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GENETIC VARIATION AND GRAIN YIELD PERFORMANCE OF IMPROVED COMMON BEAN VARIETIES UNDER IRRIGATED CONDITION: THE CASE OF BAKO TIBE DISTRICT, WEST SHOA ZONE, ETHIOPIA

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MSc. Thesis

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APPROVAL SHEET

As thesis research advisors, we here by certify that we have visited his research work on field condition, checked the collected data ,read and evaluated this thesis entitled €Genetic Variation and Grain Yield Performance of Improved Common Bean Varieties Under Irrigation Condition: The Case of Bako Tibe District, West Shoa, Ethiopia;• prepared by the candidate BELAY KEBEDE TADESSE under our guidance. We recommend that it can be submitted to school of graduate studies as fulfilling the thesis requirement.

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As members of the Board of Examiners of the MSc Thesis Open Defense Examination, we certify that we have read, evaluated the thesis prepared by Belay Kebede and examined the candidate. We recommend that the thesis be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Biology

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DEDICATION

This thesis is dedicated to my lovely mother, and father for their partnership in the success of my life.

STATEMENT OF THE AUTHOR

I declare that this thesis is submitted to School of Graduate Studies of Bahir Dar University in partial fulfillment of the requirements for Masters of Science (MSc), degree in Biology. I would like to attest through my signature affixed below that it is my own independent work and has not previously been submitted elsewhere by me or anybody for the award of any academic degree, diploma, or certificate.

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LIST OF ACRONYMS AND ABBREVATIONS

ADLI	Agricultural development Led Industrialization
CIAT	The Centro Internacional de Agricultura Tropical
CSA	Central Statistics Authority
DAT	Date After Flowering
DNA	Deoxyribo Nucleic Acid
EPPA	Ethiopian Pulses Profile Agency
FAO	Food and Agricultural Organization
HARC	Holeta Agricultural Research Center
IBPGR	International Board for Plant Genetic Resources
IFPRI	International Food Policy Research Institute
IRISAT	International research Institute for Semi Arid Tropics
MoFED	Ministry of Finance and Economic Development
MARC	Melkasa Agricultural Research Center
OESO	Oromia Economic Study Office
RCBD	Randomized Complete Block Design
USDA	United State Agricultural Development Agency

ABSTRACT

Common bean (Phaseolus vulgaris L.) is the most important food, export and cash crop and it is also the source of protein for the majority of people in Ethiopia. Screening and selecting the most promising haricot bean varieties which are high yielding and adaptable for rain-fed and/or irrigation condition is crucial in minimizing the risk of maize mono cropping that is widely practiced in Bako Tibe and its neighboring districts. To this end, twenty common bean (Phaseolus vulgaris L) varieties were evaluated under irrigated condition at Bako to assess the genetic variability and grain yield performance under this condition. The Design was Randomized Complete Block Design (RCBD) with three replications. The mean, minimum, maximum, range, deviation from the mean and standard error of mean were showed a wider ranges of variation between the tested common bean varieties for most of quantitative traits. The analysis of variance also indicated that the mean square due to varieties were highly significant (P≤0.05) for all quantitative traits recorded in the present study. This indicated the possibility to produce heterotic progeny upon crossing of genetically diverse varieties. Correlation analysis indicated that most yield and yield related traits exhibited positive association. Fore example yield per plant was positively correlated with harvest index (r=0.91), biomass yield (r = 0.802), the number of seeds per pod (r=0.549), grain yield per plot (r= 0.435), and grain yield per plant (r=0.338). The grain yield exhibited significant positive correlation with 100 seed weight indicating relative utility of this trait for selection. 100 seed weight exerted maximum positive direct effect and exhibited significant positive correlation with yield indicating a true relationship among the traits. The estimation of phenotypic coefficient of variation, genotypic coefficient of variation, broad sense heritability and genetic advance were high for the 13 quantitative traits of the tested common bean genotypes. This indicated that selection of these traits is likely to accumulate more additive genes leading to further improvement of their performance and these traits may be used as selection criteria in common bean breeding program. The overall performance of the test varieties was very good in that particular area except Awasa Dume under irrigated growing condition. Therefore, it is advisable to promote haricot bean as an arable crop in the study areas to improve production level, increase source of cash for farmers and foreign currency for the country as export crop. Some genotypes like Ramada, Nassir, Omo-95 and Seer-119 can be recommended for production under irrigated conditions. However, caution should be taken in the use of these results as the study was conducted only in one location and for one season. In order to validate the findings, the study should be conducted for a number of years and in many locations

Key words: Correlation coefficient, cluster analysis, Genetic advance, Genetic variability, haricot bean and Heritability.

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1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L. 2n= 2x= 22) originated in Latin America and has two primary centers of origin in the Mesoamerican and Andean regions that are easily distinguished by molecular means (Blair et al., 2010). All species of the genus are diploid and most have 22 chromosomes (2n=22, x=11). The genome of common bean is one of the smallest in the legume family at 625 Mbp per haploid genome

Common bean (*Phaseolus vulgaris* L.) is the third most important food legumes worldwide next to soybean and peanut (Singh, 1999). Among the pulses (i.e. annual leguminous food crops that are harvested for dry seeds), the common bean is the most important crop. The genus *Phaseolus* is of American origin and comprises over 30 species (Debouck, 1991). Five of them, namely, *P. acutifolius* A. Gray (tepary bean), *P. coccineus* (runner or scarlet bean), *P. lunatus* (lima, butter or madagascar bean), *P. polyanthus* Greenman (year long bean) and *P. vulgaris* (common bean, haricot bean, navy, French or snap bean) were domesticated (Debouck, 1999). Among these species, the common bean is the most widely distributed and has the broadest range of genetic resources. It is mostly used as food crop throughout the world, especially in Latin America and Africa (Singh, 1999).

Crop genetic resources are the product of the interaction between human and natural selection of plants, yielding a set of domesticated crops and varieties used in agricultural production (Win, 2011). Crop genetic resources are embedded in seeds and they are an important determinant of the characteristics and attributes of the crop species, together with environmental and human management factors.

Evaluation of crop genetic resources is prerequisite for which the future breeding work is based. The value of germplasm relies not only on the number of accessions it possesses, but also upon the genetic variability present in those accessions for agronomic and yield components (Win, 2011). Heritability act as predictive tool in expressing the reliability of phenotypic traits and thus high heritability could assist in effective selection of particular characters and devise future breeding programme of common bean. Generally, conserving, characterizing genetic resources and developing novel breading methods or tools are important for improving efficiency of the crop improvement (Asfaw et al., 2009).

Each race has its own characteristics, ecological adaptation, and agronomic traits (Beebe et al., 2000). Most beans are herbaceous annuals, although, under tropical conditions, some beans (such as large limas) may behave as short lived perennials. They may be of determinate or indeterminate growth habit, with pinnately compound trifoliolate leaves. Growth and development of common bean is divided into vegetative and reproductive stages. The common bean flower has an elongated twisted keel containing the style and ten stamens. Cross pollination is possible if the stigma contacts a pollen coated bee when it is extended. Otherwise the stigma will be self pollinated when it retracts and contacts its own pollen at the opening of the keel.

Self-pollination is thus the norm in the common bean, and it probably occurs automatically at or before the flower opens in the morning. For the grower, there is no yield or other economic advantage of crosspollination. For the bean breeder, cross pollination is actually a hazard to maintaining the purity of a cultivar.

Common bean (*Phaseolus Vulagris* L.), locally known as ‚Boleqe‚, and also termed as dry bean, haricot bean, kidney bean and field bean is a very important legume crop grown worldwide. Common bean form an important food and cash crop in Africa, particularly in the eastern, southern and Great lakes of continent (Fikre et al., 2012). In Ethiopia, it was most likely introduced by the Portuguese in the 16th century (Imru, 1985). Ethiopia is the third producer of bean in eastern African countries next to Kenya and Uganda (CIAT, 1996).

Common bean is the most important food, export and cash crop and also the source of protein for the majority of peoples in Ethiopia (Farris and Kaganzi, 2008). It is the second most important grain legume cultivated as cash crop in Ethiopia (CSA, 2011) and is widely produced in the rift valley area of the country. For instance, the major common bean producing areas of Ethiopia are the central, eastern and southern parts of the country in general and Oromia (169,600 tons) and Southern Nations, Nationalities and Peoples, Region (SNNPR) (106,700 tons) makes up 81.08% of the total national production of common bean in particular (CSA 2011).

It is one of the fast expanding legume crops that provide an essential part of the daily diet and foreign earnings for Ethiopians smallholder farmers particularly inhabiting the rift valley regions (Girma, 2009). It is an excellent source of protein, fiber, complex carbohydrates, vitamins and minerals and thus reduces malnutrition and improves human health, especially for the poor who cannot afford livestock products (Philip, 2013).The demand in both the domestic and export markets of beans provides a source of cash for smallholder producers (interim report by Sackatchewan and Hawasa University, 2014).

Beside supplementation of protein and vitamins beans are also rich in essential micronutrients that are found only in low amounts in cereals or root crops (Wang et al., 2003). The average composition of micronutrients in common bean per 100g edible portion is being protein 21.4g, carbohydrate 49.7g, fat 1.6g, dietary fibre 22.9g, energy 1218kj, minerals 679.5mg and vitamins 3.64mg. On the other hand the essential amino acids composition per 100g edible portion being lysine 1540mg, methionine 240mg, phynylanine 1130mg, threonine 860mg, tryptophan 210mg, valine 990mg, leucine 1640 mg and isoleucine 890mg (Kiassi, 2010).

A symbiotic relationship between a bacterium called Rhizobium and common beans provide nitrogen to the soil where they are grown. Legumes the group of plants to which beans belong, fix atmospheric nitrogen in the soil in association with Rhizobium bacteria (Kay, 1979). The fixation of atmospheric nitrogen improves the soil nitrogen level benefiting the crop that are grown thereafter, thereby reducing production costs. The fixed nitrogen is an important source of nitrogen nitrate for plant growth and development. The common bean residues left on the field improve the soil structure (Barrett, 1990).

Nodulation and N2 fixation depend on the genotype of the host plant, rhizobium strain, and their interaction with soil and environmental conditions (Kilassi, 2010). Under optimized environmental conditions, genetically superior genotypes of common bean that are nodulated with efficient rhizobium strain are able to fix enough N2 to support grain yield. Nitrogen derived from biological fixation is 50–70 % more efficient than applied N because only 30–50 % of the latter is recovered by plants (Bliss, 1993).

The major producing countries for national consumption are Brazil and Mexico while the United States, Canada, Argentina and China are all exporting countries. The crop is also important in a number of developing countries of Eastern and Southern Africa (Kilasi, 2010). In these regions beans are grown for both subsistence agriculture and for regional markets where they play an important role in food security and income generations.

Total world production cannot be calculated with certainty due to confusion with other legumes in some of the data, but is between 11 and 12 million tons are produced annually worldwide, of which 8 million tones are from Latin America and Africa (Philip, 2013). Latin America is the region of greatest production of common beans, securing about 50% of world volume, followed by Africa with 25%. Brazil, Mexico and the United States of America are the three largest producers in the western hemisphere. In Africa, most bean production is found in the eastern and southern highlands, extending from Ethiopia to South Africa, with Kenya being the largest producer in the region. In West Africa, bean production is localized in specific environments, with Cameroon being the principal producer.

Ferris and Kaganzi (2008) have shown that an average national production is approximately 150 thousand tons per annum. The level of production in 2005 was approximately 175 thousand tones with a domestic market value of USD 30 million in Ethiopia. Although haricot bean is largely growing in Ethiopia, the national average yield of haricot beans is low ranging from .50 to 0.8 ton per ha which is far below from the corresponding yield recorded at research sites (2.5–3 tones ha^{-1}) using improved varieties (EPPA, 2004). The yearly average production of common beans in Ethiopia has increased steadily up to 11.67 qt/ha (CSA, 2011). In 2011/12, total haricot bean production in the country was about 3,878,023.01 quintals (1.77% of the grain production) on approximately 331,708.15 hectares of land (which constitutes 2.74% of the total number of farms in Ethiopia or the grain crop area (CSA, 2011) by small-scale farmers without irrigation and with little use of agrochemicals. This is very low as compared to the world average of 1.4 t/ha and that of the developed world 8.0 t/ha.

In 2013/14, total Haricot bean production in the country was about 4,574,116.13 quintals (1.82% of the grain production) on approximately 326,465.88 hectares of land (2.63% of the grain crop area) (Daniel et al., 2014). Early maturity and moderate degree of drought tolerance led the crop's vital role in farmers' strategies for risk aversion in drought prone lowland areas of the country (Abebe et al., 2013). The low national mean yield observed for haricot bean could be attributed to various constraints related to low adoption of improved agricultural technologies, drought, and lack of improved varieties, poor cultural practices, disease, and environmental degradation (Legese et al., 2006).

