principal components for fourteen characters in seventy seven samples.

Parameter	Principal component	
	PCA_1	PCA_2
Variance	68.82%	8.67%
Cumulative	68.82%	77.49%
Character	Eigenvectors	
DTE	0.13	0.44
DTF	0.30	-0.13
DTM	0.30	-0.17
GF	0.30	-0.19
PPP	0.15	0.43
SPP	-0.11	0.50
BPP	0.29	0.17
TBPP	0.31	0.09
HI	0.28	-0.16
GPE	0.30	-0.07
BPR	0.22	0.43
EGR	0.29	0.11
WT	0.29	-0.16
GYP	0.32	-0.03

Days to emergence (DTE), Days to flowering (DTE), Days to maturity (DTM), Grain filling period (GF), Pod per plant (PPP), Seed per pod (SPP), Biomass per plant (BPP), Total biomass per plant (TBPP), Harvesting index (HI), Growth production efficiency (GPE), Biomass production rate (BPR), Economic growth rate (EGR), Thousand Seed weight (WT) and Grain yield per plant (GYP).

4.4 Correlation

Based on the Pearson correlation fourteen traits were correlated positively and negatively to each other (Table 9). Days to emergence was correlated positively to all traits except seed per pod. Notably, it was greatly correlated to economic growth rate (0.44) and grain yield per plant (0.38). Days to flowering vastly correlated to days to maturity, grain filing period, total biomass per plant, harvesting index, thousand seed weight and grain yield per plant. Days to maturity was highly correlated to grain filling, total biomass per plant, thousand seed weight and grain yield per plant. Grain filling period was extremely correlated to total biomass per plant, thousand seed weight and grain yield per plant. Pod per plant was correlated to biomass per plant, total biomass per plant and biomass production rate.

Unlike to other traits, seed per plant correlated negatively. Seed per pod negatively correlated to days to maturity, grain filing period, growth production efficiency and grain yield per plant highly than others. Biomass per plant was correlated to total biomass per plant, grain yield per plant, growth production efficiency and biomass production rate highly. Harvesting index was greatly correlated to grain yield per plant and growth production efficiency. Growth production efficiency to thousand seed weight and grain yield per plant, biomass production rate to economic growth rate and grain yield, economic growth rate to grain yield per plant and thousand seed weight to grain yield per plant correlated highly with each other.

Table 9. Correlation coefficients among fourteen traits in 77 field pea samples.

	Characters													
Characters	DTE	DTF	DTM	GF	PPP	SPP	BPP	TBPP	HI	GPE	BPR	EGR	WT	GYP5
DTE	1.00													
DTF	0.35**	1.00												
DTM	0.34**	0.96**	1.00											
GF	0.30**	0.94**	0.94**	1.00										
PPP	0.30**	0.40**	0.39**	0.36**	1.00									
SPP	-0.04ns	-0.32**	-0.36**	-0.36**	-0.10*	1.00								
BPP	0.33**	0.82**	0.79**	0.82**	0.46**	-0.23*	1.00							
TBPP	0.38**	0.90**	0.88**	0.90**	0.47**	-0.30**	0.95**	1.00						
HI	0.33**	0.86**	0.84**	0.84**	0.26*	-0.28*	0.66**	0.80**	1.00					
GPE	0.31**	0.84**	0.84**	0.90**	0.38**	-0.35**	0.82**	0.91**	0.84**	1.00				
BPR	0.33**	0.50**	0.47**	0.49**	0.42**	-0.12ns	0.82**	0.80**	0.46**	0.64**	1.00			
EGR	0.44**	0.81**	0.76**	0.75**	0.34**	-0.17ns	0.77**	0.85**	0.88**	0.81**	0.68**	1.00		
WT	0.28*	0.90**	0.90**	0.93**	0.37**	-0.30**	0.79**	0.86**	0.81**	0.85**	0.49**	0.75**	1.00	
GYP	0.38**	0.92**	0.89**	0.91**	0.38**	-0.32**	0.85**	0.95**	0.92**	0.93**	0.68**	0.90**	0.88**	1.00

** = highly significant ($P < 0.01$), *=significant ($p < 0.05$), ns=not significant , Days to emergence (DTE), Days to flowering (DTE), Days to maturity (DTM), Grain filling period (GF), Pod per plant (PPP), Seed per pod (SPP), Biomass per plant (BPP), Total biomass per plant (TBPP), Harvesting index (HI), Growth production efficiency (GPE), Biomass production rate (BPR), Economic growth rate (EGR), Thousand Seed weight (WT) and Grain yield per plant (GYP).

4.5 Mineral composition of field pea samples

Samples were analyzed by following steps in method section and demonstrated different value for all nutrients that was analyzed (Table 10).

Table 10. Mineral composition (ppm).

No	Sample name	Ca	Cu	Fe	K	Mg	Mn	P	Se	Zn
1	GUME	523	7.3	44	9598	1001	6.9	3850	0.21	10.8
2	DEKOKO 26	986	7.2	67	14319	1710	10.6	5739	0.09	12.7
3	P313-010	851	6.7	52	13129	1369	9.3	4565	0.10	11.3
4	Ek08023-1	725	8.8	52	12330	1432	8.0	4931	0.14	15.2
5	DEKOKO 9	1007	7.8	56	13225	1689	9.1	5541	0	14.1
6	DEKOKO 7	946	7.6	52	14474	1892	10.3	6233	0	14.9
7	P313-027	1288	7.4	42	13786	1404	5.9	5260	0	12.9
8	DEKOKO 40	1208	7.3	59	15935	2024	11.2	7182	0	20.5
9	DEKOKO 31	875	8.7	54	13789	1942	9.0	5804	0	19.2
10	DEKOKO 2	1130	9.2	57	12814	1845	9.8	5901	0	17.0
11	ADI	855	8.3	62	11486	1417	6.2	5341	0	22.1
12	WOLMERA	982	7.3	45	10919	1390	5.3	5220	0	18.2
13	MILKIY	874	7.0	52	12913	1457	7.2	5064	0	12.3
14	DEKOKO 30	704	7.6	48	13395	1680	8.7	5624	0	13.6
15	MOHANDERFER	917	8.2	64	11112	1457	6.9	4972	0	19.4
16	P313-082	653	9.3	61	11782	1759	7.1	5656	0	18.0

17	DEKOKO 8	612	8.9	53	12332	1489	8.5	5034	0	13.7
18	P313-067	729	9.3	64	10589	1455	5.8	4923	0	13.4
19	LATU	654	9.1	46	9405	1406	5.9	3988	0	12.8
20	DEKOKO 34	788	7.2	51	13376	1780	9.1	5672	0	16.6
21	DEKOKO 25	986	7.0	53	13563	1810	11.2	5834	0.01	17.6
22	DEKOKO 4	807	9.4	54	12103	1652	8.8	5089	0	15.2
23	P313-086	758	8.7	42	12307	1474	7.8	4970	0	14.7
24	G22 763-2c	712	7.2	43	9897	1327	5.6	4233	0	14.4
25	DEKOKO 5	932	9.3	84	12490	1736	10.1	5505	0.03	25.4
26	DEKOKO 13	703	9.1	44	12155	1596	8.1	4910	0	16.4
27	P313-090	724	10.5	50	10958	1304	6.6	4964	0	20.7
28	BURSA	566	12.6	61	11822	1567	6.2	5933	0	21.8
29	DEKOKO 14	751	6.0	61	13850	1780	11.9	5794	0.03	17.6
30	RAYA 1	805	5.8	55	13491	1693	9.4	5512	0	17.8
31	MARKOS	514	7.8	61	11918	1410	7.0	5002	0	14.4
32	MEGERI	777	10.9	71	14821	1875	8.5	6520	0.56	17.6
33	DEKOKO 41	728	7.3	46	11734	1356	5.8	4686	0.37	18.2
34	DEKOKO 6	805	6.0	49	13608	1569	9.8	5609	0	16.5
35	DEKOKO 19	809	6.4	150	12273	1745	10.5	5441	0	15.7
36	DEKOKO 21	903	8.1	51	14584	1776	10.6	5809	0.04	13.8
37	DEKOKO 18	710	7.6	46	12685	1502	8.1	4948	0	12.1
38	P313-068	748	7.9	47	13404	1577	6.8	4948	0	10.8

39	TEGENECH	792	5.2	37	11666	1245	6.8	4007	0.18	9.9
40	DEKOKO 3	781	7.4	53	12377	1413	9.4	4462	0.35	15.0
41	DEKOKO 43	785	6.7	47	11155	1690	10.0	4794	0.46	21.1
42	HOLETA	399	4.1	37	7389	945	4.5	3121	0.25	14.1
43	DEKOKO 42	759	6.1	51	12221	1499	10.8	5213	0.28	18.4
44	RAYA 2	719	7.7	64	12004	1545	12.4	5000	0.74	19.1
45	DEKOKO 36	828	6.3	75	12754	1570	13.8	5408	0.89	15.2
46	P313-045	661	5.8	50	10749	1222	7.5	4664	1.24	16.3
47	DEKOKO 12	754	5.6	52	12097	1554	9.9	5080	0.68	20.8
48	P313-070	707	10.0	52	11796	1451	7.2	5261	0.31	16.8
49	DEKOKO 23	722	5.7	40	14362	1498	8.1	5089	0.30	17.4
50	DEKOKO 11	1058	6.3	208	16435	1456	10.0	4372	0.24	12.5
51	P313-071	650	11.5	67	11520	1494	7.4	5483	0.34	25.1
52	DEKOKO 15	966	6.0	42	15299	1635	9.0	5888	0.44	20.9
53	DEKOKO 24	915	6.3	50	14536	1658	8.8	5240	0.36	18.2
54	DEKOKO 16	1052	6.7	51	18187	1977	8.2	6034	0.43	17.5
55	DEKOKO 33	1040	5.6	39	15869	1487	6.9	4744	0.27	12.9
56	BILALOL	1032	8.2	50	13431	1519	5.9	4943	0.39	24.6
57	DEKOKO 1	600	5.2	55	11754	1342	11.2	4431	0.92	17.6
58	DEKOKO 27	845	5.9	44	11774	1405	8.1	4355	0.25	11.5
59	DEKOKO 22	1181	4.7	317	13883	1801	13.2	5097	0.22	11.4
60	P313-042	800	7.8	43	12164	1345	7.9	4643	0.34	12.3

