PARTICIPATORY VARIETY SELECTION AND VARIABILITY OF POTATO
(Solanum tuberosum L.) VARIETIES AT JIMMA ZONNE, SOUTHWEST
ETHIOPIA

M.Sc. Thesis

BY

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DEDICATION

I make this special dedication to my family and friend my who always wished to see this day. This is in remembrance of their numerous prayers and moral support to ensure the realization of my academic achievements.
STATEMENT OF THE AUTHOR/DECLARATION

I hereby declare that this Thesis is my own work and that all sources of materials used for this Thesis have been duly acknowledged. This Thesis has been submitted in an advanced (M.Sc.) degree only at the Jimma University and is deposited at the University Library to be made available the under rules of the Library. I solemnly declare that this thesis is not submitted to any other institutions anywhere for award of any academic degree, diploma or certificate.

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Place: Jimma University,

                           Jimma

Date of submission: ___________________
BIOGRAPHICAL SKETCH

The author Meaza Hafiz was born in Seka district, which is located Jimma in 1983. She studied her Elementary, Junior Secondary at Seka and Senior Comprehensive Secondary School at Jimma high school from September 1989 to June 2000 E.C. Soon after, she joined Ambo College of Agriculture and Veterinary Medicine in October 2001 E.C and graduated with a BSc degree in Plant science in July 2003 E.C. she was employed by the Southern Nations Nationalities and peoples Regional State and stationed at Bench Majii Zone office to work as infrastructure technology supplier expert in the department of Pastoralist in September 2004 E.C, and served until June, 2004. In June 2004, the author joined the Jimma Agricultural office as a expert Seka district. Until she joined Jimma University College of Agriculture and Veterinary Medicine, School of Graduate Studies to pursue Degree of Master of Sciences in Plant Breeding in 2013.
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<table>
<thead>
<tr>
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<th>Description</th>
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<tbody>
<tr>
<td>PCA</td>
<td>Principal Component Analysis</td>
</tr>
<tr>
<td>G×E</td>
<td>Genotype with Environment</td>
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<tr>
<td>SPCs</td>
<td>Seed Producer Cooperatives</td>
</tr>
<tr>
<td>PVS</td>
<td>Participatory Varietal Selection</td>
</tr>
<tr>
<td>USA</td>
<td>United State of America</td>
</tr>
<tr>
<td>PPB</td>
<td>Participatory plant breeding</td>
</tr>
<tr>
<td>DB ARC</td>
<td>Debre_Birhan Institute of Agricultural Research</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of United Nations</td>
</tr>
<tr>
<td>GA</td>
<td>Genetic advance</td>
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<tr>
<td>GAM</td>
<td>Genetic advance as % of mean</td>
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<tr>
<td>GCV</td>
<td>Genotypic coefficient of variation</td>
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<td>GD</td>
<td>Genetic distance</td>
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<td>DAs</td>
<td>Developmental Agents</td>
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<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
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<td>V&lt;sub&gt;A&lt;/sub&gt;</td>
<td>Additive genetic values</td>
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<td>V&lt;sub&gt;G&lt;/sub&gt;</td>
<td>Genetic variation</td>
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<td>V&lt;sub&gt;P&lt;/sub&gt;</td>
<td>Phenotypic variation</td>
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<td>PC</td>
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By Meaza Hafiz

Advisors: Sintayehu Alemew (PhD, Associated Professor) and Valentine Joseph Gandhi Bavanirajan (PhD)

ABSTRACT

Wider adaptation and researchers’ criteria may not fit to all agro ecologies and fulfill farmer’s preferences. In an attempt to identify suitable potato genotypes for Jimma zone, twenty five potato genotypes were tested in a simple lattice design at jimma zone from Debre_Birihan Agricultural Research Center were used for characterization and participatory variety selection based. With the aim of studying the problem of fitting farmers target environments and users preferences extent of genetic variation and association among yield ad related traits. Analysis of variance indicated significant difference among the 13 trait with respect to all the characters except four traits among the tested genotypes studied. Wide range of variation was observed among all traits. The phenotypic coefficients of variation values were higher than genotypic coefficients of variation values. Higher heritability coupled with higher genetic advance as per cent of the mean was noticed for weight of tuber per hectare, date of flowering, plant height tuber diameter and leaf width. This indicates that there is an opportunity of selection to improve these characters. The Mahalanobis’s D2 analysis showed that the 25 genotypes were clustered into five clusters. Maximum inter-cluster distance was recorded between clusters IV and V followed by clusters III and V clusters II and IV and cluster I and II. Based on Principal Component Analysis (PCA), the first 3 components explained over 70.5 % of genetic variation with eigen values are >1. In majority of the cases, the genotypic correlation coefficients were higher than corresponding phenotypic correlation coefficients.weight of tuber per hectare was positively and significantly correlated with total tuber per plant and marketable tuber per plant at genotypic as well as phenotypic level. As per path analysis, the maximum positive direct effect on tuber yield per hectare was exhibited by unmarketable tuber number per plant followed by average tuber number, days to flowering Which have high and direct contribution towards final tuber weight/plant could be considered as selection criteria in potato breeding program. In participatory variety selection ten variety were tested variety Abateneh, Abalolarge and Gudane was best performed and highly preferable according to tuber days to 50% flowering, tuber uniformity, tuber yield, marketable tuber and date of maturity except taste. Therefore, for further utilization continues with this research and use molecular or biotechnological approaches as a complementary study.

Key words: Potato, Participatory Variety Selection, principal component, variability, path analysis
1. INTRODUCTION

There have been several scientific advances in the field of agriculture and food security, yet there are still several challenges. According to the most recent report on the state of food insecurity in the world, during 2011-2013 there were about 842 million undernourished people from which 827 million (98.2%) were in developing countries (FAO, 2013). In Sub-Saharan Africa and generally in the developing countries including Ethiopia the demand of food is likely to rise significantly as a result of population growth. To meet the ever increasing demand for food, roots and tuber crops including potato can play a major role in addressing (i.e. good nutritional quality and high yield per unit area) this issue and feed millions of people.

In Ethiopia root and tuber crops are part of the traditional food systems of the people especially in the southern, southwestern and western part of the country. There is enormous possibility for millions of poor farmers to boost production and their livelihood using root and tuber crops which are strategic crops for the country’s economy (Amsalu et al., 2008).

Among root and tuber crop potato is regarded as high-potential food security crop specially for sub Sahara African country including Ethiopia, compared to cereals, potato is a short duration crop that can potentially yield up to 30 – 35 t/ha of starch based produce in few months (mostly < 120 days). In addition, potato is one of the few major food crops that give high yields of edible energy and good quality protein per unit area and per unit time with a short vegetative cycle that can fit in to intensive cropping systems (Gebremedhin et al., 2008b). The price of cereals is strongly increased worldwide and in Ethiopia the price subsequently stabilized at a high level, whereas the price of roots and tubers remained relatively low during the entire food crisis (FAO, 2008).

Potato (Solanum tuberosum L.) was first cultivated in the vicinity of Lake Titicaca near the present border of Peru and Bolivia (Horton, 1987). Globally, it is one of most important crop in terms of production as well as consumption and ranks fourth after wheat, rice and maize (FAO, 2008). It also ranks first among root and tuber crops followed by Cassava, Sweet potatoes and Yams (Hawkes, 1990; FAO, 2008).
Potato has very good nutritional importance and it can produce more energy and protein per unit area per unit time than most other major food crops; it is fat-free and contains substantial amounts of minerals (Lutaladio and Castaldi, 2009). The crop is also rich in several micronutrients and vitamins, especially vitamin C; a single medium sized potato of 150 g provides nearly half of the daily adult requirement (100 mg) (FAOSTAT, 2008). The potato is a moderate source of iron, a good source of vitamins B1, B3 and B6 and minerals such as potassium, phosphorus and magnesium. Potatoes also contain dietary antioxidants, which may play a part in preventing diseases related to ageing, and dietary fiber (Mulatu et al., 2005).

Potato was introduced to Ethiopia in 1859 by the German botanist Schimper (Gebremedhin et al. (2008). Potato production has increased considerably through the twentieth century. In 1975, the area of cultivation was estimated at 30,000 hectares, with an average yield of approximately five tons per hectare (Gebremedhin et al., 2001). The area of cultivation had reached 50,000 hectares by the mid 1980’s, by 2001 production area raise up to 160,000 hectares, with average yields around eight tons per hectare (Gebremedhin et al., 2001). In recent years, potato production has dramatically increased by about 96.54 %, from 349,000 tons in 1993 to 863,348 tons in 2010 (FAO, 2013). Since the highlands are also home to 88% of Ethiopia's population (Gebremedhin et al., 2008b) the potato could play a key role in ensuring national food security.

According to Gebremedhin et al. (2008a), the major potential areas for potato production are the Central, Southern, Southeastern, Southwestern and Northwestern part the country, where altitude ranges from 1500 to 3000 m and the rain fall between 600 to 1200 mm. Even though Ethiopia has so suitable environment for potato production, the national average yield is very low (7.2 t/ha) (CSA, 2012a). From Africa Egypt is top potato producing country with national production of 2.6 million tons with average production of 24.80 t/ha while Ethiopia is 11th with production of 525,657 tons (FAOSTAT, 2007). The low productivity is attributed due to lack of well adapted varieties which is accepted by the farmers, unavailability and high cost of seed tubers, too low or too high planting density, diseases, insect, etc (Bereke, 1994; Gebremedhin et al., 2008; Adane et al., 2010).
In Ethiopia the variety development study was began in 1975 with the objective of develop varieties that are high yielder, widely adaptable and resistant to late blight, which is most devastating disease (Gebremedhin et al., 2008) and about 28 varieties were formally released for production for wider adaptation (MOA, 2010).

Wider adaptation and researchers’ criteria may not fit to all agro ecologies and fulfill farmer’s preferences. Agro-ecologies varied with respect to soil type, moisture and temperature regimes, fertility condition and the onset, intensity and duration of rain as well as irrigation facilities, where farmers thrive to grow potato (Gebremedhin et al., 2008). Heterogeneous environment, large diversity of farmer’s needs, lack of adapted varieties to those diverse agro ecologies facing the formal breeding methods and often fails to meet the needs of farmers and to develop cultivars or varieties showing specific or local adaptation (Desclaux, 2005). That is why most technologies developed without farmers’ participation have failed to address the issues of rural poverty appropriately (Pretty et al., 1985). Farmers have their own indicators of performance and quality not well anticipated by researchers’ criteria (Jusu, 1999). They are relatively consistent in their selection and their selections correspond with their stated criteria (Maru Aduening et al., 2006). Hence, there is a disproportional development between the large number of technologies generated by the agricultural scientists and the relatively small number of them actually adopted and used by the farmers (Ceccarelli, 2012).

Many varieties are officially released, but few are adopted by farmers. In contrast, farmers often grow varieties that have not been officially released, a phenomenon known to be associated not only with an inefficient and biased testing system prior to variety release, but also with breeders using different selection criteria from the farmers and particularly G×E interactions in the case of farmers in marginal environments (Ceccarelli, 2012). That is why in many part of Ethiopia farmers grow their own local varieties (Gebremedhin et al., 2001). This is also true in the case of Dedo and seka chekorsa district that root and tuber crop specially potato took great account in their production and food system but still they use local varieties. However, Still, Farmers as well as Seed Producer Cooperatives (SPCs) are highly demanding better yielding varieties. So Participatory Varietal Selection (PVS) has
been proposed as a solution to the problem of fitting the crop to a multitude of both target environments and users’ preferences (Ceccarelli et al., 1996).

Participatory Variety Selection (PVS) can effectively be used to identify farmer-acceptable varieties and thereby overcome the constraints that cause farmers to grow old or obsolete varieties (Witcombe et al., 1996). Moreover, participatory research complements the formal breeding system (Belay et al., 2006), increases the job efficiency of the researchers (Bellon, 2001) and farmers' knowledge that enables to be retained effectively from year to year (Grisley & Shamambo, 1993). PVS is a more rapid and cost-effective way of identifying farmer-preferred cultivars if a suitable choice of cultivars exists (Witcombe et al., 2008). Hence, Research costs can be reduced and adoption rates increased since farmers participate in variety testing and selection (Joshi et al., 1996). Researchers learned which genotypes farmers preferred and which they dislike and the reasons for these opinions.

In another way those released varieties are different from each other with regard to useful attributes such as maturity time, post-harvest quality, yielding ability and growth habit, among others. It has been postulated that commercial varieties are an important genetic resource for the breeding program because of their many useful attributes. Nevertheless, optimal use of the divergence at hand entails a systematic evaluation of these genetic resources. However, the commercial potato varieties released by the research system and local cultivars, present at the hands of farmers for quite long periods in Ethiopia, were not systematically evaluated for their diversity and acceptance by the farmers. Hence, there is a critical gap of information related to the genetic diversity of the potato germplasm in the country, since the knowledge of genetic diversity is essential to meet the diversified goals of plant breeding such as breeding for cultivation, for increasing yield, wider adaptation, desirable quality, pest and disease resistance.

Also, genetic diversity is essential to identify the sources of genes for a particular trait from the existing germplasms (Haydar et al., 2007; Arslanoglu et al., 2011) and to sort out parental lines with complementary features that can enhance breeding progress (Cartea et al., 2002; Saljoghianpour et al., 2007). Hence, precise information on the nature and degree
of genetic diversity helps the plant breeder in choosing the diverse parents for purposeful hybridization.

Therefore this study was conducted with the following objectives

➤ To characterize potato variety based on morphological traits and agronomic performance

➤ To evaluate and select potato varieties based on farmer’s preference
2. LITERATURE REVIEW

2.1 Origin and distribution of Potato

The potato was first cultivated in South America between three and seven thousand years ago, though scientists believe they may have grown wild in the region as long as 13,000 years ago. The genetic patterns of potato distribution indicate that the potato probably originated in the mountainous west-central region of South American, Peru. There are strongly evidences that potato was widely distributed throughout the Andes from Colombia to Peru and also in Southern Chile (Nonnechke, 1989; Hawkes, 1990). The geographic distribution of wild potato species is extensive, ranging from the southwestern states of the USA 38ºN, through the countries of Central America, to South America, Chile 41 ºS, where they are found along the entire length of the Andes from Venezuela to northwest Argentina, as well as lowland areas of countries occupying the southernmost half of South America (Hawkes, 1990). While cultivated species, because of their relatively narrow geographical origin, are adapted to relatively few environments and diseases (Melbourne et al., 2004).