Irrigation development in Ethiopia is in its infancy stage and not contributing its share to the growth of the agriculture sector accordingly. But the country has the potential for its development both in terms of vast suitable land and availability of fresh water resources suitable for irrigation purpose. However, currently limited land is being cultivated under irrigated agriculture and therefore, crop production is predominantly based on rain-fed agriculture.

Irrigated agriculture is being practiced under smallholders, medium and large scale farming. The small-scale irrigation schemes are understood to include traditional and modern communal schemes up to 200 ha (NRMD, 2011). However, ƒ traditional, spate irrigation and even some modern irrigation schemes are also being managed by smallholders as part of small-scale irrigation schemes, whereas the area is quite larger than indicated above. This has been confirmed by some studies carried out by IWMI (2011) which showed that some schemes have the capacity of over 2000 ha that are being managed by smallholders. Traditionally, farmers have built small-scale schemes on their own initiative, but sometimes with some technical and material support from the government and other development actors.

According to a study conducted by OESO (2000), there is 1.7 million hectares of land suitable for surface irrigation in the Oromia region that can benefit about 6.8 million household heads. OESO (2000) have also shown that the amount of water potential to be utilized for the purpose of irrigation in Oromia is estimated to be 58 billion cubic meter of mean annual run off generated in the region and 2.1 billion cubic meter of underground water.

Bako Tibe district is one of the areas in the region that possess high irrigation potential and small scale irrigation is being practiced. However, there was no adequate study which analysed the grain performance (high-yielding and high-quality) of improved haricot bean varieties under small-scale irrigation and systematic attempts have not been made on the collection of information on genotypes with reference to quantitative traits under irrigated condition in the study area.

In the study area, the productivity of haricot bean is below the national average at farmer level (discussion with farmers and profile from Bake Tibe woreda Agricultural bureau). In essence of things, the generation and transfer of technologies and improved varieties is not an end in itself. Therefore, increasing productivity and production of haricot bean will be realized if and only if the farmers adopt the technologies including improved varieties that are developed by research center for rainfed and/or irrigated agricultural conditions.

The area suitable for haricot bean production in the study area under irrigation is around 484.04 hectare. However, the area sown is only 283.41 ha for only maize, sugarcane and different vegetable crops. Haricot bean production using irrigation is not common in the study area (secondary data from Bako Tibe Agriculture bureau). Its adaptation to the area where it is cultivated is optimal to marginal, which depends on the environmental conditions in each peasant association.

In the study area, haricot bean is produced by small-scale farmers only under rain fed condition. Small-scale farmers refer to two groups of farmers: 1) those who produce haricot bean only for their subsistence and, 2) those who cultivate beans for their subsistence but who may also produce an excess for the market. Both groups of farmers are common in Bako district. It is a well established agricultural component or product in the study area and it is among the most important food legumes such as soya bean, field pea, chicken pea, lentiles and haricot bean (secondary data from the woreda agricultural bureau).

The wide range of growth habits of haricot bean among the different varieties has enabled the crop to fit many growing situations (Kristin et al., 1997). Early maturity and moderate degree of drought tolerance led the crop‚s vital role in farmers‚ strategies for risk aversion in drought prone lowland areas of the country (Abebe et al., 2013). More than 80% of the farm land in Bako Tibe district was allotted for maize production every year (secondary data from the Woreda agricultural bureau). Common bean is one of the potential crops used for maize-legume intercropping and rotation crop for maize continuous cropping. Screening and selecting the most promising common bean varieties which are high yielding and adaptable to rainfed and/or irrigation condition is crucial in minimize the risk of maize mono cropping that is widely practiced in Bako Tibe and the neighboring districts..

Horizontal increase (expansion of new farm lands) to increase crop production is over exploited to the limit and thus, increasing the productivity per unit area of the shortly maturing and widely adapted pulse crops such as common bean presents an opportunity in reversing poverty and food insecurity particularly in the rift valley regions where the rainfall duration is very short. Common bean production also depends on applied N_2 fertilizer. Relatively high rates of N fertilizer are applied regardless of the cultivars and other factors such as residual soil N. The majority of Ethiopian farmers, however, are unable to afford the high mineral fertilizer cost (Acquaah, 2012)

To mitigate this, Biological N2 fixation, a key source of N for poor farmers, constitutes a potential solution and may play a key role in sustainable bean production in Sub-Saharan Africa (Philip, 2013). Besides, the crop can fix free atmospheric nitrogen in to usable nitrates form in soils and thus improve soil fertility and save fertilizer costs in subsequent crops Apart from aforementioned advantages, inclusion of this crop in to the farming system helps to improve soil fertility through symbiotic nitrogen fixation. Common beans are also used for different cropping systems.

It is compatible for intercropping with maize and sorghum and for alley cropping with perennial leguminous shrubs which can also improve soil fertility. This system can produce an additional biomass, which can be used for fodder or for mulching or for green manuring without any significant grain yield reduction of haricot beans. Common bean is also the most preferred pulse crops for intercropping, crop rotation or green manuring to restore soil structures and fertility, and increase land equivalent ration (LER). Irrigation can therefore be used as an alternative N source, particularly under low input production system for resource limited small scale common bean producers. It also serves as a break crop in Maize-based and other crops-based farming systems to reduce decline in soil fertility.

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Yield is the principal parameter in the improvement of any crop. Like other legumes, seed yield in common bean is a quantitative character influenced by a number of yield contributing traits. Improved common bean production involves use of different agronomic practices such as improved variety, seed rate, spacing, fertilizer, irrigation practices and pesticide applications at the recommended rate.

Nonetheless, sizeable improvement in production and productivity depends on the extent to which a household has applied the recommended package practices. The selection or evaluation of desirable genotypes should therefore also be based on yield as well as on other yield components. Number of pods per plant, number of seeds per pod, and mean seed weight are the three major yield related traits (Nienhuis and Singh, 1986). Improving the yielding potential and related desirable trait is the main objective of common bean breeding program. The efficiency of breeding program increases by careful choice of parents capable of producing heterotic progeny with desirable trait combinations (Angela *et al*., 2002; Cristina et al., 2002). Information on mutual association between grain yield and yield components is necessary for efficient utilization of the genetic stock in crop improvement program of any crop.

Yield is the principal factor for determining improvement of a crop. Like other legumes, seed yield in common bean (*Phaseolus vulgaris* L.) is a quantitative character and influenced by a number of yield contributing traits. Improved haricot bean production involves use of different agronomic practices such as improved variety, seed rate, spacing, fertilizer rate, and pesticide application at the recommended rate. Nonetheless, sizeable improvement in production and productivity depends on the extent to which a household has applied the recommended package practices. To increased use of improved seeds varieties and to achieve sustainable agricultural development in the country, the Ethiopian government has identified improving the efficiency of the seed systems is one of the most effective means of meeting the Millennium Development Goals (Yonas et al., 2008).Therefore, it is needed to identify the genetic variation and grain yield potential of the existing improved haricot bean varieties under both rainfed and irrigated condition in Ethiopia.

The selection or evaluation of desirable genotypes should therefore also be based on yield as well as on other yield components both in rain-fed and irrigated condition. Number of pods per plant, number of seeds per pod, and mean seed weight are the three major yield related traits (Nienhuis and Singh, 1986). Improving the yielding potential and related desirable trait is the main objective of common bean breeding program. The efficiency of breeding program increases by careful choice of parents capable of producing heterotic progeny with desirable trait combinations (Angela et al., 2002); Cristina et al., (2002). Information on mutual association between grain yield and yield components is necessary for efficient utilization of the genetic stock in crop improvement program of any crop.

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Generally, to achieve significant progress in breeding programs, it is essential to know the relationship between grain yield and its components both under rain fed and irrigation condition (Win, 2011). Therefore, the main aim of this study was to evaluate and identify the best performing common bean varieties under irrigated condition in the study area

1.1 Objectives

1.1.1 General objective

The general objective of the present study was to assess the genetic variation and grain yield performance of improved common bean varieties under irrigated condition around Bako area.

1.1.2 Specific objectives

…To assess the genetic variability among the released common bean varieties under irrigated condition and identify promising varieties for further breeding and production activities,

..To estimate the genetic parameters, genotypic and phenotypic coefficient of variations, heritability and genetic advance for quantitative traits;

…To determine the association between grain yield and yield related components

2. Literature Review

2.1 The common bean crop, origin, evolution and distribution

Common bean (*Phaseolus vulgaris* L.) belongs to order Rosales, family Leguminosae subfamily Papilionideae, tribe Phaseolinae (CIAT, 1986). Common bean was originated in Tropical America (Mexico, Guatemala and Peru), but there are also evidences for its multiple domestication within Central America (Kay, 1979). The crop is now widely distributed throughout the world and consequently, it is grown in all continents except Antarctica (Singh, 1999). It is well adapted to areas that receive an annual average rainfall ranging from 500-1500 mm with optimum temperature range of 16-24 °C, and a frost free period of 105 to 120 days. Moreover, it performs best on deep, friable and well aerated soil types with optimum pH range of 6.0 to 6.8 (Kay, 1979). In Ethiopia the major common bean producing regions are Central, Eastern, and Southern parts of the country and in central Ethiopia; farmers grow early maturing white pea bean crop for export as their cash crop (CSA, 2005).

The current organization of genetic diversity in the cultivated gene pool of common bean is the result of evolution under both natural conditions (i.e., prior to domestication) and cultivation. Before domestication, wild *phaseolus vulgaris* had already diverged into two major gene pools, each with its characteristics and geographic distribution, in Mesoamerica and the Andes. In addition to these two major gene pools, recently discovered wild bean populations constitute a third, distinct germplasm segment of particular significance for the evolutionary history of common bean (Gepts, 1998).

These two wild gene pools can be distinguished at the morphological (Gepts and Dubouck, 1996) and molecular level (Faschiani *et al*., 2009). They also separated by incomplete reproductive isolation, which lead to F1 lethality in some, but not all, crosses (Koinange and Gepts, 1996). The existence of this reproductive isolation and the level of divergence at the molecular level suggest that these two gene pools may actually represent two subspecies. Over evolutionary time scale, *Phaseolus vulgaris* could eventually split into two geographically isolated species (Gepts, 1998). However, many crops have been marked by a progressive reduction in genetic diversity (Gepts, 1998), and common bean is no exception.

2.1.1 Origin, domestication and distribution

The genus *Phaseolus* L. includes numerous wild and cultivated species that originated in the New World, the exact number is still unknown (Debouck, 1999). *Phaseolus vulgaris* L. is the most widely cultivated species owing to its high nutritional value. There are four major gene pools; namely Mesoamerican, Andean, Northern Andean and Columbia. Two major gene pools of common bean were first recognized in the wild form, Mesoamerican and Andean (Gepts, 1998). Evidence of this distribution was based on morphological traits (Singh, 1989; Singh *et al*., 1991), phaseolin seed protein (Gepts *et al*., 1986), isozymes (Gepts, 1989), and molecular markers (Freyre *et al*., 1996 ; Tohme *et al*., 1996). A third, genetically unique gene pool was later described in the northern Andes (Debouck, 1999 ; Tohme *et al*., 1996). The northern Andes gene pool is located in Ecuador and northern Peru and is considered to be the nucleus of diversity, from where wild beans dispersed both northward and southward (Broughton *et al*., 2003). A fourth gene pool in Colombia might also exist, but it is still poorly understood (Debouck, 1999; Tohme *et al*., 1996). However, recent work done by Bitocchi *et al*., (2011) identifies the origin of *Phaseolus vulgaris* as Mesoamerican.

The first domestication of *Phaseolus vulgaris* by humans is said to have started slightly more than 4,000 years ago in Mesoamerica and South America (Kapplan and Lynch, 1999). The work of Kami *et al*., (1995) suggested that, starting from the core area of the western slopes of the Andes in northern Peru and Ecuador, the wild bean was dispersed north (Colombia, Central America, and Mexico) and south (southern Peru, Bolivia, and Argentina), which resulted in the Mesoamerican and Andean gene pools, respectively. The common bean then spread to Europe and Africa (Gepts *et al*., 1986, 1988). The common bean was taken to Africa and other parts of the world by Spaniards and the Portuguese (Rani *et al*., 2010)

2.1.2 Morphology and Botany

Common bean (*Phaseolus vulgaris* L.), also referred to as dry bean, is an annual leguminous plant that belongs to the genus *Phaseolus*, with pinnately compound trifoliate large leaves (Katungi *et al*., 2009). It is cultivated on all continents except Antarctica, under very diverse cultivation conditions (Chaco, 2005).

Common bean is largely a self-pollinated plant though cross-pollination does occur if the stigma is exposed to foreign pollen. Seeds are non-endospermic and vary greatly in size and colour from the small black wild type to the large white, brown, red, black or mottled seeds of cultivars, which are 7–16 mm long (Acquaah, 2012).

