EFFECT OF PLANTING DATE ON TUBER YIELD AND QUALITY OF POTATO (*Solanum tuberosum* L.) VARIETIES AT ANDERACHA DISTRICT, SOUTHWESTERN ETHIOPIA

MSc THESIS

BY

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Jimma University

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A Thesis Submitted to School of Graduate Studies Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) in Partial Fulfillment of the Requirements for the Degree of Master of Science in Horticulture (Vegetable Science)

By

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December, 2012
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DEDICATION

I dedicate this thesis to my family for nursing me with affections and love and their dedicated partnership for success in my life

STATEMENT OF AUTHOR

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Date of Submission_______________

BIOGRAPHICAL SKETCH

The author, Bewuketu Haile Kayacho, was born on April 28, 1987 at Gecha town, Sheka Zone of South Nations Nationalities and Peoples Regional State. He attended his elementary and junior secondary schools at Gecha primary and secondary school in Gecha and preparatory school at Masha high school in Masha. Following the completion of his preparatory education, he joined Hawassa University College of Agriculture in 2007 and graduated with BSc Degree in Horticulture in July, 2009. After graduation, he was employed by the Ministry of Education at Wollega University College of Agriculture in Plant Science Department and has been working as Graduate Assistant, until he joined the graduate studies program of Jimma University College of Agriculture and Veterinary Medicine to pursue a graduate study leading to a Master of Science degree in Horticulture (Vegetable Science).

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LIST OF ABBREVIATIONS

CIP	International Potato Center
CSA	Central Statistical Agency
DV	Daily value
EARO	Ethiopian Agricultural Research Organization
EIAR	Ethiopian Institute of Agricultural Research
Etc	Evapotranspiration
FAO	World Food and Agricultural Organization
GA	Gibberellic acid
NMA	National Meteorological Agency
SNNPR	Southern Nations, Nationalities, and People's Region

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By

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ABSTRACT

Optimum planting date is highly location specific and the most important subject in rain-fed potato production. However, there are no research recommendations pertaining to adaptable cultivars and their optimum planting date with due consideration of the environmental condition of Anderacha area. Thus, this study was conducted to assess the effect of planting date and variety on yield and quality of potato at Anderacha woreda, Western Zone of SNNPRS, from October 2011 to March 2012. Five planting times (October 20, October 30, November 9, November 19 and November 29) and three varieties (Jallene, Guidene and local) were combined in 3x3 factorial arrangement and laid out in randomized complete block design with three replicates. Data were collected on growth, yield and quality parameters and analyzed using SAS Version 9.2 statistical software. The result showed that early planting (October 20) delayed emergence and flowering by about 4 and 15 days, respectively and increased plant height by 10.68cm than the latest planting on November 29. The number of stems per plant increased with delayed planting, however tuber number decreased in late plantings and planting on October 30 that resulted in significantly ($P<0.05$) better number of tubers. Early planting produced significantly heavier tuber weight (83.80g) which progressively reduced in subsequent plantings, whereas delay in planting resulted in higher unmarketable yield. Percentage of medium sized tubers (65.17 %), tuber specific gravity (1.092) and dry matter content (23.02) showed the highest value in early planting and decreased with subsequent planting dates. Guidene took significantly longer days to emerge and flower (19.2 and 65.6 days, respectively) and plants were significantly taller (77.77cm) than Jalene and local variety. Jalene produced significantly ($P<0.05$) the highest stem number and consequently produced highest tuber numbers per plant. It also showed increased average tuber weight by 29.12% as compared to the local variety. Guidene and Jalene produced low unmarketable tuber yield by 44.35 and 31.06 %, respectively compared to local variety. The highest percentage of medium sized tubers, tuber specific gravity and dry matter value was obtained from variety Guidene.Guidene planted on earliest date took the maximum number of days (124 days) to mature, while last planted local was earliest to mature (90 days). Jalene planted at the earliest planting of October 20 produced maximum percentage of large sized tubers (17.91%), whereas the highest percentage of small sized tubers (35.83%) was recorded from late planted (November 29th) local variety. Variety Jalene planted on October 30th produced the highest harvest index (0.84), marketable and total tuber yield (34.82 and 38.6 ton/ha), respectively. The two earlier plantings and variety Jalene showed superior performance in most studied growth, yield and quality parameters even though variety Guidene was superior in some quality parameters. Correlation analysis also indicated that the relationship between marketable tuber yield with days to 50% flowering, days to maturity, plant height, total tuber number/hill, average tuber weight, harvest index and large tuber percentage was positive and highly significant($P<0.01$). Therefore, based on the findings of the current study, early planting (October 20 up to 30) and potato variety Jalene can be used for high marketable tuber yield and better quality. Since, the present study was done

only for one season at one location; it would be advisable to repeat the experiment for more number of years and places to come up with comprehensive recommendations.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is the world's fourth most important food crop (after rice, wheat and maize) in terms of production (Razdan and Mattoo, 2005; FAO, 2010). Worldwide more than 320 million tons of potatoes are being cultivated annually on 20 million hectares of land (FAO, 2010). Potato is regarded as a high-potential food security crop because the crop produces large quantities of dietary energy (30-35 t/ha starch based produce in 3-4months) and has relatively stable yields under conditions in which other crops may fall (Gebremedhin *et al.*, 2008; FAO, 2010). Recently the world food price inflation was higher and more widespread for cereals than for potato and other root crops (FAO, 2010). In Ethiopia also the price of roots and tubers remained relatively low during the entire food crisis (Adane *et al.*, 2010). This shows that root and tuber crop in general, potato in particular is a highly dependable food security crop.

In Ethiopia, potato was introduced in 1858 by a German immigrant named Wilhelm Schimper (Nunn and Qian, 2011). Since then, it became one among the most economically important crops as a source of food and cash in the country (Gildemacher *et al*., 2009; Adane *et al*., 2010). According to (FAO, 2008) potato production in Ethiopia has increased from 280 000 tons in 1993 to around 525 000 tons in 2007 and can potentially be grown on about 70% of arable land in the country. The crop is grown in four major areas: the central, the eastern, the northwestern and the southern Ethiopia. In which about 10%, of the potato farmers are located in central, 3% in eastern, 40% in northwestern and more than 30 % in southern Ethiopia (CSA, 2008/2009).

However, the current area cropped with potato (about 160,000 ha) is small and the average yield (less than 10 ton ha^{-1}) which is far below the potential (Adane *et al*., 2010). The low acreage and yield are attributed to many factors, such as lack of improved crop variety and high-quality seed potatoes, inappropriate agronomic practices, late blight and absence of proper pest management practices, unavailability of proper transport, storage and marketing facilities are the prominent ones (Tekalign, 2005; Habtamu *et al*., 2012). In addition, cropping season and inadequate moisture supply are also production constraints of potato.

Unlike most of the tropics where two seasons are common (one wet season and one dry season), three seasons are known in Ethiopia, namely *Bega* (dry season), *Belg* (short rain season) and *Kiremt* or *Meher* (long rain season) (Abebe, 2007). *Meher* season extends from June-September; however, as Ahmed (2011) reported the planting and harvesting of *Meher* season crops can extend to December or January in some areas. *Belg* is a short rainy period from February to May over much of the *Belg*-growing areas, where as over the southwestern parts of the country it denotes the start of the long rainy season (NMA, 2009). In most of the potato farming zones, two rainy seasons can be identified, the main (*Meher*) season and a short rainy season (*Belg*) (Gildemacher *et al*., 2009). However, potato growers in most high land areas do not benefited from the most reliable rain fall of the *Meher* season due to the threat of late blight (Geremedin *et al.*, 2008).

In Sheka Zone Anderacha Woreda potato production is totally dependent on natural rainfall and farmers normally produce potato after October. Long rainy season (*Mehere*) in Anderacha extends up to January/February, however amount of rain fall vary within this growing season. Further observations in this study showed that, farmers in Anderacha plant potatoes in November, regardless of the crops sensitivity to biotic and abiotic stresses and rainwater availability. This is to escape from late blight during the wettest months of the year (May to September/October). Though planting at this time enables to the crop escape severe damage from late blight, productivity of potatoes under farmers' field has remained even less than the national average. Decrease in the amounts of rain fall and raise in temperature in late stages of growing potato of this growing period are problems of production. High evaporative demands that prevail in hot growing season increases the crop water requirement and may even compound the sensitivity to water stress, resulting in greater yield decline than that from similar water stress under cooler conditions (Steyen *et al*., 2007). Tekalign and Hammes (2005) also reported that high temperature stress caused significant yield reduction and quality deterioration on potato which has been produced in many tropical climates under high temperature condition.

Like other crops, the optimum planting date for potato is highly location specific and every production region has an "optimum" planting period during which conditions are most favourable for producing the highest potential yield in a given season (Thornton and Nolte, 2005; Singh and Lal, 2009). To date there are no research recommendations pertaining to adaptable cultivars and their appropriate optimum planting date with due consideration of the environmental condition of Anderacha area.

Planting dates affect directly the match between rainwater supply and crop water demands leading to yields deceasing and quality deterioration. Hijmans (2003) predicted global yield losses for potato in the range of 18 to 32% without adaptation in production methods, or 9 to 18% without adaptation in terms of planting time and use of heat tolerant cultivars. There is ample evidence to suggest that the low productivity in rain-fed agriculture is generally more due to management aspects than to low physical potential (Tittonell *et al*., 2007). As the result, perfect timing of planting date is one of the key factors which strongly affect crop production in rain fed agriculture (Wang *et al*., 2008). Similarly, it is reported that in some parts of Ethiopia potato yields are affected significantly by planting dates (Berga *et al*., 1994, Tesfaye and Anteneh, 1999; Tesfaye *et al.*, 2006). Therefore, manipulation of planting date is one measure to overcome the negative impact of environmental problem on potato production in the area. The present study, therefore, was designed and undertaken with the following objectives:

General objective

- To improve potato tuber yield and quality by manipulating the planting date of different potato varieties at Aderacha Woreda

Specific objectives

- To determine the optimal planting time for potato under rain-fed condition of Anderacha to produce maximum yield and better quality tubers

- To evaluate the effect of variety on tuber yield and quality of potato at Anderacha condition

2. LITERATURE REVIEW

2.1. Importance of Potato

Potato is one of mankind's most valuable crops. In volume of production Potato (*Solanum tuberosum* L.) is the world's 4^{th} most important food crop (after rice, wheat and maize) (Razdan and Mattoo, 2005; FAO, 2010). Among the root and tuber crops, it ranks first followed by cassava, sweet potatoes and yams in terms of the number of producer countries (FA0, 2008). It is the third highest yielding crop on the basis of fresh matter, after sugarcane and sugar beet (Khan *et al*., 2010). 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, 2007).

It is cheep source of energy due to its large content of carbohydrate and containing significant amount of vitamin B, C and mineral. Potatoes provide more calories, vitamins, and nutrients per area of land sown than other staple crops. Potatoes were superior to cereals because they provided more vitamins and nutrients and they provided a greater supply of calories. Because potatoes contain early all important vitamins and nutrients, they support life better than any other crop when eaten as the sole article of diet (Khan *et al*., 2010; Nunn and Qian, 2011).

According to the U.S. Department of Agriculture (2007), a medium potato (150 grams/5.3 ounces) with the skin provides 29.55 milligrams of vitamin C (45 percent of the daily value [DV]). This is important since other staple crops such as wheat, oats, barley, rice, and maize do not contain any vitamin C, a necessary deterrent for scurvy. A medium potato also contains 632 milligrams of potassium (18 percent of DV), 0.44 milligrams of vitamin B6 (20 percent of DV), as well as significant amounts of thiamin, riboflavin, folate, niacin, magnesium, phosphorus, iron, and zinc. Moreover, the fiber content of a potato with skin (3.5 grams) is similar to that of many other cereals such as wheat.

Potatoes also provided indirect benefits. Being relatively easy to store, potatoes provided excellent fodder for livestock (primarily pigs and cattle). Often, a significant proportion of the potato crop would be used as fodder. This meant that potatoes also increased meat consumption, as well as manure, which was a valuable input for crop production (Nunn and Qian, 2011). 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 to overcome the transitory food shortage that occurs during rainy season. It is considered as transitional crop as it enables farmers' survive the hunger months (Stevenson *et al.,* 2001).

It is a very important food and cash crop in Ethiopia, especially in the high and mid altitude areas. Potato has a promising prospect in improving the quality of the basic diet in both rural and urban areas of the country. Apart from consumption of boiled potatoes; it is now extensively used in the wide arrays of traditional stew preparations in both rural and urban areas. In this regard, potato is supplementing and substituting pulse crops that are commonly used for these purposes. Potato consumption has expanded to include chips, crisps and mixture preparations with other vegetables which are becoming popular in urban areas in recent years. (Berga *et al.,* 1994; Gebremedhin *et al*., 2008; Gildemacher *et al*., 2009; Adane *et al*., 2010).

2.2. Tuber Induction and Bulking of Potato as Affected by Planting Date and Variety

Several stages are recognized in potato growth and development: sprout development, plant establishment, tuber initiation, tuber bulking, and tuber maturation. Timing of these growth stages varies depending upon environmental factors, such as elevation and temperature, soil type, availability of moisture, cultivar selected, and geographic location (Dwelle and Love, 1993; Khan *et al*., 2011).