It was introduced in to Europe first into Spain in about 1570 and the second in to England 1590. From this the potato began to slowly spread throughout Europe then to America and other countries (Nonnechke, 1989; Hawkes, 1990) It is generally believed that potatoes entered Africa with colonists, who consumed them as a vegetable rather than as a staple starch. (file:///G:/History_of_the_potato.htm). Potato was introduced to Ethiopia in 1859 by the German botanist Schimper (Gebremedhin et al., 2008).

2.2 Taxonomy

The scientific classification of potato will be in the kingdom plantae, Phylum – Magnoliophyta, Class – Magnoliopsida, Order – Solanales, Family – Solanaceae, Tribe – Solaneae, Genus – Solanum, Species - Solanum tuberosum L. , Subspecies - Solanum tuberosum ssp. Andigena and Solanum tuberosum subspecies tuberosum. All modern cultivars known to us as the common potato can be accommodated in S. tuberosum ssp. tuberosum (Vreugdenhil, 2007).
The genus *solanum*, in the family *solanceae* or the night shad family. This family is also includes many other important commercial plants such as tomato, tobacco, eggplant and various species of chili peppers. Potato has basic chromosome number as 12 and Polyploidy present in wild and cultivated potatoes right from diploid (2n = 2x = 24), triploid (2n = 2x = 36), tetraploid (2n = 4x = 48), pentaploid (2n = 5x = 60) to hexaploid (2n = 6x = 72) species are available. Despite of the presence of polyploidy in the *Solanum tuberosum* species the majority (75%) are diploids, though quite a large number of tetraploids and some hexaploids are occur (Nonnechke, 1989; Hawkes, 1990; Milbourne et al., 2004). The chromosome number of cultivated potato is 2n=4x=48 (tetraploids). The cultivated tetraploid species with the binominal name known as *solanum tuberosum* L. (Hawkes, 1990; Harris, 1992).

2.3 Botany

The potato plant is a perennial, but in agriculture it is used as an annual crop, since the edible portion of the plant is uprooted and used each year. It is usually propagated using seed tubers. Seed tubers produce sprouts in their eyes, which develop into shoots, and produce roots from primordia on the sprouts. On these shoots, the stems, foliage, stolons, roots, inflorescences and the next generation of tubers are formed (Vreugdenhil, 2007).

It is a herbaceous, freely branching dicotyledonous perennial (kay 1987), but grow as an annual plant with short (300–600 mm), The aboveground stems of potato plants are erect in early stages of development but later become spreading and prostrate or semi-prostrate. The tuber is an enlarged underground stem (Acquaah, 2009).

Leaves are a site where radiant energy incidence can be intercepted and photosynthate produced to be distributed to other organs to sustain growth and development or to be stored as a reserve (Nganga, 1982). The potato plant has one major leaf per node. The early leaves are small, whereas the later leaves are alternate and pinnate compound with three or four pairs of large, ovate to ovate elliptical leaflets with smaller ones in between. The rachis ends in a top leaflet that is often the largest one, with a shape that sometimes deviates from the other large leaflets. The small leaflets are sub sessile, ovate to sub orbicular. The leaf may vary in the angle of its insertion on the stem, different length and shape. In case of shape leaf
let’s be elliptic, oblong, ovate, oboutte, orbicular (round) (Rai and yadau, 2005, Vreugdenhil, 2007).

Potato is predominantly self-pollinated. The peak time of pollination is early morning. Potato has a terminal inflorescence consisting of 1–30 (but usually 7–15) flowers, depending on the cultivar. The five petals give an open flower a star shape. A flower also has a stigma that protrudes above a cluster of five large, bright yellow anthers. The corolla color varies from white to a complex range of blue, red, and purple. Flowers open, starting with those nearest the base of the inflorescence and proceeding upwards, at the rate of about 2–3 each day. At the peak bloom, there are usually 5–10 open flowers. Flowers stay open for only 2–4 days, and the receptivity of the stigma and duration of pollen production is about 2 days (Acquaah, 2009.) The plant bears fruits (berries) called potato balls. The fruit is a spherical berry about 1.5-2 cm in diameter, green or purplish, containing a large number of small seeds (key, 1987).

The underground commercial part is a modified stem (or tuber) that is borne at the end of a stolon. The “eyes” on the tuber are actually rudimentary leaf scars favored by lateral branches. Each eye contains at least three buds protected by scales. When potatoes sprout, the sprouts are lateral branches with several buds. A section across a tuber reveals a pithy central core with branches leading to each of the eyes (Acquaah, 2009.) The roots are numerous, fine, fibrous and adventitious. Short stolons with hooked tips are produced from the axils of the lower leaves and become thickened to form stem tubers which have buds (eyes) mainly towards the distal end. When the aerial part of the plant dies back following the normal maturity cycle in adverse climatic conditions the tubers remain in the ground and sprout to form new plants when the dormancy of the tuber breaks and climatic conditions are favorable (key, 1987).

**2.4 Potato adaptation**

Potato extends all over the world except for the far north and south with a strong concentration of species diversely in south and Central America. In general potato is best adapted to a high altitude 2000- 3000 meters above sea level (masl) and the frost resistant species grow from 3000- 4000 masl best yielder at 2500- 3500 masl (Poehlman, 1995).
Ethiopia Most of the Central Highlands, at altitudes ranging from 1,500 - 3,000 masl and annual precipitation of 600 - 1,200 millimeters (mm) are more favorable (Gebremedhin et. al. 2008).

The potato is a crop of temperate climate and it is moderately tolerant to frost. Tuberization is favored by long-days of high light intensity. The young plants grow best at a temperature of 24°C. Late growth is favored at a temperature of 18°C. Tuber production is the maximum 18-20°C and decrease with rise in temperature. High temperature at any growing period affects the size of leaflets, thereby reducing the tuber formation (Rai and yadau, 2005).

Soil - potatoes can be grown on all soil types, except heavy water-logged clays, but for optimum yields need a well-drained loam or sandy loam, relatively free from stones. Well-drained peat soils are particularly suitable and where the growing season is short, light, well-aerated soils are necessary. The pH may range from 4.8 to 6 (optimum 5.5-6); above pH 6 potatoes are liable to suffer from scab (key, 1987).

There are four potato production systems which are the belg (short rain), meher (long rain), and residual crops and irrigated production. In many areas the belg (January to June) crop supplemented with irrigation constitutes the bulk of potato production. This is due to less late blight pressure and favorable market during this season (Gebremedhin et al., 2008; Adane, et al., 2010).

2.5 Economic Importance of Potato

Potato is fourth most important food crop of the world after, wheat rice and corn in human diet among the root and tuber crops, it ranks first followed by cassava, sweet potatoes and yams next to maize in terms of the number of producer countries (FAO, 2008). It is an important crop and it can supplement the food requirements of the country in a considerable way as it produces more dry-matter food, has proportionate protein and produces more calories from unit area of land and time than other main food crops (Pandey, 2003).

Potato is one of economically most important crop in Ethiopia that plays a key role as source of food and cash income for small- holder producers. There is a huge potential for potato to contribute for the potential economic (Agajie et al, 2008). It has a promising prospect in
improving the quality of the basic diet in both rural and urban areas of the country (Berga et al., 1994). As a food crop, it has a great potential to supply high quality food within a relatively short period and is one of the cheapest sources of energy. In addition to the high nutritive value and lysine content of potato protein, it is a valuable supplement to cereal proteins. Potatoes thus serve as a significant source of proteins (10 to 15% of total protein requirements), cheap source of energy due to its large content of carbohydrate and containing significant amount of vitamin B, C and mineral. Moreover, it is used in many industries for starch production and an important source of energy for industrial communities of the developed countries it is a non-fattening, nutritious and wholesome food that supplies many important nutrients to the diet. Potatoes contain approximately 80% water, 20% dry matter (specific gravity) and fat-free. About 60-80 percent of dry matter is carbohydrate, mainly starch, with some dietary fiber and small amounts of various simple sugars. Although potatoes contain only relatively little protein balanced proportionate of proteins to calories, their nutritional quality is better than that of cereals or soybeans (IYP, 2008).

Furthermore, potato is also suited to small scale farmers in developing countries since its labor requirement is less than that of cereals. Its shorter growing period makes it possible for the small scale farmer to use this crop in a system where more than one crop is possible on the same land per season (Schott et al., 2000). It is mainly produced too overcome the transitory food shortage that occurs during rainy season. It is considered as transitional crop as it enables farmers' survive the hunger months. Potatoes produce 54 percent more protein per unit of land area than wheat and 78 percent more than rice. No other food, not even soybean, can match the potato for production of food energy and food value per unit of land area (Stevenson et al., 2001).

26. Participatory Varietal Selection

Participatory varietal selection to identify preferred cultivars has three phases: identifying farmers’ needs; searching for suitable material to test with farmers; and experimentation on farmers’ fields. Once identified, the seed of farmer-preferred cultivars needs to be rapidly and cost-effectively supplied to farmers.
It helps getting adapted materials by speeding up the transfer of cultivars and their adoption. Although relatively little empirical work has been done to document the speed of PPB compared to conventional breeding, recently evidence has started to emerge suggesting that PPB can lead to earlier adoption of modern varieties, with no major additional costs (Witcombe et al., 2003). But negative connotation can also be linked to this aim: indeed, it may assume that cultivars are already created by breeders and PPB appears as an opportunity to speed up the adoption by farmers.

Breeding for specific adaptation is a more sustainable strategy than breeding cultivars that can only express their superiority at high level of inputs (Ceccarelli, 1996). Local adaptation contributes to limit genetic erosion and therefore to avoid major risks due to varietal homogeneity on the territorial scale. Breeding for marginal or organic environments shall include selection of parents and segregating populations in environments similar to farmers’ conditions.

PPB may aim to empower farmers i.e. to bolster their autonomy or to increase their freedom to choose varieties. It allows rural communities to maintain genetic resources they value and enables them to participate in the development of new varieties that suit their needs. PPB methods thus can empower groups that traditionally have been left out of the development process (McGuire et al., 1999).

It is used to differentiate a formal-led PPB program which is initiated by researchers inviting farmers to join breeding research, from a farmer-led PPB program, where scientists seek to support farmer’s own systems of breeding, varietal selection, and seed multiplication and dissemination. Based on the work of Franzel et al. (2001), a more elaborated differentiation can be proposed by identifying leaders of breeding process designs and those of management.

The various modes of participation can be thought of as points along a continuum representing different levels of interaction. Each mode of participation can be characterized in terms of how farmers and plant breeders interact to set objectives, take decisions, share responsibility for decision making and implementation, and generate products (Morris &Bellon, 2004).
2.7. Formal breeding methods

Formal breeding methods are not always suitable because of in developing countries, such as (i) heterogeneous environment, (ii) large diversity of farmer’s needs, (iii) lack of adapted varieties, (iv) disinterest of formal seed sector. Facing such diversity and heterogeneity, conventional plant breeding often fails to meet the needs of farmers and to develop cultivars showing specific or local adaptation.

Professional breeders, often working in relative isolation from farmers, have sometimes been unaware of the multitude of preferences beyond yield, and resistance to diseases and pests of their target farmers.

Ease of harvest and storage, taste and cooking qualities, crop maturity speed, suitability of crop residues as livestock feed are just a sample of farmers’ criteria difficult to grasp in a conventional breeding scheme. Without close discussions with end-users and observations of their agricultural and social practices, breeders are unable to imagine or anticipate their necessary needs. During their professional training, plant breeders have little exposure to survey/methods needed to elicit structured feedback from farmers (Morris & Bellon, 2004). Moreover organic farmers have to deal with several limiting factors and high heterogeneity that they could not uniformize with inputs; therefore they are looking for specific ideotypes according to their own use and cultural practices.

Formal breeding programmes can be briefly described as a centralized sequential process in which breeders collect germplasm, evaluate it under carefully controlled experimental stations, and make crosses among superior materials. The large amount of genetic variability continuously created is then drastically reduced through selection and surviving lines are spread among farmers. The process has been effective for farming systems sufficiently similar to those on experiment stations (Sperling et al., 1993) but not adapted when GxE interactions are large. Formal breeding tends to focus on "broad adaptability” the capacity of a plant to produce a high average yield over a wide range of growing environments and years. Therefore, candidate genetic material that yields well in one growing zone, but less in another, is quickly eliminated from the breeder’s gene pool (Cecarelli and Grando, 1997).
Yet, this “specific adaptability” may be exactly what organic farmers require and aims to increase agricultural diversity (Vernooy, 2003).

Facing difficulties to target environment conditions well and register all end-users needs, to translate them into criteria of selection and to build an ideotype, breeders begin to be interested by participatory plant breeding (PPB) defined as end-users’ participation in selection process. It appears to be a suitable alternative to match up to organic agriculture expectations.

![Figure 1: Traditional extension versus participatory technology development (Tadese, 2009)](image)

2.8. Importance of Germplasm Characterization

Germplasm is the lifeblood and genetic material of plant breeding. It provides the materials used to initiate breeding program (Acquaah, 2007). Genetic variability is the basis of all plant improvement programmes. Sufficient genetic variability, if present, can be exploited for developing superior cultivar. Mostafa et al. (2011) hypothesized that genetic diversity studies provides the understanding of genetic relationships among populations and hence directs assigning lines to specific heterogeneous groups useable in identification of parents and hence choice selection for hybridization. Heritable component is the consequence of
genotype, whereas the non-heritable part is due to environmental factors. Thus knowledge of heritability for different traits is essential for improvement in crop plants.

2.9. Genetic Diversity

Genetic diversity studies have enhanced greater understanding of the extent of variation within the germplasm collections and required management practices. Study on genetic diversity is critical to success in plant breeding. It provides information about the quantum of genetic divergence and serves a platform for specific breeding objectives (Thompson et al., 1998). The information has been crucial in the development of core collections of different crops (Zhang et al., 2000) and tailoring germplasm exploration to focus on those areas with maximal genetic diversity (Graner et al., 1994). The information has also been useful for the optimal design of plant breeding programs, influencing the choice of genotypes to cross for development of new populations (Zhang et al., 2000 and Thompson et al., 1998). A lot germplasm diversity assessments have been based on morphological and agronomic traits as well a reaction to pests, diseases and other stresses. These traits, however, vary a lot with cultivars, environment, stage of growth, and cultural practices (Jarret et al., 1992; Gichuru, 2003) and hence Choice of parent has been identified to be the first basic step in meaningful breeding programme (Akroda 1987); (Aremu et al. 2007a); (Islam 2004), (Rahim et al, 2010).