Common bean shows variation in growth habits from determinate bush to indeterminate, extreme climbing types. The bushy type bean is the most predominant type grown in Africa (Buruchara, 2007).. Bush varieties form erect bushes 20–60 cm tall, while pole or running varieties form vines 2–3 m long. All varieties bear alternate, green or purple leaves, divided into three oval, smooth-edged leaflets, each 6–15 cm long and 3–11 cm wide. The white, pink, or purple flowers are about 1 cm long, and give way to pods 8–20 cm long, 1–1.5 cm wide, green, yellow, black or purple in color, each containing 4–6 beans. The beans are smooth, plump, kidney-shaped, up to 1.5 cm long, range widely in color, and are often mottled in two or more colors (Acquaah, 2012)

The leaves are broad at the blade and are attached to the stem by means of a stalk-like petiole. The leaf may be simple (have only one blade per petiole) or compound (usually three blades per petiole). There may be two simple leaves or one compound leaf attached at a spot on the stem called node. The veins of each leaf blade are arranged into a complicated network. Where the stem and leaf join, there is a swollen area of the petiole that is responsible for leaf movements. At night the bean leaves fold together and down toward the soil; at dawn the leaves unfold and are lifted into the sun (Rani *et al*., 2010).

Two special leaves may still be attached to your bean plant. These are the cotyledons or seed leaves. These leaves are very fleshy and are used by the plant to store starch and other complex molecules in the seed for the later nourishment of the growing plant. On your plant, the cotyledons may be withering due to loss of starch and may have turned green to help produce more nutrients through photosynthesis. The cotyledons may have been completely used up and abscised (fallen off). The portion of the stem below the cotyledons is called the hypocotyls (Buruchara, 2007)

The bean stem is quite long and the internodes between leaf attachments (nodes) are quite obvious. The lowest portion of the stem is below the cotyledons and is called the hypocotyl. The stem terminates at the top of the plant in the apical bud. Lateral buds are found in the axils of each leaf just above the node. This bean plant is a "bush" variety that has shorter stems than the wild type "pole" beans. The stem tips of pole beans grow very rapidly in a twisting manner and "whip around" at several cycles per day. When the stem touches an object, changes in the production of plant hormones cause the stem to twist tightly around and grow up the object. This twining habit is called circumnutation and is common among vines like pole beans. How did we get bush beans from wild pole beans? They resulted from a plant with a chance mutation in a gene coding for a plant hormone involved with stem growth. They cannot produce enough gibberellic acid for extensive stem growth (Koning, 1994).

Koning (1994) the roots of the bean plant are mostly fibrous, although a single main root (the taproot) is larger than the others. The taproot forms many lateral roots that make up the bulk of the mineral absorption area. Some plant roots are contractile; they shorten to pull the plant around in the soil. In one case the roots can pull the plant 60 cm through the soil in one year. While they operate very slowly, these roots prove that plant locomotion is possible. Many plant species have contractile roots, but they usually serve only to pull the stem deeper into the soil, not across the soil.

2.1.3 Plant Development

The development of bean (determinate and indeterminate plant types) pass through two main stages of vegetative (V), (7 to 40 days) and reproductive (R), (40 to 94 days) as indicated in Vegetative stages are determined by counting the number of fully expanded trifoliolate leaves on the main stem while the reproductive stages are described by pod and seed characters. The first pod developing on the plant is described and followed to full size. At the time of first bloom (R stage), secondary branching begins in the axis of lower nodes which will produce secondary groups of blooms or pods. To determine the growth state, the main stem is followed, which is readily discernible on both determinate and indeterminate plants. A trifoliolate is counted when it is fully unfolded (Kandel, 2010).

2.2 Importance of Common Beans in Global Agriculture.

Common bean is the world's most important grain legume for direct human consumption (Broughton et al., 2003), with 20.3 million tons of dry beans harvested from 27.9 million ha worldwide in 2008 (FAO, 2011). The annual production value of common bean is estimated to be over U.S $ 10 billion (Rao, 2001). The leading bean producer and consumer is Latin America, where beans are an important traditional food, especially in Brazil, Mexico, the Andean Zone, Central America, and the Caribbean. In Africa, beans are grown mainly for subsistence, where the Great Lakes region has the highest per capita consumption in the world. Beans are a major source of dietary protein in Kenya, Tanzania, Malawi, Uganda, and Zambia (CIAT, 2014). It is also an excellent low-fat source of complex carbohydrates, fibre, folate, potassium and B vitamins. It also serves as a break crop in Maize-based and rice-based farming systems to reduce decline in soil fertility (Canada, 2003).

2.2.1 Importance of common bean in eastern and southern Africa

It has been reported by Lunze (2001) that common bean is an important grain legume grown on over 3.7 million of hectares every year in Eastern, Central and Southern Africa (ECSA) where bean consumption per capita exceeds 50 kg a year and is perhaps the highest in the world, reaching over 66 kg in densely populated western Kenya (Wortmann et al., 1998). Common bean is mainly produced by the small scale farmers that are resource poor.

Apart from the high protein content, common bean is also a good source of energy and provides folic acid, dietary fibre and complex carbohydrates (Philip, 2013). Common bean protein is high in lysine, which is relatively deficient in maize, cassava and rice, making it a good complement to these staples in the diet. It is grown for its green leaves, green pods, and immature and/or dry seeds. Beans are appreciated throughout the Eastern and Southern Africa because they have a long storage life, good nutritional properties and can be easily stored and prepared for eating (Centro, Agricultura, and Ciat, 1999). The cost of common bean is low as compared to meat products thus its high consumption in Africa. Beyond promoting food, health and nutritional security, beans provide a steady and lucrative source of income for many rural households, with the value of bean sales exceeding US $ 500 million annually (FAO, 2011).

The cost of inorganic fertilizer keeps on increasing and particular in the Eastern and Southern Africa making the poor farmers unable to access these inputs which they need to raise their productivity. Common bean is usually grown either in a pure stand, in rotation with cereals or in crop mixtures usually with maize and the bean fixes nitrogen which benefits the next crop. In this way, the poor resource farmer is able to increase their productivity. The yield of common bean in Eastern and Southern African ranges from 0.60 to 0.80 ton ha^{-1} though the potential yield of some improved varieties can go up to 2.00 ton ha^{-1} (Philip, 2013).

2.2.2 Common bean Production and its Economic Importance in Ethiopia

In Ethiopia, faba bean is the crop that has the highest absolute production, and the largest area cultivated. Ethiopia is also the second largest producer of faba bean in the world (after China). Common bean and chickpea are also major legumes, with both a production of more than 200,000 metric ton grain. On the world market, Ethiopia ranks 6th in chickpea production, and 14th in production of common bean. Among African countries, Ethiopia is the largest producer of both chickpea and common bean (ICRISAT, 2011). In total, the area cultivated with legumes is more than 1 million ha. Production per ha is low and far below the potential production of e.g. 2.9 t/ha for chickpea and 4 t/ha for common bean and faba bean (IFPRI, 2010; USAID, 2011).

Grain legumes occupy about 13% of cultivated land in Ethiopia and their contribution to agricultural value addition is around 10%. Pulses are the third largest export crop of Ethiopia after coffee and sesame, contributing USD 90 million to export earnings in 2007/08 (IFPRI, 2010). Apart from the legumes presented in above topic, field pea and grass pea are also important grain legumes. Faba bean and common bean together account for half of the total area under production of legumes.

The importance of common bean as a source of income, nutrition and its role in food security at a household level is very high (Simane et al., 1998). There is a wide range of common bean seed color classes grown in Ethiopia including mottled, red, white, tan and black varieties (Ali et al., 2003). The most commercial varieties are pure red and pure white colored beans and these are becoming the most commonly grown types with increasing market demand (Ferris and Kaganzi, 2008).

To support both the growth in domestic and export bean markets, the Ethiopian Institute of Agricultural Research (EIAR) and Regional Agricultural Research Institutes (RARI) has developed a range of high yielding, multi-disease resistant bean varieties (Ali et al., 2003). The focus of this genetic improvement program has been on the pure red and white beans to support the commercial sector (Ali et al., 2003). Within the red bean types, the most favored and most commercially accepted varieties include Red Mel, a mottled medium sized red; Red Wolaita, a medium sized pure light red; and Nasser, a small pure dark red variety (Alemayehu, 2014). With regard to economic importance of common bean, it is used as source of foreign currency, food crop, means of employment, source of cash and plays great role in the farming system (CSA, 2005). During 2000, 2001 and 2002, Ethiopia exported 23994.4, 32932.7 and 42127.0 tones and earning 8.2, 9.98 and 13.2 million USD, respectively (EPPA, 2004).

The main destination markets were Pakistan, Germany, Yemen, United Kingdom, South Africa, India and Mexico, having 12.5, 7.8, 6.9, 5.79, 4, 4, 4 % share, respectively (EPPA, 2004). The country's exports of common beans have increased over the last few years, from 58,126 Metric Tons in 2005 to 78,271 Metric Tons in 2007 and Ethiopia gets 63 million dollar from common bean market in 2005 (Legese et al., 2006).

Common bean production is very heterogeneous in terms of ecology, cropping system and yield. It predominantly grows from low land (300-1100 m.a.s.l.) to mid highland areas (1400-2000 m.a.s.l.) of the country. The national average yield of common beans is 0.5-0.8 ton ha^{-1}. The estimated mean yield/ha of common bean in the study area is 0.64 ton ha^{-1} (IPMS, 2005). Majority of the smallholder farmers do not use fertilizer and use local seed instead of improved seeds for planting. Common bean is harvested by hand, heaped and sun dried for a week and then threshed by beating the dried vines with sticks or by chasing oxen on threshing floor.

White beans from the northern Rift Valley were sold into export markets to supply European canning factories and red beans were exported from the southern Rift Valley areas to supply drought affected areas in north Kenya (Ferris and Robbins, 2004). The major storage and trading sites in the southern Rift Valley area are concentrated in the towns of Sodo, Hawassa and Shashemene while the major collection centers for white beans being in Nazareth, prior to exportation through Djibouti (Ferris and Kaganzi, 2008).There are good prospects that this market will grow as consumers in industrialized countries seek evermore competitive suppliers (Ferris and Kaganzi, 2008). For the major processing companies, Ethiopia is a relatively new source of supply and recent investments by a number of international companies from Italy, UK and Turkey, indicating that market prospects are good (CIAT, 2013)

2.3 Climate requirements and adaptation

Common bean is adapted to deep well drain, sandy loam, sandy clay loam or clay loam soils with clay content of between 15 and 35% with no nutrient deficiencies (Thung and Rao, 1999). The optimum soil pH range is pH 4.5-6.0 ($CaCl_2$). Heavy clay soils with poor oxygenation and capping clay sands are not suitable. Thus, it will not grow well in soils that are compacted, too alkaline or poorly drained (Lunze, 2001). The common bean thrives well in a warm climate. It grows optimally at temperatures of 18 to 24 °C. The maximum temperature during flowering should not exceed 30 °C. High temperatures during the flowering stage lead to abscission of flowers and a low pod set, resulting in yield loss. Day temperatures below 20 °C will delay maturity and cause empty mature pods to develop. Cultivated under rain-fed conditions, the crop requires moderate amounts of rainfall (300 – 600 mm) but adequate amounts are essential during and immediately after the flowering stage (Katungi et al., 2009). Generally, common bean is considered a short season crop with most varieties maturing in a range of 65 to 110 days from emergence to physiological maturing (Buruchara, 2007). Maturity period can continue up to 200 days after planting amongst climbers that are used in cooler upland elevations (Gomez, 2004).

In Africa, common bean crop cultivation is concentrated at altitude above 1000 metres above sea level, with adequate amounts of precipitation (> 400 mm of rain) during crop growing season and soil pH above 5.5.

2.4 Phosphorus and Nitrogen fertilizers on common bean production

Application of fertilizer in a recommended amount is essential for high yield and quality of grains (Morgado, 2003). The use of fertilizer is considered to be one of the most important factors to increase crop yield per unit area. However, the response to the type and rate of fertilizer application varies widely with location, climate and soil type (Khan et al., 2003; Marshner, 2002). Nitrogen deficiency occurs almost everywhere unless nitrogen is applied as a fertilizer or manure (Desai, 1988). It has been reported that there was increased yield responses of pulse for nitrogen fertilizer (Morgado, 2003).

2.4.1 Phosphorus (P) use efficiency of Common bean

Phosphorus is a critical nutrient element for plant growth since it is involved in cellular energy transfer, respiration and photosynthesis. Phosphorus is also a structural component of the nucleic acids of genes and chromosomes and of many coenzymes, phospho-proteins and phospholipids. Plants need P throughout their life cycle but most importantly during early growth stages for cell division (Havlin et al., 1999).