Tuber bulking results from two basic processes, tuber initiation and tuber growth. Timing and duration depend upon geographic location, environmental factors, and cultivar. Tuber initiation occurs at about 20 to 30 days or more (up to 45 days under long day conditions) after plant emergence and last for a period of 10 to 14 days. The potential tuber number that can be successfully produced by a plant varies with the genotype (most cultivars having a consistent number of tubers on each stem), physiological age of seed, number of stems per hill (stem population) and environmental conditions during this initiation phase of growth. Environmental conditions affecting tuber initiation include planting date, early season temperature, nutrition and water management, and weather extremes such as hot climate, hail or frost (Kleinkopf *et al*., 2003; Mihovilovich *et al*., 2009).

Although many tubers may be initiated during the first four to six weeks of growth, only a fraction of these tubers actually achieves commercial size (greater than 30 mm diameter) (Levy and Veilleux, 2007). After initiation, both the weight and volume of the tubers increase almost linearly, a process referred to as tuber bulking (Levy and Veilleux, 2007). Tuber growth can last from 60 to over 90 days and tuber enlargement which takes place during this phase continues as photosynthates are translocated from the vines into the tubers (Mihovilovich *et al*., 2009).

The duration and rate of tuber bulking vary among cultivars and depend on environmental conditions (Levy and Veilleux, 2007; Mihovilovich *et al*., 2009). Bulking rate is greater under short days and moderate temperatures. These conditions favour dry matter partitioning to the tuber, promote tuber growth and restrict haulm growth. Long days and higher temperatures favour dry matter partitioning to the haulm, promote haulm and root growth and delay tuber growth. Tuber bulking restricts shoot and root growth, acting as an alternative and strong sink for plant resources (Levy and Veilleux, 2007).

2.3. Climatic Factors Influencing Potato Tuber Bulking

Each crop has certain environmental requirements. To attain the highest potential yields a crop must be grown in an environment that meets these requirements. A crop can be grown with minimal adjustments if it is well matched with its climate or growing condition. Unfavourable environmental conditions can produce a stress on plants resulting in lower yields (Decoteau, 1998). According to Pereira and Nova (2008) the potential yield is the maximum yield of a given species or cultivar possible achievable under the existing conditions of solar radiation flux density, with all the other environmental factors considered to be optimal. Meteorological factors directly influence crop potential productivities, regulating its transpiration, photosynthesis, and respiration processes in such away as to control the growth and development of the plants throughout their physiological cycle at a given site (Pereira *et al.*, 2008).

2.3.1. Temperature

Heat stress is one of the major environmental factors influencing the adaptation and productivity of crops such as the potato, especially when temperature extremes coincide with critical stages of plant development (Levy, 1982). Cooler temperatures result in delayed maturity, which provides more time for the interception of solar radiation and conversion of intercepted radiation into dry matter (Pereira and Nova, 2008).

High temperatures adversely affect plant growth and tuber yield at least in three ways: through an overall reduction in growth, apparently in similar fashion to that produced by water stress; through a reduction in the photosynthetic rate and stomata resistance and an increase in dark respiration; through a reduction in rapid tuber enlargement and maturity (Tsoka *et al.*, 2012).

Depending on the temperature regime and the crop, high temperatures can lead to low yields due to increased development rates and higher respiration. However, a short growth cycle can also be beneficial, e.g., to escape drought or frost, and the use of late-maturing cultivars could offset the effect of high development rates. Potato is grown in many different environments, but it is best adapted to cool climates such as tropical highlands with mean daily temperatures between 15 and 18^{o}C as encountered in its center of origin. High temperatures can lead to low yields due to increased development rates and higher respiration. Higher temperatures favour foliar development and retard tuberization. In addition, heat stress leads to a higher number of smaller tubers per plant; lower tuber specific gravity with reduced dry matter content (Hijmans, 2003).

According to Levy and Veilleux (2007) the adverse effects of high temperature stress on the potato plant can be: haulm growth is accelerated, with assimilates partitioned more towards the haulm, photosynthesis is reduced and respiration is increased, tuber initiation is inhibited, tuber growth is inhibited, tuber disorders are more likely, tuber dormancy is shortened or abolished, tuber dry matter content may be reduced and tuber glycoalkaoid level may be raised.

The tuberization process of potato is understood to be controlled by environmental factors, mainly photoperiod and temperature, which regulate levels of endogenous growth substances (Mihovilovich *et al*., 2009). Short days and cool night temperatures (inducing conditions) have been reported to favour tuberization while long days and high night temperatures delay or inhibit the process. Among the plant growth regulators that have been used to study the potato tuberization phenomenon, GA3 has been reported to have a consistent delaying or inhibiting effect on potato tuberization (Jackson and Prat, 1996).

The optimum temperature for tuber initiation and growth ranges from 15-19^{o}C, higher temperature lower tuber yields and this is due to reduced participation of photosynthates to the tuber (Tadesse *et al*., 2001). Temperature from 20 to 29^{o}C leads to small tubers and temperature above 29^{o}C prevent tuber development (Girma *et al*., 2004). Potato has been produced in many tropical climates under high temperature stress, resulting in significant yield reduction and quality deterioration. This is attributed to the synthesis of high amounts of endogenous GA, that in turn delay or inhibit tuber initiation, reduce partitioning of assimilates to the tubers, and impede the synthesis of starch and tuber specific proteins (Tekalign and Hammes, 2005). Balamani *et al.* (1986) report tuberization to be promoted by short days and low temperature (<25^{o}C) whereas long days and high temperature delay or inhibit the process. As Modisane (2007) reported stolons and tuber formed at low temperature (22/14^{o}C) were higher than at higher temperature (27/17^{o}C) and rapid plant top growth at higher temperature (27/17^{o}C) than at low temperature (22/14^{o}C).

2.3.2. Moisture

Soil moisture is one of the most important factors which influence yield and quality of crops as it affects the chemical, biological and physical conditions of the soil. Water is necessary for growth, nutrient absorption, transpiration, biological reactions and many other life activities. The potential yield of crops is dramatically affected by the amount of water applied during the crop-growing season at a given region (Abdel-Ati *et al*., 2007; Pereira and Nova, 2008).

The amount of water capable of being held in a soil depends on soil texture (sand, silt, clay etc) and structure (loose, compacted etc). In a saturated soil, all spaces are filled with water. Drainage due to gravity progressively removes water from the pores of the soil. As more water is lost, so the forces holding it around the soil particles increase until equilibrium is reached. This stage is known as 'field capacity'. As the crop grows, water is extracted from the soil, and lost by transpiration from the leaves and evaporation from the soil and leaf surfaces. The combined effect is known as evapo-transpiration. The accumulated amount of water lost from the soil is referred to as the Soil Moisture Deficit (Buckley *et al*., 2012).

Crop consumptive water use which is the amount of water transpired by the plants plus the water evaporated from the soil plus the fraction of water held by the plant tissues is determined. The amount of water retained by the plant metabolic activity is about 1% of the overall water taken up by the plants. Thus, in practical terms crop water consumption corresponds to crop maximum evapotranspiration (ETc), which included the evaporation e.g. from the soil surface. Potato ETc can be estimated using weather data and is the amount of water to be replenished during the growing season in order to assure potential tuber yields at a given site. Evapotranspiration varies according to meteorological conditions, plant and soil surface wetness, crop type, soil water status, and amount of crop cover (LAI – leaf area index). The mainly meteorological parameters that affect ETc are solar radiation, relative humidity, ambient air temperature and wind speed (Pereira and Shock, 2006).

Potato crop (example typical main crop potatoes grown in England) will use approximately 350 mm of water in an average growing season, although some of this can be provided by the soil, most must come in the form of rainfall and irrigation (Buckley *et al*., 2012). Bosnjak *et al*. (1997) found that tubers yield were highest in the 75-80% field capacity which was equivalent to a water requirement of 460-480mm / season. Ali (1993) showed that the seasonal water consumptive use by potato grown at Qalubia region, Egypt, varies between 300.4 mm and 419.3 mm for fall plantation, while in summer the values ranged from 443.4 mm to 626.9 mm. The variation is mainly due to climatic conditions and to the irrigation treatments, which were irrigated according to the local farmer practice. Gbadun *et al*. (2005) reported the average crop water requirements for rain-fed potato was 484mm and crop water use was within the rage of 320mm and 450 mm/season. They also observed evapotranspiration deficit range from 74.46 to 199mm and the crop water productivity of rainfall for potato varied from 0.712 kg/m^3 to 3.07 kg/m^3. These deficits are associated with low rainfall, midseason drought or early cessation of rainfall.

Lack of water is a most common stress in potato. The potato does not compost for drought period by prolonged growth. Even a short period of drought affects the yield, especially at tuber initiation. Dry soil causes reduction in number of stem, influence yield directly by restricting respiration and photosynthesis. Indirectly it leads to reduced evaporation from soil and leaves resulted to increased soil and plant temperature. Too much irrigation water or heavy rain falls also result to reduce emergence, poor root development and rotting of newly formed tubers. In rain fed potato production the amount of soil water at time of planting plus additional precipitation during the growing season is sometimes sufficient for potato production (Haverkort, 1982).

There is a very close association between heat and water stress, in fact it is very difficult to separate these two types of stress. Crop water use increases greatly with increasing temperature, resulting in rapid depletion of soil moisture. As the soil dries out a couple of things happen. First, the pores on the leaf responsible for evaporative cooling start to close resulting in an increase in leaf temperature. Evaporative cooling is also an important factor in soil temperature, so the drier the soil, the closer the soil temperature will be to the air temperature (Thornton, 2002).

The extent tuber yield and quality are adversely affected by drought will depend upon the severity, timing, and duration of water stress during the growing season. Water stress during the vegetative growth stage (begins at seed piece sprouting and extends to stolon formation) reduces leaf area, vine and root expansion, plant height, and delays canopy development. Water deficits during vegetative growth have also been shown to decrease the number of tubers set per plant, which then results in fewer and larger tubers at harvest. Water stress during tuber initiation can substantially reduce tuber yield and quality. The tuber bulking growth stage extends from the time tubers are about one-half inch in diameter to canopy senescence. Under ideal conditions, this growth stage is characterized by a relatively constant rate of increase in tuber size and weight. Interruptions in tuber growth by water stress often result in misshapen tubers having knobs, growth cracks, and irregular shapes characterized as "bottlenecks," "dumbbells," and other irregular curved shapes (King *et al.*, 2003)**.**

Levy (1982) investigated the response of six potato cultivars to water stress under high ambient temperature. The author observed that both yield and quality are adversely affected by drought occurring in the early and middle parts of the season, which corresponding to the stages of growth of tuber initiation and bulking. Varieties also shown difference in yield and quality under stress conditions (both in terms of frost damage and moisture stress). In the same experiment it was observed that tuber number per plant also tended to decrease in response to water stress in some cultivars, however, no consistent effect of water stress on tuber number per plant was observed (Levy, 1982).

2.4. Effect of Climatic Factors and Variety on Potato Late Blight *(Phytopthtora infestans)* Development

Late blight can infect potato plants and tubers at any time during the growing season, harvest and storage (Syrovy *et al*., 2009). Symptoms initially appear on the lower leaves as water-soaked spots, and develop into chocolate-brown coloured lesions surrounded by a pale green halo (Agrios, 2005). Potato cultivars genetic resistance to the *Phytopthtora infestans* is one of the main achievements of potato breeding programs. Resistance of plants to pathogens often depends on the activation of defence responses after pathogens attack. A key factor in this type of resistance is the perception of the pathogen by the host, which triggers the appropriate defence responses. When defence responses completely block pathogen development, the interaction between pathogen and plant is called incompatible (Razukas *et al*., 2008).

Disease spread depends to meteorological conditions, high infection, and potato growing period at disease attack time. Meteorological conditions are very important factor for late blight disease. They have straight influence to the potato plant growth, but also to disease spread and development. The optimal conditions for late blight spread are higher than 75% comparative air humidity and 13°C temperature. High temperature over 25°C and low temperature below 10°C, stops late blight development (Razukas *et al.*, 2008).

Late blight epidemics are sever only when weather conditions are suitable, i.e. heavy rains, cool temperatures, high relative humidity, and presence of moisture on the potato leaves for an extended period (Harris, 1992). In the studies of Muhinyuza *et al*. (2007) the conducive weather conditions for late blight was during the season having (rainfall:145.5mm/month, relative humidity: around 90% , temperature: 15-20^{o}C) and this consequently results to lower yield at harvest. In the same experiment where weather condition were not favourable for late blight development (rainfall: 45.5mm/month, relative humidity: below 75%, temperature: 14-21^{o}C) reduced amount of potato late blight was observed.

The National Potato Program within the Ethiopian Institute of Agricultural Research (EIAR), together with the International Potato Center (CIP) and several Ethiopian Universities have worked over the last two decades to introduce potato cultivars with resistance to *Phytopthtora infestans.* But, some of them have lost their resistance soon after dissemination (Habtamu *et al*., 2012). Jallene and Guidene varieties are relatively resistant and both have wide-range of environmental adaptation in Ethiopia. Jallene was released in 2002, while Guidene was released in 2006 (Geremedin *et al.*, 2008).