61	DEKOKO 29	893	11.7	44	12594	1505	9.0	4461	0.25	17.3
62	DEKOKO 10	779	6.6	46	12378	1551	8.1	4458	0.23	12.0
63	DEKOKO 20	835	7.1	61	14341	1711	10.4	5044	0.42	13.7
64	DEKOKO 17	897	8.5	55	14035	1840	11.5	5466	0.42	13.4
65	P313-053	646	10.9	57	13799	1455	8.3	5594	0.58	14.4
66	DEKOKO 37	1007	6.3	52	12014	1671	9.8	4970	0.28	14.3
67	DEKOKO 39	801	9.7	56	12909	1658	11.1	5449	0.21	15.0
68	BIRKITU	899	11.5	230	11534	1430	7.7	5851	0.70	19.9
69	DEKOKO 32	770	6.6	62	12097	1529	10.9	5522	0.68	22.4
70	DEKOKO 35	819	7.6	49	10766	1425	9.5	5284	0.40	14.2
71	P313-059	1153	8.2	51	9757	1083	7.9	4676	0.22	13.2
72	P313-046	517	11.5	59	9719	1168	5.9	5227	0.52	14.5
73	P313-003	724	8.2	45	10587	965	7.0	4519	0.47	14.5
74	P313-061	1034	6.1	33	10457	937	6.5	4465	0.58	15.0
75	P313-026	634	11.0	67	10775	1167	7.0	5450	1.42	21.7
76	HASABE	736	9.9	65	12274	1330	6.8	5959	0.53	21.3
77	P313-089	618	8.6	48	12218	1091	8.1	5239	0.35	15.2

For Ca, DEKOKO 40 and P313-027 had scored top from all samples used which was 1288 and 1208 ppm. DEKOKO 43 and MARKOS noted that they were the lowest with the value of 399 and 514 ppm. For Cu Bursa and P313-042 had the highest value which was 12.6 and 11.7 ppm individually. The lowest concentration of Cu was recorded by DEKOKO 43 and

DEKOKO 27 4.1 and 4.7 ppm respectively. For Fe, DEKOKO 27 and DEKOKO 39 had peak value of 230 and 317ppm and P313-061and P313-068 had bottom value which was 33 and 37 ppm. DEKOKO 16 and DEKOKO 11 was top varieties having 18,187 and 16,435 ppm of K nutrient. DEKOKO 43 and LATU noted that they were lowest. Mg nutrient was highest on DEKOKO 40 and DEKOKO 16 and DEKOKO 43 and P313-061 were the lowest had value of 2024, 1977, 945 and 937 ppm. For Mn, DEKOKO 27 and RAYA 2 had ultimate value of 13.2 and 13.8 ppm DEKOKO 43 and WOLMERA and had bottom value which was 4.5 and 5.3 ppm. P was in high concentration on DEKOKO 40 and MEGERI and in low concentration in DEKOKO 43 and GUME with the value of 7182, 6520, 3121 and 3850 ppm sequentially. Varieties, which was from Australia, P313-026 and P313-045 scored top of 1.42 and 1.24 ppm for concentration of Se besides P313-090 and MARKOS scored bottom -0.40 and -0.38 (Table 11).

Table 11 highest two samples for each nutrient was

Nutrient	Samples
Ca	P313-027, DEKOKO 40
Cu	BURSA, DEKOKO 29
Fe	DEKOKO 22, BIRKITU
K	DEKOKO 16, DEKOKO 11
Mg	DEKOKO 40, DEKOKO 16
Mn	DEKOKO 36, DEKOKO 22
P	DEKOKO 40, MEGERI
Se	P313-026, P313-045
Zn	DEKOKO 5, P313-071

4.5.1 Cluster based on nutrient concentration

The samples were grouped in to 3 different groups based on mineral concentration (Figure 15). Cluster C_1 accounted 89% from the total materials used. Cluster C_2 and C_3 were recorded about 11%. Holeta variety was the one in C_3. All the samples from Australia was grouped in C_1. Landrace varieties was clustered in C_1 excluding six samples (Table 12). In cluster 1 peak result were on Cu and Mn concentration, where as in cluster 2 it were on Ca, Fe, K, Mg, Mn, Se, P and Zn. Low concentration of Ca, Cu, Fe, K, Mg, Mn, P and Zn was showed in cluster 3 (Table 13). K and P mineral concentration was higher than the others (Figure 14).

Table 12. Distribution in cluster

Origin	Number of samples	Number of samples in each cluster		
		C1	C_2	C_3
Australia	18	18	0	0
Burundi	1	1	0	0
India	1	1	0	0
Ethiopia, Holeta	14	12	1	1
Ethiopia, North Wollo	19	17	2	0
Ethiopia, South Tigray	22	18	4	0
Ethiopia, Alamata	2	2	0	0

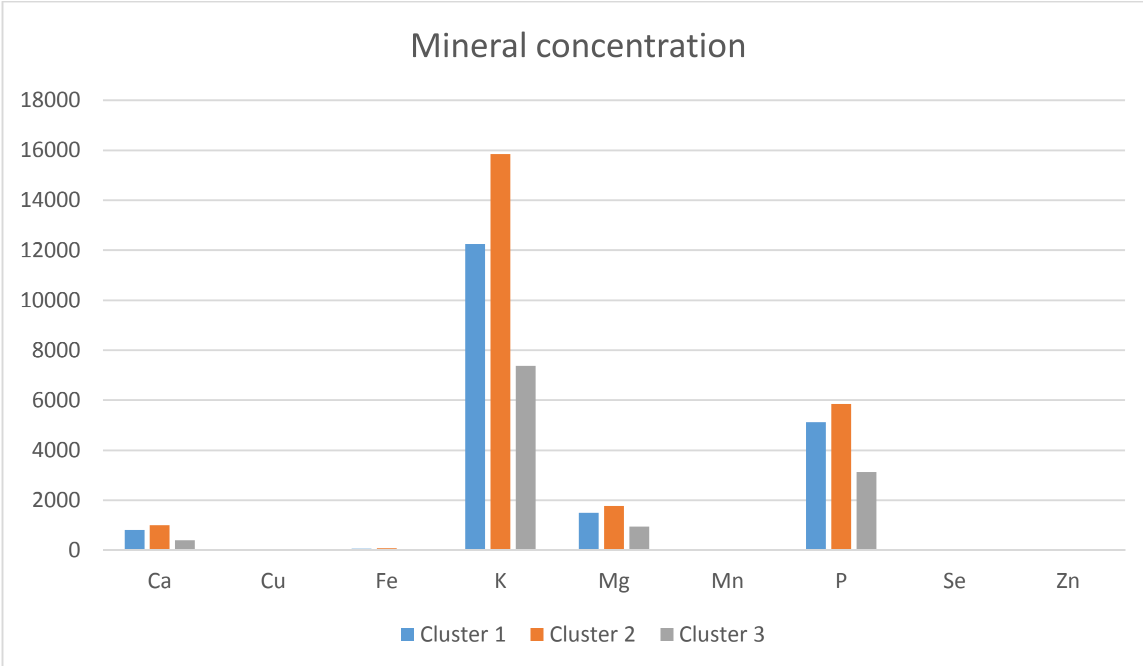


Figure 14 Graph based on mineral concentration clusters

Table 13. Cluster mean on base of mineral concentration

	Cluster 1	Cluster 2	Cluster 3
Ca	803	1007	399
Cu	8	7	4
Fe	61	75	37
K	12256	15860	7389
Mg	1497	1764	945
Mn	9	9	5
P	5117	5853	3121
Se	0.25	0.28	0.25
Zn	16	17	14