Wide range of variability for yield and associated characters in potato has been reported by a number of workers (Mishra et al., 2006; Mondal et al., 2007 and Regassa and Basavaraj, 1992). Estimation of expected genetic advance is important to have an idea of effectiveness of selection. Johnson et al. (1955a) found it more useful to estimate the heritability together with genetic advance in predicting the expected progress to be achieved through selection. Consequently this confirms that the variability for all the characters in the test genotypes was as a result of genetic effects which are less affected by the growing environment.
2.10. Heritability and expected genetic advance under selection

Knowledge of heritability of a trait thus guides a plant breeder to improve phenotypic values by identifying and selecting superior genotypes because environment also affects phenotype, there is not a perfect correspondence between phenotypic and genotypic values. To predict the outcome of selection in a collection of genotypes a breeder must know the level of correspondence between phenotypic and genotypic values. Heritability \((H)\) is a value that expresses the degree of this correspondence. To predict behavior of succeeding generations and helps to predict the response to selection (http://passel.unl.edu). Heritability is the ratio of genetic variance to total variance for a plant trait and is related with progress from selection (Hanson, 1963). Heritability estimates indicate that certain morphological traits that influence yield in potato are more heritable than yield because yield is a polygenic trait and is greatly influenced by the environment. Heritability estimates were high for stolon length, plant height, leaf area, number of shoots per plant, tuber volume, tuber dry matter content, specific gravity of tubers, shoot girth and tuber yield per plant in a study of genetic variability, heritability and genetic advance in Potato by Mishra et al. (2006).

There is broad and narrow sense estimated method of heritability. Heritability in the broad sense is the sum of additive, dominance and epistatic effects (Falconer and Mackay, 1996; Nyquist and Baker, 2008). Additive genetic variance is the most important since; it determines the correlation and opportunities for genetic change by natural or artificial (Hill et al., 2008. The proportion of phenotypic variance among individuals in a population that is due to heritable genetic effects known as heritability in the narrow sense, which estimates more useful to plant breeders than the broad sense estimates since the additive component of genetic variance determines the response to selection.
Use of the broad sense heritability is generally restricted like; identical twins or asexual propagates of an individual it gives the total fraction of variation in a trait differences due to in genotypic values (Walsh, 2010). High heritability percentage reflects the large heritable variance which may offer the possibility of improvement through selection (Ansari et al., 2004). When heritability is high, selection based on phenotype used for plant breeding methods was successful in improving the population in the desired direction for the trait of interest (Acquaah, 2007).

Genetic advance measures the expected genetic progress that leads to selecting the best performing genotypes (Allard, 1999). The genetic advance achieved through selection depends on the factors of total variation in the population in which selection was conducted (Acquaah, 2007). High heritability estimation is helpful in making a selection of superior genotypes. However, heritability estimates along with genetic gain are more useful in predicting the selection of best individual (Jonson et al., 1955).

Regarding potato, research results were published on heritability and genetic advance values that have been done at different locations with different genotypes and year. Sattar et al. (2007) reported that on 28 genotypes of potato high heritability coupled with high genetic advance as percent of mean and high genotypic coefficients of variation were observed for number of tubers per plant, yield per plant and average weight of a tuber suggesting selection for these traits would give good response.

2.11. Cluster Analysis

Breeding specialist is going to classify different varieties and cultivates to find their genetic distance and use their diversity in breeding program using cluster analysis methods (Brayan and Manly, 2004). Genetic relationship among and with breeding materials can be identified and classified using multivariate grouping methods. The use of established multivariate statistical algorithms is important in classifying breeding materials from germplasm, accessions, lines, and other races into distinct and variable groups depending on genotype performance (Aremu, 2012). Cluster analysis is a method often extended to genotype grouping in order to cluster entries that show similarity in one or more traits and thus guide in the choice of genotypes for crop improvement (Akintobi et al., 2002). Both
morphological descriptors and molecular markers are able to group the variety to distinct clusters independent of locality collected (Asare et al., 2011). Such groupings are helpful to breeders in recognize expected genotype that may be used as parents inbreeding for any of the morphological traits that were studied. Above all, the information generated will reduce the overall time required by plant breeders to screen large populations for potential breeding (Odewale et al., 2012).

In terms of several workers identified cluster analysis in potato. Mondal et al. (2007) in 31 potato variety was grouped into five different clusters Haydar et al. (2007) determined cluster analysis of 30 potato genotypes into six group; Haydar et al.,2009 grouped 30 potato genotypes into five cluster; Sattar et al.(2011) grouped Twenty eight genotypes were grouped into five clusters; Regassa and Basavaraja (2005) clustered One hundred potato genotypes into 8 groups based on performance of genotypes. Arslanoğlu et al. (2011) classified 146 potato genotypes, based on 15 variables identified 27 groups.

2.12. Genetic Distance Measurement

First defined Genetic distance as the difference between two entities that can be described by allelic variation Nei, (1973). Betterstill, in 1998, Beaumont et al., 1998 Provided a more comprehensive definition of genetic distance as any quantitative measure of genetic difference at either sequence or allele frequency level calculated between genotype individuals or populations.

Measurement of genetic distance was proposed over the past few decades for various objectives. Mahalanobis generalized distances approach, adopting, multiple measurements provided a measure of the generalized distance (Mahalanobis, 1936). This method of measurement was important for identification of genetically divergent genotypes to facilitate grouping and characterization for agronomic and morphological characteristics. The utility of multivariate analysis in quantifying the degree of divergence between populations was important to assess the relative contribution of different components to the total divergence (Morishima and Oka, 1960; Murty and Qadri, 1966). Moreover, such studies were also permitted the choice of genetically divergent parents to obtain desirable recombinants in segregating generations (Osiru et al., 2012). According to Zhu et al. (2000) noted that a
mixture of susceptible and resistant plants had increased the performance of susceptible type and delayed the evolution of new pathotypes.

Genetic distance between two genotypes, populations, or individuals may be calculated by various statistical measures depending on the data set. According to Nei (1987) Euclidean or straight-line measure of distance is the most commonly used statistic for estimating genetic distance (GD) between individuals (genotypes) for morphological data.

2.13. Principal Component

This analysis seeks to explain variance by linear function of original random variables. Principal component analyses determined from Patterns of variation and major traits contributing to the delineation (Fundora et al., 2004). Principal components analysis first determines Eigen values which explain the amount of total variation displayed on the component axes. The central idea of principal component analysis is to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set. This is achieved by transforming to a new set of variables, which are uncorrelated (Jolliffe, 2002).

Three principal components was extracted from, 18 traits which accounted for 65% of the total variation of all the traits. Traits that accounted for most of the observed variations were leaf area, final plant stand, tuber number, dry tuber yield, fresh tuber yield, dry matter, plant height angle of branching, height of branching, and sprouting ability in potato (Raji et al., 2007).

Afonso et al. (2014) reported that the major components and their respective totals and accumulated variations obtained for the 16 quantitative morphological characters, it is noticed the characters was concentrated to 9th main component, accounting for 83.76%. It was found that petiole length, middle lobe length, plant height, weight of foliage, stems and strains weight, number of lobes and the width of the middle lobe per plant had the highest weight for variability among the observed potato characters.

2.14. Correlation among Traits
Relationships between two metric characters can be positive or negative, and the cause of correlation in crop plants can be genetic or environmental (Hallauer & Miranda, 1988; Falconer, 1989). The correlation coefficient is a measure of the degree of association between two traits worked at the same time (Hayes et al., 1955). The covariance is a measure of the joint variation of two or more variables (Pearson, 1895 and Fisher, 1831). The correlation also play important role in the selection of two or more traits simultaneously. Determination of correlation coefficients between the traits could help in identifying the relative importance of different traits to be emphasized in selecting breeding materials for further breeding program (Afroz et al., 2004).

Phenotypic correlation among traits provides a preliminary sign of the relationship between such traits. This relationship may be important to know which components are useful indicators to improve preferred traits and improvement of one trait will result in simultaneous changes in other traits (Zaldivar et al., 2004).

The assessment genotypic correlation for determining the relationships among agronomic traits in a genetically diverse population at genotypes was an effective tool for making progress in crop improvement (Bello et al., 2006). Haydar et al. (2009) reported that the genotypic correlation coefficient was higher than phenotype correlation coefficients and suggesting that the character association had not been largely effected by environment. hence concluded that the genotypes constitute a pool of germplasm with adequate genetic variability and selection of desirable traits among these genotypes will lead to significant progress in potato improvement.

Khayatnezhad, et al. (2011) found positive correlation of plant tuber yield with main stems/plant, plant tuber weight, plant height and negative correlation tuber yield with medium tuber percentage, Main stem/plant with medium tuber correlation with mean stems/plant, tuber percentage, tubers/plant with medium tuber percentage. Fekadu et al. (2013) reported that Tuber yield was positively correlated with plant height, biological yield, harvest index and big tuber percentage and negatively with small and medium tuber percentage.
Correlation coefficient showed that tuber weight and harvest index have positive and significant correlation with tuber yield was reported by Felenji et al. (2011). Sattar et al. (2007) reported that Plant vigour, number of compound leaves per plant and number of tubers per plant, average weight of a tuber and dry matter content of tuber had high degree of positive association with tuber yield per plant.

2.15. Path Coefficient Analysis

Interrelationship may be estimated by correlation analysis (Stoskopf et al., 1999). Yet they do not provide an exact picture of the relative importance of direct and indirect influences of each of the component traits, because as the number of independent variables influencing a particular dependent variable increases, there is bound to be certain amount of independence (Rao et al., 1997). Correlation and path coefficient analyses assist in the choice of traits result in the improvement of complex traits such as yield. Path analysis is useful to know the indication of which variables exert an influence on other variables (Akanda and Mundit, 1996). Dewey and Lu (1959) used path coefficient analysis in breeding programme for the first time and they calculated direct and indirect effects.

Sattar et al. (2007) on path analysis indicated great contribution of Number of tubers per plant and Number of compound leaves per plant on yield. Haydar et al. (2009) obtained in a path analysis main shoot number showed highest and positive direct effect followed by fresh weight/plant at 80 days after planting and number of leaves/plant on potato.
3. MATERIALS AND METHODS

3.1. Description of the study area

The study was conducted in kersa (serbo), Seka Chekorsa and Dedo Districts of Jimma Zone in Oromia Regional State.

**Dedo** district whose administrative town is Sheki, located at a distance of 377 km from Addis abeba. Dedo is Part of the Jimma Zone bordered by the Gojeb River from South that separates the region from the Southern Nations, Nationalities and Peoples Region, from West by Gera, from North by Kersa, and from East by Omo Nada.

It is situated at an altitude ranging from 2500 to 3360 meters above sea level. The area receives an average annual rainfall ranging from 1600-2600mm. These has an average minimum and maximum daily temperatures of 20 and 28°C, respectively.

**Seka Chekorsa**; district is located at a distance of 375 km, south-West of Addis Ababa. It is bounded by Gomma and Manna district in the North, Gera district in the South, Dedo district and Jimma Town in the East and Shabe Sombo woreda in the West.

It is situated at an altitude ranging from 1580 to 2560 meters above sea level. The district receives rainfall, ranging from 1,200 – 2,800 mm per annum. The average minimum and maximum daily temperatures of the area are 12.6°C and 29.1°C, respectively.

**Serbo district whose administrative town is Kersa** located at 20 km away from Jimma town in Southwestern direction. Its altitude is 1500-2660 meters above sea level, and has an average annual temperature ranging 11.2°C and 29.6°C and the annual rainfall is 1150 mm (Jimma zone Office of Agriculture and Rural Development, 2006).
Figure 2 Study area Map
3.2. Experimental Materials

In this study a total of 25 varieties consisting of 15 improved varieties, and 10 advanced genotypes were evaluated.

The experimental material were kindly provided by Debre-Birihan Agricultural Research Center.

From fifteen (15) improved varieties the breeder selects ten of them by observing their growth performance and tag for participatory variety selection.

Table 1: Experimental materials to be used in this study

<table>
<thead>
<tr>
<th>Entry NO</th>
<th>Genotype name</th>
<th>Breeder/Maintainer</th>
<th>altitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Zengena</td>
<td>AWARK</td>
<td>2000-2800</td>
</tr>
<tr>
<td>2</td>
<td>39511_13</td>
<td>DB ARC</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>392640_514</td>
<td>DBARC</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Gorobela</td>
<td>ShARC</td>
<td>2700-3200</td>
</tr>
<tr>
<td>5</td>
<td>390162_3</td>
<td>DBARC</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>Gudane</td>
<td>HARC</td>
<td>1600-2800</td>
</tr>
<tr>
<td>7</td>
<td>Guassa</td>
<td>ADARC</td>
<td>2000-2800</td>
</tr>
<tr>
<td>8</td>
<td>Arrarsa</td>
<td>SARC</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>Gera</td>
<td>ShARC</td>
<td>2700-3200</td>
</tr>
<tr>
<td>10</td>
<td>Belate</td>
<td>HARC</td>
<td>1600-2800</td>
</tr>
<tr>
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<td>Jallane</td>
<td>HARC</td>
<td>1600-2800</td>
</tr>
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<td>Shenkola</td>
<td>AwARC</td>
<td>1700-2700</td>
</tr>
<tr>
<td>13</td>
<td>Ayito</td>
<td>DBARC</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>15</td>
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<td>Abalolarge</td>
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<td>DB ARC</td>
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<td>AwARC</td>
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<td>HU</td>
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<td>HU</td>
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<td>21</td>
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<td></td>
</tr>
<tr>
<td>25</td>
<td>Abateneh</td>
<td>DB ARC</td>
<td></td>
</tr>
</tbody>
</table>
3.3. Experimental Design, Field Management and Season

The experiments were conducted in the crop season of 2015 and laid out in 5x5 simple lattice design with two replications at three location. All the treatments were allocated completely at random to the experiential plot. Medium sized potato tubers (35-45) mm in diameter was used and spaced at 0.75 m apart between rows and 0.30 m between plants. The spacing between replication was 1.5 meter width where as the spacing between experimental plots was 1 meter. Fertilizer rate as recommended by research center (195 kg DAP/ha and 165 Urea /ha) were applied. Urea fertilizer was applied in split that is 50% during time of planting and the rest 50% urea was applied near to tie of flowering while all DAP applied at time of planting (JARC, 2006).