2.5. Factors Affecting Planting Time of Potato under Rain-fed Production

Rain-fed agriculture plays, and will continue to play, an important role in global food production as 80% of agriculture is rain-fed and contributes about 58% to the global food basket. The importance of rain-fed agriculture varies regionally but produces most food for poor communities in developing countries. In sub-Saharan Africa more than 95% of the farmed land is rain-fed. The optimum field planting practise is important for high tuber yield and quality. In rain-fed agriculture time of planting depends mainly on the amount of rainfall prior to planting, but also on cultivar and dormancy of the seed tubers used. The large variation of dormancy that affects plant growth and yield is caused primarily by differences in accumulated temperature sum (as affected by planting time, elevation of growth and storage, and season), genetics (variety), and their interaction with cultivation techniques (He *et al.*, 1998; Wani *et al*., 2009).

Every production region has an “optimum” planting window during which conditions are most favourable for producing the highest potential yield in a given season. Planting too early can lead to seed tuber disease and rot, slow emergence, and decreased plant vigor, which can slow tuber growth rates. Planting too late also delays canopy development and reduce the time available for tuber bulking. The optimal planting date varies by region. Therefore, it is best to determine when to plant by considering the critical period for plants and how that will relate to environmental conditions. The critical period for potato plants is during the vegetative growth stage. At this stage they should not get too much rain or wind, or be too dry. Soil should be sufficiently moist when planting, as moist soil can accelerate plant growth (Dwelle and Love, 1993; Thornton and Nolte, 2005; Lemaga *et al*., 2012).

Among different factors affecting the planting time of potato in Ethiopia, the major ones are on-set and pattern of rain fall, disease pressure, availability of irrigation water, market situation and food shortage mainly encouraged before the harvest of cereal crops in many high land areas. The potato production systems in the country (*belg*/short rain, *meher*/long rain, residual and irrigated crops) are influenced by the above factors (Geremedin *et al.*, 2008).

2.6. Effects of Planting Date and Variety on Yield of Potato

Environmental factor influence potato growth such as temperature, rainfall and sunlight, are not controlled by growers. One of the most important grower controlled factors is the decision on when to plant. The risks associated with the wrong planting date are increased incidence of disease problems, slow or erratic emergence, frost damage, hollow heart, and slow canopy development (Thornton and Nolte, 2005; Khan *et al*., 2011).

Research result reported from southern India revealed that tuber yield of potato is significantly influenced by planting dates. The highest tuber yield recorded by early planting mainly due to increased yield components such as number of tubers and tuber weight per plant, higher plant height, increased LAI and increased total dry matter production with early planting of potato and these all parameters were decreased with delayed planting dates (Yenagi *et al*., 2005)

A similar report from Chain indicated that earlier planting in spring increased yield at 500 masl and the effect was associated with better light use efficiency, higher rates of photosynthesis and more tubers per plant, but increased yield with delayed planting at 750 masl and no significant effect at 1200 masl. Effects of planting time in autumn on yield were generally absent at all elevations, although plant stands at early planting were consistently and often severely reduced. These all reveled that the effect of date of planting on potato yield depends on altitude and climate of the area (He *et al*., 1998).

As per the study of Garba *et al*. (2005) earlier planting resulted in higher yield than late planting. The authors stated that the observed decline in yield in late planting is related with temperature of the area. As planting date delayed the crop tends to mature outside the cold period and potato tends to grow vegetatively as the expense of tuber yield. This is because potato vines and potato tubers are often competing with each other for limited nutrient resources, and excessive vine growth can result in reduced tuber growth and temperature is one among factors that can shift the balance between vine and tuber growth (Dwelle and Love, 1993; Garba *et al*., 2005). According to Khan *et al*. (2011) total tuber yield and plant dry bio-mass were higher at earlier planting date as compared to planting at later dates. Planting the tubers on September 24th (the earliest planting) resulted in the highest tuber yield (15.57 t ha^{-1}), followed by 13.72 t ha^{-1} and 13.02 t ha^{-1} on October 1st and October 7th, respectively. Minimum yield (12.69 t ha^{-1}) was obtained by planting on October 15th.

Some studies were made to determine optimum planting time for potatoes in some parts of Ethiopia. Among these, studies conducted at Holetta and Emdeber using five different varieties, six planting dates revealed that yield was higher for the first planting (10^{th} of June) at Emdeber for all varieties and year with average 25.7t/ha followed by 10.6t/ha for the last planting date, 23^{rd} of August and the corresponding yields at Holetta were 11.3t/ha and 3.0t/ha (Berga *et al*., 1994).

A study was conducted at Adet to evaluate the effect of planting date on yield and blight incidence on two potato cultivars and significant differences were reported in respect of yield and disease incidence among the cultivars over the tested planting dates (Tesfaye and Anteneh, 1999). As the authors reported yield of the last planting dates (late June) was comparatively low with high disease score and delaying resulted in high disease incidence at the earlier crop growth stage and lower yield as a consequence. According to Tesfaye and Anteneh (1999) planting susceptible cultivars early May to mid May while moderately resistant cultivars early May to early June depending on the onset of rain is the appropriate time for higher yield with low disease incidence in the area.

In 1998, a different set of planting dates (end of May, mid-June, end of June and mid-July) were evaluated at Ankober using late blight tolerant variety Wechecha. Planting at the end of May to early June gave better mean tuber yield (14.5t/ha), while the lowest yield was obtained from the early July planting 4.0t/ha. Disease pressure was progressively higher in late planting than early June (Tesfaye *et al.*, 2006). This shows planting date is a way of escaping severe crop damage caused by late blight.

2.7. Effects of Variety and Planting Date on Potato Quality Parameters

2.7.1. Tuber size category

Food industry demands for crisps or French fries potato cultivars with specific tuber characteristic shape and size. The size distribution of harvested crop is one of the factors determining its economic value and specific grades are required for specific market outlets (Bekuma and Van der Zaag, 1990). Potato tubers are categorized into large, medium and small sizes, based on their size. Tubers less than 35 mm are considered small, those between 35-55mm are medium and greater than 55mm are large and tubers which are healthy with a size more than or equal to 35 mm are generally considered as marketable tuber (Hassanpanah *et al*., 2009; Khan *et al*., 2011; Abbas *et al*., 2012). Most consumers require big size potatoes since large tubers are required for processing, while medium sized tubers are preferred for home consumption and the small once are often used by the farmers for seed and home consumption (Govinden, 2006).

Effects of planting date and variety on tuber category have been reported by several researchers. Hassanpanah *et al*. (2009) reported that potato tuber size distribution (large, medium and small) significantly affected by variety and panting time. Khan *et al*. (2011) found that planting and harvesting times both significantly affected the percentages of larger (>55mm), medium (35-55) and small (<35) tubers size.

2.7.2. Tuber specific gravity and dry matter content

Tubers' dry matter is an important element of industries' interest (Khan *et al*., 2011). Specific gravity is highly correlated with dry matter content and the lower tuber specific gravity may result in poorer processing quality (Storey and Davies, 1992). Specific gravity of raw potatoes is widely accepted by the potato processing industry as a measure of total solids, starch content and other qualities. It is an indication that the raw potatoes will produce high chip volume due to high dry matter content. Fitzpatrick *et al*. (1964) categorized tuber specific gravity values as low (less than 1.077), intermediate (between 1.077 and 1.086, and high (more than 1.086). Numerous workers have shown that potato quality is directly associated with dry matter content. Potatoes with high dry matter content are believed to yield quality and crispy chips (Storey and Davies, 1992). The higher the dry matter content the lower the water content and the higher the specific gravity. Lower specific gravity potatoes are more costly to process, because more water must be fried out of lower specific gravity potatoes in order to meet minimum quality standards. Consequently, more potatoes must be processed in order to produce the same volume of product and the longer fry time results in the potatoes absorbing more fat (Hegney, 2005).

Many attempts have been made to correlate variations found in specific gravity of tubers with cultural practices and environmental conditions. Variety has been reported by many researchers to be the most important factor determining potato quality (Hegney, 2005; Musa *et al*., 2007; Abubaker *et al*., 2011). If potato tubers are able to complete their full potential growth cycle without periods of stress, their specific gravity will usually be high (Hegney, 2005). The length of growing season on specific gravity depends upon the length of time need to reach physiological maturity, which is defined as point in the growth cycle of the potato when maximum specific gravity occurs (Myhre, 1959). Mature tubers have higher specific gravities than immature tubers. Therefore, anything that shortens or interrupts the tuber growth cycle will reduce tuber specific gravity (Hegney, 2005). Heat stress leads to lower tuber specific gravity with reduced dry matter content (Hijmans, 2003).

Potato dry matter content can be affected by time of planting, soil moisture, temperature, etc. Temperature probably has one of the greatest effects. At high temperatures increased respiration rates mean that solids accumulated through photosynthesis are burnt up more quickly than they were formed, resulting in a decrease in dry matter. The potato is classified as a "cool season" crop and so temperature probably has more effect on dry matter than any other single environmental factor. Continual cloud cover will decrease dry matter by reducing the photosynthetic rate, and also by the moisture effect if rain accompanies the cloud (Khan *et al*., 2011).

According to Khan *et al*. (2011), delay in planting helps in improving the dry matter accumulation. Tubers’ dry matter was increased with delay in planting. These variations can be the result of differences in the time of planting, soil moisture, temperature, etc. However, Kuruppuarchchi (1987) reported that tuber specific gravity decreased in late planting (during cooler period) which were harvested during warmer part of the season, showing that cooler temperature during harvesting time is more crucial to the tuber dry matter contain at warm conditions. Modisane (2007) also observed higher tuber dry mass at low controlled temperature (22/14^{o}C).

3. MATTERIAL AND METHODS

3.1. Description of Experimental Site

The experiment was conducted in Getiba Kebele, Andiracha Woreda, Sheka Zone of Southern Nations, Nationalities and Peoples (SNNP) Regional States in the year 2011/2012 on farmers' field under rain-fed condition. Geographically, the Zone lies between 7°24'–7°52' N latitude and 35°13'–35°35' E longitude. Sheka Zone covers about 2175.25 km^2, out of which, 47% is covered by forest, including bamboo. Aderacha woreda is located 712km away from south west of Ethiopia from Addis Ababa and the experimental field is at elevation of 1960 masl and 8 Km from the center of the woreda (Gecha). The altitudinal range of the areas in the Zone falls between 900–2700 masl, and it receives high amount of rainfall, with an annual average of 1800–2200 mm annually and the annual mean temperature ranges between 15.1-27.5^{o}C (Tadesse and Masresha, 2007).

During the experimental period the lowest amount of precipitation (42.9 mm) was in months of February, while the highest (165.3 mm) was in November which was higher than the ten years' average by 20.81 mm (Appendix Table 1 and Appendix Fig 1). The amount of precipitation in January (107.6 mm) was 39.73 mm higher than the average. Amount of precipitation was about the ten years average in December and February, but the monthly amount precipitation in October (96.1 mm) almost the half of the average. Precipitation in March (66.73 mm) was 29.34 mm lesser than the ten years' average. The monthly average temperature was 1.55^{o}C, 1.73^{o}C, 1.26^{o}C and 1.66^{o}C higher than the ten years' average in October, December, January and February respectively (Appendix Table 1 and Appendix Fig 2). In November and March average temperature was about the ten years' average. The average monthly temperature in February (21.09^{o}C) and March (19.62^{o}C) is higher than optimum temperature for potato tuber initiation and growth (15-19^{o}C).

As per the FAO/UNESCO system of classification, the soil of the area is characterized by Acrisol (soils with sub surface layer of accumulated Kalonitic clay in the order Oxisol). In the western, south western and southern highlands, Acrisols are characterized by high Kaolintic clays, low cation exchange capacity, low base saturation and low pH values (Berhane and Sahlemedhin, 2003). This may be due to the high rainfall and hot climate, which result in intensive leaching. The soils are deep, well-drained and reddish brown when moist and dark red when dry (Berhane and Sahlemedhin, 2003).

3.2. Experimental Materials

Potato varieties namely Jalene and Guidene obtained from Holleta Agricultural Research Center and a local variety which has been cultivated for more than a decade by Anderacha farmers were obtained from one of Anderacha woreda farmers were used for the experiment. Jallene and Guidene potato varieties are relatively resistant and both have wide-range of environmental adaptation in Ethiopia. Both varieties adapt in altitude rage of 1600-1800 m and 750-1000 mm rainfall and mature within 90-120 days. Jalene is high yielding under research (44.8 ton/ha) and farmers' field (29.13 ton/ha) compared to Guidene that yield (29.2 and 21.0 ton/ha at research and farmers' field, respectively) (Geremedin *et al.*, 2008)

3.3. Experimental Design and Treatment

The study was conducted using a 3 x 5 factorial experiment arranged in a Randomized Complete Block Design, replicated three times. The treatments consisted of three varieties of potato (Jallene, Guidene and Local) and five planting dates (October 20, October 30, November 9, November 19, and November 29). Most farmers in Anderacha practice potato planting in early November up to mid November. Hence, the above planting dates were chosen as treatment in such a way that the extremes enclosed the period normal in practice in the area.

3.4. Experimental Procedures

The experimental land was cleared and ploughed five times by oxen plough according to farmers' practice. The whole field was divided into three blocks each containing 15 plots. The size of each unit plot was $9m^2$ (3mX3m), having intra and inter row spacing of 0.3m and 0.75m, respectively. A distance of 0.5m and 1m was maintained between unit plot and blocks respectively. Each plot had four rows (ridges) which consisted of ten hills (40 hills per plot). Seed tubers of each variety were planted by hand five times at ten days interval: (October 20, October 30, November 9, November 19, and November 29) in furrows at a depth of about 15 cm. Each variety of seed tubers used for the present study was harvested in June and was kept at room temperature up to first planting and was planted every ten days for successive dates of planting by keeping the rest of seed tubers at room temperature.