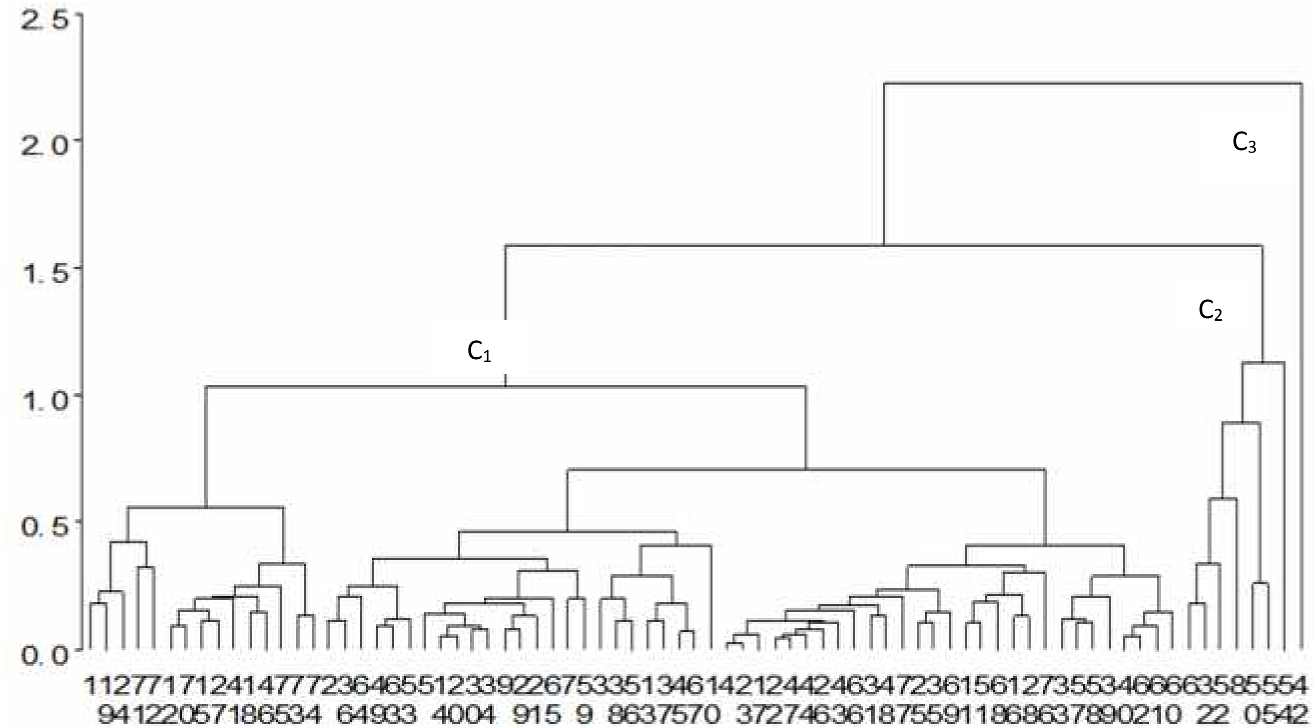


Figure 15. Dendrogram of samples based on mineral concentration

4.5.2 Correlation of nutrients

Nutrients had relation positively or negatively in the result of analysis by being highly significant ($p<0.01$), significant ($p<0.05$) and not significant ($p\geq0.05$). As can be seen below, there was positive strong relation ($p < 0.01$) between Ca with K, Mg, Mn, and P, Cu with P and Zn, Fe with Mn, K with Mg, Mn and P, Mg with Mn and P and P with Zn (Table 14). There were also nutrients which didn't had any relationship for instance Ca with Cu, Se with Zn, Mn with Se and Mg with Zn.

Table 14. Correlation of nutrients

	Characters								
Characters	Ca	Cu	Fe	K	Mg	Mn	P	Se	Zn
Ca	1.00								
Cu	-0.22ns	1.00							
Fe	0.26*	-0.01ns	1.00						
K	0.53**	-0.16ns	0.16ns	1.00					
Mg	0.41**	0.00ns	0.17ns	0.71**	1.00				
Mn	0.29**	-0.28*	0.32**	0.47**	0.58**	1.00			
P	0.32**	0.31**	0.12ns	0.57**	0.70**	0.38**	1.00		
Se	-0.11ns	-0.08ns	0.10ns	-0.06ns	-0.28*	0.20ns	-0.08ns	1.00	
Zn	-0.01ns	0.31**	-0.02ns	0.01ns	0.19ns	0.02ns	0.43**	0.21ns	1.00

4.6 Susceptibility to disease

Around study area powdery mildew and ascochyta disease was there. It was scaled using (1-9) on the field. The prevalence of powdery mildew was high in Debrezeit field relatively than Holeta. The level of occurrence was smaller at the time of pod setting (Table 15). As the time past, manifestation been vast from the root to 5 to 6 nod (Figure 16).

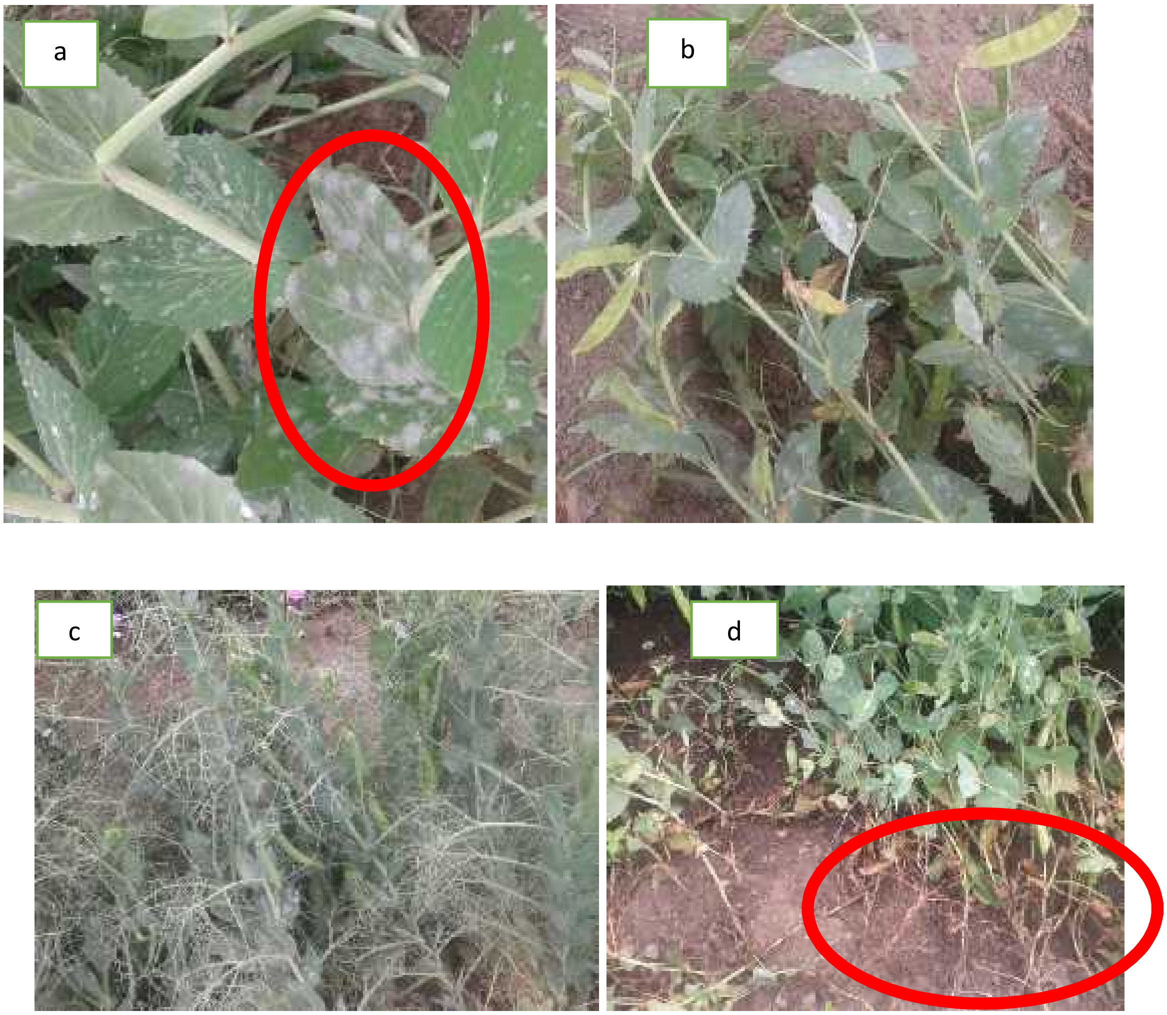


Figure 16. Powdery mildew (a, b & c) and ascochyta (d) disease occurrence and prevalence

The result showed that RAYA1, DEKOKO 41 and DEKOKO 15 was the most resistant samples from 77 samples for both powdery mildew and ascochyta blight with using 1-9 scale. DEKOKO 22, DEKOKO 11, DEKOKO 35, DEKOKO 18, MEGERI, and P33-067were susceptible for powdery mildew. From all samples that were tested, DEKOKO 32, P313-082, DEKOKO 22, DEKOKO 17, DEKOKO 18 and DEKOKO 12 were susceptible.

Table 15. Scale rating for disease examined.

Rating Scale	Ascochyta Blight	Powdery Mildew
1-3 (Resistant)	31,1	62,54,26,2,58,20,36,8,9,29,21,15,61,39,14,46,22,44,30,48,34,52,42,43,40,6,17,60,33
4-6(Moderately Resistant)	69,16,59,64,37,47,18,62,25,10,51,48,45,50,71,63,20,6,73,28,41,14,35,56,61,26,55,74,21,68,43,12,29,22,67,36,5,70,23,8,19,2,44,54,72,34,76,58,32,42,65,17,39,49,11,57,7,9,27,4,77,38,3,40,53,66,75, 52,33,46,13,60,15,30,24	73,7,77,47,16,75,71,64,4,23,3,27,76,28,69,45,19,12,41,67,11,74,65,31,35,38,10,66,72,68,24,56,49,1,53,25,13,57,5,63,55,51
>6 (Susceptible)		59,50,70,37,32,18

4.6.1 Correlation of traits with diseases

Ascochyta blight and powdery mildew had positive, negative, strong and weak relation with other traits. Ascochyta blight with powdery mildew had significant positive relation. Ascochyta blight hadn't relation with days to maturity (Table 16). Nonetheless, powdery mildew had positive strong relation with days to maturity. Ascochyta blight hadn't relation with pod per plant, seed per pod, total biomass production per plant, thousand seed weight and grain yield per plant but with grain filling period had significant relation. Powdery mildew had positive strong relation with grain filling period, total biomass production per plant, thousand seed weight and grain yield per plant. On the other hand powdery mildew hadn't have relation with pod per plant and seed per pod (Appendix 6).

Table 16. Correlation of disease with Days to maturity

CHARACTERS	CHARACTERS		
	AB	PW	DTM
AB	1.00		
PW	0.29*	1.00	
DTM	-0.047^{ns}	0.61**	1.00

Ascocayta blight (AB), powdery mildew (PW) and days to maturity (DTM)

CHAPTER FIVE

5. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

5.1.1 Phenotypic diversity

The yield variation is also comes from sample environment interaction, it was highly significant. As Gemechu Keneni (2012) and Tamene Tolessa *et al*. (2013) reported, crop samples grown in different environments would frequently encounter significant fluctuation in yield performance, particularly when the growing environment are markedly different, the test samples respond to changes in the growing environment or both. In other words if two locations were distinctly different, for some of the characters and that better samples at one location may not also be better performing at another. But landraces have well structural and functional fitness to survive and reproduce under harsh environment than the improved samples (Gemechu Keneni, 2012).