3.4 Data Collection

3.4.1 Breeder Data Collection (Quantitative Traits)

For all the study traits, the middle two rows were used for recording the data.

1. **Days to emergence**: Recorded as the number of days from planting to 50% of the plants emerged in each plot.

2. **Plant heights (cm)**: Determined by measuring the height of five randomly selected plants from the base of the main shoot to the apex when 50% of the plants produce flowers.

3. **Days to 50% flowering**: The number of days from emergence to a stage when 50% of the plants in the plot produce flowers.

4. **Days to maturity**: The number of days from emergence to a stage when 50% of the haulms (vines) turned yellow and leaves show senescence.

5. **Number of stems/Plant**: Recorded as the average stem count of five hills per row at flowering,

6. **Total tuber number/Plant**: the total number of tubers produced per hill (count).

7. **Number marketable tubers /Hill average** number of marketable tubers per plant
(more than 50g) were counted at harvest

8. **Number unmarketable tubers /Hill average**: The number of tubers that were diseased and small-sized which were not marketable

9. **Total tuber yield /Plant (ton/ha)**: It was recorded by the sum of both marketable and unmarketable tuber yields.

10. **Average tuber weight (kg)**: It recorded by dividing total fresh weight of tubers per plot by the total number of tubers

11. **Tuber diameter (cm)**: was measured by caliper

12. **Leaf width (cm)**: It was measure from the widest part of the middle leaf lobe.

13. **Leaf length(mm)**: It was measured along the middle of the leaf vine

### 3.4.2 Farmers participatory Data Collection

The genotypes were separately evaluated before harvest and at harvest by a group of DAs, District experts of Agriculture office and a group of fifteen farmers (eight males and seven females) at each site. The selected farmers were knowledgeable about potato production and consumer preferences. At each site, the evaluation before harvest was carried out at time of flowering and two days before harvesting the trial. Before the evaluation process was carried out, both groups at each site were familiarized with the selection procedure and criteria. Both groups used the same evaluation criteria. A rating scale of 1-5 was used for all the traits. For maturity, early matured genotype was scored 1 and a late matured genotype, 5. Then the mean score for each trait was separately determined for each of the two groups per site. Roots were sampled from each plot of each genotype, boiled, taste tested and then scored and the same rating scale of 1-5 was used as above (Demolish *et al.* (2013)).

1. **Number of stem per hill**: situation at flowering
2. **Earliness to maturity**: As early maturing, late maturing
3. **Tuber yield**: High yielder, low yielder, moderate yielder...
4. **Tuber uniformity**: As high, low moderate...
5. ** Marketable tuber yields**: very high, high, moderate...
6. **Un Marketable tuber yields**: very high, high, moderate...
7. **Taste.** poor, good very, good

### 3.5 Statistical Analysis and Procedures

#### 3.5.1 Data analysis

The mean values of the genotypes were subjected to analysis of variance (ANOVA) based on simple lattice design (Panse and Sukhatme, 1967) using SAS procedure. Also Cluster analysis and principal component analysis were done by using SAS Version 9.2 (SAS, 2008) and Minitab 16. The phenotypic and genotypic correlation coefficients and path coefficient analysis were estimated using GENRES Statistical Software or Package (PISS, 1994). Statistical Package for Social Science (SPSS) Version 16 was used to analyze the participatory varietal selection data collected through farmer participation.

The model used for simple lattice design:

\[ Y_{ijr} = \mu + A_r + G_{ij} + B_{ir} + B_{jr} + e_{ijr}, \]

where: \( Y_{ijkr} \) = response of \( Y \) trait from the \( i^{th} \) accession, \( j^{th} \) replication,

\( \mu \) = Overall mean effects,

\( A_r \) = Effects of \( i^{th} \) level of treatments,

\( G_{ij} \) = Effects of \( ij^{th} \) level of treatments,

\( B_{ir} \) = Effects of \( j^{th} \) level of replication,

\( B_{jr} \) = Effects of \( K^{th} \) level of blocks within replications (adjusted for treatments),

\( \chi_{l} \) = Effects of \( l^{th} \) level of intra block error,

\( \pi_{m} \) = Effects of the \( m^{th} \) randomized complete block error and

\( e_{ijr} \) = is a random error component.
Table 2: Analysis of Variance (ANOVA) Table for each quantitative character

<table>
<thead>
<tr>
<th>Sources of variation</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication (r)</td>
<td>r-1</td>
<td>SSr</td>
<td>MSR</td>
<td></td>
</tr>
<tr>
<td>MS_R/MS_E</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genotypes (G) - [Unadj.]</td>
<td>G-1</td>
<td>SS_G</td>
<td>MS_G</td>
<td>MS_G/MS_E</td>
</tr>
<tr>
<td>- [adj.]G-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block within replication (b) [adj.]</td>
<td>r(b-1)</td>
<td>SSb</td>
<td>MSb</td>
<td>MSb/MS_e</td>
</tr>
<tr>
<td>Intra-block error (e)</td>
<td>(b-1) (rb-b-1)</td>
<td>SSE</td>
<td>MSE</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>rb^2-1</td>
<td>SST</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

where: r = number of replication, G = number of genotypes, D.F = degree of freedom, b = block, SS = Sum of squares, MS = mean squares, SSr and MSR are sum of squares and mean squares of replication, respectively; SS_G and MS_G are sum of squares and mean squares of genotypes, respectively; SS_b and MS_b are sum squares and mean squares of blocks within replication respectively, SS_e and MSE are sum of squares and mean square of intra-block error, respectively and SST is sum of squares of the total

3.5.2 Phenotypic (PCV) and Genotypic (GCV) Coefficient of Variation analysis

The phenotypic and genotypic variations and coefficient of variations will be calculated according to the method suggested by Burton and de Vane (1953) as follows:

\[
\sigma^2_p = \sigma^2_g + \sigma^2_e
\]

Where: \( \sigma^2_p \) = phenotypic variance

\[
\sigma^2_g = \text{genotypic variance}
\]

\[
\sigma^2_e = \text{environmental variance}
\]

\[
\sigma^2_g = \frac{\text{MSt} - \text{MSe}}{r}
\]

Where: MSt = mean square of treatments

\[
\text{MS}_e = \text{mean square of Error}
\]

\[
\delta^2_e = \text{MSe}
\]
\[ r = \text{number of replications} \]

\[
PCV = \frac{\sqrt{\sigma^2_x}}{ \bar{x} } \times 100 \quad \text{Where: } PCV = \text{Phenotypic Coefficient of Variation}
\]

\[
GCV = \frac{\sqrt{\sigma^2_g}}{ \bar{x} } \times 100 \quad \text{Where: } GCV = \text{genotypic Coefficient of Variation}
\]

According to Deshmukh et al. (1986), PCV and GCV value greater than 20% are considered as high, while values less than 10% are considered low and values between 10% and 20% will consider medium.

### 3.5.3 Estimation of broad sense heritability and genetic advance as percent of the mean

The broad sense heritability will be calculated according to the method suggested (Robinson et al. 1949).

\[
h^2_B = \frac{\sigma^2_x}{\sigma^2_p} \times 100 \quad \text{Where: } h^2_B = \text{broad sense heritability}
\]

The broad sense heritability estimates were categorized according to the method suggested by Robinson et al. (1949), which categorized as 0-30% Low, 30-60% Moderate and 60% and above high heritability.

Expected genetic advance (GA) with one cycle of selection and expected genetic advance as present of mean was calculated to compare the extent of predicted genetic advance of different traits under selection according to Shukla et al. (2006b) formula as follows:

\[
GA = (K) (\sigma_{ph}) (h^2_B) \quad \text{Where } GA = \text{expected genetic advance}
\]

\[
K = \text{selection differential which varied with selection intensity (5% intensity was used at } K = 2.06)\]

\[
GAM = \frac{GA \times 100}{\bar{x}}
\]

\[
\sigma_{ph} = \text{phenotypic standard deviation}
\]
GAM = genetic advance as percent of mean

Genetic advance as percent of population mean was categorized according to Johnson et al. (1955), high which are above 20%, moderate (10-20) % and low less than 10%.

### 3.5.4 Cluster Analysis (CA)

Clustering analysis procedure was performed to group sets of genotypes with similar characteristics into homogenous groups based on quantitative traits. Hierarchical clustering was employed using the similarity coefficients among the genotypes. The number of clusters were determined according to Copper and Miligan (1988), by looking into three statistics, namely Pseudo F, Pseudo $t^2$ and cubic clustering criteria using the proc cluster procedure of SAS 9.2 (SAS, 2008) and cluster analysis was performed. MINITAB version 16 statistical computer package was employed to summarize the observation by constructing dendrogram (Webster and Oliver, 1990).

### 3.5.5 Genetic divergence analysis

Genetic divergence was determined using the generalized Mahalanobis’s statistics (Mahalanobis, 1936) as follows:

$$D^2_{ij} = (X_i - X_j) S (X_i - X_j)$$

Where: $D^2_{ij}$ = the distance between two groups i and j

$X_i$ and $X_j$ = the two vectors mean $i^{th}$and $j^{th}$ accessions respectively

$S$ = is the inverse of the pooled divergence matrix

The $D^2$ values obtained for pairs of genotypes were tested for significance at the required level of probability against the tabulated values of $\chi^2$ for p degrees of freedom, where p is the number of traits considered (Singh et al., 1987).
3.5.6. Principal component analysis

Principal component was analyses using the correlation matrix by employing procedure Proc FACTOR in SAS 9.2 (SAS, 2008) in order to examine the traits that accounts for maximal variance in the observed component among 1.0 (Kaiser, 1960). Large loading was considered according to Stevens (1986) with absolute value exceeds 0.40.

3.5.7. Correlation coefficient analysis and path coefficient analysis; was calculated using Genress statistical software.
4. RESULTS AND DISCUSSION

4.1. Analysis of Variance (ANOVA)

Combined Analysis of variance showed significant variations among all genotypes for the 13 characters studied except four traits (Table 3). The result indicated that there is significant difference among 25 potato genotypes for 9 traits (days to emerge, days to flowering, plant height, total tuber number per plant, weight tuber yield per hectare, number of marketable tuber per plant, average tuber weight, tuber diameter and leaf width). This finding was in agreement with Regassa and Basavaraj (2005) who reported significant difference for traits such as days to emergence, Days to flower, Plant height (cm), Number of small sized tubers per plant, Weight of medium sized tubers per plant (g), Weight of large sized tubers per plant (g), Total number of tubers per plant, Total weight of tubers per plant (g) and Total tuber yield (t ha-1).

Several researchers reported significant differences among potato genotypes studied. Nishizawa et al. (2014) found significant difference 13 characters of plant height, days to 50% flowering; Also Sattar et al. (2007) reported significant difference among 28 genotypes of potato for number of tubers per plant, yield per plant and average weight of a tuber, days to maturity. Joseph et al. (2005) reported significant differences among 13 potato genotypes for days to 50% emergence, days to 50% flowering, plant height(cm), tuber diameter(cm), tuber yield (kg), number of tuber per plant, small tuber percentage, medium tuber percentage and big tuber percentage. Mondal et al. (2007) reported significant difference in days to emergence, plant height, big tuber percentage, and small tuber percentage per plant in 31 potato varieties.

Source of variation for Genotypes by environment responded similar to the different environmental conditions. This indicated that there was a no difference between the testing location causing different genotypes to perform differently across the testing location. my result disagree with Gedif1 and Yigzaw (2014) indicated that the effects due to genotype by environment interaction were highly significant using eight potato genotypes at five
Similarly, Genotype X environment interactions were estimated for several traits in potato from a combined analysis of 11 genotypes grown at 3 locations for 2 years. These interactions were significant for the majority of the traits studied (Metin B. Yildirim and Celal F. Calikan, 1985).
Table 3: Analysis of variance (Mean squares) for the 13 characters of 25 potato genotypes evaluated at three location (2015)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Replication (Adj)</th>
<th>Genotypes (Adj)</th>
<th>Location</th>
<th>Location X genotype</th>
<th>Block with in Rep</th>
<th>Intra block Error</th>
<th>R² (%)</th>
<th>C.V (%)</th>
<th>Relative Efficiency to RCBD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degrees of Freedom</td>
<td>1</td>
<td>24</td>
<td>2</td>
<td>48</td>
<td>8</td>
<td>66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DE</td>
<td>0.67</td>
<td>42.61**</td>
<td>187.89</td>
<td>22.51</td>
<td>17.73</td>
<td>18.81</td>
<td>68.8</td>
<td>26.8</td>
<td>94.26</td>
</tr>
<tr>
<td>DF</td>
<td>48.16</td>
<td>420.68**</td>
<td>1970.2</td>
<td>70.51</td>
<td>105.46</td>
<td>86.49</td>
<td>778</td>
<td>14.9</td>
<td>121.93</td>
</tr>
<tr>
<td>PH</td>
<td>199.29</td>
<td>887.5**</td>
<td>5524.5</td>
<td>220.81</td>
<td>149.50</td>
<td>124.35</td>
<td>848</td>
<td>14.6</td>
<td>120.23</td>
</tr>
<tr>
<td>DM</td>
<td>450.7</td>
<td>57.902 ns</td>
<td>757.78</td>
<td>37.061</td>
<td>48.75</td>
<td>30.59</td>
<td>722</td>
<td>5.30</td>
<td>159.37</td>
</tr>
<tr>
<td>NS</td>
<td>225.706</td>
<td>55.02 ns</td>
<td>481.12</td>
<td>54.85</td>
<td>54.688</td>
<td>4.30</td>
<td>60</td>
<td>25.9</td>
<td>102.55</td>
</tr>
<tr>
<td>TTN</td>
<td>8.6400</td>
<td>20.00**</td>
<td>71.84</td>
<td>7.267</td>
<td>13.35</td>
<td>20.00</td>
<td>74</td>
<td>27.7</td>
<td>66.75</td>
</tr>
<tr>
<td>WT</td>
<td>32259.0</td>
<td>32414.2**</td>
<td>64527</td>
<td>9203.0</td>
<td>7490.74</td>
<td>6451.46</td>
<td>775</td>
<td>27.3</td>
<td>116.11</td>
</tr>
<tr>
<td>MTY</td>
<td>49.31</td>
<td>8.549**</td>
<td>35.207</td>
<td>5.037</td>
<td>7.9579</td>
<td>3.591</td>
<td>7334</td>
<td>31.9</td>
<td>221.61</td>
</tr>
<tr>
<td>UMTY</td>
<td>15.36</td>
<td>6.18 ns</td>
<td>36.726</td>
<td>2.8481</td>
<td>3.55</td>
<td>5.18</td>
<td>604</td>
<td>23.20</td>
<td>57.38</td>
</tr>
<tr>
<td>AT</td>
<td>3949.89</td>
<td>2651.06*</td>
<td>34287</td>
<td>888.04</td>
<td>2751.94</td>
<td>139.08</td>
<td>7007</td>
<td>14.56</td>
<td>196.81</td>
</tr>
<tr>
<td>TD</td>
<td>4.68</td>
<td>5.87**</td>
<td>1.34</td>
<td>2.63</td>
<td>1.11</td>
<td>5.87</td>
<td>7076</td>
<td>21.02</td>
<td>18.91</td>
</tr>
<tr>
<td>LW</td>
<td>1.72806</td>
<td>1.34841**</td>
<td>0.528</td>
<td>0.6974</td>
<td>0.65190</td>
<td>0.64</td>
<td>629</td>
<td>16.41</td>
<td>101.86</td>
</tr>
<tr>
<td>LL</td>
<td>0.58906</td>
<td>0.806 ns</td>
<td>5.27360</td>
<td>0.8209</td>
<td>1.51978</td>
<td>1.194</td>
<td>5215</td>
<td>16.24</td>
<td>127.28</td>
</tr>
</tbody>
</table>