Phosphorus is among the principal nutrient elements needed for growth of many legumes in arid and semi arid agriculture regions due to low available P in the soils and advantageous effects of P (Rathju et al., 1987; Frizzone, 1982). Amos et al. (1998, 1999) also indicated that P application is key to enhance bean yield on farmer,s field in their study on the low fertile Orthic Acrisols of western Kenya. The researchers also indicated that P significantly enhanced the establishment of beans, number of pods per plant, and the bean grain yields. Similarly, Dadson and Acquaah (1984) also reported that the formation of nodes and pods was promoted with the application of P in P deficient soil. Thus, P application from external sources/fertilizers/ becomes very essential to obtain optimum yield.

2.5 Irrigation and its advantage in Ethiopia

Water scarcity became a common phenomenon in Ethiopia with drought frequency of at least once in three years while the country owns a large irrigation potential that should be exploited sustainably. Various national and international institutions are currently engaged in developing small scale irrigation schemes for poverty alleviation. A monitoring and evaluation exercise was conducted in 2004 and in 2006 in four administrative regions of Ethiopia, namely Tigray, Southern regions, Oromia and Amhara, to assess the benefits and associated environmental effects of small scale irrigation investments of the International Fund for Agricultural Development (IFAD). Inefficient water management in the rain-fed agriculture coupled with accelerated land degradation plays an important role in aggravating the recurrent food insecurity in the country (NRMD, 2011)

In the recent years, drought became a common phenomenon, happening in any part of the country at any time of the year, with a frequency of at least once in three years. Four different drought scenarios were identified in the mixed crop-livestock systems of Ethiopia namely, terminal drought, intermittent drought, foreseeable drought and define drought (Amede, et al., 2004). In situations where agricultural production is operating under these various drought scenarios, with annual rain fall variability of 40 to 50%, supplementary irrigation became a necessity for food production, particularly for intensifying systems through high yielding and input responsive varieties and breeds. Currently, the growth in food production in Ethiopia is primarily due to expansion of agricultural land while production per unit of investment remained stagnant

On the other hand, Ethiopia owns a wide range of irrigation opportunities with about 9.85 million ha of potentially irrigable arable land, while only 3 to 5% of the potential is currently under irrigation (Yalew et al., 2011) accounting for approximately 3 percent of total food crop production. Current yield from rain-fed land is only about 50% of the irrigated land, given all other inputs remain the same, thanks to the recurrent drought and limited adoption of water management practices. If the country is to achieve its stated aims of food self-sufficiency and food security, the current production shortfalls call for drastic measures to improve production efficiency of both irrigated and rain-fed agriculture. In response, the government of Ethiopia as stated in its Poverty Reduction Strategy Paper (PRSP) emphasized the importance of improved water resource development and its utilization to achieve food security through enhanced use of small scale irrigation. Since the early 1990s, the federal and regional governments of Ethiopia, with financial assistance from donors, have been attempting to upgrade traditional small scale schemes, built small scale dams, diversions and water harvesting ponds to respond to these environmental calamities (Yalew et al., 2011).

However, the performance of the irrigation systems has been poor. There exists a substantial yield gap in irrigated farms between achievable and actual yield both in terms of yield per unit of land but also yield per unit of water depleted. The positive effect was more visible with horticultural crops. There has been also a shift towards improved varieties with access to irrigation. Farmers replaced early maturing but low yielding varieties with high yielding varieties. Crop diversification increased significantly, in some sites from three to about 15 species, although this decision making process did not favour legumes (Yalew et al., 2011).

To mitigate the effect of drought several strategies can be employed including irrigation and drought tolerant varieties. Drought tolerant varieties are not a viable option for most small scale farmers due to the cost factors, while the use of irrigation is a preferred option (Kilasi, 2010). The main advantage of irrigation is that it maximizes the productivity of water. Although a certain reduction in yield is observed, the quality of the yield (e.g. sugar content, grain size) tends to be equal or even superior to rain-fed (Zhang et al., 2006; Spreer et al., 2007).

2.6 Improved Common bean Varieties

Farmers in Eastern and Central Africa grow bean cultivars of wide range of seed types, often in phenotypically diverse mixtures. The genetic diversity is expected to give stability to bean production, buffering it against biotic and abiotic stresses. But, as higher yielding varieties become available, traditional cultivars are lost with a resultant decline in genetic diversity. Frequently, breeders have several promising lines of similar seed type and face the choice of either releasing and promoting only the best variety (s) (CIAT, 2011).

The choice of one technology and/or practice over others is greatly influenced by the balance between its positive and negative characteristics (NSIA, 2010). Any new technology presented to farmers will either improve or substitute for the technological options they currently have. It is fundamental to identify these options and understand perceptions about the advantages and disadvantages of each one of them. The researchers are be able to assess the appropriateness of potential new technologies or practices, evaluate the likelihood that they will be adopted, and if necessary modify them to suit farmers, needs better (Table 1).

Table1 List of improved Haricot bean varieties and their characteristics (EARO, 2011).

Variety name	Released year	Type Ex port	 Domestic	 Both	Recommended Agroecology
Awash Melka	1998	†			In all haricot bean production area
Mexican 142		†			In all areas
Gofta	1990		†	†	In all haricot bean production area
Fedis	1998		†		Southern rift valley
KatB-9	**		†		**
Seer-125	**			†	**
Hawasa dume	2001		†		Southern Ethiopia
Nasir	2003			†	In all haricot bean production area
Dinkenesh	2003			†	In all haricot bean production area
Gebisa			†		In all areas
Ibado	2003			†	Southern Ethiopia
Loko	2003			†	Southern Ethiopia
KatB-1			†		In all area
Durstu			†		Southern Ethiopia
Deme	2008			†	In all haricot bean production area
Ramada	**	**	**		**
Waju	**	**	**		**
Haramaya	2006	food	Export		In cold area of Harer
Omo-95	2003	food			South rift valley

** =Not accessed by this study

2.7 Heritability, genetic advance and association of major quantitative traits

Heritability interests plant breeders primarily as a measure of the value of selection for a particular character in various types of progenies and as an index of transmissibility. If the percentage is high, the character is heritable but if it is small, the environment is correspondingly prominent in the character expression (Hayes et al., 1955). Allard (1960) indicated that the heritability values for quantitative traits are low mainly due to their sensitivity to environmental factors. Moreover, heritability should be used along with genetic advance in predicting the efficiency of selection. High heritability values could be obtained with genotypes having small or large genetic variance but genetic progress would be larger with larger genotypic variance (Allard, 1960).

High heritability associated with high genetic advance is chiefly due to the additive gene effect but if heritability is mainly due to dominance and epistasis, the genetic gain would be low (Panes, 1957). In general, genetic variability, heritability and genetic advance are prerequisites for a breeding program and provide opportunities to breeder to select high yielding genotypes or to combine or transfer genes having desirable traits (Philip, 2013). Pandey and Tiwari (1983) indicated the importance of estimating heritability to know the inheritance of quantitative traits as it indicates the genetic gains that may be achieved through selection.

Acquaah (2012) Seed yield is an important and priority trait for plant breeders and other crop researchers. However, seed yield is a complex character and is considered the ultimate product of its components. Hence, selection of superior genotypes based on grain yield is diffcult due to the integrated structure of a plant in which most of the characters are interrelated and being governed by a larger number of genes. This necessitates a thorough knowledge on the nature of the relationship prevalent between the contributory characters and grain yield and the extent of genetic variability.

2.8 Agronomic Practices on Common bean Production

Improved agronomic practices are used to increase crop yield and are recommended by researchers after testing on the research field and on a farmer field.

Seeding rate

Ethiopian farmers, in general, use lower seed rate than research recommendations which result in lower grain yields (Ali et al., 2003). The seed yield of bean is the result of many plant growth processes which ultimately influence the yield components such as pods/plant, seeds/pod, and unit weight of seed. The highest seed yields were obtained when all the above got maximized (Tessbo et al., 2004).

The spatial distribution of plants in a crop community is an important determinant of yield (Egli, 1988) and many experiments have been conducted to determine the spacing between rows and between plants that maximizes yield. Two general concepts are frequently used to explain the relationship between row, spacing, plant density and yield. First, maximum yield could be obtained only if the plant community produced enough leaf area to provide maximum light interception during reproductive growth (Tessbo et al., 2004). Secondly, equidistant spacing between plants affected interplant competition (Pendleton and Hartwing, 1973). Hence, it will be very important to adjust the spatial distribution of the recommended population in order to have maximum yield.

To avoid nutrient competition sufficient spacing between plants and rows is vital to get maximum yield in a given plot of land. Appropriate spacing enables the farmer to keep appropriate plant population in his field. Hence, a farmer can avoid over and less population in a given plot of land which has negative effect on yield.

Harvesting

Timely harvest is important to reduce mold, bird and insect damage and also to decrease losses due to shattering and wet weather (Ali et al., 2003). Crops may be harvested when they are physiologically mature. Common bean is harvested when the foliage of the crop is turned to yellow and before starting shattering (Setegne and Leggese, 2003).

2.9 Evaluation of Improved Crop Varieties by Farmers

Farmers' criteria vary greatly between households, depending on the productive resources controlled by the household. However, the criteria also vary within a household. Farmers identify and select the type of crops most likely to do well in their areas and selection is normally preceded by extensive discussions both within the farm family and with neighbors (Getinet et al., 2001). Characteristics of the varieties play a vital role in adoption of improved crop varieties. Accordingly, if the characteristics of the varieties satisfy the need and interest of the farmers they eventually adopt the improved crop varieties (Gebre-Egziabher et al., 2014). Farmers, technology evaluation criteria include growth habit, yield, color of grain, ease of threshing main uses in the diet, storage, qualities, marketability (Farrington and Martin, 1988), cost, ease of sale, desirability for home consumption, compatibility with existing practices, taste, nutritional value, cooking quality and resistance to pest (Abebe et al., 2013).

The choice of one technology practice over others is greatly influenced by the balance between its positive and negative characteristics (Daniel et al., 2014). Depending on the preferences, resources, and constraints that individual farmers face, a beneficial characteristic for one farmer may be a negative one for another, or the balance between positive and negative traits may be acceptable for one farmer but not for another (Bunders et al., 1996). Any new technology presented to farmers will either improve or substitute for the technological options they currently have. It is fundamental to identify these options and understand perceptions about the advantages and disadvantages of each one then will researchers be able to assess the appropriateness of potential new technologies or practices, evaluate the likelihood that they will be adopted, and if necessary modify them to suit farmers, needs better (Acquaah, 2012).

2.10 Overview of Technology Adoption

Adoption is a mental process through which an individual passes from first knowledge of an innovation to the decision to adopt or reject and to confirmation of this decision (Ray, 2001).

According to Feder et al. (1985) adoption refers to the decision to use a new technology, method, practice, etc by a farmer or consumer. Kebere et al., (2006) indicate that the decision to adopt an innovation is not normally a single instantaneous act, it involves a process. The adoption is a decision-making process, in which an individual goes through a number of mental stages before making a final decision to adopt an innovation.

Decision making process is the process through which an individual passes from first knowledge of an innovation, to forming an attitude toward an innovation, to a decision to adopt or reject, to implementation of new idea, and to confirmation of the decision (Ray, 2001). However, as emphasized by Delmer (2005), adoption does not necessarily follow the suggested stages from awareness to adoption; trial may not always be practiced by farmers to adopt new technology. Farmers may adopt the new technology by passing the trial stage. In some cases, particularly with environmental innovations, farmers may hold awareness and knowledge but because of other factors affecting the decision making process, adoption does not occur (FAO, 2011).

3. Materials and Methods

3.1 Description of the Study Area

The experiment was conducted at Bako on model farmer field under irrigated conditions in 2014/2015. Bako Tibe district is located about 251 and 125 km west of Addis Ababa and Ambo, respectively. The total area of the district is about 644.94 km^2 and the total population size was estimated 65,293 men and 68,291 women of totally 133,584. Bako is located at $37^0 09'$E and $9^0 16'$N and an altitude of 650m.a.s.l. The major agro-ecological zone of the study area is humid to sub-humid with uni-modal rain fall characteristics. The mean annual rain fall is 1217 mm. Its has a warm humid climate with mean minimum, maximum and average temperature of 14^0C, 28^0C and 21^0C, respectively. The soil is nitosol specifically clay loam soil. This location was purposely selected as it is among the potential areas for both irrigation and common bean production.

Figure 1 Map of the study area (BakoTibe Woreda Land Use Management and Environmental Protection office.)

3.2 Experimental/Plant Materials

Twenty improved common bean varieties which were released by the different Agricultural Research Centers such as Awasa, Bako, Haramaya and Melkasa from 1976 to 2009 were used (Appendix 1).