5.1.2 Cluster of samples

The 77 samples was clustered in two clusters. Landrace samples were grouped in C_1 except few outlier samples by way of Martin-Sanz *et al*. (2010).

DEKOKO can mature with in few days than other varieties (Ater). The other character of DEKOKO is having low yield production and lower seed volume and seed weight than the common field pea, 'Ater' like that of Haddis Yirga *et al*. (2013) and Berhane Gebreslassie & Berhanu Abraha (2016). The local accessions were also more closely related among themselves than with the introductions from foreign sources for both symbiotic and agronomic characters.

It is not possible, to find out a single sample combining all desirable characters. Recombining and selection of useful genes is mandatory to increase production (Gemechu Keneni, 2012). Parents with one or more of the desired characters can be chosen from the sources grouped in this study, based on not only group performance, but also on performances of individual accessions for specific traits will be selected.

5.1.3 Principal Component

Normally it is assumed that characters with larger eigenvector values closer to unity within the first principal component influence the clustering more than those with lower values closer to zero (Gemechu Keneni *et al*., 2013). Resembling to Gemechu Keneni *et al*. (2013) and Ouafi *et al*. (2016) the first PCA accounted more result based on days to flowering, days to maturity, grain filling period, biomass per plant, total biomass per plant, total biomass per plant, harvesting index, grain production efficiency, thousand seed weight and grain yield per plant . The second component was great eigenvalue on days to emergence, pod per plant, and seed per pod and biomass production rate.

5.1.4 Correlation

Days to maturity was correlated to all positively like that of Teshome Legese (2010) except seed per pod. Negative direct effect exerted on seed yield by number of seed per pod like that of Million Fikreselassie (2012).

Total biomass per plant and thousand seed weight seems (r= 0.95) related. As high total biomass per plant was there, high grain yield will be produced. Pod per plant, biomass per plant, and harvest index towards seed yield plant and concluded their originality as yield components (Teshome Legese, 2011). An overall analysis of path coefficient suggested that selection should be made for plants with high biomass yield followed by harvest index to increase seed yield on field pea.

5.1.5 Chemical Composition of Field Pea

While field pea have different nutrients, the content vary from nutrient to nutrient and samples to samples. Variation in chemical composition was due to variety, soil and climatic conditions (Danilovic and Soltysova, 2010). Like that of Harmankaya *et al*. (2010) Fe found in all samples by ranging from 33-317ppm. Ca, which have value for bone and teeth strength, was 339-1288ppm. Cu from 4.1 to 12.6 ppm, K from 7389-18187ppm, Mg starting from 937 to 2024ppm, P up to 7182ppm and Se up to 1.42 was found. Zn from 9.9 to 25.9 ppm. There was positive correlation Ca and K, Mg and P, Ca with P, P with Mg similar to Harmankaya *et al*. (2010).

Field pea samples which were analyzed had high Fe and P than chickpea. When the samples was compared to lentil and faba bean, it had high Ca, Fe and P (EHNRI, 1997).

Farmer's varieties had high concentration of Ca, Fe, K, Mg, P and Mn than improved and introduced ones. Therefore it is important to evaluate the nutritional quality of locally grown cultivars of pea (Talat *et al*., 1988).

5.1.6 Disease Prevalence

As reported on Seid (2015) field pea is host for powdery mildew and ascochyta blight. Infestation of powdery mildew on Debrezeit was vast and high in stage. Infestation depends mainly on environment (Mulusew Fikere, 2010). The powdery infestation favors in Debrezeit than Holeta. Unlike to Mulusew Fikere (2010) powdery mildew and ascochyta blight had significant association with each other. Starting at landrace samples RAYA 1, DEKOKO 41 and DEKOKO 15 was best to resist diseases than others particularly to powdery mildew, since DEKOKO has novel genes to control and resistance (Berhane Gebreslassie & Berhanu Abraha, 2016). The result showed disease had interfered on yield production. This result was also alike to Mulusew Fikere (2010) and Teklay Abebe (2014).

After pea harvest powdery mildew pathogens and blight causing fungus may survive as colonies on volunteer pea plants, on alternative hosts or as resting states on plant debris until the next season (Zaumeyek, 1962, Nilimini, 2008 and Attanayake *et al*., 2010). Attributable to this fact the harvested field pea was put in refrigerator.

5.2 Conclusion

Differences were observed on leaf sizes, flower colors and seed colors of field peas. Among environments, varieties and locations there was significant variation. Landraces grouped in one cluster by having same character and released and semi-leaf less samples groped in the other cluster. Days to flowering, days to maturity, grain filling period, biomass per plant, total biomass per plant, total biomass per plant, harvesting index, grain production efficiency, thousand seed weight and grain yield per plant had high contribution for the grouping in principal component analysis.

Ca, Fe, K, Mg, P and Mn concentration was high in Farmer's varieties. Cu, Se and Zn was high in the remaining ones. For Ca P313-027, Cu BURSA, Fe DEKOKO 27, K DEKOKO 24, Mg and P DEKOKO 40, Mn RAYA 2, Se P313-026 and Zn DEKOKO 5 were top for each nutrient. Disease prevalence was scaled and RAYA 1, DEKOKO 41 and DEKOKO 15 were the best in resistance to diseases like ascochyta blight and powdery mildew.

5.3 Recommendations

Based on the results of this study, the following recommendations are made for future work.

- The DEKOKO genotypes are early genotypes to mature and can be used in drought prone areas or can be used in double cropping.
- The study was based on phenotypic diversity but if molecular attributes can be included more information can be obtained.
- Nine nutrients were analyzed in the study, but other micronutrient (Na, I, Mo and Co), vitamins and amino acid contents could be done for the future.
- Lines (raya1, dekoko 41 and dekoko 15) that can resist to diseases like ascochyta blight and powdery mildew could be used in breeding programs.
- The samples can be used for sources for different desirable agronomic practices (landrace accessions) and nutritive traits (dekoko 40, dekoko 22 and dekoko 16).

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Appendices

Appendix 1.Combined analyses of variance for 14 traits of 77 field pea varieties tested using RCBD at Debrezeit in 2016/17.

no	Name of samples	DTE	DTF	DTM	GF	PPP	SPP	BPP	TBPP	HI	GPE	BPR	EGR	WT	GYP5
1	Gume	7.33bc	68fghi	134bcd	65.3bcd	25cd	2cd	24.17bcdef	58.28xyz	27.74g	15.46i	43.60k	24.77e	168.22a	16.18bc
2	Dekoko 26	7.67bc	39nopq	85ghij	46.7klmn	20hijkl	4abcd	21.69efghi	48.74ijk	34.42abvwxyz	20.25cdefg	57.12abc	35.94abxyz	136.40bcdef	16.77ab
3	P313-010	9ab	68ghij	134abcd	66.7b	6jklm	4abcd	41.07efgh	71.18j	32.29bcde	24.55rstuvwx	57.45abcz	37.37stuvwxyz	187.01cdefg	24.92pqrs
4	Ek08023-1	7.67bc	66jk	131e	65.7bcd	24cdef	2cd	31.68opqrstu	68.35pq	37.79hijklmnop	25.83opqrstu	52.05ghi	50.87efg	140.193bcd	25.8333mnopq
5	Dekoko 9	8.67ab	39nop	84ij	45mno	22defghi	5a	29.01qrstuvwx	58.41xyz	32.47abcde	21.71abcdyz	68.27jk	29.7rs	83.93abcdxyz	18.9667yz
6	Dekoko 7	6.33c	38nopqr	85hij	46.3klmno	20hijkl	3abcd	28.73aqrstuvwxyz	58.10axyz	29.57fg	20.77bcd	68.63jk	37.09tuvwxyz	86.44abcstuvwxyz	17.1833ab
7	P313-027	7.33bc	76b	133bcde	56.7ij	14uvw	4abcd	38.08fghijkl	72.62mn	37.48ijklmnop	20.12cdefgh	54.47def	48.03ghi	121.68efghijk	27.2133ijklm
8	Dekoko 40	8abc	38nopqr	85ghij	46.7klmn	14tuvw	3abcd	19.31hi	45.27m	32.76abcdez	18.06fgh	53.25efgh	31.77cd	59.13f	14.83cd
9	Dekoko 31	7.67bc	38nopqr	84ij	46klmno	23defg	4ab	31.24qrstuv	63.96st	35.13qrstuvwxy	26.96jklmnopqr	75.85ef	10.45def	89.20abstuvwxyz	22.47uv
10	Dekoko 2	8.33ab	38nopqr	84ij	46klmno	13vw	3abcd	21.06ghi	46.55lm	32.67abcdez	18.25efgh	55.19cde	33.05abc	125.93cdefghi	15.2cd
11	Adi	9.67a	69efgh	133bcde	64bcde	20hijkl	2d	40.07efghijk	79.44i	42.34cd	31.05defg	59.58tuvwxyz	52.55ef	134.58bcdefg	33.63cd
12	Wolmera	7.67bc	72cd	136a	64.7bcd	29ab	2cd	40.65efghi	82.44gh	38.38ghijkl	28.55hijklm	60.47rstuvwxy	48.94fgh	126.24cdefghi	31.64fg
13	Milkiy	8.67ab	70defg	136a	66.7b	26bc	3abcd	46.96bc	92.96d	43.16bc	38.40b	68.19kl	60.18bc	136.33bcdef	40.12b