Fertilizers were applied as per the recommendation of (EARO, 2004), accordingly, 110 Kg N and 90 Kg of P_2O_5 ha-1. Nitrogen was applied in the form of Urea (46% N) 165 Kg/ha (split: half at planting and the rest during flowering) and P_2O_5 in the form of DAP (46% P_20_5 and 18% N) 195 Kg/ha side dressing at the time of planting (EARO, 2004). Management practices such as weeding; cultivation and ridging were practiced as per the recommendation (Gebremedihin *et al.*, 2008), but no irrigation water was applied as the experiment was set for rain-fed condition. Harvest was under taken by hand when the leaves of 50% the plants in the plot turned yellowish.

3.5 Data collected

To evaluate the effect of variety and planting date on potato yield and quality, data were collected for individual response variables from the two harvestable middle rows of each plot.

3.5.1. Growth parameters

1. **Days to 50% emergence: -** Days to 50% emergence was recorded by counting the number of days from the date of planting to the date at which about 50% of the plants in a plot emerge out.

2. **Days to 50% flowering:-** Days to flowering was recorded by counting the number of days, in which 5 plants flowered out of 10 plants.

3. **Number of stems per hill: -** The actual number of stem per plant was recorded only by counting the main stem which came out from the seed tuber from randomly selected five hills per plot (Zelalem *et al*., 2009).

4. **Plant heights (cm):** Plant height was determined by measuring the height of the plant from the base of the main shoot to the apex at full blooming stage from randomly selected five hills per plot (Zelalem *et al*., 2009).

5. **Days to physiological maturity: –** It was recorded when the haulms (vines) of 50% of the plant population have yellowed.

6. **Disease incidence: -** Plots were assessed weekly for incidence, starting from plant emergence and continuing until senescence. Disease incidence on each experimental plot was recorded by counting number of diseased plants and calculating as the proportion of the diseased plant over the total number of stand count in the respective plot (Habtamu *et al*., 2012).

3.5.2. Yield parameters

Parameters such as number of tubers per plant, average tuber weight, marketable tuber yield, unmarketable tuber yield, total tuber yield and harvest index were measured to assess the effect of variety and planting date on yield and quality of potato.

1. Total number of tuber (count/hill): – The average number of total tubers per hill from middle hills of central rows (16 hills) was taken.

2. Average tuber weight (g): – It was recorded by dividing total fresh weight of tubers per plot by the total number of tubers (Zelalem *et al*., 2009).

3. Marketable tuber yield (t ha^{-1}): - At harvesting the middle sixteen plants were taken from each plot for determination of marketable tuber yield. Weight of healthy tubers with a size equal or more than 35 mm in diameter were taken as marketable (Hassanpanah *et al*., 2009; Khan *et al*., 2011 and Abbas *et al*., 2012).

4. Unmarketable tuber yield (t ha^{-1}): - Rotten, diseased, insect attacked, deformed tuber and tubers with diameter less than 35mm (non-marketable) were weighed and data were tabulated.

5. Total tuber yield (t ha^{-1}):- Sum of both marketable and unmarketable tuber yields.

6. Harvest index: It was determined as the ratio of fresh weight of tubers to the total biomass fresh weight. This was taken at harvest (Frezgi, 2007).

3.5.3. Quality parameters

Tuber specific gravity, tuber dry matter content, and tuber size categories (large, medium and small) were recorded as follows.

1. Tuber size categories: Tuber size distribution: Tubers from two central rows were graded into three groups considering size of tubers: <35mm (small), 35- 55mm (medium) and >55mm (large) (Hassanpanah *et al*., 2009; Khan *et al*., 2011; Abbas *et al*., 2012). Tubers in each grade were counted and weighed.

2. **Specific gravity of tubers (g/cm^3):** Tuber specific gravity was measured by using the tuber weight in air and water method as described by Dinesh *et al.* (2005). Specific gravity was calculated using the following formula:

$$\text{Specific gravity (g/cm}^3\text{)} = \frac{\text{Weight of tuber in the air}}{\text{Weight in air - weight in water}}$$

3.Tuber dry matter content (%): Tubers from randomly chosen five plants per plot were washed, chopped and mixed. 200g of sample was taken and pre-dried at a temperature of 60°C for 15 hrs and further dried for 3 hrs at 105°C in a drying oven (Zelalem *et al*., 2009). It was calculated as

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.6. Data Analysis

The data were checked for normality and meeting all ANOVA assumptions. Disease incidence data was transformed by Arc sin transformation. Analysis of variance (ANOVA) and correlation was done using SAS Version 9.2 statistical software (SAS Institute, 2008). Means were compared by using least significant difference (LSD) test at 5% probability level.

4. RESULTS AND DISCUSSION

4.1. Growth Parameters

The results obtained in days to 50% emergence, flowering, and maturity, number of stem per plant, plant height and disease incidence (%) are presented (Table 1 and 2) and discussed as follows.

Table 1. Mean squares for potato growth parameters and disease incidence

Source of Variation	Mean Squares						
	Df	Days to 50% Emergence	Days to 50% Flowering	Days to maturity	Average stem number/hill	Plant height (cm)	Disease incidence (%)
Block	2	32.09	8.02	7.22	0.01	51.81	23.66
Variety	2	43.89**	298.15**	1132.69**	0.24*	604.53**	769.41**
Planting date	4	26.3**	365.59**	485.24**	3.64**	205.21**	2276.21**
Variety * Planting date	8	0.17^{ns}	8.15^{ns}	33.83*	0.07^{ns}	11.49^{ns}	182.96**
Error	28	3.04	11.62	13.913	0.084	11.52	17.17
SE±		1.74	3.41	3.73	0.29	3.39	4.14
CV (%)		10.07	5.63	3.67	8.01	4.79	19.57

*= significant,**= highly significant, ns= non significant, Df=degree of freedom

4.1.1. Days to 50% emergence

The analysis of variance indicated that there was highly significant ($P<0.01$) variation in respect of days to emergence between cultivars and among date of plantings. However, no significant ($P>0.05$) interaction effect was observed between variety and planting date on days to 50 % emergence (Table 1 and Appendix Table 2). The result revealed that Guidene took significantly longer days to 50% emergence (19.2) than Jalene and local variety which took 16.87 and 15.87 days, respectively (Table 2). This could be attributed to the genetic variation among different varieties used (Abubaker *et al*., 2011). Early planting of potato (October 20) prolonged days to 50% emergence by about 3, 5 and 4 days than on November 9, 19 and 29 plantings, respectively. However, there was no significant difference between the first two planting dates. It was observed that as planting date was delayed, the number of days from planting to 50% emergence was shortened. Earlier planted tubers produced lesser sprouts before planting while tubers planted later had already sprouted and produced maximum number of sprouts before planting, which finally resulted in fast emergence in late plantings. Physiologically old tubers develop more sprouts than physiologically young tubers (Wiersema, 1987). In contrast, Mikitze and Knowles (1990) observed that seed-tuber age apparently had no effect on time to emergence, and 100% emergence was recorded 10 DAP in a study of effect of potato seed-tuber age on plant establishment and amelioration of age-linked effects with auxin.

The results are also in agreement with findings of Caruso *et al.* (2010) who reported planting delay led to crop cycle shortening and also to faster emergence of the more mature seeds. However, no statically significant different was observed among potato planted at first and second plantings dates and also between the late three planting dates in respect of days to 50% emergence. This might be due to nearly the same number of sprouts prior to planting. Nevertheless, in last planting of potato slightly delayed to 50% emergence was observed than the fourth planting, but it is not statically significant ($P>0.05$). This also complies with the general principle that tubers which are physiologically too old, sprouts became too weak for successful emergence (Wiersema, 1987).

4.1.2. Days to 50% flowering

Days to 50 % flowering was highly and significantly (P<0.01) affected by variety and planting date. However, no significant (P>0.05) interaction effect was observed between variety and planting date on days to 50 % flowering (Table 1 and Appendix Table 3). It was observed that variety Guidene took longer days to 50% flowering (65.6) which was significantly longer period than local and Jalene that required 57.4 and 58.48 days to flower, respectively (Table 4). The Local variety was the earlier to flower (57.4 days) than improved varieties (Jalene and Guidene), however, this value was statistically similar with days Jalene took to reach its 50% flowering. The observed variation in terms of flowering date could be attributed to intrinsic or genetic variation among varieties in completing their vegetative growth and commencing reproductive phase by mobilizing assimilates to the sink sites. The arrival of developmental stages and their duration is often quite varied depending on the biological characteristics of a variety, the quality of seed potato, climatic and soil conditions and agro technical measures used (Christiansen *et al*., 2006). Musa *et al*. (2007) also reported considerable differences with respect to the vegetation period, depending on the varieties peculiarities.

Days to 50% flowering was significantly delayed by early planting of potato, while delayed planting after November 19th resulted in significantly earlier flowering. Early planting of potato on October 20 delayed flowering by 15 days than November 29 planting. In general, as planting date was delayed, the number of days to flowering was significantly decreased. This early flowering is also related with days to emergence; potatoes which emerged earlier did also flower earlier than those emerged later. The physiological condition of potato seed tuber affects emergence and growth of potato crop (Wiersema, 1987).

4.1.3. Days to maturity

As depicted in Table 1 days to 50% maturity was significantly (P< 0.05) affected by the interaction of variety and planting date. In the local agro-ecological condition of Aderacha, the vegetation period for potato varied from 90 to 124 days depending to varieties used and planting time. The longest days to maturity was recorded from early planted (October 20 and

30) Guidene while the late planted (November 29) local and Jallene matured early. The maturity is a varietal characteristic which of course can be influenced by planting date, climatic condition and adopted cultivation practices (Musa *et al.*, 2007).

As planting was delayed, time required to reach maturity progressively shortened in all tested varieties. Early maturity in this experiment was observed to be related with early emergence and flowering. The results in this study are in agreement with findings of Caruso *et al.* (2010) who reported that delayed planting led to crop cycle shortening and faster emergence of more mature seeds. Moreover, early maturity in late planted potatoes might be due to water and temperature stress at later stages of the growing season. Water stress causes early falling of leaf and senescence (Knowles and Botar, 1992; Shiri-e-Janagard *et al.*, 2009)

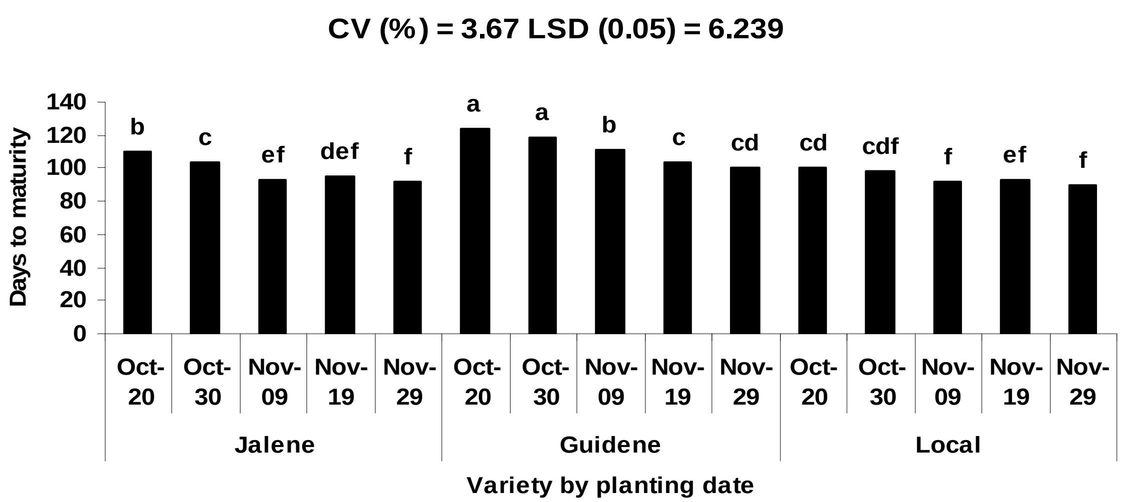


Fig.1. Days to maturity as influenced by the interaction effect of variety and planting. Means followed by the same letter are not significantly different at $p<0.05$

4.1.4. Number of stems per hill

Number of stems per hill was highly and significantly ($P<0.01$) affectedly by planting date and significantly affected by variety ($P<0.05$). However, the interaction effect between planting dates and variety was found to be non significant (Table 1). The highest number of stems was recorded for Jalene (3.75) on average per plant and this value was statistically not significant with stem numbers obtained from local, while the lowest was obtained from Guidene (3.49) and this was statistically not significant with number of stems produced by local variety. Production of higher stem number per hill by Jalene was probably due to the greater number of sprouts observed in Jalene at planting which might have resulted from its genetic potential for sprouting capacity.