DE= Days to emergence, days to 50% flowering and Days to maturity) DF= days to flowering  PH=plant height DM= Days to maturity, NS=number of stem per plant TTN= total tuber number per plant MTY=marketable tuber number per plant, UMTN=unmarketable tuber number, ATW=average tuber weight, TD=tuber diameter, LW=leaf width, WTY/ku=weight tuber yield, LL=leaf length

* = significant at 5% probability level and ** = highly significant at 1% probability level, C.V = Coefficient of Variation, RCBD = Complete Block Design
4.2. Estimation of Variability

4.2.1 Range and Mean Performance

The estimated range and mean values of 13 studied traits are presented in Table 4. Comparatively a wide ranges variation for different trait showed that the presence of a good variability among the genotypes. High range of values were observed for days to emerge (6-30), days to flowering (31-72), plant height (32-118.6), Days to maturity (88-127), number of stem per plant (3-17) total number of tuber per plant (2-17), number of marketable tuber per plant (4-14), number of unmarketable tuber (1-10), average tuber weight (29.9-232.6), tuber diameter (3-9.8), leaf width (2.9-7.4), weight tuber yield ku/ha(63.2-587.3), leaf length(3.8-9.4).

High yield was recorded from the genotypes Abalolarge (565.3ku/ha) Gudane (501 ku/ha) Abateneh (587.3ku/ha), 390412-2 (417.06 ku/ha), 390162-3 (517.49ku/ha). Also high number of marketable tubers per plant was counted for Abalolarge(14), Abateneh (12), 392640-514(11), 395011-2(11), 390412-2 (10), Gorobella (10), Gudane (10). In similar way Abalolarge (9.8), Abateneh (9.5), 390412-2 (8.3), 389703-3 (8.1), Guassa (8.7), Balete (8.2), Gudane (9), Gorobela (8.4) showed larger tuber diameter.

Table 4. The range and the mean values of potato genotypes for 13 characters

<table>
<thead>
<tr>
<th>Character</th>
<th>Mean</th>
<th>Range</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE</td>
<td>16.15</td>
<td>6</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>DF</td>
<td>62.02</td>
<td>31</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>PH</td>
<td>75.99</td>
<td>32</td>
<td>118.6</td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>104.2</td>
<td>88</td>
<td>127</td>
<td></td>
</tr>
<tr>
<td>NS</td>
<td>8.00</td>
<td>3</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>TTN</td>
<td>9.06</td>
<td>6</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>WT</td>
<td>293.5</td>
<td>63.2</td>
<td>587.3</td>
<td></td>
</tr>
<tr>
<td>MTN</td>
<td>5.93</td>
<td>4</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>UMTN</td>
<td>9.8</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>AT</td>
<td>80.95</td>
<td>29.9</td>
<td>232.6</td>
<td></td>
</tr>
<tr>
<td>TD</td>
<td>6.37</td>
<td>3</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>LW</td>
<td>4.88</td>
<td>2.9</td>
<td>7.4</td>
<td></td>
</tr>
</tbody>
</table>
From the fifteen released varieties, 8 (53%) of them showed better yield performance whereas 3 (30%) of the advanced genotypes were characterized by higher yield than the grand mean value. Furthermore, most of the advanced genotypes were found to be better yielders than most of those released varieties (Appendix 4).

These wider ranges of mean values for most of the studied characters indicates the existence of variation among the tested genotypes Hence these characters provide chance for selection and desire for further improvement. This finding supported by Fekadu et al.,(2013) who recorded similar observations for various characters like days to 50% emergence, days to 50% flowering, days to 90% maturity ,plant height (cm), stems per plant, tuber diameter (cm), tuber yield (kg), number of tuber per plant , biological yield(kg), harvest index, small tuber percentage , medium tuber percentage and big tuber percentage.

4. 2.2. Phenotypic (PCV) and genotypic (GCV) coefficient of variation

Values of phenotypic and genotypic coefficient of variation, genetic advance as percent of mean and broad sense heritability for the potato genotypes are presented in Table 5. The maximum GCV was estimated for number of stem per plant (49.40) followed by unmarketable tuber number per plant (45.52) average tuber weight (31.19) total tuber number per plant (28.49) plant height (26.53) tuber diameter (25.59) marketable tuber number per plant (25.49) days to emerge (25.43) days to flowering (21.87) while the minimum was for leaf width, Date of maturity and leaf length. According to Deshmuk et al. (1986) High GCV percentages were estimated for days to emerge, days to flowering, plant height, number of stem per plant, total tuber number per plant, number of marketable tuber per plant, number of unmarketable tuber per plant, average tuber weight, tuber diameter, weight tuber yield per hectare and leaf length, leaf width, leaf length traits had low GCV.

PCV ranges from 6.16 to 85.22 for date of maturity and number of stem per plant and GCV ranged from 3.93 for date of maturity to 49.40 for number of stem per plant traits respectively. High values of both phenotypic and genotypic coefficient of variation had been estimated for number of stem per plant (85.22, 49.40%), unmarketable tuber number per plant (61.18, 45.52%), average tuber weight (55.43, 31.19%), weight of tuber per hectare
(45.81, 40.79%), marketable tuber number per plant (42.21, 25.49%), total tuber number (40.31, 28.49%), days to emerge (31.41, 25.43%), plant height (28.87, 26.53%), tuber diameter (28.14, 25.59%) days to flowering (24.81, 21.87%).

For the studied characters, showed the phenotypic coefficients of variation (PCV) values were higher than the corresponding genotypic coefficients of variation (GCV) values for all the traits. This indicates the apparent variations in the genotypes were not only due to genotypic effect but also due to environmental influences, since phenotypic variances were contributed by the effect of interaction of genotypes and environment. This shows that the environmental variance had high share of variance on the expression of this trait. It indicates that the observed variations for the trait were due to environmental and genetic factors. Bisne et al. (2009) reported that high phenotypic variations composed of high genotypic variations and on contrary less of environmental variations indicate the presence of high genetic variability for different traits and less influence of environment.

The result of this study is in conformity with Mishra et al. (2006) reported high GCV and PCV percentages were for plant height and tuber yield per plant. This implies that the traits were sensitive to environmental effects. Barik et al. (2009) recorded phenotypic variance was higher than the genotypic variance for plant height, number of tubers per plant and total yield. Weyessa et al. (2005) found high PCV and GCV for the number of tubers per hill and moderate PCV and GCV for leaf width. Regassa and Basavaraj (2005) recorded a higher PCV and GCV for total tuber number per plant, total tuber yield, number of small size tuber per plant and number of large size tuber per plant. Fekadu et al. (2013) reported that number of stem per plant, number of tuber per plant and total tuber yield showed high genotypic and phenotypic coefficients of variation on potato germplasm.

Leaf length showed moderate PCV while low GCV and days to maturity showed low PCV and GCV (How Low PCV and GCV indicate it indicate the trait is not improved by phenotypic selection of this trait. However low gap between PCV and GCV indicate low environmental influence. This result is in agreement with Sattar et al. (2007) who reported that low GCV and PCV for days to maturity
4.2.3. Estimation of broad sense heritability ($h^2_B$)

The estimate of broad sense heritability, the base to the plant breeder for selection on the basis of phenotypic performance, is presented in Table 5. According to Robinson et al. (1949) heritability between 0-30% categorized as Low, 30-60% as Moderate and 60% and above as high heritability traits. High heritability was recorded for days to emergency, days to flowering, plant height, leaf width, tuber yield per hectare, tuber diameter suggesting that, greater effectiveness of selection and improvement to be expected from these characters in future breeding program. Similar results were reported by Sattar et al. (2007) for Plant height (cm), average weight of a tuber and on the contrary days to maturity, number of Tubers/plant and Tuber yield/plant (g). Similarly, Regassa & Basavaraj (2005) reported moderate to high heritability and high genetic advance for plant height, and total yield per plant for 100 potato genotypes. Joseph et al. (2005) recorded heritability values were moderate to high for 17 potato genotypes. Gulsum and Zihin moderate to high level heritability values were found for plant height, leaf width, leaf length, single tuber weight and plant yield. Tekalign (2009) (h2) estimate found heritability from moderate to high.

Moderate heritability was found for marketable tuber number per plant, unmarketable tuber number, average tuber weight, days to maturity, number of stem per plant, total tuber number per plant. The lowest heritability was for leaf length and it was the least suggesting for selection because this trait was greatly influenced by environmental factor. The magnitude of heritability of a given trait is affected by the type of genetic material involved (Ceccarelli, 1994).
4.2.4 Genetic advance and Genetic Advance as percent of mean

The expected genetic advance expressed as a percentage of the mean (GAM) is shown in Table 5 and ranged from 0.80 to 74.93%. This indicated that selecting the top 5% of the base population could result in an advance up to 74.93% over the population mean.

Falconer and Mackay (1996) classified genetic advance as percent of mean as low (0-10%), moderate (10-20%) and high (20% and above). High genetic advance as percent of population mean was observed for days to emergence (42.48), followed by days to flowering (39.28), plant height (50.3), number of stem (59.08), Total number of tuber (41.55), weight of tuber per hectare, tuber diameter (48.02), marketable tuber number (31.76), average tuber weight (36.21) and unmarketable tuber per plant (69.89). The estimates of genetic advance help in understanding the type of gene action involved in the expression of various polygenic characters. High values of genetic advance are indicative of additive gene action whereas low values are indicative of non-additive gene action (Singh and Narayanan, 1993). Similarly genetic advance was low for date of maturity and leaf length. Johnson and Hernandez (1980) reported that high heritability and high genetic advance as percentage of mean provide better information than each parameter alone.

High heritability coupled with high genetic advance as percent of mean recorded from days to emerge, days to flowering, plant height, and weight of tuber per hectare, tuber diameter, and leaf width indicated that those trait more inherited trait and this is due to additive gene effect of trait. Therefore, these characters could be having ample scope of selection for further improvement. On the other hand characters had low genetic advance coupled with low heritability considered less effective for selection.

This is in agreement with Panse (1967) suggested that effective selection may be done for the characters having high heritability accompanied by high genetic advance which is due to the additive gene effect. He also reported that low heritability accompanied with genetic advance is due to non-additive gene effects for the particular character and would offer less scope for selection because of the influence of environment. Also according to Tsegaye et al., 2007 High heritability along with high genetic advance is an important factor for
predicting the resultant effect for selecting the best individuals and characters content and relatively moderate genetic advance. The presence of high heritability and moderate genetic advance is the effects of equal contribution of additive and non-additive gene action (Shelby, 2000). Therefore, days to emergence, days to flowering, plant height, weight of tuber per hectare, unmarketable number of tuber, tuber diameter, and leaf width will be effective to consider in selection since they showed high heritability along high genetic advance. Desai and Jaimini (1997) also reported high heritability along high genetic advance as part of mean for tuber yield, number of stem, number of leaves, maturity, number of tubers and average tuber weight.