14	Dekoko 30	7.67bc	38nopqr	85hij	46.3klmno	15qrstuv	4abcd	28.08abstuvwxyz	57.05ayz	33.37abcxyz	23.02abvwxyz	67.38kl	41.09nopqrs	86.60abcdvwxyz	19.0367yz
15	Mohanderfer	8.33ab	68fghi	133bcde	65cbd	30a	3abcd	41.25efgh	84.07fg	36.58klmnopqrstuv	29.25efghijk	63.05nopq	47.31ghij	141.67bc	30.7533g
16	P313-082	8.67ab	66ijk	132de	66bcd	20hijkl	3bcd	37.96ghijkl	77.04j	34.74arstuvwxyz	26.63klmnopqr	58.22abzy	42.55opqrst	102mnopqrstuvw	26.7667ijklmn
17	Dekoko 8	8.33ab	36r	84j	47.7klm	18klmnop	4abc	27.72abuvwxyz	51.85defg	36.73klmnopqrstu	24.99pqrstuv	61.73nopqrst	39.96pqrstu	97.52pqrstuvwyz	19.0467yz
18	P313-067	8.33ab	68fghi	135abc	66.3bc	16qrstuv	3abcd	36.28jklm	63.03tuv	34.49abtuvwxyz	21.11abcd	46.80j	32.78bcd	107.50jklmnopq	21.74vw
19	Latu	7.33bc	65k	135ab	70a	21ghijk	3abcd	34.14lmno	58.97xy	41.91cde	26.48lmnopqr	43.57k	35.30abcxyz	109.13ijklmnop	24.71pqrs
20	Dekoko 34	8.67ab	40mno	84ij	44.7no	16qrstuv	3abcd	27.83abtuvwxyz	52.82bcde	34.23abvwxyz	20.36cdef	62.62nopqr	40.48opqrst	87.56abcuvwxyz	18.08az
21	Dekoko 25	8abc	39nopq	85ghij	46.klmn	12w	4abc	30.86opqrstuvw	56.19a	47.79a	32.42cd	65.84lm	57.56c	67.64def	26.85ijklm
22	Dekoko 4	7.67bc	40mno	85hij	45mno	19jklmno	3abcd	26.75abcdefyz	49.91hij	34.52abtuvwsyz	19.55defgh	58.95avwxyz	38.29qrstuvwx	76.93abcdef	17.227ab

23	P313-086	8.33ab	70defg	135ab	65.7bcd	20hijkl	4abcd	32.84mnopq	65.33s	38.34ghijklm	23.61tuvwxyz	48.28j	38.16qrstuvwx	112ijklmnop	25.053opqrs
24	G22 763-2c	8.33ab	74c	134bcd	60gh	28ab	3abcd	37.94hijkl	68.04q	38.73ghijk	21.46abcdz	50.90hi	43.92jklmno	102.63mnopqrstu	26.3467lnmo
25	Dekoko 5	7.67bc	39nopq	86fghij	47klmn	21ghij	4ab	17.99i	34.93n	22.67h	26.63klmnopqr	40.78l	16.86f	89.70aqrstuvwxyz	7.92e
26	Dekoko 13	7.67bc	39nop	87fg	47.7klm	15rstuv	4ab	21.39fghi	46.93klm	35.94nopqrstuvw	20.42cdef	53.98defg	35.37abcxyz	84.15bcdwxyz	16.853ab
27	P313-090	9ab	67hijk	132de	65bcd	14stuvw	3abcd	28.76aqrstuvwxyz	67.29qr	38.53fghijk	25.04pqrstuv	50.85i	48.27gh	96.73pqrstuvwxyz	25.93lmnop
28	Bursa	7.33bc	69efgh	132de	63.7cdef	14stuvw	2cd	42.15efd	74.23lm	32.56abcdez	22.40abcxyz	56.09bcd	37.96qrstuvwx	107.29jklmnopq	24.1667rst
29	Dekoko 14	7.33bc	38nopqr	87fgh	48.3k	15rstuvw	4abc	30.25opqrstuvw	53.01bcd	37.81hijklmnop	25.27opqrsttuv	61.17pqrstuv	41.47mnopq	70.87cdef	20.0433xy
30	Raya 1	9.67a	40mn	86fghij	45.3lmno	24cdef	4ab	28.61arstuvwxyz	51.99def	31.10cdef	18.17efgh	60.69qrstuvwxyz	35.69abwxyz	104.34lomnpqrs	16.17bc
31	Markos	8.33ab	70def	134bcd	63.33def	24cdef	3bcd	46.99bc	88.11e	36.48klmnopqrstuv	28.94fghijkl	65.91lm	50.75efg	146.57b	32.14ef
32	Megeri	7.33bc	68fghi	133cde	64.3bcde	18klmnop	3bcd	36.01lmno	72.04no	36.98klmnopqr	25.09pqrstuv	54.30defg	41.41mnopq	86.96abcstuvwxyz	26.64klmn
33	Dekoko 41	8.33ab	39nopq	85ghij	46.7klmn	16opqrstu	3abcd	36.01klmn	65.59rs	36.11lmnopqrstuvw	28.57ghijklm	76.87e	50.77efg	89.4arstuvwxyz	23.6833stu
34	Dekoko 6	8.33ab	39nopq	85ghij	46.33klmno	29ab	4ab	38.04fghijkl	72.03no	34.04abwxyz	29.38efghij	84.74b	52.92de	76.67abcdef	24.5167qrs
35	Dekoko 19	8.33ab	38opqr	86fghij	48kl	13vw	3bcd	31.61opqrstu	63.08tu	36.53klmnopqrstuv	29.38efghij	73.64fg	48.01ghi	85.16abcduvwxyz	23.0467tuv
36	Dekoko 21	8.33ab	39nopq	87fg	48.3k	16opqrstu	4abcd	34.03lomn	63.82stu	31.21cdef	24.90rstuvw	73.35g	41.21nopqr	76.72abcdef	19.9167xy
37	Dekoko 18	7.67bc	70defg	133bcde	63.7cdef	18klmnop	4abc	49.10ab	83.01mn	35.67opqrstuvwx	31.21def	71.80ghi	53.65de	137.4bcde	34.1533cd
38	P313-068	8.33ab	69efgh	133bcde	64.7bcd	14stuvw	3abcd	49.01ab	83.31g	34.84rstuvwxyz	27.34jklmnopq	62.48nopqr	44.89ijklm	133.68bcdefgh	29.0267h
39	Tegenech	7.33bc	38nopqr	86fghij	47.7klm	13vw	3abcd	28.90qrstuvwxyz	57.99axyz	30.88def	22.27abcxyz	67.44kl	3.57rstuvwxy	68.06def	17.91az
40	Dekoko 3	7.67bc	37pqr	85hij	47.3klmn	16qrstuv	4ab	24.88abcdefgz	49.73hij	32.31bcde	20.38cdef	58.74wxyz	33.95abcyz	86.96abcstuvwxyz	16.0667bc

41	DEKOKO 43	7.67 bc	80a	134bcd	54j	18klmnop	3abcd	40.75efgh	83.73g	38.26ghijklmn	21.71abcdyz	62.63nopqr	59.32bc	82.877abcdeyz	32.0333efg
42	HOLETA	7.33 bc	40mn	88f	47.3klmn	20ijklm	4abcd	27.84abtuvwxyz	48.88ij	30.61ef	17.56hi	55.76cd	31.62cd	67.82def	14.96cd
43	DEKOKO 42	7.33 bc	38nopqr	85ghij	47klmn	17mnopqr	4a	27.19abcvwxyz	47.99jkl	33.04abcdyz	19.44defgh	56.24bcd	33.73abcz	72.67abcdef	15.8567bc
44	RAYA 2	8abc	40mno	86fghij	46.7klmn	13vw	4abc	32.08opqr	61.10vw	35.65qrstuvwx	25.64opqrstu	70.78hij	46.68hij	100.53nopqrstuvwxy	21.7833vw
45	DEKOKO 36	7.67 bc	74c	134abc	61fg	29a	2cd	45.51bcd	80.09i	31.05cdef	20.59bcde	59.47auvwxyz	40.76opqrst	122efghijkl	24.8667pqrs
46	P313-045	8.33 ab	39nopq	85ghij	46.7klmn	18klmnop	4abc	27.65abuvwxyz	52.97bcd	36.03lmnopqrstuvw	23.04abvwxyz	62.07nopqrs	40.93opqrs	77.04cdef	19.0867yz
47	DEKOKO 12	8abc	69efgh	134bcd	65.3bcd	14tuvw	3bcd	43.07cde	76.82jk	40.45defg	29.57efghi	57.32abcz	47.56ghij	106.19klmnopqr	31.0733fg
48	P313-070	7.67 bc	39nop	87fgh	47.3klmn	20hijkl	4ab	26.69abcdxyz	51.89defg	33.02abcdyz	20.63bcde	59.87stuvwy	36.21abvwxyz	71.27cdef	17.1333ab
49	DEKOKO 23	8.67 ab	38nopqr	87fgh	49.3k	17nopqrst	4abc	26.71abcdxyz	59.29wx	37.49klmnopqr	27.71hijklmno	68.41jk	45.46hijk	81.67abccdez	21.9733vw
50	DEKOKO 11	8.33 ab	70def	134abcd	64.3bcde	23defgh	3abcd	32.71mnopqr	68.91pq	34.58abstuvwxyz	21.90abcdyz	51.3hi	37.05tuvwxyz	107.97jklmnop	23.8333stu
51	P313-071	8.33 ab	37pqr	85ghij	48kl	22efghi	4abcd	25.76abcdeyz	54.05b	36.92klmnopqrs	25.67oprqstu	63.38nop	41.59lmnopq	85.94abcuvwxyz	19.9633xy
52	DEKOKO 15	8.33 ab	42m	85ghij	43.7o	18lmnopq	4abc	21.24fghi	46.17lm	36.79klmnopqrst	17.80ghi	54.10defg	38.89pqrstuvwx	73.76abcdef	16.9833ab
53	DEKOKO 24	8.33 ab	38opqr	84ij	46.7klmn	19ijklmn	4abcd	24.44bcdefg	50.17fghi	33.84abwxyz	21.05abcd	59.49atuvwxyz	36.38abuvwxyz	67.33def	16.9767ab
54	DEKOKO 16	7.67 bc	37pqr	84ij	47klmn	14stuvw	4abcd	25.11abcdefgyz	50.0ghi	39.74efghi	25.02pqrstuv	59.28auvwxyz	42.28lmnop	65.47ef	19.87xy
55	DEKOKO 33	8.67 ab	78ab	134bcd	56.33ij	21ghijk	3bcd	43.33cde	80.94hi	40.86cdef	23.99stuvwxy	60.40rstuvwxy	58.72bc	124.46cdefghij	33.0767de
56	BILALOL	9ab	40mno	84ij	44.7no	14stuvw	4abcd	36.59ijklm	75.08kl	35.58pqrstuvwx	30.09defgh	89.03a	59.79bc	102.13mnopqrstuv	26.71jklmn