Table 2. Effect of variety and planting date on days to 50% emergence, days to 50% flowering, average stem number and plant height of potato

Treatments	Days to 50% Emergence	Days to 50% Flowering	Average stem number/hill	Plant height (cm)
Varieties				
Local	15.87[b]	57.4 [b]	3.62[ab]	65.39[c]
Guidene	19.2[a]	65.6 [a]	3.49[b]	77.77[a]
Jalene	16.87[b]	58.48 [b]	3.75[a]	69.14[b]
LSD (5%)	1.3044	2.549	0.217	2.5384
Planting dates				
October 20	19.56[a]	68.67 [a]	2.88[c]	75.77[a]
October 30	18.56[ab]	65.33 [b]	3.2[b]	75.28[a]
November 9	16.89[bc]	59.33 [c]	3.47[b]	70.63[b]
November 19	15.44[c]	55.00 [d]	4.31[a]	67.09[c]
November 29	16.11[c]	54.11 [d]	4.24[a]	65.09[c]
LSD (5%)	1.684	3.291	0.278	3.277
CV (%)	10.07	5.63	8.01	4.79

Means followed by the same letter per column are not significantly different at $p > 0.05$

It was observed that delay in planting resulted in increased number of stem per plant. Delayed planting from October 20 to November 19 increased stem number per hill from 2.88 to 4.31 (Table 4). Seed tubers of each potato variety used for the present study were kept at room temperature and were planted every ten days for successive dates of plantings. The seed tubers planted at the earliest dates received shorter time at room temperature as compared to tubers used for later plantings. Earlier planted tubers produced lesser sprouts before planting while tubers planted later had already sprouted and produced maximum number of sprouts before planting, which finally resulted in higher number of stems per plant at late plantings. Bohl *et al.* (1995) compared the seed tubers of two ages; old vs. young and reported that young seed grew slower and produced fewer stems per hill while older seed had rapid growth and produced more stems per hill. These results are also in conformity with finding of Firman and Daniels (2011) and Khan *et al.* (2011) who obtained increased number of stem per plant in delayed plantings.

4.1.5. Plant height

Plant height was highly and significantly ($P<0.01$) affected by variety and planting date. However, the interaction between variety and planting date was not significant ($P>0.05$) (Table 1). The variety Guidene had significantly the tallest (77.77cm) plant height, while local variety (65.39cm) was the shortest. Recorded plant height of Guidene was higher by 12.38cm and 8.63cm than local and Jalene, respectively. This could be attributed to direct effect of genetic variation among different varieties used.

On the other hand, time of planting resulted to difference in plant height. Significantly the tallest plant height (75.77 and 75.28 cm) was recorded from the first two planting (October 20 and 30, respectively), while the shortest (65.09cm) from the last planting on November 29th and this value was statistically not significant with the fourth planting on November 19th . Early planting on October 20th increased plant height by 10.68 cm than the last planting date. Generally, as planting delayed decreasing trend on plant height was observed. This might be due to early stage moisture stress at late planted potatoes. Water stress during the vegetative growth stage reduces leaf area, vine and root expansion, plant height, and delays canopy development (King *et al.,* 2003). Fleisher *et al.* (2008) also observed the reduction in plant height and elongation rates with water stress.

4.1.6. Disease incidence

Potato late blight was the only disease observed on potato during the experimental period. The interaction effect of variety and planting date on disease incidence was highly significant

(P<0.01) (Table 1). The highest incidence was observed on first planted local variety (48.37%) which is statistically not significant with second planting (45.97%) (Fig.2). The highest disease incidence on early planted local variety was probably due to the susceptibility of local variety and the prevailed conducive weather conditions for late blight development in this growing period (relatively high rain fall and warm temperature in months of November up to first decade of December) (Appendix Table 1). Disease incidence depends on meteorological conditions, cultivars susceptibility to potato late blight, and growth stage of the potato during disease attack (Razukas *et al.*, 2008).

The current finding is in agreement with the experiment of Habtamu *et al*. (2012) who observed low incidence on improved varieties (Jalene and Guidene) than local varieties and significantly lower incidence was observed on Jalene and Guidene. However, incidence was significantly lower in all planting dates for late maturing variety (Guidene) than Jalene (early maturing). This is because of the fact that potato blight development intensity in various potato cultivars depends on their maturity group, genetic and biologic features (Razukas *et al*., 2008). The high disease incidence on Jalene was probably due to early luxuriant vegetative growth following its early emergence which caused early ground cover than late matured Guidene, as the canopy formed across rows creates a humid microclimate which promotes the spread of disease (Agu, 2004). Similarly, Razukas *et al.* (2008) observed more intensive disease spread in early than in late maturing potato cultivars.

No incidence was observed for the last two plantings for all varieties used in the experiment. Late blight epidemics are sever only when weather conditions are suitable, i.e heavy rains, cool temperatures, high relative humidity, and presence of moisture on the potato leaves for an extended period (Harris,1992). Moreover, in present experiment the initial sources of infection dried up because decreased rain fall and increase in temperature starting second decade of December were not suitable for late blight development. In agreement with this experiment, Muhinyuza *et al*. (2007) observed drying up of the initial sources of infection owing to the absence of suitable rainfall and temperature for late blight development.

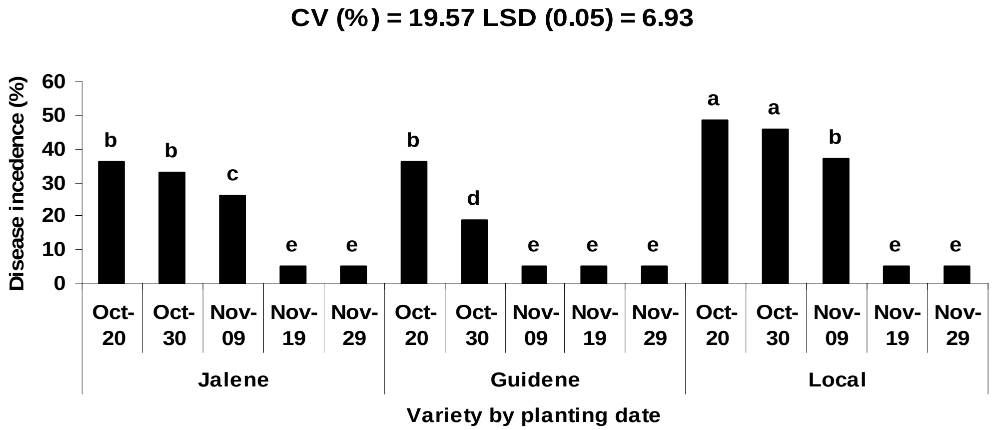


Fig.2. Late blight incidence as influenced by the interaction effect of variety and planting date. Means followed by the same letter are not significantly different at p<0.05

4.2. Yield Parameters

The results obtained in yield parameters such as number of tubers per plant, marketable tuber yield, unmarketable tuber yield, total tuber yield, average tuber weight and harvest index are presented (Table 5 and 6) and discussed as follows.

Table 3. Mean squares for potato yield parameters

Source of Variation	Df	Mean Squares					
		Total tuber number (Count/hill)	Marketable tuber yield (ton/ha)	Unmarketable tuber yield (ton/ha)	Total tuber yield (ton/ha)	Average tuber weight (g)	Harvest index
Block	2	2.19	20.95	0.02	9.74	188.65	0.004
Variety	2	5.43**	332**	28.23**	240.94**	1380.89**	0.028**
Planting date	4	1.29*	153.40**	4.86**	107.57**	467.05**	0.014*
Variety * Planting date	8	0.49^{ns}	17.59**	0.27ns	18.68**	68.23^{ns}	0.011*
Error	28	0.35	4.58	0.63	1.60	45.08	0.003445
SE±		0.59	2.14	0.79	1.26	6.71	0.058694
CV (%)		7.78	10.29	17.58	5.00	8.95	7.87

*= significant,**= highly significant, ns= non significant, Df=degree of freedom

4.2.1. Total number of tubers

Total number of tubers per hill statistically displayed highly significant ($P<0.01$) difference among potato varieties and significant ($P<0.05$) difference among different planting dates (Table 3 and Appendix Table 8). On the other hand, the interaction effect of variety and planting date was found to be not significantly ($P>0.05$). The potential tuber number that can be successfully produced by a plant varies with the genotype, physiological age of seed, number of stems per hill (stem population) and environmental conditions during the initiation phase of growth (Kleinkopf *et al*., 2003; Mihovilovich *et al*., 2009). Jalene was superior in tuber number per plant (8.09) followed by local variety with 7.96 tubers per plant; while Guidene produced the lower number of tubers per plant (6.92). The apparent variation could be due to the difference in genetic potential among potato varieties. Moreover, the number of stems per plants might have contributed to the difference. The results are also in line with that of Abbas *et al*. (2012) who observed a statistically significant difference in tuber number among potato genotypes which the author attributed to the occurrence of sufficient growth (stem number and plant height).

The highest tuber number (8.20) was recorded in plots planted in second planting on October 30. The other four planting dates showed statistically similar total tuber number per hill. Second planting increased total tuber number by 8.04% from first and 14.21% from the last planting date. Probably because of optimal environmental condition like temperature and rain fall for plant growth during the first few weeks of crop development reflected in good tuber count. Even though the environmental condition was favourable, potato planted at first planting date produced lower tuber number than the second planted and this might be related with the limited number of stem at first planting. Hassanpanah *et al.* (2009) and Khan *et al*. (2011) have reported similar trends of producing total tuber per plant at earlier plantings.

The number of stems per plant generally increased with delay in planting so that stem populations were greater at later plantings. However, this did not account for differences in the number of tubers; it rather resulted in decreased tuber number in late plantings. Firman and Daniels (2011) and Khan *et al*. (2011) observed the same phenomenon. Decrease in tuber number in late plantings probably because of unsuitable environmental condition like low rainfall and relatively high temperature during potato growing season (starting second decade of December) (Appendix Table 1). The results obtained are fairly supported by the findings of Levy (1982), who investigated the response of six potato cultivars to water stress under high ambient temperature and observed that tuber number was adversely affected by drought occurring in the early and middle parts of the season, corresponding to the stages of growth of tuber initiation and bulking.

4.2.2. Average tuber weight

Data regarding average tuber weight (Table 3 and Appendix Table) depicted a highly significant ($P<0.01$) difference among potato varieties and planting dates. However, the interaction between variety and planting date did not impart a significant effect ($P>0.05$) on average tuber weight. Irrespective of the planting dates, Jalene produced the heaviest tuber weight (82.89g) followed by Guidene (77.89g) compared to local variety (64.34g) which had significantly the lowest average tuber weight among all the varieties. Using improved variety Jalene increased average tuber weight by 29.12% as compared to the local variety. The variation may be attributed to the inherent genetic variation on tuber bulking among potato varieties. The duration and rate of tuber bulking vary among cultivars (Levy, 2007).

Regardless of the variety used for the study, all potato varieties showed significant differences in their average tuber weight at different planting times. The early planting on October 20 was resulted in a significantly heaviest tuber weight (83.80g) followed by October 30 planting (80.35g), while delayed in planting progressively reduced tuber average weight of potato. Early planting on October 20 increased average tuber weight by 26.76% than the last planting (November 29). The achievement of producing the heaviest tubers in the first two earlier plantings might be due to the favourable soil moisture and temperature for tuber growth with early planting than late planting under rain-fed ecosystem. This is in agreement with results of Yenagi *et al*. (2004).

Generally when there is high number of stems/hill there will be more number of tubers/ hill and when few numbers of tuber /hill it is expected to have high average tuber weight, however in present experiment, in delayed plantings potatoes those had higher number of stems/hill produced lower number of tubers/hill with low average tuber weight. This could be attributed to water and temperature stress prevailed at tuber initiation up to bulking stages of potato planted in delayed plantings. Water and temperature stress during vegetative and tuber initiation growth stages have also been shown to decrease the number of tubers set per plant (King *et al.,* 2003; Modisane, 2007)**.** After initiation, both the weight and volume of the tubers increase almost linearly, but either water or temperature stress interrupt this process and often result to small, misshapen and irregular shaped tubers (King *et al.*, 2003; Levy and Veilleux, 2007). Firman and Daniels (2011) and Khan *et al*. (2011) also observed the same phenomenon of producing higher stem number in delayed planting due to maximum number of sprouts at planting, however low number of tubers and low average tuber weight due to unsuitable environmental condition in delayed plantings. Levy (1982) also reported both tuber number and size are adversely affected by drought occurring in the early and middle parts of the season, corresponding to the stages of growth of tuber initiation and bulking.

4.2.3. Marketable tuber yield

The interaction of variety and planting date highly and significantly ($P < 0.01$) influenced marketable tuber yield. The highest marketable tuber yield (34.82 ton/ha) was produced by planting the potato variety Jalene on October 30, while the lowest (12.69 ton/ha) was obtained from late planted (November 29) local variety and this value was statistically non significant with November 9 and 19 planted local and November 29 planted Guidene (Fig. 3). The variation might be attributed to different effect of genetically variation among potato varieties and environmental factor on tuber bulking. The duration and rate of tuber bulking vary among varieties and depend on environmental conditions (Levy, 2007).

In all potato varieties used in the experiment the trend of earlier planting with higher marketable yield, this could be explained by the longer growing period. Tubers planted at earlier dates received more time of optimum moisture and temperatures than the late plantings, which resulted in higher marketable tuber yield. The phenomenon is well supported by Yenagi *et al*. (2004) and Khan *et al.* (2011) who recorded reduced marketable yield with delay in planting due to unfavourable climatic condition for tuber growth. In the present study early plantings provided maximum period of optimal temperature and rainfall for crop development (Appendix Table 1) which resulted in excellent foliage growth and longer maturation time with improved photosynthesis which ultimately helped increasing the size of tubers.