3.3 Experimental Designs and Treatment arrangements

The experiment was arranged in Randomized Complete Block Design (RCBD) with three replications. Each plot consisted of three rows of 1.8 m long and 0.4m between rows. The spacing between plants within row was 10cm.

3.4 Phenological and growth parameters recorded

Ten individual plants were selected randomly per plot, marked before flowering and used as samples for the measurable quantitative traits. The following parameters were recorded following common bean descriptors.

Date of emergence (DE): It was recorded when 50% of plants in the plots emerged, and will be used to calculate days to flowering and days to maturity. It is the data at which about 50% of the seedling expected from the plot have emerged out of the ground or become visible above the ground.

Days to 50 % flowering (DF): it was recorded as the number of days from planting to the time when 50% of the plants in the plots started flowering(in case of dry sowing) or it is the number of from sowing (if sowing is done when the soil is wet enough to initiate germination).

Days to 95 % maturity (DM): days to physiological maturity was recorded when 95% of the plants in a plot turns their leaves to yellow. It is the number of days from day of sowing to day of 95 % physiological maturity.

Plant height (PH) (cm): was measured from above ground to top of apex once at physiological maturity on ten randomly selected sample plants.

Number of seeds per pod (SPP): it is the number of seed in each pod. It was determined by dividing the total number of seeds from ten sampled plants by the total number of pods.

Number of mature pods per plant (PPP): It is the average number of effective pods on a plant. It was determined as the average number of well-filled pods of ten randomly taken plants divided by the plant sampled.

Seed yield per plant (g) (SYPP): Recorded as the average weight of seeds obtained from ten sampled plants divided by the number of sample plants.

Pod filling period: Calculated as the number of days from flowering to physiological maturity (days to maturity minus days to flowering).

Harvest Index: Calculated as:

$$HI = \frac{Grain yield}{Biomass Yield} \times 100$$

Where HI is harvest Index, GY is grain yield per plot and BY is biomass yield per plot.

100-seed weight (g) (HSW): Recorded as the weight of 100 seeds of a variety after it was dried to optimum level of storage moisture.

Biomass yield (BM): was measured from net plot by harvesting close to ground level and kept separately; sun dried to a constant weight and then tied in to small bundle and weighted.

Grain yield/plot (g) (GY/PLOT): This was recorded by weighing seeds obtained from the net plot area after sun drying for one week. The data was used to calculate seed yield per hectare.

3.5 Data analysis

3.5.1 Analysis of variance

Data collected for all quantitative characters were subjected to analysis of variance (ANOVA) using General Linear Model of the SAS statistical package (SAS, 2012). Least Significant Difference Test (LSD) at 5% and 1% level of significance was used and treatment means were separated by Duncan‚s multiple range test.

3.5.2 Cluster analysis

Hierarchal clustering of the average linkage method with squared Euclidian distance was performed using MINITAB14 (MINITAB, 2003). It is used for small varieties test (i.e., less than 30). Data for all quantitative traits were standardized to mean of zero and variance of one before clustering to avoid any bias that may have arisen due to differences in measurement scales. The distances between clusters were calculated using the average linkage method of squared Euclidian distance.

3.5.3 Principal component analysis (PCA)

Principal component analysis for standardized quantitative traits was computed by using MINITAB14 (MINITAB, 2003) software to identify the most important traits contributing to the total variations observed among the accessions, countries/regions of origin and altitude classes. As suggested by Johnson and Wichern (1988), principal components with Eigenvalues/variance greater than one were considered.

3.5.4 Estimation of correlation coefficient

The Pearson‚s correlation coefficients between all possible pairs of quantitative traits were tested for their significance using SAS software (SAS, 2012).

3.5.5 Phenotypicand Genotypic coefficient of variation

The variability of each quantitative trait was estimated by simple statistical measures such as mean, range, phenotypic and genotypic variances and coefficient of variation. Phenotypic coefficient of variation (PCV) and Genotypic coefficient of variation (GCV) values below 10%, 10%-20% and above 20% were considered to be low, intermediate and high, respectively (Khorgadeet al., 1985). The phenotypic and genotypic variation and coefficient of variations were calculated following the formula suggested by Singh and Chaundhary (1985) and Allard (1960) as follows;

$\text{ˆ}^2_p = \text{ˆ}^2_g + \text{ˆ}^2_e$ where, ˆ^2_p = phenotypic variance,

ˆ^2_g = genotypic variance and

ˆ^2_e = environmental variance

$\text{ˆ}^2_g = (MS_g \text{„} MS_e)/r$ where, MS_g = mean square of genotype,

MS_e = mean square of error and

r = number of replications

$$PCV = \frac{\sqrt{d^2{}_p}}{\bar{x}} \times 100$$ where, PCV = phenotypic coefficient of variation,

ˆ^2_p = phenotypic variance and

$\bar{x}$ = population mean for the trait considered

$$GCV = \frac{\sqrt{d^2 g}}{\bar{x}} \times 100$$ where, GCV = genotypic coefficient of variation,

ˆ^2_g ‰ genotypic variance and

$\bar{x}$ = population mean for the trait considered

3.5.6 Estimate of Broad sense heritability

Broad sense heritability was estimated according to the suggestion of Allard (1960) by dividing genotypic variances by phenotypic variance: $HŠ = \text{ˆ}^2_g / (\text{ˆ}^2_p) \times 100$, where ˆ^2_g = genotypic variance and ˆ^2_p = phenotypic variance. Expected genetic advance under selection assuming a selection intensity of 5% was computed following the formula developed by Allard (1960) as:

$GA = (K)\ (\hat{}_p)\ (H^2)$, where GA = expected genetic advance

K= selection differential that varies depending up on the selection intensity and stands at 2.056 for selecting 5% of the genotypes.

$\hat{}_p$ = phenotypic standard deviation and

H^2= heritability (in broad sense)

Genetic advance as percent of mean (GA as % mean) = $\left(\frac{GA}{\bar{x}}\right)$ x 100%: where,

GA= genetic advance and

$\bar{x}$ = population mean for the trait considered

3.5.7 Estimation Shannon-weavers diversity index (H€) for qualitative traits

Genetic diversity index was estimated to measure the diversity of five qualitative traits such as seed color, seed shape, seed size, flower color and pod color were employed in this study. The amount of genetic variation was determined using Shannon-weaver diversity index (Shannon and Weaver, 1949)

4. Result and Discussion

4.1 Mean, range and standard deviation for quantitative characters

Mean, range and standard deviation for agronomic traits are widely used to determine variations between varieties. The mean, minimum, maximum, range, deviation from the mean and standard error of mean for 20 released haricot bean varieties are presented in Table 2.

As can be seen from table 2, wider ranges of variation were observed between the tested common bean varieties for most of quantitative traits. Days to flowering ranged from 37 (for variety Gofta) to 50 (for Deme). Common bean variety Nasir was early maturing (83 days), but Deme took the highest number of days to mature (109). The highest plant height recorded for Waju (172cm) and the lowest for Kat B1 (46.3cm). Pod per plant ranged from 10.93 for Hawasa dume to 33.07 for Dinkinesh.

Extremely wider range of variation was noted for grain yield per hectare (772 kg to 5767 kg). Of all tested common bean varieties, the highest grain yield per hectare (5767 kg) was noted for Ramada released from Melkasa Agricultural Research Center, but the lowest (772 kg) for Hawassa dume released from Hawasa Agricultural Research Center.

The descriptive analysis for major quantitative traits showed the existence of wide range of variation among the released common bean varieties. The wide range in the extreme values of each of the traits studied offers broad opportunities for further utilization in the breeding program to develop varieties suitable for different agro-ecologies of the country and for different purposes

The broad range of variation for phenologies such as days to flowering, days to maturity and grain filling period offer great flexibility for developing improved varieties suitable for various agro-ecologies of the country which have variable length of growing period and also to use in various cropping systems. The wider variation in number of pods per plant, seeds per pod, hundred seed weight and seed per plant among the varieties implied the possibility to create a variety with higher grain yield and/or other biological yields. Early flowering and maturity is the most important mechanism to escape terminal drought stress in rain-fed condition. The highest plant height in Waju (172 cm) indicates that this trait is less influenced by environmental fluctuations and also attributed to the semi-climbing nature of the genotype. The findings in this study are in agreement with Win, (2011); Nielson and Nelson, (1998); and Philips, (2013) in common bean under irrigated condition. They all reported that, the difference can be attributed to genetic variability among the genotypes. Bray (1993) found similar results in soybeans.

Table 2 Descriptive statistics on yield and 13 yield related parameters

Variable	Minimum	Maximum	Range	StDev	Mean ±SEM
Plant height	46.27	172.13	125.86	31.91	104.9±7.13
Days to flowering	37.33	49.80	12.47	4.10	42.54±0.916
Days to maturity	82.67	109.33	26.66	8.51	95.15±1.9
Grain Filling Period	40.67	65.00	24.33	6.80	52.75±1.52
Pod per plant	10.93	33.07	22.14	5.23	21.35±1.17
Seed per pod	3.08	6.20	3.12	0.96	4.67±0.215
Seed per plant	33.37	154.63	121.26	37.21	101.85±8.32
Hundred seed weight	20.67	52.53	31.86	10.88	35.25±2.43
Grain yield per plant	9.18	61.81	52.63	11.92	34.25±2.66
Grain yield per plot	144.40	1093.60	949.20	252.60	515.10±56.5
Grain yield per hectare	772.00	5767.00	4995.00	1362.00	2779±305
Biomass weight per plant	1.40	3.10	1.70	0.48	2.2±0.108
Harvest index	0.11	0.36	0.25	0.07	0.23±0.015

source: model

4.2. Pearson correlation coefficient analysis

Correlation coefficients were computed to assess the relationships between yield and yield related components of the 20 released common bean varieties in Ethiopia under irrigated condition in the study area. The association of yield and yield related attributes was based on the mean of 20 released common bean varieties for 13 quantitative traits. The result showed that about 69.23% of the total traits showed positive correlation and 30.77% showed negative correlation (Table 3). The yield per plant exhibited significant positive correlation ($P < 0.05$) with most of yield related traits indicating relative utility of these traits for selection. This positive correlation could be resulted from the presence of common genetic elements or micro environments (or both) that controls the characters to the same direction. Similarly, Khan and Qureshi (2001) have reported that number of pods per plant is positively correlated with seed yield per plant in chickpea. Also, Guler et al. (2001) informed that the direct effect of the number of pods per plant on seed yield in chickpea was significant. Positive significant correlation due to effect of genes can be the result of strong linkage between their genes or the characters may be the result of pleiotropic genes that control these characters in the same direction (Abebe et al., 2013). Similar results were reported by Lule et al., (2012) for finger millet and Ayana (2001) for sorghum. There is a small and non significance correlation (r= 0.0930) between grain yield (kg/ha) and plant height. This may be due to lodging and canopy effect.

Polygenic traits such as pod per plant, biomass yield, and seed per pod, hundred seed weight and harvest index showed positive correlation with grain yield. This implied the possibility to combat the low yielding ability of common bean varieties by improving and selecting for these important agronomic traits. Similarly, Gebre Egziabher et al., (2014) found positive correlation for grain yield with number of pod per plant, number of seeds per plant and hundred seeds weight. Supportive results to the present study were also reported for common bean (Mesfin et al. (2014); Kebere et al., 2006; Abebe et al., 2013; and Daniel, 2012); for bread wheat (Tarekegn, 1994; Salado-Navaro et al., 1993; and Karmaker and Bhatnagar, 1996); for linseed (Worku, 2005), and for tef (Assefa et al., 2002); and for sorghum (Ayana, 2001). Plant height has negative correlation with grain yield and most of yield related traits (Table 3). Similarly, Gebre Egziabher et al. (2014) found negative correlation between plant height and grain yield in some released common bean varieties. Win, (2011) also found negative correlation between plant height and pod per plant, seed per plant and yield per plant in chickpea under similar condition. Negative correlation between grain yield and plant height in the present study was in contrary with the finding of Riggs et al., (1981) which reported positive association in wheat.

However, number of pods per plant was negatively correlated with days to 50% flowering, and days to maturity. This may be due to flower suppression during irrigated condition. Those results indicated that prolong reproductive phase in such environment may lead to decrease in yield. Negative correlation between number of pod per plant and days to 50% flowering, and days to maturity in the present study was in contrary with the finding of Win (2011) which reported positive association in chickpea under rain fed condition.

Therefore, from the present correlation study there were strong correlations between some traits (Table 3), which allows for simultaneous selections and use of the related traits interchangeably in selection. The strongly correlated traits are possibly under the influence of the same genes or pleiotropic effects (Misko, 2008). Practically, during bean improvement, if two strongly correlated traits are desired, they can both be selected simultaneously basing on one of the traits.