Table 5: Estimate of ranges, mean, standard error, phenotypic ($\sigma^2_p$) and genotypic ($\sigma^2_g$) component of variances, broad sense heritability and genetic advance as percent of mean for 13 characters of potato genotypes tested at Serbo, Seka and Dedoo (2014)

<table>
<thead>
<tr>
<th>Character</th>
<th>$\sigma^2_p$</th>
<th>$\sigma^2_g$</th>
<th>PCV (%)</th>
<th>GCV (%)</th>
<th>$H^2_{bs}$ (%)</th>
<th>GA (k=2.063)</th>
<th>GAM (k=2.063)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE</td>
<td>25.74</td>
<td>16.87</td>
<td>31.41**</td>
<td>25.43**</td>
<td>65.56**</td>
<td>6.86</td>
<td>42.48**</td>
</tr>
<tr>
<td>DF</td>
<td>236.71</td>
<td>183.98</td>
<td>24.81**</td>
<td>21.87**</td>
<td>77.72**</td>
<td>24.67</td>
<td>39.78**</td>
</tr>
<tr>
<td>PH</td>
<td>481.13</td>
<td>406.38</td>
<td>28.87**</td>
<td>26.53**</td>
<td>84.46**</td>
<td>38.22</td>
<td>50.30**</td>
</tr>
<tr>
<td>DM</td>
<td>41.14</td>
<td>16.76</td>
<td>6.16</td>
<td>3.93</td>
<td>40.75*</td>
<td>5.39</td>
<td>5.17</td>
</tr>
<tr>
<td>NS</td>
<td>41.18</td>
<td>13.84</td>
<td>85.22**</td>
<td>49.40**</td>
<td>33.60*</td>
<td>4.45</td>
<td>59.08**</td>
</tr>
<tr>
<td>TTN</td>
<td>13.34</td>
<td>6.66</td>
<td>40.31**</td>
<td>28.49**</td>
<td>49.96*</td>
<td>3.76</td>
<td>41.55*</td>
</tr>
<tr>
<td>WT</td>
<td>18079.78</td>
<td>14334.41</td>
<td>45.81**</td>
<td>40.79**</td>
<td>79.28**</td>
<td>219.93</td>
<td>74.93**</td>
</tr>
<tr>
<td>MTN</td>
<td>6.26</td>
<td>2.29</td>
<td>42.21**</td>
<td>25.49**</td>
<td>36.48*</td>
<td>1.88</td>
<td>31.76*</td>
</tr>
<tr>
<td>UMTN</td>
<td>3.98</td>
<td>2.20</td>
<td>61.18**</td>
<td>45.52**</td>
<td>55.37*</td>
<td>2.28</td>
<td>69.89**</td>
</tr>
<tr>
<td>AT</td>
<td>2013.51</td>
<td>637.54</td>
<td>55.43**</td>
<td>31.19**</td>
<td>31.66*</td>
<td>29.31</td>
<td>36.21*</td>
</tr>
<tr>
<td>TD</td>
<td>3.21</td>
<td>2.66</td>
<td>28.14**</td>
<td>25.59**</td>
<td>82.72**</td>
<td>3.06</td>
<td>48.02*</td>
</tr>
<tr>
<td>LW</td>
<td>0.84</td>
<td>0.51</td>
<td>18.75*</td>
<td>14.65*</td>
<td>61.07**</td>
<td>1.15</td>
<td>23.62</td>
</tr>
<tr>
<td>LL</td>
<td>0.78</td>
<td>0.02</td>
<td>13.17*</td>
<td>2.26</td>
<td>2.94</td>
<td>0.05</td>
<td>0.80</td>
</tr>
</tbody>
</table>

DE= Days to emerge Df= days to flowering PH=plant height, DM= Days to maturity, NS=number of stem per plant TTN= total tuber number per plant MTY=marketable tuber number per plant, UMTN=unmarketable tuber number, ATW=average tuber weight, TD=tuber diameter, LW=leaf width, WTY/ku=weight tuber yield, LL=leaf length

*=significant at 5% probability level and **=highly significant at 1% probability level, C.V= Coefficient of Variation, RCBD=Randomized Complete Block Design
4. 3. Cluster Analysis

Cluster analysis based on the average values of the 13 studied characters resulted in the grouping of the 25 potato genotypes into five major clusters. The Mahalanobis distances $D^2$ (Inter and intra cluster) value based on the mean of the genotypes were computed for all possible pairs of clusters as shown in Table 6.

As the cluster analysis showed the maximum number of genotypes were in the Cluster II which consisted of 11 genotypes and accounts 44% of the total genotypes. 40% of the genotypes fallen under cluster I that had 10 genotypes within it. The minimum number of genotype was grouped in cluster IV and V, each of this cluster contain only one genotype and cover 4% each. Cluster III consists of 2 genotypes. In cluster two and cluster one both released varieties and other unreleased genotypes were grouped under the same cluster. Haydar et al. (2009) grouped 30 potato varieties to five clusters. Also Khan et al. (2013) grouped 11 potato genotypes into five clusters. Five clusters were reported by Mondal et al. (2007) using 31 potato genotypes. Similar work were done by Sattar (2011) grouped twenty eight genotypes of potato in to five cluster.

Table 6: Distribution of 25 potato genotypes tested at serbo, seka & Dedoo (2015) into 5 clusters based on $D^2$ analysis

<table>
<thead>
<tr>
<th>Cluster no</th>
<th>No of genotype</th>
<th>Name of genotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>10</td>
<td>Zengena, 392640_514, Balate, 390162_3, Gera, Shenkola, 385021_6, 379058_1, 389703_3, 395011_2</td>
</tr>
<tr>
<td>II</td>
<td>11</td>
<td>39511_13, Gorobella, Arrarsa Guassa, Jallene Ayito, 386389_1, 395112_36, Challa, Gebbisa, 390412_2</td>
</tr>
<tr>
<td>III</td>
<td>2</td>
<td>Gudane, Abateneh</td>
</tr>
<tr>
<td>IV</td>
<td>1</td>
<td>Abalolarge</td>
</tr>
<tr>
<td>V</td>
<td>1</td>
<td>Bulle</td>
</tr>
</tbody>
</table>
4.3.1. Cluster mean analysis

All clusters were also noted to have variability in the respective mean values for all 13 characters (Table 7). Genotypes in cluster one were characterized by the highest mean value for days to emerge, date of flowering and minimum for leaf width. Cluster two was unique for high plant height, number of stem per plant, days maturity and the low value for leaf length while the rest traits intermediate. Cluster three was characterized by highest value of leaf width and lowest value for date to emerge, number of stem. Cluster four unique in most of trait in the mean of genotype record high value for leaf length, total tuber number per plant, weight of tuber per hectare, marketable tuber per plant average tuber weight, tuber diameter and low for date of flowering, plant height, date of maturity. Cluster five was characterized by highest mean value of unmarketable tuber number and least for total tuber number per plant, weight of tuber per hectare, marketable tuber number, average tuber weight, tuber diameter.

Generally cluster mean analysis showed variability among genotypes. High yielder, early maturity are in cluster four on contrary cluster five and two had low yielder, late matured variety. Therefore Comparison of means of various traits in different clusters revealed that clusters IV showed higher performance for the most traits of interest. Regarding to quality and yield aspects, clusters IV showed desirable aspects. The genetic differences between the clusters were reflected in the intra cluster means. The characters contributing maximum to the divergence are given greater emphasis for deciding on the cluster for the purpose of further selection and the choice of parents for hybridization. The cluster IV had the highest mean values for yield characters. Therefore considering cluster means genotypes in cluster IV were important for these selective characters.
Table 7: Mean value of 13 characters of the five clusters for the 25 potato genotypes tested at serbo, seka and dedoo

<table>
<thead>
<tr>
<th>Treats/Clusters</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE</td>
<td>18.27</td>
<td>16.85</td>
<td>9.00</td>
<td>10.50</td>
<td>15.50</td>
</tr>
<tr>
<td>DF</td>
<td>66.73</td>
<td>63.33</td>
<td>38.83</td>
<td>38.33</td>
<td>59.50</td>
</tr>
<tr>
<td>PH</td>
<td>79.47</td>
<td>84.15</td>
<td>44.03</td>
<td>41.75</td>
<td>78.50</td>
</tr>
<tr>
<td>LW</td>
<td>4.64</td>
<td>4.77</td>
<td>6.18</td>
<td>5.73</td>
<td>4.83</td>
</tr>
<tr>
<td>LL</td>
<td>6.67</td>
<td>6.63</td>
<td>6.98</td>
<td>7.85</td>
<td>6.70</td>
</tr>
<tr>
<td>NS/p</td>
<td>6.37</td>
<td>8.73</td>
<td>4.85</td>
<td>5.83</td>
<td>7.17</td>
</tr>
<tr>
<td>DM</td>
<td>103.82</td>
<td>109.26</td>
<td>91.57</td>
<td>88.00</td>
<td>103.67</td>
</tr>
<tr>
<td>TTN/p</td>
<td>8.90</td>
<td>10.36</td>
<td>14.50</td>
<td>19.00</td>
<td>7.00</td>
</tr>
<tr>
<td>WT/ha</td>
<td>312.22</td>
<td>259.32</td>
<td>544.15</td>
<td>565.30</td>
<td>133.35</td>
</tr>
<tr>
<td>MTN/p</td>
<td>6.44</td>
<td>6.52</td>
<td>11.25</td>
<td>14.00</td>
<td>4.83</td>
</tr>
<tr>
<td>UMTN/p</td>
<td>2.46</td>
<td>3.85</td>
<td>3.25</td>
<td>5.00</td>
<td>2.17</td>
</tr>
<tr>
<td>ATw</td>
<td>97.72</td>
<td>62.67</td>
<td>117.07</td>
<td>232.60</td>
<td>54.05</td>
</tr>
<tr>
<td>TD</td>
<td>6.87</td>
<td>6.49</td>
<td>9.25</td>
<td>9.80</td>
<td>4.78</td>
</tr>
</tbody>
</table>

4. 3.2. Genetic Distance Analysis

Divergence analysis is usually performed to classify the diverse genotypes by using Mahalanobis (1936) generalized distance D-square techniques which has been one of the important statistical tools to provide a rational basis for selection of parents in breeding program since the genetic improvement through hybridization and selection depends upon the extent of genetic diversity between parents. The more divergent the two genotypes are the more will be the probability of improving through selection and hybridization.

As the result in table 8 presented the inter-cluster and intra-cluster distance, Intra cluster distance was being much lower than the inter cluster that ranges 0-53.67 suggests, heterogeneous and homogeneous nature between and within groups, respectively. The
wider inter-cluster distance that varied from 69.29 to 363.05 suggests wider genetic diversity among the genotypes of different groups.

The pair-wise generalized square distances \((D^2)\) showed presence of significant (\(P < 0.01\)) distance between clusters. The maximum inter-cluster distance \((D^2 = 363.5**\)) was observed between clusters IV and V followed by clusters III and V \((D^2 = 286.92**\)), clusters II and IV \((D^2 = 248.48**\)), cluster I and II \((D^2 = 69.29**\)). Within a high significant level but, indicating the existence of less genetic variability or diversity within this cluster.

Genotypes belonging to different clusters separated by significant genetic distance will be used in hybridization program expected to produce maximum heterosis and generate wide variability in genetic architecture than those with smaller inter cluster distances. On the other hand, information on the most similar pairs is useful in program involving backcrosses, where the use of similar parents, differentiated basically by the allele to be transferred, makes the recovery of the recurrent parent possible (Nick et al., 2008). In general genetic differentiation among accessions will be providing an opportunity for establishing breeding program (Osiru et al., 2012).

**Table 8**: Average intra cluster (bold) and inter cluster (off diagonal) \(D^2\) values among five clusters in potato genotypes tested at Serbo, seka dedoo (2015)

<table>
<thead>
<tr>
<th>Cluster</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td><strong>44.34</strong></td>
<td>69.29**</td>
<td>108.1**</td>
<td>184.28**</td>
<td>185.08**</td>
</tr>
<tr>
<td>II</td>
<td>53.67</td>
<td>172.34**</td>
<td>248.48**</td>
<td>116.9**</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>21.99</td>
<td></td>
<td>77.64**</td>
<td>286.92**</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td></td>
<td></td>
<td><strong>0.00</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td></td>
<td></td>
<td></td>
<td><strong>0.00</strong></td>
<td></td>
</tr>
</tbody>
</table>

\(*=\text{significant at } P<0.05\) for \(\chi^2 = 22.36\) and \(**=\text{significant at } P<0.01\) for \(\chi^2 = 27.69\), respectively
4.4. Principal Component Analysis

PCA was performed to assess the relative importance of each quantitative character to characterize genotypes. PCA is a technique that identifies plant characters that contributed more to the observed variation within a group of genotypes (Fundora et al., 2004; Afuape et al., 2011). The result of PCA showed that only the first three principal component axes (PCA1, PCA2 and PCA3) had eigen values up to 1.0, which explained 70.5% of the variation present among genotypes (Table 9). This indicates that the identified characters within these components exhibited great influence on the phenotype of the genotypes and could effectively be used for selection among them. Loading value closer to +1 indicates strong positive relationship while; closer to -1 indicates a strong negative relationship. The sign on the loadings indicates the direction of the relationship between the factor and the trait measured (Biabani & Pakniyat, 2008). The higher the loading, regardless of the direction (positive or negative), the more effective they will be in discriminating between accessions (Sanni et al., 2010).

Principal component one had an eigen value of 6.04 and accounted for 46.47% of the variation while Principal component two and three had contributed 14.97% and 9.07% of the variability among the genotypes for the characters under study and had an eigen value of 1.95 and 1.18, respectively.

The first principal component had maximum and minimum positive loading value of 0.85 and 0.20, respectively. However the maximum negative loading value was -0.85. This principal component was strong and positively loaded by marketable tuber number per plant, total tuber number, average tuber number, tuber diameter, leaf width and weight of tuber per hectare. Days to emergence, days to flowering, plant height and days to maturity was strongly but negatively loaded principal component one. This indicates that the first principal component absorbed and accounted for maximum proportion of total variability in the set of all variables and it can be designated as representative component.

Unmarketable tuber per plant, number of stem and days to maturity were the discriminator for the second principal component which were positively and strongly load it. Similarly
the third principal component was positive and strongly loaded by number of marketable
tuber and total number of tuber but negatively loaded by leaf width.

Similar works have been done by Ahmadizadeh and Felenji (2011) three principal
components had eigen values up to 1.0, presenting cumulative variance of 80.1%. Felenji et
al. (2011) reported three principal components for 22 potato cultivars accounted for about
80.05 percent of the total variation among traits. Placide et al. (2015) reported seven
principal components (PC) that explained 77.83% among fifty four sweet potato genotypes
in Rwanda.