57	DEKOKO 1	8.33ab	37qr	85ghij	48.3k	18klmnop	4abcd	31.08pqrstuv	61.90uv	35.35qrstuvwxy	28.59hijklm	72.54ghi	45.28hijkl	77.83abcde	21.8833vw
58	DEKOKO 27	7.67bc	39nopqr	85hij	46.3klmno	16opqrstu	3abcd	28.85qrstuvwxyz	53.93bc	31.39cdef	20.47cdef	63.69mno	36.55auvwxyz	70.47cdef	16.93ab
59	DEKOKO 22	8.33ab	68ghij	134bcd	66bcd	20klmn	3abcd	33.63mno	62.70tuv	44.79b	27.39ijklmnop	46.90j	42.56klmnop	124.59cdefghij	28.0833hij
60	P313-042	8.33ab	39opqr	84ij	45.7klmno	18klmnop	4abc	23.05defgh	49.97ghi	37.73hijklmnop	22.27abcxyz	59.27auvwxy	41.31mnopqr	71.48bcdef	18.8567yz
61	DEKOKO 29	8.33ab	38opqr	84ij	46.7klmn	15qrstuv	4abc	32.05opqrs	59.56wx	35.13qrstuvwxy	25.91opqrst	70.62ij	17.79wxy	84.08abcdxyz	20.92wx
62	DEKOKO 10	8.33ab	39opq	85fghij	47klmn	19jklmn	4ab	33.12mnop	62.70tuv	40.01defgh	34.04c	81.69cd	59.59bc	98.37opqrstuvwxyz	28hijk
63	DEKOKO 20	8.33ab	39nop	84ij	45mno	18klmnop	3abcd	31.95nopqrst	67.86q	37.44klmnopq	29.06efghijk	80.46d	56.48cd	104.20mnopqrst	25.4nopqr
64	DEKOKO 17	8.33ab	68fghi	133bcde	65bcd	18klmnop	4abcd	40.18efghij	81.09hi	40.75def	31.43de	60.82qrstuvw	50.84efg	147.11b	33.14ef
65	P313-053	8.33ab	39nopq	84ij	45.7klmno	15rstuvw	4abcd	24.67abcdefg	50.95efgh	37.35jklmnopq	22.47abcwxyz	60.41rstuvwxy	41.70lmnopq	102.67mnopqrstu	19.03yz
66	DEKOKO 37	7.67bc	45l	85hij	39.3p	19jklmn	4abcd	27.13abcdvwxyz	56.83az	37.01klmnopqr	18.25efgh	67.12kl	53.49de	116.19ijklmno	21.0333wx
67	DEKOKO 39	7.67bc	70def	135abc	64.3bcde	22eghi	2d	36.01klmn	75.01kl	41.88cde	28.73ghijklm	55.70cd	48.82fgh	123.32defghijk	31.4100
68	BIRKITU	8.33ab	38opqr	85ghij	47.7klm	18klmnop	4abc	25.73abcdeyz	49.78hij	27.87g	17.56hi	58.34abxyz	29.12d	78.13abcde	13.8733d
69	DEKOKO 32	8.67ab	39opqr	84ij	45.7klmno	19jklmn	4abcd	25.22abcdefyz	52.02cdef	36.48klmnopqrstuv	22.42abcxyz	61.68nopqrstuvw	41.57lmnopq	72.64abcdef	18.98yz
70	DEKOKO 35	8abc	68fghi	134bcd	65.3bcd	20ijklm	3abcd	49.53ab	97.67b	45.07b	42.09a	73.08gh	67.40a	141.38bc	44.0233a
71	P313-059	8.667ab	68fghi	135ab	66.7b	16qrstuv	2cd	30.27opqrstuvwx	65.17s	41.35cde	26.27mnopqrs	48.23j	40.39opqrst	118.75fghijklm	26.9267ijklm
72	P313-046	8.667ab	38opqr	85hij	46.3klmno	13vw	4abcd	23.45cdefg	51.98def	32.47abcde	20.41cdef	61.39opqrstu	36.45abuvwxyz	81.96abcdez	16.88ab

73	P313-003	8.66 7ab	70defg	135ab	65.7bcd	12w	2cd	53.02a	113.46a	36.02mnopqrstu v	38.51b	83.84bc	62.23b	117.36hijklm n	40.8633b
74	P313-061	8.66 7ab	78ab	135abc	57.3hi	23defg	3abcd	42.07def	85.92f	39.57efghij	25.10pqrstuv	63.80mn	59.29bc	130.60bcdef gh	33.9967cd
75	P313-026	8abc	72cd	131e	59.7gh	17opqrs	2cd	35.83lmn	72.95mn	38.53fghijk	23.40auvwxyz	55.54cde	47.12ghij	101.48mnop qrstuv	28.1033hi
76	HASABE	8.33 ab	74c	133bcd e	59.7gh	15qrstuv	2cd	43.19cde	92.09d	37.98hijklmno	28.33hijklmn	69.07jk	58.65bc	101.42mnop qrstuvwx	34.9767c
77	P313-089	8.33 ab	71de	132de	61.7efg	18lmnop q	3abcd	35.96klmn	70.13op	38.59fghijk	23.62tuvwxyz	52.99fghi	43.89jklmno	76.2abbcdef	27.0667ijklm
Mean		8.12	52.68	106.65	53.98	18.62	3.42	32.88	65.00	36.07	24.61	61.72	43.67	100.67	23.70
Cv (%)		6.03	1.14	0.61	1.53	4.46	14.67	3.59	0.85	1.86	2.88	1.11	2.46	5.07	1.66

Appendix 2**.** Combined analyses of variance for 14 traits of 77 field pea varieties tested using RCBD at Holeta in 2016/17.

No	Name of samples	DTE	DTF	DTM	GF	PPP	SPP	BPP	TBPP	HI	GPE	BPR	EGR	WT	GYP5
1	GUME	8.33bcd	61hijk	133abc	71.3bcde	7hijkl	5ab	48.21hijk	81.33no	30.78op	29.15opq	61.30nop	35.09nop	199.88abc	25.0400nop
2	DEKOKO 26	8 bcd	48n	98f	49.7m	5klm	4abc	38.34nopqr	48.90abc	9.75e	4.9g	49.90wxy	9.5ef	58.74uvwxyz	4.7600yz
3	P313-010	8.67bcd	62fghi	131de	68.3ghij	17nopqrst	4abc	36.72opqrs	67.29t	35.16ghij	25.91st	51.50uvw	34.57opq	166.13a	23.6333p
4	Ek08023-1	8bcd	62ghij	132abc	70.7cdef	11bcd	3abc	41.81lmn	86.75kl	41.42bc	41.18e	65.56jkl	39.35pqrstuvw	204.96ab	35.9300ef
5	DEKOKO 9	8bcd	48n	98f	49.7m	11bcd	5ab	39.5nopq	58.81v	25.08rs	15.51v	60.01opq	42.16klmnop	64.67stuvwxy	14.7467r
6	DEKOKO 7	8bcd	48n	98f	49.7m	8fghij	4abc	27.86abxyz	42.62fgh	28.81pq	12.62w	43.49cde	24.74t	66.21stuvwxy	12.2833s
7	P313-027	8.33bcd	64cdef	132abcd	68.3ghij	8fghij	4abc	41.47mno	75.93qr	36.60fghi	29.85nop	57.52qrs	40.67k	169.75hijklm	27.7933kl
8	DEKOKO 40	8bcd	49n	98f	49.3m	9cdefg	3bc	28.15axyz	38.93ijk	22.65stuvw	8.94axyz	39.72fgh	17.88wxy	71.36stuv	8.8200uv
9	DEKOKO 31	8bcd	48n	98f	49.7m	7ghijk	4abc	22.88cdefgh	30.10rs	17.25ab	5.33fg	30.72op	48.87fgh	63.35stuvwxy	5.190yz
10	DEKOKO 2	8.33bcd	49n	98f	49.3m	7hijkl	3bc	23.28bcdefgh	33.03opqr	18.81ayz	6.3bcdefg	33.70lmn	12.9abcd	55.28wxyz	6.2133xy
11	ADI	8.33bcd	61ijkl	133ab	72.3abcd	8efghi	4abc	63.83b	94.7ef	25.42r	28.72opqr	71.20ef	33.28pq	190.61bcdef	24.070op
12	WOLMERA	8.33bcd	60jkl	133abc	72abcd	9cdefg	3abc	54.18cdef	106.21cd	34.75hij	44.04bcd	80.26c	1.25ef	172.65ghijkl	36.9033de
13	MILKIY	9abc	61ijkl	132abcd	71.3bcde	13b	4abc	54.02cdef	106.55c	37.52fg	46.99a	80.72c	56.02bc	167.62hijklm	39.9567ab
14	DEKOKO 30	8.33bcd	48n	98f	49.7m	9cdefg	4abc	35.88qrst	50.97axyz	15.45bc	8.09abcdyz	52.0uvw	15.86xyz	61.81stuvwxy	7.8767vw
15	MOHANDERFER	9.33ab	62ghij	133abc	71.3bcde	18a	4abc	72.14a	121.03a	32.22klmno	45.11ab	91.23a	54.66cd	175.68fghijk	38.9900bc