For example giving emphasis to number pods/plant, number of seeds/pod and number of seeds /plant is a paramount important in improving seed yield of common bean genotypes through indirect selection in high moisture stress area like Bako. Such studies are useful in disclosing the magnitude and direction of relationships between the different characters and seed yield as well as among the characters (Sharma and Arora, 1978).

Table 3. Correlations coefficient of yield and yield related components of the common bean genotypes

Traits	PH	DF	DM	GFP	PPL	SPPOD	SPPL	HSW	GYPPL	GYKgh	BIO	HI
DF	0.150											
DM	0.429*	0.645*										
GFP	0.414*	0.187	0.862*									
PPL	-0.003	-0.067	-0.152	-0.207								
SPPOD	-0.050	0.207	-0.088	-0.281	0.430							
SPPL	-0.021	-0.008	-0.174	-0.263	0.828*	0.819*						
HSW	-0.142	0.434*	0.362	0.208	-0.269	-0.442*	-0.469*					
GYPPL	-0.062	0.407*	0.253	0.010	0.533*	0.361	0.468*	0.499*				
Gy kg ha^{-1}	0.093	0.384	-0.076	-0.368	0.098	0.549*	0.338	0.140	0.435*			
BIO	-0.147	0.405	0.062	-0.225	0.181	0.570*	0.391	0.139	0.547*	0.802*		
HI	0.082	0.216	-0.305	-0.532*	0.195	0.564*	0.410*	0.002	0.331	0.913*	0.577*	

Key: * = significant at 5% level of significance.

4.3. Principal component analysis

Principal component Analysis for 13 standardized quantitative traits were computed by using MINITAB14 software MINITAB(2003) to identify the most important traits contributing to the total variations observed among the 20 common bean varieties. PCA results illustrated the overall picture of the pattern of genetic diversity of the common germplasm based on 13 quantitative traits. As speculated or suggested by Johnson and Wichern (1988), principal component with Eigen-values greater than one was considered.

The first four principal components having Eigen-value greater than one were extracted from the mean of 13 normalized quantities traits of 20 improved common bean varieties (Table 4). A variance of 39.2, 22.1, 14.6 and 10.6% were extracted from the first to fourth components, respectively. Agronomic and phenotypic characters such as grain yield per plot, grain yield kg/ha, harvest index, biomass yield, seeds per pod, number of seeds per plant and grain yield per plant were the major contributors for the variation observed in the first principal components. The variation in the second principal were mainly due to days to maturity, days to 50% flowering, hundred seed weight and grain feeling period. Likewise pod per plant, seed per plant, grain felling periods and hundred seed weight were the major contributors to the variation in the third components. Plant height, grain yield per plant, hundred seed weight pod per plant, seed weight and harvest index were the major contributors for the variation observed in the fourth components. The above traits are highly recommended for use in common bean characterization, conservation and breeding. Similar result was also reported by Atilla et al., (2001).

Table 4 Principal Component Analysis of 13 quantitative traits of 20 improved common bean genotypes

Traits	PC1	PC2	PC3	PC4
Plant height	0.029	0.196	0.263	0.589
Days to flowering	-0.134	0.453	-0.002	0.010
Days to Maturity	0.088	0.517	0.277	0.096
Grain filling period	0.219	0.371	0.325	0.117
Number of Pods Per plant	-0.208	-0.154	0.475	-0.317
Number of Seeds Per Pod	-0.353	-0.086	0.248	0.124
Number of Seeds Per Plant	-0.312	-0.177	0.446	-0.091
Hundred seed weight	0.033	0.411	-0.313	-0.418
Grain yield per plant (g)	-0.261	0.262	0.167	-0.468
Grain yield per plot (g)	-0.408	0.066	-0.178	0.173
Grain yield per hectare (kg	-0.388	0.134	-0.222	0.193
Biomass yield per plot (g)	-0.362	0.168	-0.108	-0.041
Harvest index (%)	-0.377	-0.015	-0.208	0.206
Eigenvalue	5.0942	2.8706	1.9003	1.3779
Proportion	0.392	0.221	0.146	0.106
Cumulative	0.392	0.613	0.759	0.865

PC: Principal components

4.4. Cluster analysis

At 80% similarity level, all the 20 released varieties were grouped into five clusters based on 13 standardized quantitative traits (Fig. 1). Common bean varieties such as Gofta, Seer-125, KatB-9, KatB-1, Fadis, Awash Melka, Mexican-142, Seer-119, Dursitu, Dinkinesh and Gebisa were grouped together in the first cluster (Fig. 1). This cluster recorded the least in plant height (96 cm) and days to grain filling period (42 days). Waju, Ebado and Loko were grouped in the second cluster. This cluster showed the highest in average number of pods per plant (25.32), hundred seed weight (46.7 g) and grain yield per plant (48.5 g) but the least in number of seeds per pods and harvest index.

The third cluster comprised of two varieties (Deme and omm-95) and this cluster showed the highest average plant height (132 cm), days to flowering (49 days), days to maturity (109 days) and days to grain filling period (61 days). Haramaya and Awash Dume were grouped in the fourth cluster due to their relatedness for plant height, pod per plant and seed per pod. Besides, the fourth cluster portrayed the least in number of pods per plant (18.8), seeds per plant (78) hundred seed weight (27.8) and biomass weight per plant (1.9 g). The fifth cluster comprised of two varieties such as Ramada and Nasir, and those varieties showed the highest in seed per pod (5.8), seed per plant (126) and grain yield per hectare (5.01 tons).

Overall, the aggregation of those 20 released common bean genotypes based on plant height, days to flowering, days to maturity, grain filling period, pod/plant, seed/pod, hundred seed weight, grain yield/ plant, grain yield/plot, grain yield/ha, biomass yield/plot and harvest index into five clusters at 80% similarity level having 2-11 varieties per cluster indicated a morphological diversity between the tested materials. It is generally agreed that genetically diverse parents will exhibit maximum heterosis and offer the best chance of isolating transgressive segregants (Mirko, 2008). The result of hierarchal clustering of the varieties revealed crossing of early maturing and short plant height varieties in cluster I with late maturing and long plant height cultivars in cluster three could result in several new lines with heterotic characters. Likewise, it is possible to generate a diverse parental line for hybridization from distantly related clusters with diverse functional traits as observed from hierarchical clustering (Fig. 2).

The clustering pattern indicated that varieties in clusters 3 to 5 were genotypically more divergent from the other collections for they formed single genotypic clusters. This method of clustering germplasm collections can also be used in the elimination of the duplicated and genetically redundant accessions along with other relevant information and documents of the germplasm (Greene and Pederson, 2001). Hence, they recommended the elimination of duplicates as an effective way of reducing germplasm maintenance cost without losing valuable genetic resources. Likewise, it is possible to generate a diverse parental line for hybridization from distantly related clusters with diverse functional traits as observed from hierarchical clustering (Fig. 1). The present study was confirmed the finding of Mali et al., (2004). He reported that cluster analysis using dendrogram find out genetic variability among common bean genotypes.

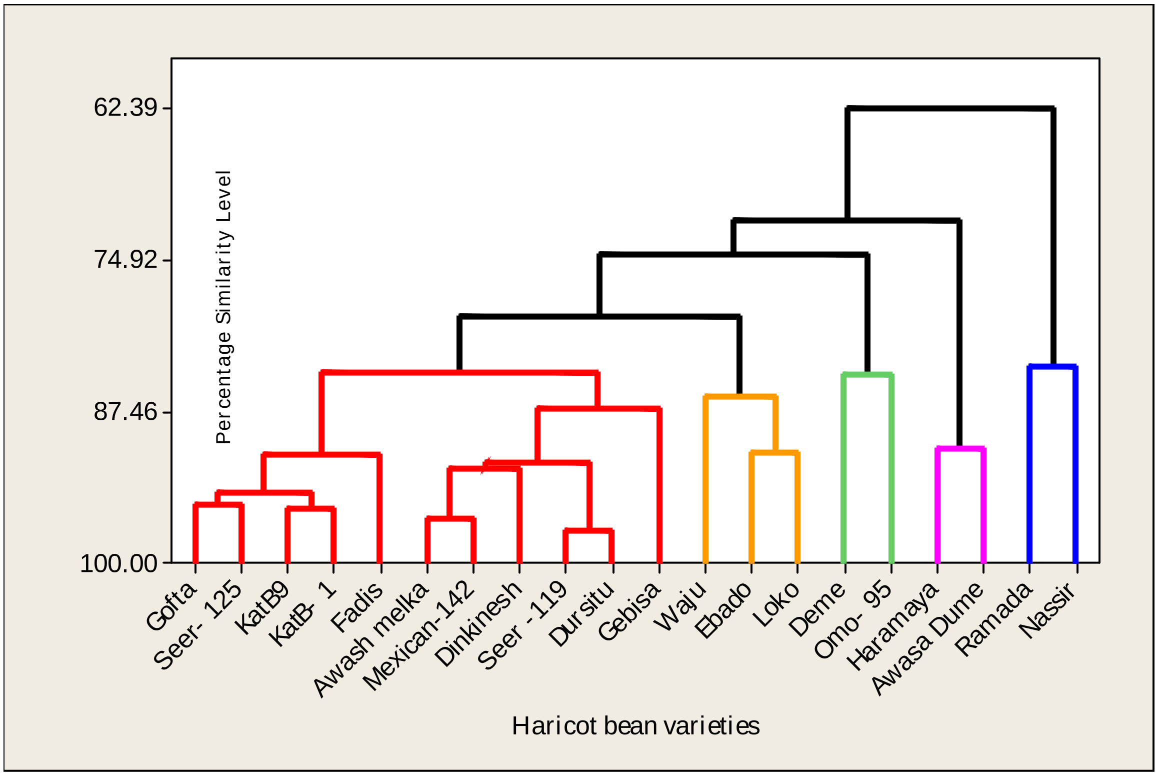

Figure 2 Dendrogram showing genetic similarity and differences between 20 improved common bean genotypes evaluated for 13 major phenotypic traits at 80% similarity level for standardized data

4.5 Phenotypic and Genotypic coefficient of variation

The estimates of phenotypic coefficient of variation (PCV) were higher than genotypic coefficient variation (GCV) for all the characters under consideration. Comparatively maximum PCV values were observed for grain yield per plot (47.8%), grain yield per plant (39.09%), number of seed per pod (37.5%), harvest index (35%), hundred seed weight (29.94%), plant height (22.29%), and pod per plant (26.5%), and biomass weight per plot (23.19). Intermediate PCV values were observed for grain feeling period only. However, days to 50% flowering and days to maturity exhibit very low PCV values, 9.64% and 8.56%, respectively. Estimates of genotypic coefficient of variation (GCV) were lowest for traits such as days to maturity and days to 50% flowering. Intermediate

GCV values were observed for days to grain feeling period and biomass yield per plot. The highest genotypic coefficient of variation (GCV) was obtained for grain yield per plot (46.16%), number of seed per plant (33.9%), grain yield per plant (31.56%), hundred seed weight (29.12%), harvest index (25.2%) and number of pod per plant (22.5%) (Table 5). Similar results have also been reported by Abemayehu et al. (2014) for yield per plant and pods per plant; Redy & Singh (2009) for yield per plant, pods per plant, plant height and 100 seed weight; Pandey et al. (2013) for pods per plant.

The PCV and GCV values for most of the traits considered in this study were found to be high (Table 5). High GVC and PCV for number of pod per plant and number seeds per plant were earlier reported by Fikre et al. (2012). The large percentage of both GCV and PCV values were due to their respective large variances and lower mean, as shown in table 5. In other words, traits that had relatively large genetic variances also showed higher genotypic coefficient of variation, suggesting that selection for these characters might be more effective than the remaining ones since they had less environmental influences. Genotype Nassir and Ramada can be considered as the best variety and be recommended for use under irrigated condition in the study area because the cumulative effects of the 13 quantitative traits make them well adapted and performed.

4.6. Broad sense heritability (H2) and Genetic advance

A fair measure of efficiency of selection for any quantitative traits can be derived from the estimates of heritability for the characters under consideration. But reliability of selection depends not only on heritability but it should also be accompanied by high genetic advance (Johnson et al., 1955). High heritability coupled with high genetic advance indicated that genetic progress can be made through selection as it suggests the presence of additive gene effects (Panse, 1957).

In the present study, estimates of heritability (H^2) ranged from 51.88% for harvest index to 97.99% for days to maturity (Table 5). Hence, the highest heritability estimates were observed for days to maturity (97.99%), grain feeling period (97.4%), plant height

(96.7%), hundred seed weight (94.9%), grain yield per plot (93.14%), days to 50% flowering (85.76%) and number of seed per plant (81.8%).