Table 9: Eigen values and Eigenvectors of the first six principal components (PCs) for 13
characters of 25 potato genotypes tested at serbo, seka & dedoo (2014)

<table>
<thead>
<tr>
<th>Characters</th>
<th>PC1</th>
<th>PC2</th>
<th>PC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE</td>
<td>-0.70*</td>
<td>0.02</td>
<td>0.21</td>
</tr>
<tr>
<td>DF</td>
<td>-0.85*</td>
<td>-0.16</td>
<td>0.25</td>
</tr>
<tr>
<td>PH</td>
<td>-0.82*</td>
<td>0.19</td>
<td>0.17</td>
</tr>
<tr>
<td>DM</td>
<td>-0.68*</td>
<td>0.57*</td>
<td>-0.10</td>
</tr>
<tr>
<td>NS</td>
<td>-0.33</td>
<td>0.53*</td>
<td>0.26</td>
</tr>
<tr>
<td>MTY</td>
<td>0.77*</td>
<td>0.04</td>
<td>0.58*</td>
</tr>
<tr>
<td>UMTY</td>
<td>0.20</td>
<td>0.80*</td>
<td>-0.03</td>
</tr>
<tr>
<td>TTN</td>
<td>0.76*</td>
<td>0.31</td>
<td>0.52*</td>
</tr>
<tr>
<td>AT</td>
<td>0.78*</td>
<td>-0.39</td>
<td>0.08</td>
</tr>
<tr>
<td>TD</td>
<td>0.72*</td>
<td>0.23</td>
<td>0.00</td>
</tr>
<tr>
<td>LW</td>
<td>0.64*</td>
<td>0.14</td>
<td>-0.55*</td>
</tr>
<tr>
<td>LL</td>
<td>0.35</td>
<td>0.56</td>
<td>-0.23</td>
</tr>
<tr>
<td>WTY</td>
<td>0.85*</td>
<td>0.03</td>
<td>0.07</td>
</tr>
<tr>
<td>Eigen value</td>
<td>6.04</td>
<td>1.95</td>
<td>1.18</td>
</tr>
<tr>
<td>% of variance</td>
<td>46.47</td>
<td>14.97</td>
<td>9.07</td>
</tr>
<tr>
<td>% cumulative variance</td>
<td>46.47</td>
<td>61.44</td>
<td>70.50</td>
</tr>
</tbody>
</table>

*‘* indicates loading Values greater than 0.4

DE= Days to emergency, Days to flowering, PH=plant height, DM= Days to maturity,
NS=number of stem per plant TTN= total tuber number per plant MTY=marketable tuber
number per plant, UMTN=unmarketable tuber number, ATW=average tuber weight,
TD=tuber diameter, LW=leaf width, leaf length, WTY=weight tuber yield.
4.5. Correlation Analysis of Traits

Improvement for a target character can be achieved by indirect selection via other characters that are more heritable and easy to select (Khayatnezhad et al., 2011). Therefore, it requires understanding of the magnitude and the interrelationship of the characters among themselves and with the target yield or quality character. The correlation analysis helps in determining the direction and number of characters to be considered in improving yield as well as quality. Traits may either be positively or negatively correlated due to the mutual association with other characters.

Estimates of the phenotypic and genotypic correlation coefficients between each pair of characters in this study are presented in Table 10. In majority of the cases, the genotypic correlation coefficients ($g_r$) were higher than corresponding phenotypic correlation coefficients ($p_r$). This revealed that association among these characters was under genetic control and indicating the preponderance of genetic variance in expression of characters. This means the influence of environmental factor is lower than the inherent genetic effect and has inherent associations among various characters in potato.

At genotypic level days to emerge, days to flowering, plant height, days to flowering & number of steam per plant showed significant negative correlation (at P<1%) with weight of tuber whereas traits such as average tuber weight, tuber diameter, leaf width & leaf length showed positive significant correlation (at P<1%) with weight of tuber. This means the influence of environmental factor is lower than the inherent genetic effect and has inherent associations among various characters in potato.

At Genotypic level tuber yield had positive and high significant correlations with total tuber number, number of marketable tuber, average tuber weight, tuber diameter and leaf width. However, it had high significant and negative correlation with days to emergence (-0.85), days to flowering and plant height. Likewise, plant height (0.91**) and days to 50% flowering (0.94**) showed positive and highly significant correlation with days to maturity but it showed negative and high significant correlation with number of marketable tuber number per plant(-0.66**), average tuber weight(-0.77**), tuber diameter(-0.79**), leaf
width (-0.95**), leaf length (-0.63**) and tuber yield (-0.77**). High significant and positive correlation was found between marketable tuber number and total number of tubers per plant. While marketable number of tuber had negative and significant correlation with number of stem, days to maturity, plant height, and days to emergence, Leaf length was negatively correlated with days to flowering, plant height & date of maturity (at P>1%) but it showed positive significant correlation with average tuber weight & tuber diameter. Therefore, traits which have highly significant and positive association will be used in selection for the improvement of the tuber yield based upon these characters will be effective. Yildirim et al. (1997) found the similar results for plant height, and On the contrary main stem/plant, average tuber weight, tuber weight/plant and tuber yield. Gedamu et al. (2010) report positive association between for root diameter and average storage root weight on sweet potato.

At phenotypic level among characters studied Most of the correlation coefficients were smaller than the corresponding genotypic correlation coefficients. Maximum positive and significant correlation was recorded for total tuber number per plant with tuber weigh per hectare (0.59) followed by marketable tuber number per plant (0.57), tuber diameter (0.66) and leaf width (0.42. The minimum positive and insignificant correlation was average tuber weight tuber weight per hectare (0.38) followed by unmarketable tuber number per plant with (0.27) and leaf length (0.26). While the maximum negative significant correlation was recorded for plant height with weight of tuber per hectare (-0.59) followed by plant height (-0.58), date of maturity (-0.5), days to emerge (-0.45) and minimum for number of stem per plant (-0.06). Similar result reported by Gedamu et al. (2010) total storage root yield had highly significant positive association with root diameter in sweet potato.

This indicated that most of the association existed between total tuber yield and other traits were controlled by genetic factor (Gedamu et al., 2010). Nandpuri et al., (1973) reported that Higher genotypic correlations than phenotypic ones might be due to modifying or masking effect of environment. Therefore, a trait had positive and significant correlation for potato yield indicated that higher values for selection criteria to improve yield.
Table 10: Estimates of phenotypic coefficient (below diagonal) and genotypic correlation (above diagonal) among yield and yield components in 25 Potato genotypes tested at Serbo seka, dedoo (2015)

<table>
<thead>
<tr>
<th></th>
<th>DE</th>
<th>DF</th>
<th>PH</th>
<th>DM</th>
<th>NS</th>
<th>TTN/p</th>
<th>MTN/p</th>
<th>UMTN/p</th>
<th>ATW</th>
<th>TD</th>
<th>LW</th>
<th>LL</th>
<th>WT</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE</td>
<td>0.109</td>
<td>0.08</td>
<td>0.44*</td>
<td>0.37</td>
<td>-0.571**</td>
<td>-0.69**</td>
<td>-0.34</td>
<td>-0.73**</td>
<td>-0.62**</td>
<td>-0.26</td>
<td>-0.21</td>
<td>-0.21</td>
<td>-0.85**</td>
</tr>
<tr>
<td>DF</td>
<td>0.65**</td>
<td>0.94**</td>
<td>0.94**</td>
<td>0.04</td>
<td>-0.878**</td>
<td>-0.04</td>
<td>-0.66**</td>
<td>-0.042**</td>
<td>-0.63**</td>
<td>-0.05</td>
<td>-0.22</td>
<td>-0.79**</td>
<td></td>
</tr>
<tr>
<td>PH</td>
<td>0.55**</td>
<td>0.68**</td>
<td>0.96**</td>
<td>-0.540**</td>
<td>-0.78**</td>
<td>-0.25</td>
<td>-0.43**</td>
<td>-0.78**</td>
<td>-0.93**</td>
<td>-0.11</td>
<td>-0.74**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>0.28</td>
<td>0.45*</td>
<td>0.58**</td>
<td>0.38</td>
<td>-0.421**</td>
<td>-0.664**</td>
<td>-0.14</td>
<td>-0.77**</td>
<td>-0.79**</td>
<td>-0.95**</td>
<td>-0.63**</td>
<td>-0.77**</td>
<td></td>
</tr>
<tr>
<td>NS</td>
<td>0.12</td>
<td>-0.11</td>
<td>0.199</td>
<td>0.158</td>
<td>0.274</td>
<td>-0.85**</td>
<td>0.73**</td>
<td>-0.080</td>
<td>-0.51**</td>
<td>-0.53**</td>
<td>0.71**</td>
<td>-0.343</td>
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<td>0.960**</td>
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<tr>
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<td>-0.45*</td>
<td>-0.49*</td>
<td>-0.32</td>
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<tr>
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<td>-0.27</td>
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<td>0.56**</td>
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<td>-0.62**</td>
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<td>0.63**</td>
<td>0.76**</td>
<td></td>
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<td>-0.47**</td>
<td>-0.34</td>
<td>-0.38</td>
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<td>WT</td>
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<td>0.42*</td>
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</table>

\[ t=0.39 \ (P<0.05) \text{ and } t=0.50 \ (P<0.01) \text{ for df=n-2, where n is the number of genotypes, DE= Days to emergency , Days to flowering. PH=plant height, DM= Days to maturity, NS=number of stem per plant TTN= total tuber number per plant MTY=marketable tuber number per plant, UMTN=unmarketable tuber number, ATW=average tuber weight, TD=tuber diameter, LW=leaf width, leaf length, WTY=weight tuber yield. ]
4.6. Path Coefficient Analysis

Correlation analysis describes merely the mutual relationship between different pairs of characters without providing the nature of the cause and effect relationship of characters. Hence, the phenotypic and genotypic correlations were analyzed further by path coefficient technique, which involves partitioning of the correlation coefficients into direct and indirect effects via alternative characters or pathways. This allows separation of direct influence of each component on total yield of potato from the indirect influence caused by the mutual relationship among them. The estimates of genotypic direct and indirect effects of those characters are presented in Table 11.

The path coefficient analysis has shown a residual effect of 23 %. This indicated that 77 % of the total variation was accounted for by the studied traits. The highest positive direct effect on tuber yield per hectare was exhibited by unmarketable tuber number per plant (0.69) followed by average tuber number (0.59) while the minimum positive effect was with total tuber number per plant (0.05). On the other hand the only negative direct effect was from number of stem per plant (-0.08). Khayatnezhad et al. (2011) indicated that on Correlation and path analyses that tuber weight/plant, average tuber weight and tubers/plant were the main components to tuber yield. For this reason, these traits could be used more significantly for potato improvement. Which have high and direct contribution towards final tuber fresh weight/plant could be considered as selection criteria in potato breeding program (Ara et al., 2009).

Maximum positive direct effect was for unmarketable tuber number per plant (0.69) followed by average tuber weight (0.59), date of flowering (0.58), leaf width (0.53), tuber diameter (0.44), marketable tuber number per plant (0.41), days to emerge (00.13), date of maturity (0.09), plant height (0.08), leaf length (0.08) and total tuber number per plant (0.05). similarly number of stem per plant (-0.08) had negative direct effect on yield. The indirect positive effect ranged from 0.01 to 1.1 while indirect negative effect ranged -0.001 to -1.83.

Result indicated from correlation coefficient showed for marketable tuber per plant, average tuber weight, leaf width, tuber diameter, total tuber number per plant positively correlated
with weight of tuber per hectare also path analysis proved that positive and direct effect on weight of tuber per hectare. Therefore, direct selection would be effective.

Similarly Khayatnezhad et al. (2011) reported plant height, medium tuber weight and big tuber weight evolved the direct influence. Also Yildirim et al. (1997) recorded that average tuber weight, tubers/plant, tuber weight/plant and plant had positive and direct effects on tuber weight/plant. Fekadu et al. (2013) reported that plant height had positive direct effect on yield, whereas number of stem per plant showed negative direct effect on potato germplasm. Lamboro et al. (2014) obtained positive direct effect for days to emergence, plant height and conversely positive direct effect for stems per plant.
<table>
<thead>
<tr>
<th>Character</th>
<th>DE</th>
<th>DF</th>
<th>PH</th>
<th>DM</th>
<th>NS</th>
<th>TTN/p</th>
<th>MTN/p</th>
<th>UMTN/p</th>
<th>ATW</th>
<th>TD</th>
<th>LW</th>
<th>LL</th>
<th>r_g</th>
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<td>-0.03</td>
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<td>-0.43</td>
<td>-0.2</td>
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<td>0.075</td>
<td>0.084</td>
<td>-0.00</td>
<td>-0.05</td>
<td>-0.43</td>
<td>-0.45</td>
<td>-0.02</td>
<td>-0.3</td>
<td>-0.56</td>
<td>0.105</td>
<td>-0.68**</td>
</tr>
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<td>0.5494</td>
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<td>-0.32</td>
<td>-0.17</td>
<td>-0.26</td>
<td>-0.3</td>
<td>-0.49</td>
<td>0.09</td>
<td>-0.54**</td>
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<td>-0.28</td>
<td>-0.14</td>
<td>-0.64**</td>
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<tr>
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<td>-0.04</td>
<td>-0.037</td>
<td>-0.02</td>
<td>0.05</td>
<td>0.404</td>
<td>0.66</td>
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<td>0.12</td>
<td>0.38</td>
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<tr>
<td>MTY</td>
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<td>-0.059</td>
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<td>0.051</td>
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<td>0.622</td>
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<td>-0.13</td>
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<tr>
<td>UMTY</td>
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<td>-0.02</td>
<td>-0.02</td>
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<td>0.050</td>
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<tr>
<td>AT</td>
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<td>-0.03</td>
<td>-0.06</td>
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<td>-0.02</td>
<td>-0.01</td>
<td>-0.52</td>
<td>0.59</td>
<td>0.24</td>
<td>0.29</td>
<td>-0.02</td>
<td>0.55**</td>
</tr>
<tr>
<td>TD</td>
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<td>-0.37</td>
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<td>-0.071</td>
<td>0.0414</td>
<td>0.014</td>
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<td>0.0439</td>
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<td>0.35</td>
<td>-0.05</td>
<td>0.85**</td>
</tr>
<tr>
<td>LW</td>
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</tr>
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<td>0.877</td>
<td>0.147</td>
<td>0.27</td>
<td>0.679</td>
<td>0.08</td>
<td></td>
</tr>
</tbody>
</table>

Residual Effect= .23

DE= Days to emerge , Days to flowering , PH=plant height, DM= Days to maturity, NS=number of stem per plant TTN= total tuber number per plant MTY=marketable tuber number per plant, UMTN=unmarketable tuber number, ATW=average tuber weight, TD=tuber diameter, LW=leaf width, leaf length, WTY=weight tuber yield.
4.7. Participatory Variety Selection

Farmer to employ to evaluate 10 released potato variety on own field. Farmer based on Different evaluation and selective system can be employed that showed vary with farmers preferences. Among most important or top character in potato evaluation system Farmers employed nine different selection criteria to select their preferred varieties including Cooking time, Freedom from disease, Tuber uniformity, Tuber yield, Marketable, Unmarketable and taste (Appendix table1).