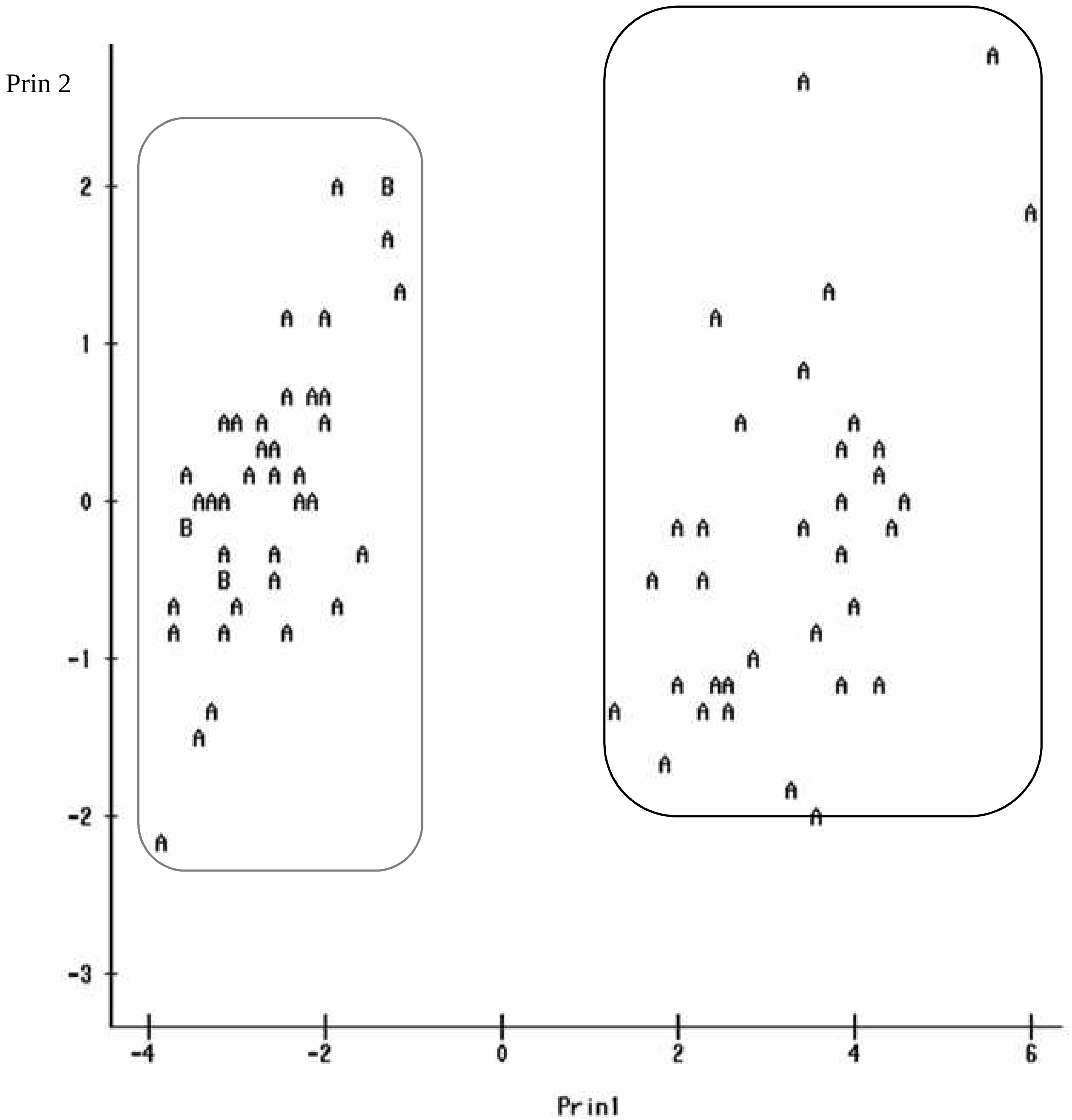
16	P313-082	9abc	58m	132bcd	74a	8efghi	4abc	36.12qrst	72.73s	34.19ijkl	31.92lmn	55.24st	33.61pq	172.13ghijkl	24.87nop
17	DEKOKO 8	7.67cd	49n	98f	49.3m	5klm	3bc	29.05awxyz	37.79jklm	13.21cd	5.06fg	38.56ghi	10.12def	56.89vwxyz	4.993yz
18	P313-067	8.33bcd	62ghij	132abcd	70.3defg	8efghi	4abc	48.88ghij	90.98ghi	40.49cd	42.02cde	68.92fghi	52.38de	176.92fghij	36.8400e
19	LATU	8bcd	60jkl	132abcd	71.7bcde	9cdefg	4abc	55.86cde	92.99fg	30.93nop	34.17jkl	70.45efg	40.13kl	163.52jklmn	28.7600k
20	DEKOKO 34	8bcd	48n	98f	49.7m	8efghi	3abc	38.66nopqr	51.09xyz	15.55bc	8.29abyz	52.78tuv	16.24xyz	63.61stuvwxy	8.0667vw
21	DEKOKO 25	8bcd	48n	98f	50m	6ijklm	3abc	30.09uvwxy	45.14efd	17ab	7.99abcdz	45.91abc	15.26ayz	69.61stuvw	7.6800vw
22	DEKOKO 4	8.33bcd	48n	99f	50.3m	11bc	4abc	52.70efgh	77.84pq	18.51az	15.02v	78.90c	28.63s	64.8stuvwxy	14.410r
23	P313-086	8.67bcd	65abcd	131cde	66.7ijk	7hijkl	5ab	71.91a	104.93cd	23.80rst	25.74st	73.90c	37.46lmn	175.94fghijk	24.97nop
24	G22 763-2c	10.33a	65abcd	132abc	67hijk	2410cde	4abc	58.73c	89.80hij	30.12opq	27.74pqrs	67.86ghij	40.37k	128.89qr	27.0433lm
25	DEKOKO 5	8bcd	48n	98f	50m	7hijkl	3bc	36.17qrst	46.20cde	10.65e	31.93lmn	46.98abz	9.84ef	54.07xyz	4.9200yz
26	DEKOKO 13	8bcd	48n	98f	50.3m	7hijkl	4abc	53.98cdef	73.99rs	13.40cd	10.39wxy	75.25d	19.69vw	68.9stuvwx	9.9133tu
27	P313-090	8.67bcd	64cdef	133abc	69fgh	10cedf	3abc	41.02mnop	87.98jkl	46.36a	44.21bc	66.32jk	59.11a	146.85op	40.7867a
28	BURSA	8.33bcd	60jkl	133abc	72.3abcd	9efgh	4abc	52.02cdef	89.00ijk	41.26bc	44.02bcd	67.09hijk	50.78efg	211.88a	36.7200e
29	DEKOKO 14	8bcd	48n	98f	49.7m	6ijklm	4abc	22.78cdefgh	36.90klmn	19.36axyz	7.34abcdef	37.65hij	14.38abz	72.76ts	7.1433wx
30	RAYA 1	8.33bcd	48n	98f	49.7m	7ghijk	4abc	33.92rstu	51.82axyz	23.17rstu	12.34w	52.8tu	24.17tu	73.86st	12.0067s
31	MARKOS	8bcd	63defg	132abc	69fgh	7hijkl	4abc	52.51egh	92.22fgh	37.27fgh	37.45gh	69.69fgh	49.82egh	211.42a	34.3733gh
32	MEGERI	8bcd	59lm	132abcd	72.6abc	6ijklm	4abc	48.12hijk	75.28qrs	33.35jklmn	30.75mno	57.03rs	34.55opq	165.86ijklmn	25.1033no
33	DEKOKO 41	8bcd	48n	98f	50m	8efgh	3abc	24.25abcdefg	38.99ijk	22.81stuv	9.26axyz	39.79fgh	17.78wxy	72.49stu	8.8933uv
34	DEKOKO 6	8bcd	48n	98f	49.7m	4m	3c	44.91klm	55.11w	9.61e	5.45efg	56.23s	1066def	54.27xyz	5.2967yz
35	DEKOKO 19	8bcd	49n	98f	49.3m	6ijklm	4abc	19.96fghi	30.76qrs	19.23ayz	5.99bcdefg	31.38no	11.99bcdef	51.07yz	5.9167xyz
36	DEKOKO 21	8bcd	48n	98f	49.7m	7hijkl	4abc	21.39efghi	31.14qr	25.41r	8.13abcdyz	31.78no	15.93xyz	74.41s	7.9133vw
37	DEKOKO 18	8.67bcd	60jkl	37a	73ab	7hijkl	4abc	50.47fghij	83.01mn	34.79hij	34.95ijk	62.26mno	39.56klm	151.44nop	28.880k
38	P313-068	8bcd	62efgh	133ab	70.3defg	6iklm	3abc	53.91cdef	97.19e	40.08cde	43.72bcd	73.07de	55.39bc	195.76bcd	38.9567bc