CV (%) = 7.65 LSD (0.05) = 3.578

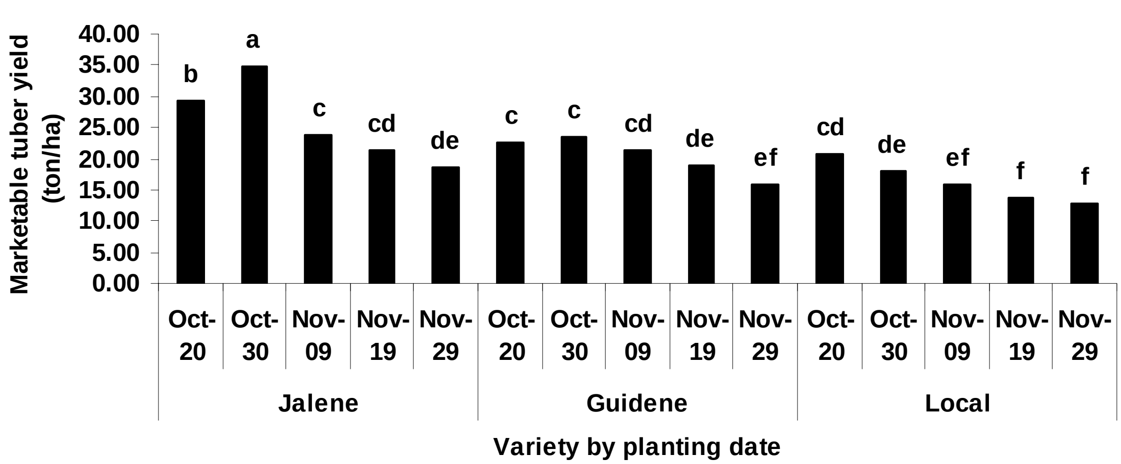


Fig.3. Marketable tuber yield as influenced by the interaction effect of variety and planting date. Means followed by the same letter are not significantly different at p<0.05

4.2.4. Unmarketable tuber yield

Unmarketable tuber yield was highly and significantly (P < 0.01) affected by both variety and planting date, however interaction effect between variety and planting time was non significant (P>0.05) (Table 3 and Appendix Table 11). Higher non-marketable yield was registered by local variety, while the low non-marketable yield was produced by Guidene. Guidene and Jalene produced reduced unmarketable tuber yield by 44.35% and 31.06 %, respectively as compared to local variety. Variation among genotypes respects of non marketable yield could be attributed to there genetic make up which influenced tuber size. The observed maximum yield of small size tubers (unmarketable) might be due to presence of more number of tubers as well as varietal character and adaptability or establishment effect of other growth attributes (Kumar *et al*., 2007). Stem number and plant height can strongly influence non-marketable yield of many potato cultivars (Arsenault and Christie, 2004).

Table 4. Effects of variety and planting date on total tuber number /hill, unmarketable tuber yield and average tuber weight of potato

Treatments	Total tuber number (count/hill)	Unmarketable tuber yield (ton/ha)	Average tuber weight (g)
varieties			
Local	7.96[a]	6.02[a]	64.34[b]
Guidene	6.92[b]	3.35[c]	77.89[a]
Jalene	8.09[a]	4.15[b]	82.89[a]
LSD (5%)	0.44	0.59	5.02
Planting dates			
October20	7.59[b]	3.66[d]	83.80[a]
October 30	8.20[a]	3.89[cd]	80.35[ab]
November 9	7.58 [b]	4.57[bc]	74.63[bc]
November 19	7.43 [b]	5.03[ab]	70.28[cd]
November 29	7.18 [b]	5.39[a]	66.11[d]
LSD (5%)	0.57	0.76	6.48
CV (%)	7.78	17.58	8.95

Means followed by the same letter per column are not significantly different at $p > 0.05$

With regard to planting time, recorded unmarketable tuber yield from plots planted on October 20 was lower by 32.1% than unmarketable tuber yield from plots planted on November 29 (the last planting). Results of this experiment revealed that the delay in planting resulted in higher percentage of small sized tubers as a result of which high unmarketable tuber number lead to higher unmarketable tuber yield. Moreover, higher number of malformed tubers and pre-harvest sprouting on tubers was observed in late plantings. When high temperature stress is combined with drought stress under field conditions, tuber malformation and tuber sprouting are aggravated (Levy, 1986). High temperatures during tuber maturation interfere with the onset of tuber dormancy, shorten their rest period, or even release the inhibition of tuber buds, resulting in pre-harvest sprouting (Levy, 2007).

4.2.5. Total tuber yield

Total tuber yield was highly and significantly ($P < 0.01$) affected by the interaction effect between variety and planting date (Table 3 and Appendix Table 12). The highest total tuber yield (38.6 ton/ha) was produced by planting Jalene on October 30 (Fig. 4). All varieties produced low yield in November 29 planting, however Local and Guidene (19.24 and 19.21 ton/ha, respectively) produced significantly low yield. In particulars, Jalene was the highest yielding cultivar but only in the earlier plantings. The higher total yield in early planted Jalene might be due to favorable climatic condition and the ability of the variety to produce faster and early top growth followed by formation of large sized and higher number of tubers per plant. This goes along with the conclusions of Levey (1982).

Jalene planted at earlier dates showed the highest number of stems and tubers per plant, and highest average tuber weight and consequently the highest total yield. It is in agreement with the report of Abubaker *et al.* (2011) who observed the highest total yield on potato cultivar having higher stem and tuber number. Mehdi *et al*. (2008) also concluded the increase in yield was mainly on account of higher number of tubers/plant and tuber size. Tubers planted at earlier dates received more time of optimum moisture and temperatures than the late planting, which resulted in higher total tuber yield. The results are well supported by Yenagi *et al*. (2004) and Khan *et al.* (2011) who recorded higher total yield with early planting due to favourable climatic condition for tuber growth. Water stress usually causes early senescence of leaves there by shorting the growing season, resulting in lower tuber yield (Shiri-e-Janagard *et al*., 2009). However, the first planting showed reduced total tuber yield perhaps due to lower number of stems and tubers obtained in this planting.

Under Ethiopian condition Tesfaye and Anteneh, (1999) and Tesfaye *et al.* (2006) also observed decreased yield in late plantings due to higher disease incidence in late planting. In contrast, higher late blight incidence was observed on early planted potato in this experiment.

However, no clear yield reduction attributable to late blight was observed. It might be due to occurrence of the disease incidence at a later growth stage of potato. Moreover, the initial infection was dried up within short period due to reduced rainfall and high temperature just a few days after infection. Similarly, Muhinyuza *et al*. (2007) observed drying up of the initial sources of infection because of low rain fall and high temperature that is not suitable for late blight development and consequently higher yield for all the varieties including susceptible control.

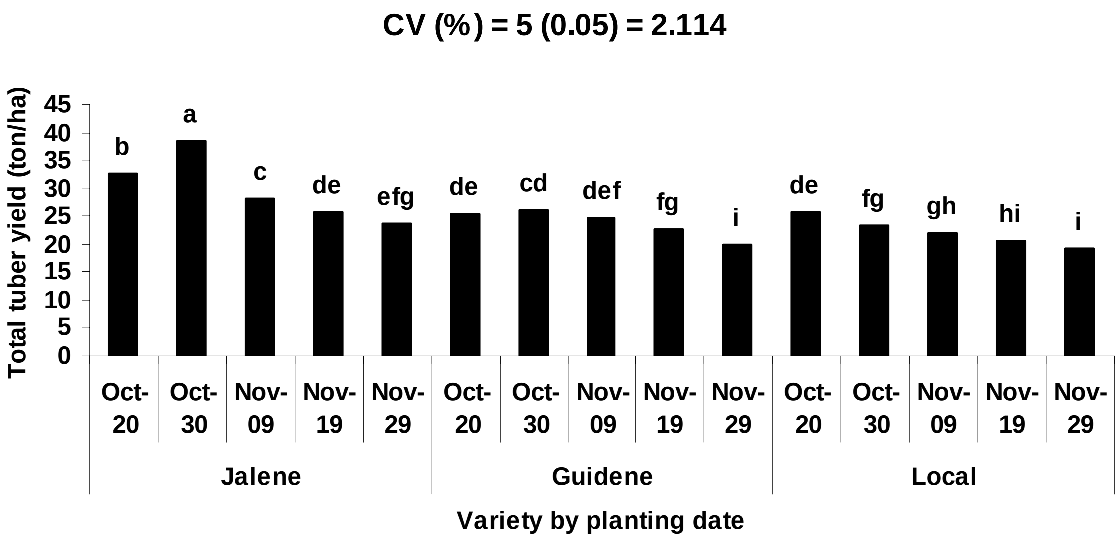


Fig.4. Total tuber yield as influenced by the interaction effect of variety and planting date. Means followed by the same letter are not significantly different at $p<0.05$

4.2.6. Harvest index

Harvest index was significantly ($P < 0.05$) affected by the interaction effect occurred between variety and planting time (Table 3). The maximum harvest index (0.84) was observed by planting Jalene on October 30 while the lowest harvest index (0.58) was obtained by planting local variety on November 29th (Fig 5). In the present study treatments which produced the higher yield had also produced the maximum harvest index. Tuber bulking restricts shoot and root growth, acting as an alternative and strong sink for plant resources (Levy and Veilleux, 2007). Harvest indices of 0.75 to 0.85 are more common in temperate zone but in hotter climates, the harvest index tends to be lower and often a wider variation is also observed between cultivars or growing conditions (Beukema and Vander Zaag, 1990).

In delayed plantings potato varieties showed lower harvest index probable due to increased temperature in late planting resulted to excessive top growth than tuber bulking. There are research reports which show exposing to higher temperature toward maturity increases the ability of plant to grow vegetativilly. Higher temperatures favour foliar development and retard tuberization (Hijmans, 2003). Modisane (2007) also observed rapid plant top growth at higher temperature (27/17^{o}C) than at low temperature (22/14^{o}C). High temperature stress accelerate haulm growth, assimilates partitioned more towards the haulm, photosynthesis is reduced and respiration is increased (Levy and Veilleux, 2007).

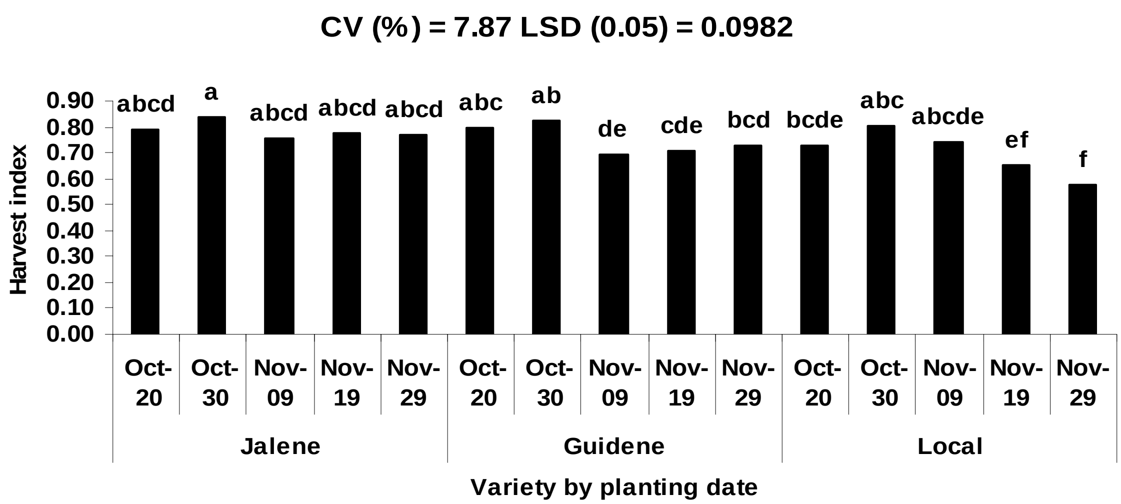


Fig.5. Harvest index as influenced by the interaction effect of variety and planting date. Means followed by the same letter are not significantly different at $p<0.05$

4.3. Quality Parameters

The results obtained in terms of potato quality parameters such as tuber size categories (percent large, medium and small tubers plant^{-1}), tuber specific gravity and dry matter content (%) are presented (Table 7 and 8) and discussed as follows.