According to Win (2011) heritability estimate for canopy height was higher under irrigated condition than non-irrigated condition. It indicated that genetic variation for canopy height of these tested genotypes was high under water stress condition. Similar finding was reported by John (2006). High estimates of heritability on plant heights were also reported by, Sharma et al. (1990), Asefa et al., (2002) and Gebre Egziabher et al., (2014). All of the traits considered in the current study showed heritability percentage greater than 50%. However, the heritability value was not accompanied by genetic advance. Genetic advance was least for days to flowering (17.01%) and highest for grain yield per plot (91.6%). Relatively higher heritability followed by higher genetic advance were recorded for grain yield per plant, grain yield per plot, number of seed per plant, number of pod per plant and harvest index. Days to maturity and days to 50% flowering portrayed lower percentage of genetic advance. Broad sense heritability was high for grain yield, pod per plant, seeds/plod and hundred seeds weight (Alemayehu, 2014). Similar observations were reported by Singh et al. (1994) for yield per plant, and pods per plant; Abebe, (2013) for yield per plant, pods per plant, plant height and 100 seed weight.

High broad sense heritability was indicating a significant contribution for traits evaluated and the additive effects played a greater role in the total genetic variation (Allan Klynger da Silva Lobato et al., (2014). So, this result suggests that selecting for traits with high H^2 value could lead to better progress than those with lower H^2, as the latter were more influenced by environment than the former. On the other hand, characters with lower H^2 may have poor response to selection due to substantial effect of the environment. Generally, in this study, yield per plant, pod per plant yield per plot and grain yield per hectare showed relatively high genotypic coefficient of variability, heritability and genetic advance. Therefore, these traits need to be given more emphasis in phenotypic selections. Thus selection for these traits is likely to accumulate more additive genes leading to further improvement of their performance and these traits may be used as selection criteria in common bean breeding program under irrigated condition.

Table 5. Estimation of the different variance parameters, heritability and genetic advance for 13 major quantitative traits of 20 released varieties.

Variables	Mean	MSg	MSe	ˆ2g	ˆ2e	ˆ2p	GCV%	PCV%	H 2%	GA	GA%
PH	104.90	3054.25	31.12	912.99	31.12	944.11	28.80	29.29	96.70	61.09	58.24
DF	42.53	50.10	2.40	14.44	2.40	16.83	8.93	9.65	85.76	7.23	17.01
DM	95.15	217.07	1.33	65.03	1.33	66.36	8.48	8.56	98.00	16.41	17.25
GFP	52.75	138.59	1.08	41.45	1.08	42.53	12.21	12.36	97.46	13.07	24.77
PPL	21.35	81.96	8.86	23.17	8.86	32.04	22.55	26.51	72.33	8.42	39.43
SPPOD	4.65	1.54	0.681	0.49	0.681	1.17	15.1	23.3	41.9	0.93	20.05
SPPL	101.85	4154.00	265.8	1193.3	265.80	1459.05	33.92	37.50	81.78	64.23	63.06
HSW	35.24	355.23	5.70	105.63	5.70	111.33	29.17	29.94	94.88	20.58	58.41
GYPPL	34.25	426.01	62.38	116.90	62.38	179.28	31.57	39.09	65.20	17.95	52.41
GYPPLO	515.14	191426.3	4162.8	56549.6	4162.8	60712.4	46.16	47.83	93.14	471.7	91.60
Gykgha^{-1}	2772.49	3223809.9	360024.4	954595.2	360024.4	1314619.6	35.2	41.3	72.6	1711.4	61.73
BIO	2.21	0.70	0.07	0.19	0.07	0.26	19.84	23.19	73.17	0.77	34.89
HI	0.23	0.01	0.00	0.00	0.00	0.01	25.21	35.00	51.89	0.08	37.34

4.7 Agronomic Performance of some (20) Released Common bean Varieties

There were significant differences ($p < 0.05$) among genotypes with respect to yield and yield attributes, which demonstrates high genetic variance among them that enabled to screen irrigation tolerant genotypes (Table 6). The analysis of variance indicated significant differences among the varieties for all traits also revealing that the varieties tested were highly variable. The mean values for grain yield ranged from 1,947 to 4,519 kg/ha with an average yield of 3,400 kg/ha (data not shown).

Number of pods per plant: Significant differences (P<0.05) were exhibited among common bean varieties for number of pods per plant. More numbers of pods per plant were recorded from the varieties Ramada and Nassir with respective 33.07 and 27.6 pods per plant. On the other hand, the variety Awash Dume had the lowest number of pods per plant (10.93). The data ranged from 10.93 to 33.07 for this parameter (Table 6). These finding confirmed the study of Abebe et al., (2013).

Number of seeds per pod: Common bean varieties were exhibited variation (P<0.05) for number of seeds per pod. The Ramada and Nassir produce more number of seeds per pod (6.20 and 6.10) respectively compared to the other varieties. On the other hand, Awash Dume produces the lowest number of seeds per pod (3.08). The remaining varieties were in the range of 6.10 to 3.53 for the character noted (Table 6). The variation in yield components and seed yield among the haricot bean genotypes were also reported by Daniel et al., (2012).

Number of seed plant: Significant differences (P<0.05) were exhibited among common bean varieties for number of seeds per plant. More numbers of seeds /plant were recorded from the varieties Nassir and Mexican-142 with respective 152.10 and 147.33 seeds per plant. On the other hand, the variety Awash Dume had the lowest number of Seeds per plant with seed number/plant of 33.37. The data ranged from 38.33 to 140 for this parameter (Table 6). Significant variability in seeds per pod in chickpea was also observed by Ahmad et al. (2003).

Plant height: Highly significant variation (P<0.05) was observed among the studied varieties for plant height. The variety Waju (172.13 cm) was the longest variety while the variety Kat B-1 (46.27cm) was the shortest variety (Table 6). High variability in plant height of chickpea genotypes was also reported by Win, (2011).

Days to flowering and Days to maturity: Days to 50% flowering and days to maturity had significant difference (P<0.05) among the varieties. Days to flowering and days to maturity were maximum for Deme (50, 109 days) and minimum for Gofta (37, 85 days), respectively. From this result, one can conclude that the line with early phenology (early flowering and early maturity) would be less vulnerable to terminal drought and hence suited as drought escaping genotypes in rain-fed condition and this associated with high initial growth vigour. Sabaghpour et al. (2003) who found that early flowering and maturity was the most important mechanism to escape terminal drought stress. Similar result was found by Beaver and Rosas (1998) in their study for terminal drought tolerance in common beans, where selection for early flowering in red beans permitted the identification of the genotype with short reproductive period. Similar results were reported by Guar et al., (2008) on chickpea.

According to Win (2011) generally, observations on days to maturity under irrigated conditions revealed that there was a delay of 8-16 days in maturity in all genotypes under irrigated condition. The reason may be the fact that the moisture stress creates internal stress on different parts, which quickens flowering and maturity. Similar observations were recorded by Dhiman et al., (2006) who reported that there was delay in maturity under irrigated condition.

Total biomass weight: Significant differences (P<0.05) were exhibited among common bean varieties for total biomass weight per plot. The highest was recorded from Omo-95 (3.1kg/plot) followed by Nassir (3.03kg/plot). The least biomass was recorded by Awasa dume (1.4 kg/plot) (Table 6). Win (2011) reported that increased biomass yield in chickpea can contribute to higher seed yield. In the present study these high seed yielding genotypes could produce the highest value of biomass yield under irrigated condition. These genotypes can be assumed as average maturing genotypes, which can accumulate large amount of total plant biomass due to reduced total photosynthetic period compared to the relatively longer maturing varieties.

Hundred seed weight: The common bean varieties tested had significant variation ($p<0.05$) among each other for hundred seed weight. The variety Loko produces the highest hundred seed weight (52.53 gm) followed by Deme (52.07gm). The variety Dursitu was the least in seed weight (23.33gm) (Table 6). Similar results were reported by Fikru (2007).

Harvest index: Harvest index, the ratio of grain yield to total biomass yield, is a measure of the degree to which a crop partitions photo assimilate into grain. For grain crops, harvest index (HI) is the ratio of harvested grain to total shoot dry matter, and this can be used as a measure of reproductive efficiency. Significant variation ($p<0.05$) was observed among varieties evaluated for harvest index. The varieties Ramada (0.38) and Nasir (0.36) recorded highest harvest index while the varieties Awasadume (0.11) and Gebisa (0.15) recorded lowest (Table 6). Improved HI represents increased physiological capacity to mobilize photosynthates from source to sink. Kumar *et al.*, (2001) reported that HI as an important criterion for improvement in yield which is strongly influenced by environment.

However, the results of present study showed that the decrease in HI by irrigation. Pandey *et al.*, (2001 and 2003) found that the decrease in HI by irrigation was due to suppression of flowering and number of pods. This led to a decreased requirement of dry matter and N in reproductive sink. Consequently, more of dry matter is retained in vegetative tissues. The results of present study showed that reduction in HI was high of magnitude in Awasa dume (0.11) and Gebisa (0.15). Similarly, Dhiman *et al.* (2006) reported that HI was reduced under irrigated condition.

Gain feeling period: Common bean varieties were exhibited variation ($P<0.05$) for grain feeling period per plot. Awash Dume and Deme had long grain feeling period (65 and 61 days) respectively compared to the other varieties. On the other hand, Nassir and Dinkinesh revealed the shortest number of days per plot (41 and 44), respectively (Table 6).

Grain yield per plant: A significant variation (p<0.05) was observed among common bean varieties for grain yield per plant. The highest yield was recorded from the varieties Ramada and Ebado with the values of 61.81g/plant and 58.53g/plant, respectively. On the other hand, Awash Dume was the lowest yielder (9.18 g/plant) Table 6. The higher yield of these two genotypes was due to the production of higher number of pods per plant which was supported by the greater number of seeds per plant. The result of present study was in agreement with the results of Win (2011).

Grain yield/plot: A significant variation (p<0.05) was observed among common bean varieties in their response to grain yield. The highest yield was recorded from the varieties Ramada and Nassir with the values of 1093.63 and 1086.6g/plot, respectively. Awasa Dume on the other hand was the lowest yielder with the value of 144.4 g/plot (Table6).

Grain yield potential (kg/ha): Ramada (5767.15 Kg/ha) and Nassir (5674.82 Kg/ha) out yielded the remaining varieties. This could be due to their inherent genetic potential Although this result is a single year and single location trial, the two varieties could be better recommended for production under irrigated condition. These two varieties are also superior to most of the varieties studied for the traits such as number of pods per plant, number of seeds per pod, grain yield per plant, grain yield per plot, total biomass yield per plot and harvest index. This result is in agreement with the finding of Gebre Egziabher et al. (2014) ; Kebere et al. (2006) ; Abebe et al., (2013) for common bean who stated that the seed yield of some released common bean is the result of many plant growth processes which ultimately influence the yield components such as pods per plant, seeds per pod and unit weight of seed.

The highest seed yields were obtained when all the above traits got maximized. According to this study, Ramada, a medium red variety and Nassir, a small pure dark red variety are the most favored and most commercially accepted varieties within the red bean types. These two improved varieties were released in Ethiopia for all common bean production areas. These food type varieties (Ramada and Nassir), released in 2003, were found potential for smallholder farmers. The varieties were good yielder in research stations (up to 2500kg/ha) compared to formerly released ones and also have short maturity cycle (80 to 95 days). They pose an opportunity for the farmers who at times hardly wait too long to feed the family, to improve soil fertility as it is a legume crops, to grow multiple crops per plots per season.

Similarly, Alemayehu (2014) reported that of the variation among common bean genotype were significant for grain yield and yield related traits under both sole and intercropping system. Overall, the present study revealed that significant variations were recorded among the common bean varieties for grain yield and yield related traits under irrigated condition implying the presence of substantial variability among the studied genotypes. This irrigated condition may influences economic characters such as grain yield that is mostly controlled by many genes and has complex inheritance. Highly significant yield differences, earliness good grain (not shown) and adapted to the agro-climatic condition of this particular area indicates the need to develop genotypes that adapted to specific environmental condition. Maximizing seed yield through simultaneously increasing biomass yield and other important yield related traits are a worthwhile strategy (Wallace, 1985; Wallace et al., 1993), especially for production regions like Bako.