39	Tegenech	8bcd	48n	98f	49.3m	4m	3bc	21.86efghi	31.14qr	19.04ayz	6.01bcdefg	31.78no	12.01bcde	59.50uvwxyz	5.9267xyz
40	Dekoko 3	8bcd	48n	98f	49.7m	6ijklm	4abc	20.06fghi	34.18nop	20.12xyz	7.05abcdefg	34.87klm	13.80abcz	57.46uvwxyz	6.8567wx
41	Dekoko 43	8.33bcd	64bcde	133ab	68.7fghi	9defgh	5ab	33.11stuvw	63.16u	34.70ijk	23.39u	47.49ayz	31.91qr	118.44r	21.9133q
42	Holeta	8bcd	48n	98f	49.7m	6jklm	4abc	36.03qrst	49.84abyz	9.68e	4.96g	50.86uwx	9.71ef	62.95stuvwxy	4.8267yz
43	Dekoko 42	8bcd	49n	98f	49m	6jklm	4abc	36.23qrst	48.99abcdz	14.45c	7.12abcdefg	50.17vwxy	14.44abz	59.7stuvwxy	7.0733wx
44	Raya 2	8.67bcd	49n	98f	49m	6ijklm	4abc	26.65abcdyz	38.19jkl	15.59bc	5.95bcefg	38.97gh	12.14bcde	56.13vwxyz	5.9533xyz
45	Dekoko 36	8.33bcd	63defg	132abcd	68.7fghi	8fghij	4abc	52.08efgh	90.00hij	36.57fghi	35.69hij	68.18ghij	47.93hi	158.22lmno	32.9133hi
46	P313-045	8bcd	49n	98f	49.3m	5lm	3abc	21.52efghi	34.94mnop	17.04ab	6.04bcdefg	35.65jkl	12.07bcde	56.25vwxyz	5.953xyz
47	Dekoko 12	8.67bcd	60jkl	133abc	72.3abcd	9cdefg	3abc	55.41cde	92.04fgh	37.93ef	41.87de	69.37fgh	48.27gh	168.96hijklm	34.9133gf
48	P313-070	8.33bcd	49n	98f	49m	6ijlm	3bc	35.14qrstu	50.16abyz	11.75de	5.89cdefg	51.18uvwx	12.03bcde	59.10tuvwxyz	5.8933xyz
49	Dekoko 23	7.67cd	49n	98f	49.3m	9defgh	4abc	52.67efgh	68.87t	14.31c	9.99xyz	70.27fg	19.98vw	62.02stuvwxy	9.8567tu
50	Dekoko 11	8.67bcd	66ab	132abcd	63.3jk	9cdefg	5ab	66.73b	110.16b	34.81hij	38.74fg	83.45b	57.81ab	180.25efghi	38.3433cd
51	P313-071	7.67cd	48n	98f	50m	5lm	3c	25.47abcdez	35.23lmno	13.24cd	4.85g	35.94ijkl	9.33f	44.76z	4.6633z
52	Dekoko 15	8.33bcd	48n	98f	49.7m	7ghijk	4abc	2.90awxyz	42.03gh	18.95ayz	8.18abcyz	42.88de	16.04xyz	62.9stuvwxy	7.9633vw
53	Dekoko 24	7.33d	48n	98f	49.7m	7hijkl	4abc	27.31abcxyz	37.91jkl	15.52bc	6.05bcdefg	38.68gh	11.85bcdef	54.63wxyz	5.8867xyz
54	Dekoko 16	8.33bcd	48n	98f	49.7m	7ghijk	4abc	35.06qrstu	53.91wx	20.27wxyz	11.23wx	55.0st	21.99uv	68.60stuvwx	10.9233st
55	Dekoko 33	8.33bcd	66ab	133abc	66.3jk	7ghijkl	4abc	46.55jkl	92.10fgh	49.21b	39.80ef	69.42fgh	60.00a	175.61fghijk	39.8abc
56	Bilalol	8.33bcd	48n	98f	50m	7hijkl	4abc	17.76i	27.97s	20.51vwxyz	5.97bcdefg	28.53p	11.47cdef	59.39stuvwxyz	5.7367xyz
57	Dekoko 1	8.33bcd	49n	98f	49m	7ghijk	4abc	55.23cdef	67.26t	13.34cd	8.97axyz	68.64fghi	18.32wx	59.81stuvwxyz	8.9767uv

58	Dekoko 27	8.33bcd	49n	98f	49m	8fghi	3abc	24.40abcdef	40.40hij	14.45c	5.83defg	41.23efg	11.89bcdef	61.56stuvwxy	5.83xyz
59	Dekoko 22	8bcd	60kl	131cde	71.7bcde	7ghijk	4abc	48.43hijk	83.04mn	33.67jklm	33.58jkl	63.23lmn	39.02klm	160.77klmno	27.960kl
60	P313-042	8.33bcd	49n	98f	49m	5lmn	5ab	22.36defghi	36.56klmn	21.23uvwxy	7.763abcdez	37.30hijk	15.84xyz	65.45uvwxyz	7.7633vw
61	Dekoko 29	8bcd	48n	98f	50m	7ghijk	5ab	31.68tuvwx	47.85bcd	18.59az	9.12axyz	48.65xyz	33.61pq	68.77stuvwx	8.8967uv
62	Dekoko 10	8bcd	48n	98f	49.7m	5klm	4abc	19.25hi	33.06opq	18.12az	6.16bcdefg	33.73lmn	12.07bcde	65.73stuvwxy	5.9933xyz
63	Dekoko 20	8bcd	48n	98f	49m	6jklm	4bc	21.24efghi	32.01pqr	18.65az	6.14bcdefg	32.66mno	12.02bcde	68.71stuvwx	5.9700xyz
64	Dekoko 17	8bcd	60jkl	132abcd	71.7bcde	7ghijk	5a	58.24cd	90.99ghi	38.26def	41.36e	68.93fghi	48.58fgh	194.71bcde	34.8133fg
65	P313-053	8bcd	49n	98f	49m	7ghijk	3abc	29.81vwxyz	43.85efg	18.15az	7.96abcdz	44.74bcd	16.24xyz	56.32vwxyz	7.960vw
66	Dekoko 37	8bcd	48n	98f	49.7m	8fghij	4abc	38.12nopqr	51.96xy	17.42ab	9.30axyz	53.02tu	18.23wx	60.10stuvwxyz	9.050uv
67	Dekoko 39	8bcd	62fghi	132abcd	69.7efg	8fghij	5ab	63.76b	103.57d	31.79lmno	36.75ghi	78.46c	47.22hi	181.26defgh	32.89i
68	Birkitu	8bcd	48n	98f	50m	7hijkl	3abc	27.33abcxyz	41.06ghi	14.35c	6.14bcdefg	41.89ef	11.79bcdef	59.49stuvwxyz	5.8933xyz
69	Dekoko 32	8.67bcd	48n	98f	49.7m	7hijkl	4abc	19.57ghi	32.03pqr	21.86tuvwx	7.19abcdefg	32.67mno	14.10abcz	63.44stuvwxyz	7.0wx
70	Dekoko 35	8.67bcd	60jkl	131cde	71.3bcde	7hijkl	4abc	41.91lmn	80.13nop	34.90hij	33.07klm	61.01nop	39.21klm	166.78ijklm	27.97kl
71	P313-059	8.33bcd	60kl	132abcd	72.3abcd	7ghijk	4abc	55.92cde	87.98jkl	28.22q	30.10no	66.65ijk	34.33pq	166.87hijklm	24.833nop
72	P313-046	8bcd	49n	98f	49.3m	6jklm	4abc	34.28srtuv	50.98axyz	13.92cd	7.19abcdefg	52.02uvw	14.39abz	58.84tuvwxyz	24.8333wx
73	P313-003	8.67bcd	63efgh	132abc	697efg	8efghi	4abc	53.38efg	91.02ghi	28.47pq	28.81opqr	68.78fghi	37.21mno	120.41r	25.9133mn
74	P313-061	8.67bcd	66ab	132abcd	66k	11bcd	4abc	53.77def	80.00op	31.36mno	25.09tu	60.61nop	38.02klm	155.52mnop	25.1nop
75	P313-026	8.33bcd	63efgh	132abc	69.7efg	7ghijk	4abc	47.57ijk	82.72mno	28.82pq	26.51rst	62.51mno	34.23pq	179.61efghi	23.8467op

76	HASABE	9abc	64cdef	132abc	68.7fghi	10cde	4abc	51.58efghi	85.34lm	36.53fghi	33.62jkl	64.48klm	45.40ij	142.34pq	31.1733j
77	P313-089	8.67bcd	66ab	130e	63.7l	7ghijk	4abc	48.11hijk	76.89qr	36.40fghi	26.87qrst	59.15pqr	43.97j	160.16lmno	27.9933kl
Mean		8.26	54.53	113.10	58.58	7.59	3.84	40.18	64.11	25.05	19.69	55.04	28.02	109.97	17.86
Cv (%)		4.76	1.02	0.35	1.11	7.91	13.62	3.43	1.32	2.88	3.40	1.41	2.73	3.96	2.34

Appendix 3. Plot showing pri 1and pri 2



Appendix 4. Correlation of disease with six determinant traits

CHARACTERS	**CHARACTERS**							
	AB	PW	GF	PPP	SPP	TBPP	WT	GYP
AB	1.00							
PW	0.29*	1.00						
GF	0.07*	0.35**	1.00					
PPP	-0.28ns	-0.05ns	-0.02ns	1.00				
SPP	0.001ns	-0.15ns	-0.23*	-0.10ns	1.00			
TBPP	-0.03ns	0.54**	0.45**	0.47**	-0.30**	1.00		
WT	-0.08ns	0.57**	0.27*	0.37**	-0.30**	0.86**	1.00	
GYP	-0.08ns	0.57**	0.28**	0.37**	-0.31**	0.95**	0.88**	1.00

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/our supervision.

Name: __________________________ Signature: __________________ Date: ___________

__________________________ Signature: __________________ Date: ___________

__________________________ Signature: __________________ Date: ___________