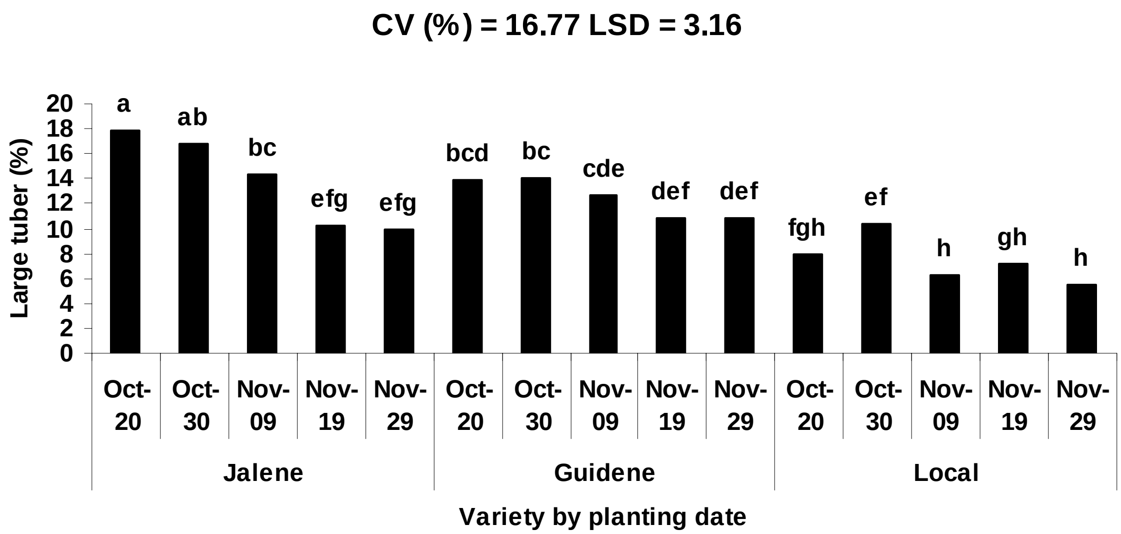
Table 5. Mean squares for potato quality parameters

Source of Variation	Mean squares					
	Df	Small tuber (%)	Medium tuber (%)	Large tuber (%)	Dry matter content (%)	Specific gravity (g/cm^3)
Block	2	1.42	44.36	55.81	3.16	0.00001262
Variety	2	769.51**	251.01**	169.02**	2.58**	0.00037181**
Planting date	4	95.88**	22.98**	44.55**	11.88**	0.00064908**
Variety * Planting date	8	9.61**	5.93^{ns}	7.06*	0.35^{ns}	0.00004839^{ns}
Error	28	2.29	4.98	3.56	0.45	0.00002935
SE±		1.51	2.23	1.89	0.67	0.005418
CV		6.12	3.49	16.77	3.06	0.50

*=significant,**=highly significant, ns= non significant, Df=degree of freedom

4.3.1. Percent large tubers per plot (>55mm)

Interaction between planting times and varieties was found statistically significant ($P<0.05$) (Table 5). Jalene planted on October 20 resulted in maximum larger sized tubers (17.91%) while only 6.2% of larger sized tubers were harvested by planting local variety on November 29th (Fig. 6). Foliage growth as well as variety development and performance might be the causes for variation in tuber size among different genotypes and it depend on environmental conditions at bulking stage (Levy, 2007; Abbas *et al*., 2012). Since earlier planting provided longer period of favourable conditions to the crop (Appendix Table 1) and prolonged the crop cycle which improved tuber bulking process resulted to large tuber weight. In contrary, in all varieties delayed planting resulted to moisture and temperature stress which led to crop cycle shortening and minimum ratio of larger tubers. Khan *et al*. (2011) have reported a similar trend of producing larger tubers at earlier plantings.



Means having the same letter on the top of bars are not significantly different at $p<0.05$

Fig.6. Interaction effect of variety and planting date on large tuber percentage

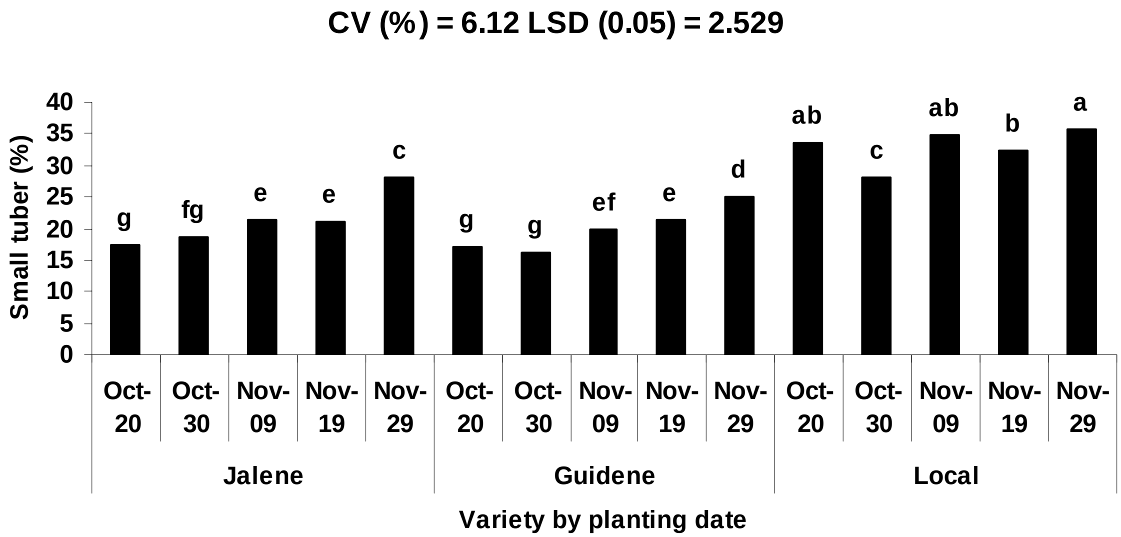
4.3.2. Percent medium tubers per plot (35-55 mm)

The percentage of medium sized tubers was highly and significantly ($P<0.01$) affected by planting time and varieties, but interaction between the planting dates and variety was found non significant (Table.5 and Appendix Table 15). The lowest percentage of medium sized tubers (61.51%) was recorded in plots planted on November 29 (the latest planting). The other four planting dates showed statistically similar percentage of medium sized tubers (Table 8). Planting on October 20, Oct 30, November 9 and November19 produced 64.15, 65.17, 63.56 and 64.56% medium tubers, respectively (Table 6). Results of this experiment revealed that the trend of earlier planting was with higher percentage of medium sized tubers. Tubers planted at earlier dates received more time of optimum temperatures and rainfall than the late planting, which resulted in higher percentage of medium tubers. Khan *et al*. (2011) have reported the similar trend of producing medium tubers at earlier plantings.

The ratio of medium sized tubers was also significantly different among genotypes. The maximum percentage of medium sized tubers (67.57%) was produced from Guidene, which was significantly higher than percentages of medium sized tubers obtained from Jalene (64.86%) and local variety (59.53%). While significantly lowest percentage of medium sized tubers was recorded from local variety. Plant growth and heredity might be the reason for differences in ratio of medium sized tuber among potato varieties. Production of higher percentage of medium sized tubers from Guidene might be due to lower number of stem and tubers produced. This is in agreement with results of Caruso *et al*. (2010) who observed bigger sized tubers on variety which produced lower number of shoots and tubers. Similarly Abbas *et al*. (2012) observed significant difference among potato varieties where number of factors such as vegetative growth, genotypes, and plant growth rate and emergence time were suggested as responsible for this variation in number of medium sized tubers.

4.3.3. Percent small tuber per plot (<35mm)

Percentage of small sized tubers was highly and significantly ($P<0.01$) affected by varieties and planting time. The interaction between the planting dates and variety was also found highly significant (Table 5 and Appendix Table 16). The lowest percentage of small sized tubers (16.2%) was obtained from early planted (October 20) Guidene which is statistically not significant with result obtained from October 20 and 30 planted Jallene and October 30 planted Gudene, while the highest percentage (35.83%) was recorded from late planted (November 29) local variety (Fig. 7). For all varieties used as planting delayed production of small sized tubers showed increasing trend. This indicates that soil moisture and air temperature do have an influence on the bulking phase. Kuruppuarchchi (1987) showed the importance of the diurnal temperature difference and low night temperature for satisfactory bulking. Similarly, Balamani *et al.* (1986) reported tuberization to be promoted by short days and low temperature whereas long days and high temperature delay or inhibit the process. Girma *et al*. (2004) also stated temperature from 20 to 29 ^{o}C leads to small tubers and temperature above 29 ^{o}C prevent tuber development.



Means having the same letter on the top of bars are not significantly different at p<0.05

Fig.7. Interaction effect of variety and planting date on small tuber percentage

4.3.4. Specific Gravity

The effect of variety on specific gravity was found to be highly significant (P<0.01). The highest specific gravity was registered for variety Guidene (1.087), while the lowest was from the local variety (1.077). This value was statically similar with tuber specific gravity recorded for variety Jalene (1.079) (Table 5). Potato tubers should have a specific gravity value of more than 1.080 and tubers with specific gravity value less than 1.070 are generally unacceptable for processing (Kabira and Berga, 2003). In this study, all cultivars had a specific gravity higher than 1.070 regardless of planting date, indicating that they are suitable for processing. The variation in the specific gravity of potato genotypes might be due to response of genotype/variety factor, because potato varieties vary widely in their ability to accumulate starch in the tubers. Similarly, variety has been reported by many workers that it was the most important factors affecting potato quality or specific gravity (Hegney, 2005; Musa *et al*., 2007; Abubaker *et al*., 2011).

Planting the tubers on various dates also highly and significantly (P<0.01) affected the tuber specific gravity (Table 5). However, the interaction effect of variety and planting date was not significant (P>0.05). Planting potato on October 20 resulted in the highest tuber specific gravity (1.092) while the lowest (1.072) was obtained from November 29 planting (the last planting) and the value is statistically similar with specific gravity obtained on November 19 planting (1.074). Results of this experiment revealed that the trend of earlier planting was with higher specific gravity. Earlier planting provided maximum period of optimal temperature and rainfall for crop development which resulted in excellent foliage growth and longer maturation time with improved photosynthesis which ultimately high tuber bulking. This subsequently resulted in higher tuber specific gravity. Similarly, Yenagi *et al*. (2004) observed higher specific gravity in early planted potato due to the advantage of favourable soil moisture with early planting under rain-fed ecosystem.

On other hand, delay in planting showed decreasing trend of tuber specific gravity and this probably is due to high temperature and moisture stress at late planting. Similarly, Kuruppuarchchi (1987) reported that tuber specific gravity decreased in late planting (during cooler period) which were harvested during warmer part of the season. Increment in specific gravity at early planting might be also related to the longer tuber bulking period as a result of favourable temperature and rain fall in early planting time. Earlier planting date lead to earlier tuber initiation. Tubers that set earlier may be able to avoid heat stress during early bulking. This is inline with Hegney (2005) who opined that potato tubers which complete their full potential growth cycle without periods of stress will usually have higher tuber specific gravity.

4.3.5. Dry matter content

The effect of both variety and planting date on dry matter content were found to be highly significant (P<0.01), while interaction between the planting dates and variety was found non significant (Table 5 and Appendix Table 18).The highest dry matter content was produced by variety Guidene (22.34%), while the lowest was accumulated by the local variety (21.56%). Variety Jalene had a dry matter content of 21.7% which was statically similar with value registered for the local variety as given in Table 8. Variation in tuber dry matter content may be attributed to the inherent vareital difference in the production of total solids. Similarly Elfnesh *et al* (2011) observed variation in dry matter contents of some Ethiopian potato varieties. In the present study, maximum dry matter was obtained from late maturing variety (Guidene) than early maturing Jalene and local varieties. Assuming planting is common for both early and later clones and a similar ability to intercept radiation at any point in time, a shorter growing season would obviously restrict the total radiant energy available for conversion to tuber dry matter (Midmore, 1982).

Tubers' dry matter is an important element of industries' interest. In this study, clear effect of various growing periods on dry matter content of potato was observed. It was observed that early planting helped in improving the dry matter accumulation. The highest dry matter content was observed at first planting (23.02%) and this value was statistically similar with value obtained at second planting (22.8) (Table 6). Dry matter content of tuber decreased gradually in subsequent planting dates and the lowest tuber dry matter content (20.42%) was observed at last planting. Increment in dry matter content with early planting might be also related to the longer tuber bulking period as a result of favourable temperature and rain fall in early planting time. In contrast, decreased dry matter content at late planting might be due to temperature and moisture stress occurred during tuber bulking. At high temperatures increased respiration rates mean that solids accumulated through photosynthesis are burnt up more quickly than they were formed, resulting in a decrease in dry matter. The potato is classified as a "cool season" crop and so temperature probably has more effect on dry matter than any other single environmental factor (Khan *et al*., 2011). Kuruppuarchchi (1987) and Hijmans (2003) showed cooler temperature during harvesting time is more crucial to the tuber dry matter contain. Modisane (2007) also observed higher tuber dry mass at low controlled temperature (22/14^{o}C) than at high controlled temperature (24/17^{o}C). In general, dry matter content is subjected to the influence of both the environment and genotypes (Musa *et al*., 2007).

Table 6. Effect of variety and planting date on tuber size distribution (small, medium and large), dry matter content and specific gravity of potato

Treatments	Medium tuber (%)	Dry matter content (%)	Specific gravity (g/cm^3)
varieties			
Local	59.53^c	21.7^b	1.077^b
Guidene	67.57^a	22.34^a	1.087^a
Jalene	64.86 ^{b}	21.56^b	1.079^b
LSD (5%)	1.67	0.5005	0.0041
Planting dates			
October 20	64.15a	23.02^a	1.092^a
October 30	65.17^a	22.8^{ab}	1.087^b
November 9	63.56^{ab}	22.18^b	1.081^c
November 19	64.56^a	20.93^c	1.074^d
November 29	61.51^b	20.42^c	1.072^d
LSD (5%)	2.154	0.646	0.0052
CV (%)	3.49	3.06	0.50

Means followed by the same letter per column are not significantly different at $p > 0.05$

4.4. Correlation Analysis among Growth, Yield and Quality Parameters

Correlation analysis showed that total tuber number per plant (r = 0.55), average tuber weight (r = 0.77), marketable tuber yield (r =0.96), large tuber percentage (r = 0.74) and harvest index (r = 0.52) correlated significantly and positively (P<0.01) with total tuber yield. These result showed that any positive increase in such characters had boasted total tuber yield (Table 7). These findings were in similar with the results of other researches (Khayatnezhad *et al*., 2011). On the other hand, negative and significant (P<0.01) correlations were determined between yield and unmarketable yield (r = -0.44) and small tuber percent (r = -0.47).