The result from participatory variety selection showed that based on yield Abalolarge and Abateneh, where higher yielder genotypes while gabbisa the leas preferable. tuber uniformity Abateneh, Marketable, Abateneh, Unmarketable Gabbisa and Ayito date of maturity Abalolarge and zengena number of steam Gabissa and ayito and Taste Jallane and Abateneh were selected by famers as the most preferred attributes h owed in appendix table .The three characteristics, high yield, disease tolerance and Marketable are the most important trait in. in potato.

![Figure 3](image.jpg)

**Figure 3** participatory variety selection at field stage and after harvest

Yield and tuber quality play an important part in the successful production and marketing of potato. Traditionally, high yielding ability alone was the most important factor to the producer. In the three sites Serbo, Seka and Dedo Varieties which show higher yield and
score high percent response rate in participatory variety selection were ranked as 1{\textsuperscript{st}}, 2{\textsuperscript{nd}} and up to 10{\textsuperscript{th}}. As shown in table 9 varieties which has dedoo Abalolarge 1{\textsuperscript{st}} abateneh 2{\textsuperscript{nd}} and Gudane 3{\textsuperscript{rd}} this shows as the three variety to yield (Appendix table 1 and Figure 5) while the other is varieties were low yielder and selected less by the farmers in the study area. Nkongolo et al. (2008) reported that farmer select 20 accessions based on its yield and yield components were in two experimental stations. So farmer based on this result they can use released variety because most of times many farmers believed that improved cultivars would give no benefit unless provided with additional inputs, and the same variety was multiplied by selected farmers or purchase the same variety from research center. Similar work was conducted by (Yihenewet al., 2012)

![Image](image.png)

**Figure 4 participatory variety selection for Marketable and unmarketable**

Larger (marketable) Tuber was separated from small (unmarketable). There were differences in number and size of marketable tuber between varieties. Result from participatory variety selection indicated that Gudane, Abalolarge and Abateneh ranked as 1{\textsuperscript{st}} this is because this varieties has large number and big size potato tubers when compared to other varieties such as Gabbisa, Jallane and Ayito which has low yield and small size tubers. This is in agreement with the work of Masumba et al.,(2004) variety Ukerew had score the highest number of marketable sweet potato While the highest unmarketable tuber yield was obtained from Gabissa, Jallane and Ayito across location. Small sized, diseased, deformed and green potato tubers less quality products has identified as unmarketable potato tubers.
At Serbo in most cases variety ayito was fewer acceptances because of color of tuber. The lowest percent number of marketable tuber of Gabbisa, Jallane and Ayito was recorded in Serbo. In seka received the highest score number of marketable tuber is for Abateneh, Gudane and Abalolarge the same results in Dedoo districts. Gabissa scored the highest percent of unmarketable tuber which was, however, the lowest percent of unmarketable tuber which was recorded for Abalolarge. According to Dan et al., (2013), The final goal of seed (planting material) improvement is to increase the financial position of smallholder farmers therefore unmarketable tuber is decrease income of farmer and even if not take place for house consumption.

Figure 5 Farmers preferences potato tubers
Improved flavor (aroma and taste, volatile and non-volatile compounds) Appropriate texture (ranges from waxy to floury (or mealy) and even distribution for processing) Freedom from after-cooking blackening and enzymic browning Light-colored fry products post-harvest and after storage (lower reducing sugars) were set as PVS criteria. In terms of taste variety ballate, gorobela, Zengena and Gudane were highly preferable at seka and ballate, gorobela and Abateneh highly preferable at serbo jallane and Abateneh whereas highly preferable at Dedoo. Ayito was moderately preferred at Serbo, gabissa,abalolarge and shenkolla varieties were the least preferable across location. Laurie and Magoro (2008) reveled similar result on sweet potato.

From the farmers’ point of view Abateneh and Abalolarge has drawbacks such as poor test when eaten, bitter and pungent taste up on swallowing while eaten boiled, the remedy for this variety for “wat” preparation may reduce its distasteful taste because of spices and hot paper. Similar result reported by (Tefsaye, 2013) the farmers selected both varieties by different merits but it feels bitter and pungent taste up on swallowing while eaten boiled. participatory variety selection is same low input farming conditions that farmers use, addressing the needs of more marginalized farmers and a rapid and cost effective way to assess and select potential varieties (Weltzein et al., 2003, Abidin, 2004 and Dawson et al., 2007).
Farmers had give

Figure 7 **participatory variety selection for taste**

Differences in days to maturity among variety according to farmer point of view variety abalolarge preferred for its early matured. The score of days for maturity was higher for Gudane, ballate in three testing locations, shenkolla, gabissa and ayito except at seka, showed late matured variety similarly. Abalolarge, Zengena and gudane early matured variety across location similarly gorobella and jallane showed early maturity except at dedoo and serbo Variety preferable by date of maturity which is early only one research location ayito only in seka gabissa only at seka and shenkolla preferable or early matured only at one location (Appendix table 1). Simon *et al.* (2014) similar research on four commercially released varieties of Potato they are closely related except guassa.
Varieties which have Regular shape and shallow eyes to reduce wastage Round shape for (chips) and long oval for French fries Lack of external defects (growth cracks, mechanical damage and bruising, and greening) Lack of internal defects (hollow heart, brown center, and internal rust spot) were selected by PVS. Abateneh and Abalolarge show high percent of tuber uniformity and ranked as 1st and 2nd in across location.

Tuber uniformity helps for processing (preparation), market preference, and to facilitate loading and unloading and according to tuber uniformity variety abateneh(48.90), abalolarge (46.67) showed as high percent of tuber uniformity so may be it helps producer, consumers and for marketers like it reduce time to take for boiling and pill. Similarly Tesfaye (2013) reported that farmers’ preferred Marachere for its excellent ground cover, establishment, stem thickness, freedom from foliar and tuber disease, and uniform tuber size.

The present study showed that farmers’ characterization of several released variety with yield and yield component were useful in selecting the best performed variety that had been acceptable by the farmers at large. This multidisciplinary approach ensured the selection of accessions with acceptable of the materials released. Variety Gabbisa (9.33%), ayito (7.33%), abateneh (7.33%) scored the highest number of steam.

Figure 8 participatory variety evaluations for taste and tuber uniformity (TU)
Figure 9 participatory variety selections for date of flowering, number of stem and date of flowering
Table 12: The new selected genotypes ranked by farmers in order of preference, 2015, jimma zone

<table>
<thead>
<tr>
<th>Variety name</th>
<th>NT Rank</th>
<th>TU rank</th>
<th>TY rank</th>
<th>MT rank</th>
<th>UMT rank</th>
<th>Taste rank</th>
<th>DM rank</th>
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<tbody>
<tr>
<td>Ayito</td>
<td>22.20</td>
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<td>35.53</td>
<td>4</td>
<td>15.57</td>
<td>33.33</td>
<td>2</td>
</tr>
<tr>
<td>Jallane</td>
<td>7.33</td>
<td>2</td>
<td>17.77</td>
<td>9</td>
<td>8.90</td>
<td>91.13</td>
<td>1</td>
</tr>
<tr>
<td>Abalolarge</td>
<td>7</td>
<td>4</td>
<td>46.67</td>
<td>2</td>
<td>91.13</td>
<td>1</td>
<td>4.43</td>
</tr>
<tr>
<td>Gudane</td>
<td>6.67</td>
<td>6</td>
<td>37.80</td>
<td>3</td>
<td>68.90</td>
<td>3</td>
<td>86.63</td>
</tr>
<tr>
<td>Ballate</td>
<td>7</td>
<td>5</td>
<td>17.80</td>
<td>8</td>
<td>15.57</td>
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<td>9</td>
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<td>13.37</td>
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</table>

TU=tuber uniformity, TY=tuber yield, MTY=marketable tuber yield, UMTY=unmarketable tuber, DM=date of maturity
Table 9 cont.…..

<table>
<thead>
<tr>
<th>Variety name</th>
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<tr>
<td></td>
<td>%</td>
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<tr>
<td>Jallane</td>
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<td>Zengena</td>
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</tr>
</tbody>
</table>

NT=Number of tillers

Even if the performance of the tested varieties is different among each other, the farmers selected the three varieties by different merits. They preferred Abateneh, Abalolarge and Gudane for its excellent yield, marketable preferences and less amount of marketability disease resistance, tuber uniformity, early maturity, cooking time, number of steam and date of flowering in over all location (Appendix Table 1).
Figure 10 Variety Abateneh at field, yields from five plants and tuber diameter.
5. SUMMARY AND CONCLUSION

To meet the needs of farmer and develop cultivars which is best performed participatory variety selection and variability very important in potato production. The present study involve to evaluate at Jimma zone on total of 25 potato (\textit{solanum tuberosum}) with the objective of characterization and participatory variety selection among ten improved potato variety in simple lattice design based on 13 quantitative and 8 qualitative characters during crop season 2015 at Jimma Zone.

Combined Analysis of variance showed significant variations among all genotypes for the 13 quantitative characters studied except four (4) traits. Range and mean performance indicated Wide range of mean values was recorded for most traits indicating the existence of variation among the tested genotypes. Among 25 tested genotype higher yield were recorded from the genotypes Abalo large (565.3 ku/ha) Gudane (501 ku/ha) Abateneh (587.3 ku/ha), 390412-2 (417.06 ku/ha), 3900162-3(517.49 ku/ha).

The phenotypic coefficients of variation (PCV) values were higher than genotypic coefficients of variation (GCV) values for all the traits studied indicating that apparent variations in the genotypes were not only due to genotypic effect but also due to environmental influences, since phenotypic variances were contributed by the effect of interaction of genotypes and environment. Days to emergency, days to flowering, plant height, number of stem per plant, total tuber number per plant, marketable tuber number per plant, unmarketable tuber number, average tuber weight, tuber diameter, and weight tuber yield showed higher PCV along with high GCV. Therefore, selection based on these traits will be important for the breeding program to yield improvement. High heritability was recorded for Days to emerge, 50% Days to flowering, plant height, leaf width, weight tuber yield, tuber diameter. High heritability coupled with high genetic advance as percent of the mean was obtained for days to emergency, days to flowering, plant height, weight of tuber per hectare, tuber diameter and leaf width suggesting that selection for these traits would be effective to improve yield.
Mahalanobis D2 analysis involving the 25 potato genotypes formed five major clusters with maximum number of genotypes in the Cluster I (10) followed by the cluster II (11) where as minimum number (3) in clusters IV and V, cluster III (2) However, clusters IV and V contained single genotype each. The inter-cluster (D2) values varied from 69.29 to 363.05 indicating range of diversity present among the genotypes. The inter cluster distances were higher than the average intra cluster distances, this indicated wide genetic diversity among the genotypes of different groups than those of same cluster. The highest intra cluster distance was observed for the cluster IV and V and minimum for the cluster I and II. Therefore, crossing of parents selected from genotypes belonging to clusters separated by high estimated statistical distances could result in desirable recombinants in view of genetic diversity.

PCA showed that only the first three principal component axes (PCA1, PCA2 and PCA3) had eigen values up to 1.0, which explained 70.5% of the variation present among genotypes. Principal component one had an eigen value of 6.04 and accounted for 46.47% of the variation while Principal component two and three had contributed 14.97% and 9.07% of the variability among the genotype for the characters under studies. This principal component was strong and positively loaded by marketable tuber number per plant, total tuber number, average tuber number, tuber diameter, leaf width and weight of tuber per hectare. it can be designated as representative component.

The genotypic correlation coefficients were higher than corresponding phenotypic correlation coefficients. This revealed that association among these characters was under genetic control and indicating the preponderance of genetic variance in expression of characters. The maximum significant positive correlation was between total tuber number per plant and marketable tuber number per plant both at phenotypic level and genotypic. Weight of tuber per hectare was positively and significantly correlated with total tuber number per plant, marketable tuber number per plant, average tuber number per plant, tuber diameter and leaf width on the other hand days to emerge, days to flowering, plant height and days to maturity showed negative significant. Therefore it implies a trait which has positive and significantly correlated one help full for further improvement of potato tuber yield.
The path coefficient analysis has shown a residual effect of 23%. This indicated that 77% of the total variation was accounted for by the studied traits. Maximum direct positive effect on weight of tuber per hectare was exerted by Unmarketable tuber number per plant followed by average tuber weight. In addition remain traits except number of stem per plant had also exerted positive direct effect on potato yield. The indirect positive effect ranged from 0.01 to 1.1 while indirect negative effect ranged -0.001 to -1.83. Therefore, path coefficient analysis based on tuber yield as a dependent variable revealed that all traits, except steam number, showed positive direct effects. This had high and direct contribution towards final tuber yield weight per hectare considered during selection process of potato breeding program.

Farmer based on Different evaluation and selective system can be employed that showed vary with farmers preferences. Through participatory variety selection three varieties which are best performed. In general participatory variety selection showed as variety Abateneh, Abalolarge and Gudane selected by farmers preferences based on tuber yield, marketable tuber per plant, unmarketable tuber per plant, tuber uniformity, tuber uniformity, taste and date of maturity. Generally the study has shown that there is a wide genetic variability and diversity between potato genotype at Jimma zone for further utilization potato improvement program. the result of the present investigation may vary season since this study was conducted in one season. That means, the available genotypes should be further studied with due importance on quantitative characters required to resolve further variations. Furthermore, the presence of morphological variation between genotypes is not a guarantee for high genetic variation. Hence, molecular or biochemical studies need to be considered as complementary to this study. Since simple selection of superior types among the existing genotypes could result in identification of promising lines.
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### APPENDICES

Appendix Table 1 Pair-wise ranking of farmers-preferred potato characteristics in the study areas among 10 varieties.

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<th>Tuber uniformity%</th>
<th>Tuber yield%</th>
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Appendix Table  2 Mean performance values for 13 quantitative traits of 25 potato variety testing at Jimma zone 2015.

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Appendix Figure 3 Dendrogram of 25 potato variety