Table 6. Grain yield (kg ha^{-1}) and other major agronomic traits of 20 released common bean varieties under irrigated condition, 2015, Bako

Genotypes	PH	DF	DM	GFP	PPL	SPPOD	SPPL	TSW	GYPPL	GYPPLO	GYkgha^{-1}	BIO	HI
Gofta	107.50FE	37.33J	88.67IJ	51.33FE	21.20FE	3.53	74.80HG	37.77EF	28.27FEDG	403.60FGH	2157.49EF	1.93GF	0.21FECDG
Awash melka	109.47F	44.33DE	90.67H	46.33J	24.03CEBD	5.45	117.00DEC	20.97L	24.60FEG	443.77FG	2378.31EF	1.73GHF	0.27BCD
Fadis	76.27H	47.00BC	96.33F	49.33HG	18.47FHG	4.07	74.53HG	46.73CB	34.80FCEBDG	556.90DE	2967.54BDAC	2.67BAC	0.21FECDG
Mexican-142	114.40FE	38.00JI	87.00KJ	50.67FG	21.47FE	5.35	147.33BA	20.67L	23.63FG	427.33FG	2279.81F	1.80GHF	0.24FBECD
KatB9	54.23I	41.67GF	86.67K	48.33HI	14.57HJI	4.20	60.37IH	43.37CD	26.20FEG	557.50DE	2967.22EBDFC	2.10EGDF	0.27BC
Seer- 125	54.23I	39.00JHI	89.67IH	50.67FG	21.50FE	4.66	99.57FEG	31.13GH	30.98FCEDG	422.00FG	2223.03BDAC	2.13EDF	0.21FECDG
Deme	137.50CB	48.67BA	109.33A	61.00B	16.23HGI	4.23	68.77H	52.07A	35.83FCEBD	611.33DC	4921.67EBDAC	2.40EDC	0.30BA
Ramada	111.63FE	49.67A	96.67F	46.67JI	21.03FEG	6.10	129.10BDAC	48.07B	61.81A	1093.63A	5767.15A	3.03A	0.36A
KatB- 1	46.27I	39.00JKI	84.67L	46.00J	18.53FHG	3.56	66.13H	45.37CB	30.00FCEDG	350.17IGH	1868.77EF	1.97EGF	0.18FEHDG
Waju	172.13A	40.00GHI	98.67E	59.00CD	27.20CDB	3.95	106.80FDE	39.93ED	42.62CB	401.27FGH	2305.65F	1.67GH	0.25BCD
Nassir	125.93D	40.00GHI	82.67M	40.67FL	22.43FED	5.50	122.87BDEC	27.10IKJ	33.28FCEBDG	1086.63A	5674.82BA	2.90BA	0.36A
Seer-119	89.03G	38.67JHI	90.67HF	51.67FE	22.83FCEBD	6.20	140.80BAC	29.57IH	40.95CBD	674.27C	3416.14BAC	2.73BAC	0.25BECD
Haramaya	134.00CD	43.00DEF	96.00G	53.00E	13.53JI	3.53	38.33IJ	34.57GF	22.37G	315.17IH	1671.25EBDF	2.03EGDF	0.15FHG
Dursitu	84.30HG	41.33GHF	93.67BA	52.33FE	27.50CD	5.60	154.63A	23.33LK	36.45FCEBD	583.33DC	3076.99	2.40EDC	0.24FBECD
Omo- 95	126.30D	48.33BA	108.67D	60.33CB	22.67FCED	5.76	130.00BDAC	25.57KJ	33.18FCEBDG	856.00B	3826.87A	3.10A	0.24FBECDG
Awasa Dume	143.83B	37.67JI	102.33D	65.00A	10.93J	3.08	33.37J	27.70IHJ	9.18H	144.40J	771.66EF	1.40H	0.11H
Gebisa	110.27FE	45.00DC	102.67C	57.67D	21.00FEG	5.67	115.53DEC	26.40IKJ	30.90FCEDG	265.43I	1404.20EDFC	1.80GHF	0.15FHG
Ebado	89.57G	42.00GEF	105.67BC	63.67A	27.60B	4.40	121.13BDEC	47.60B	58.53A	363.77FIGH	1940.64FBDAC	2.47BDC	0.15H
Loko	106.43FE	48.67BA	107.00KL	57.67D	21.17FE	3.87	83.87FHG	52.53A	44.23B	286.47I	1537.65EDF	1.83GHF	0.16FEHG
Dinkinesh	104.77F	41.33	85.33	43.67K	33.07A	4.60	152.10A	24.33LKJ	37.21BD	459.83FE	2432.98ECD	2.10EGDF	0.22FBECDG
Mean	104.9	42.53	95.15	52.75	21.35	4.65	101.85	35.24	34.25	515.14	2779.49	2.21	2.0244
CV(%)	2.0244	2.0244	2.0244	2.0244	2.0244	2.0244	2.0244	2.0244	2.0244	2.0244	2.0244	2.0244	2.0244
LCD(%)	9.221	2.559	1.908	1.719	4.921		26.945	3.947	13.055			0.439	0.0908
F-value	**	**	**	**	**	**	**	**	**	**	**	**	**

Source: Model result; ** = significant at 5% significant level.

4.8 Morphological diversity

Results from the Principal components analysis (PCA) and Shannon-Weaver diversity index (H) values for the 5 phenotypic traits studied are presented in Table 7. The PCA was used to show the traits which accounted for significant variation in the common bean germplasm. It reduced the data to a few dimensions and explained 64% of total phenotypic variation in the germplasm. The first two Principal components with Eigen value (latent roots) greater than 1.0 was contributed most of the total variation in the germplasm.

PCA results illustrated the overall picture of the pattern of genetic diversity of the common germplasm based on morphology. The germplasm clustered into two major groups with most variations attributed to seed color, flower color, seed size, and seed shape. The above traits are highly recommended for use in common bean characterization, conservation and breeding. The Eigen-value formed the basis. Hence, selection of genotypes with high PCA and low are suitable for both stress and non-stress environments (Golabadi et al., 2006 and Shahryari and Mollasadeghi, 2011). According to Koinange et al. (1996), plant type and seed size are important for pre- and post common bean crop,s domestication and were employed logically to help interpretation of trait distributions among the genotypes in the PCA plot.

Results from the Shannon-Weaver diversity index (H) values for the 5 traits studied are presented in Table 7. The H value ranged from 0.249 „ 0.337, with a mean of 0.34±0.35. The mean Shannon diversity index (H) estimate of indicates that different classes of traits and genotypes have a balanced representation of the collection. Yada et al. (2010) used Shannon-Weaver diversity (H) analysis index on 1256 sweet potato accessions using 20 morphological descriptors and reported mean H of 0.71±0.03 and inferred high diversity among the sweet potato clones from Uganda. The traits observed as critical for bean characterization in this study like seed size and flower colour, were also found to be important in beans from Ethiopia and Kenya (Asfaw et al., 2009), which indicates similar diversity manifestation in the East African region. Blair et al. (2010) observed considerable variations in landraces in Central Africa, in seed size and color predominated by the red mottled types which was very frequent in this study.

There is a broad genetic diversity of bean germplasm in Ethiopia. The traits in Table 7 are highly recommended for use in common bean characterization, conservation and breeding. Blair et al. (2010) reported farmer,s preference for many landraces, where diversified bean types are used for various agronomic and cultural reasons. In addition, varieties preferred for home cooking with unique seed colours are selected for sale in the local markets, hence, maintaining bean diversity in the tropics

Table 7 PCA and Shannon-Weaver diversity index (H) estimates for the 5 traits used to classify the 20 common bean germplasm in Ethiopia

Variable	PC1	PC2	H
Seed size	0.423	0.208	0.334
Seed color	0.565	-0.055	0.331
Flower color	-0.509	-0.112	0.337
Pod color	-0.067	0.671	0.249
Seed shape	0.168	0.595	0.305
Eigenvalue	2.4114	1.4281	
Proportion	0.402	0.238	
Cumulative	0.402	0.640	
Mean diversity index (H)			0.34±0.35

5. Conclusion and Recommendation

5.1 Conclusion.

Performance of some (20) improved haricot bean varieties and 13 yield related traits were considered in this analysis. Polygenic traits such as pod per plant, biomass yield, and seed per pod, hundred seed weight and harvest index showed positive correlation with grain yield. This implied the possibility to combat the low yielding ability of common bean varieties by improving and selecting for these important agronomic traits. Agronomic and phenotypic characters such as grain yield per plot, grain yield kg/ha, harvest index, biomass yield, seeds per pod, number of seeds per plant and grain yield per plant were the major contributors for the variation observed in the first principal components. Overall, the aggregation of those 20 released common bean varieties into five clusters at 80% similarity level having 2-11 varieties per cluster based on the 13 quantitative traits indicated a morphological diversity between the tested genotypes. It is generally agreed that genetically diverse parents will exhibit maximum heterosis and offer the best chance of isolating transgressive segregants

The study shows the existence of a broad range of genetic variability, in the tested collections for grain yield and yield related traits based selection. This variability also confirmed by the analysis of principal components that explained the overall diversity by 13 eigenvectors. In this study yield/plant, pod/plant, and yield per plot, grain yield/ha showed relatively high genetic coefficients of variability, heritability, and genetic advance. Therefore, these traits need to be given more emphasis in phenotypic selections The first four eigenvectors accounted about 86.5% of the total variability among the tested genotypes. The principal component analysis showed that the main contributing characters were evenly distributed among the evaluated characters. However, grain yield per plot, grain yield kg/ha, harvest index, biomass yield, seeds per pod, number of seeds per plant and grain yield per plant were the most useful in distinguishing the tested haricot bean genotypes

The presence of wide diversity among the 20 released haricot bean genotypes was confirmed by cluster analysis that grouped them into five classes based on the measurement of 13 agro-morphological characters. The clustering pattern indicated that varieties in clusters 3 to 5 were genotypically more divergent from the other collections for they formed single genotypic clusters. This method of clustering germplasm collections can also be used in the elimination of the duplicated and genetically redundant accessions along with other relevant information and documents of the germplasm.

The results of the ANOVA analysis pointed out the relative variation of yield performance and different yield related traits of the 20 improved haricot bean varieties. Thus, grain yield potential and most of yield related parameters were found to have significant variation ($p < 0.05$) among the varieties investigated. The analysis of variance among the 20 tested genotypes also showed highly significant ($p < 0.05$) difference in terms of their yield performance under irrigated condition. There was also a wide range of difference between the maximum and the minimum values of the phenometric characters. This considerable variability could be ascribed partly to the differences in the evaluated genotypes and partly to the genotypes and environment interaction effects.

The study measured thirty parameters and the results revealed that all genotypes were different in grain yield potential and morpho-physiological traits. The differences indicated presence of genetic variation for these traits, a key factor in plant breeding and selection for bean crop improvement. The trial sites are characterized with high moisture and medium soil fertility condition, hence varieties which tolerate these stresses perform best. Successful genotypes must have good yield and other essential agronomic characters. Besides, their performance should be reliable over a wide range of environmental conditions.

The overall performance of the test varieties was good in that particular area except Awasa Dume under irrigated growing condition (i.e., this variety generally performs poorly under irrigated growing condition). Some genotypes like Ramada, Nassir, Omo-95 and Ser-119 were the best performed genotypes under irrigated conditions in the study.

area. However, Ramada and Nasser were the out yielded varieties. The greatest yield of these four varieties could be due to their inherent genetic potential. It could be also due to better local adaptation to the Western Ethiopia environments. Therefore, it is advisable to promote haricot bean as an irrigable crop in the study areas to improve production level, increase source of cash for farmers and foreign currency for the country as export crop.

5.2 Recommendation

1. Some genotypes like Ramada, Nassir, Omo-95 and Seer-119 can be recommended for production under irrigated conditions. That means, these varieties could be the best choice for localities with better moisture condition or for irrigated growing condition. However, caution should be taken in the use of these results as the study was conducted only in one location and for one season. In order to validate the findings, the study should be conducted for a number of years and in many locations.

2. The majority of Ethiopian farmers, however, are unable to afford the high mineral fertilizer cost. Nitrogen derived from biological fixation is 50-70 % more efficient than applied N because only 30-50 % of the latter is recovered by plants (Bliss, 1993). Biological N_2 fixation, a key source of N for poor farmers, constitutes a potential solution and may have a lion share for sustainable bean production in Ethiopia. Therefore, all stakeholders who work in Ethiopian agriculture should not under estimate the importance of irrigation using legumes crops as an alternative N source, and its role as a break crop in Maize and other crops based farming systems to reduce decline in soil fertility.

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7. Appendices

Appendices 1 list of common bean studied under irrigated condition with their randomization on the 60 plots

Variety	Rep 1	Rep 2	Rep3	Remark
Gofta	1	32	54	
Awash melka	2	26	50	
Fadis	3	29	60	
Mexican-142	4	24	51	
KatB9	5	27	59	
Seer 125	6	21	42	
Deme	7	38	57	
Ramada	8	40	55	
KatB- 1	9	22	41	
Waju	10	39	56	
Nassir	11	25	43	
Seer-119	12	23	44	
Haramaya	13	33	45	
Dursitu	14	30	48	
Omo- 95	15	34	58	
Awasa Dume	16	31	46	
Gebisa	17	28	47	
Ebado	18	35	53	
Loko	19	37	49	
Dinkinesh	20	36	52	

Appendices 2 Field photo