Plant characters also showed significant association with one another. Marketable tuber yield associated positively and significantly (P<0.01) with average tuber weight (r = 0.85), days to flowering (r = 0.45), days to maturity (r = 0.43), plant height (r=0.47), harvest index (r = 0.50), large tuber percentage (r = 0.78). Also medium tuber percentage associated positively with marketable tuber yield (r = 0.33, P<0.05), while unmarketable tuber yield (r = -0.61) and small tuber percentage (r = -0.75) were negatively correlated with marketable tuber yield (P<0.01). Unmarketable yield associated positively with stem number (r = 0.48, P<0.1), small tuber percentage (r = 0.75, P< 0.01) and total tuber number (r = 0.29, P<0.05). Highly significant (P<0.01) negative correlation between unmarketable tuber yield and days to flowering (r = -0.60), days to maturity (r = -0.73), plant height (r = -0.69), average tuber weight (r = -0.75), large tuber percentage (r = -0.61) and medium tuber percentage (r = -0.72) were observed. In this study, it is proved that tuber specific gravity associated positively with dry matter content (r = 0.70, P<0.01) indication that the former is an excellent indicator of the latter which agrees with the report of Tekalign and Hammes (2005).

The relationship between total and marketable tuber yield with average tuber weight and total tuber number per plant was positive and highly significant. This means that tuber number and tuber weight have more effect on yield. The correlation coefficients between days to flowering and days to maturity with average tuber weight, marketable tuber yield, large tuber percentage, medium tuber percentage, dry matter content and specific gravity were positive and significant (P<0.01). Days to flowering and days to maturity also associated positively with total tuber yield (P<0.05). The result indicated that the above mentioned parameters can be increased by extending crop cycle by early planting in which the plant can accumulate high dry matter due to the extended vegetative growth of the plant. Gunel *et al*. (1991) determined that highly positive and significant correlation between tuber yield with big tubers percentage and vegetation period.

Table 7. Pearson Correlation coefficient for growth, yield and quality parameters of potato

	DE	DF	DM	SN	PH	TTN	ATW	MTY	UMTY	TTY	HI	LTP	MTP	STP	DMC	SG
DE	1	0.71**	0.70**	-0.61**	0.70**	-0.06ns	0.39**	0.34*	-0.63**	0.28*	0.28ns	0.30*	0.5**	-0.35**	0.42**	0.61**
DF		1	0.84**	-0.76**	0.78**	-0.04ns	0.48**	0.45**	-0.60**	0.36*	0.30*	0.46**	0.39**	-0.38**	0.66**	0.76**
DM			1	-0.57**	0.84**	-0.18ns	0.53**	0.43**	-0.73**	0.32*	0.31*	0.52**	0.60**	-0.57**	0.65 **	0.74**
SN				1	-0.6**	-0.16ns	-0.42**	-0.48**	0.46**	-0.44**	-0.40**	-0.36*	-0.07ns	0.12ns	-0.75*	-0.75**
PH					1	-0.18ns	0.56**	0.47**	-0.69**	0.35*	0.30*	0.52**	0.56**	-0.55**	0.60**	0.61**
TTN						1	-0.11ns	0.38**	0.29*	0.55**	0.41**	0.19ns	-0.28*	0.1ns	0.12ns	-0.05ns
ATW							1	0.85**	-0.75**	0.77**	0.32*	0.75**	0.46**	-0.63**	0.46**	0.55**
MTY								1	-0.61**	0.96**	0.50**	0.78**	0.33*	-0.58**	0.48**	0.50**
UMTY									1	-0.44**	-0.34*	-0.61**	-0.72**	0.75**	-0.49**	-0.68**
TTY										1	0.52**	0.74**	0.20ns	-0.47**	0.44**	0.42*
HI											1	0.48**	0.24ns	-0.37*	0.34*	0.35*
LTP												1	0.26ns	-0.74**	0.55**	0.45**
MTP													1	-0.73**	0.13ns	0.34*
STP														1	-0.33*	-0.36*
DMC															1	0.70**

ns*, ** indicate non significant, significant at 5% and 1% probability level respectively

DE= Days to Emergence, DF=Days to Flowering, DM=Days to Maturity, SN=Stem Number, PH= Plant Height, DI = Disease Incidence, TTN=Total Tuber Number, ATW= Average Tuber Weight, MTY=Marketable Tuber Yield, UMTY=Unmarketable Tuber Yield, TTY=Total Tuber Yield, HI= Harvest Index, LTP= Large Tubers Percentage, MTP= Medium Tubers Percentage, STP= Small Tubers Percentage, DMC= Dry Matter Content= SG= Specific Gravity

5. SUMMERY AND CONCLUSION

Potato is one among the most economically important crops as a source of food and cash in Ethiopia and mainly produced under rain-fed condition. Perfect timing of planting date is one of the key factors which strongly affect crop production in rain fed agriculture. Like other crops, the optimum date of planting for potato is highly location specific. However, there are no research recommendations pertaining to adaptable cultivars and their optimum planting date with due consideration of the environmental condition of Anderacha area. Therefore, the present study was conducted to evaluate the effect of planting date and variety on yield and quality of potato at Anderacha woreda, south western Ethiopia. Three varieties of potato (Jallene, Guidene and Local) and five planting dates (October 20, October 30, November 9, November 19, and November 29) were used and resulting in 15 treatment combinations. The design used was 3 x 5 factorial experiment arranged in a Randomized Complete Block, replicated three times. Potato growth, yield and quality parameters were collected and data were analyzed using SAS Version 9.2 statistical software.

The result of the study revealed that all of the parameters considered were significantly affected by the treatments or their interaction effects. Guidene took significantly longer days to emergence and to flower, while Jalene produced the highest stem number than other varieties used. Similarly, date of planting significantly affected days to 50% emergence, days to 50% flowering, plant height and stem number per plant. Planting potato at earlier dates resulted to delayed emergence and flowering and maximum plant height. Guidene planted on 20^{th} of October took the longest days (124 days) to mature while on 29^{th} of November planted Local was the earliest (90 days). Plant height shown decreasing trend for delayed planting, while early planting on October 20 increased plant height by 10.68cm than the last planting date. The number of stems per plant generally increased with delay in planting. However, this did not account for differences in the number of tubers; moreover decreased tuber number was observed in late plantings.

Considering the yield of potato, the combined effect of planting date and variety showed a significant variation on marketable tuber yield, total tuber yield and harvest index. The highest value of marketable and total tuber yield (34.82 and 38.6 ton/ha, respectively) were recorded from Jalene planted on October 30th. In the present study treatments which produced the higher yield had also produced the maximum harvest index. Jalene was superior in its tuber number per plant and also produced the heaviest tuber weight. Using improved variety Jalene resulted in increased average tuber weight by 29.12% as compared to the Local variety. On other hand, Guidene and Jalene showed reduced unmarketable tuber yield by 44.35 and 31.06 %, respectively as compared to local variety. With regard to planting time, unmarketable tuber yield from plots planted on October 20 was lower by 32.1% than obtained from plots planted on November 29.

Furthermore, the current experiment showed that planting date significantly affected potato quality parameters such as percentage of medium sized tubers, tuber specific gravity and dry matter content. These all showed the highest value in early planting and decreased in subsequent planting dates. Potato quality was also significantly different among genotypes. In the present study, high tuber specific gravity (1.087) and dry matter value (22.34%) was obtained from late matured variety (Guidene) than early maturing Jalene and local variety. The highest percentage of medium sized tubers was also produced by Guidene. Combined effect of variety and planting date showed significant effect on percentage large and small sized tubers. Jalene planted on 20th of October resulted in maximum percentage of large sized tubers (17.91%), while only 6.2% of large sized tubers were harvested by planting local variety on 29th of November. The highest percentage of small sized tubers (35.83%) was also recorded from late planted (on November 29) local variety.

The relationship between total and marketable tuber yield with average tuber weight and total tuber number per plant was positive and highly significant. The correlation coefficients between days to flowering and days to maturity with average tuber weight, marketable tuber yield, large tuber percentage, medium tuber percentage, dry matter content and specific gravity were positive and significant ($P<0.01$). Days to flowering and days to maturity also associated positively with total tuber yield ($P<0.05$). The results of correlation study indicated that most yield and quality parameters can be increased by extending crop cycle by early planting in which the plant can accumulate high dry matter due to the extended vegetative growth of the plant.

In general, the overall result of the present study showed that different planting time and potato varieties and their interaction effect significantly influenced yield and quality of potato in Anderacha area. The two earlier plantings and variety Jalene showed superior performance in most studied growth, yield and quality parameters even though variety Guidene was superior in some quality parameters. Therefore, according to the current study, early planting (October 20 up to 30) and Jalene variety can be used for better and improved marketable tuber yield and quality of potato at Aderacha area.

Future line of work

Since, the present study was done only for one season at one location; it would be advisable to repeat the experiment at different years and locations to come up with comprehensive recommendations. It appears to be worthy of conducting in-depth study on potato late blight disease using different potato varieties and fungicide combinations during the wettest months of the year (May to September) at Aderacha area.

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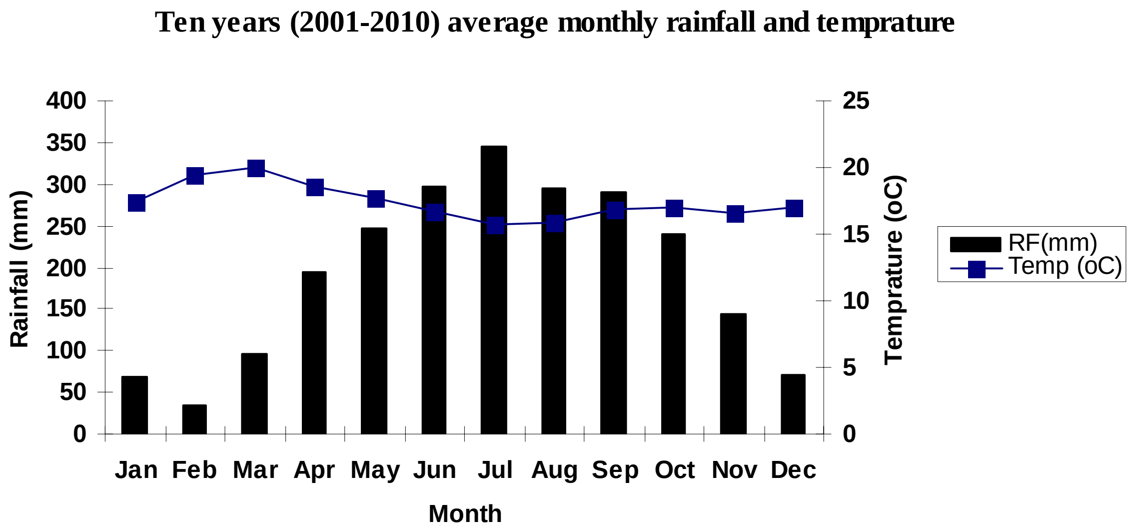
7. APPENDICES

Appendix Table 1. Rain fall and temperature of the study area during the experimental period

Month	Rain fall (mm)	Maximum T°(°C)	Minimum T° (°C)	Average T° (°C)
October				
First decade	38.7	23.09	14.12	18.61
Second decade	25.3	23.03	14.4	18.72
Third decade	32.1	23.36	13.47	18.42
Monthly total/average	**96.1**	**23.16**	**14.00**	**18.57**
November				
First decade	74.3	21.29	13.305	17.30
Second decade	53.8	22.16	13.21	17.69
Third decade	37.2	22.25	11.55	16.90
Monthly total/average	**165.3**	**21.90**	**12.69**	**17.30**
December				
First decade	65.4	24.34	12.08	18.21
Second decade	26.6	25.1	13.41	19.25
Third decade	15.6	23.83	13.45	18.64
Monthly total/average	**107.6**	**24.42**	**12.98**	**18.72**
January				
First decade	0	24.97	13.05	19.01
Second decade	26.7	24.29	13.87	19.08
Third decade	33.4	24.33	12.3	18.315
Monthly total/average	**60.1**	**24.53**	**13.07**	**18.80**
February				
First decade	26.6	27.60	14.44	21.02
Second decade	4.3	27.05	15.07	21.06
Third decade	12	27.15	15.23	21.19
Monthly total/average	**42.9**	**27.27**	**14.91**	**21.09**
March				
First decade	13.6	26.59	13.73	20.16
Second decade	23.8	25.43	13.62	19.53
Third decade	29.33	24.67	13.29	19.17
Monthly total/average	**66.73**	**25.56**	**13.55**	**19.62**

Source: - (Jimma sub-branch meteorological office, 2012).



Appendix Figure 1. Ten years (2001-2010) average monthly rainfall and temperature of the study area (Jimma sub-branch meteorological office, 2012)

Appendix Table 2. Days to emergence

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	87.79	43.89	14.43	.0012
Date of planting	4	105.20	26.30	8.65	.0015
Variety X Date of planting	8	1.33	0.17	0.05	0.99
Error	28	85.16	3.04		
Total	44	343.64			

R-Square	Coeff. Var.	Root MS	DE Mean
0.75	10.07	1.74	17.31

Appendix Table 3. Days to flowering

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	596.31	298.16	25.66	.002
Date of planting	4	1462.36	365.59	31.47	.003
Variety X Date of planting	8	65.24	8.16	0.70	0.69
Error	28	325.29	11.62		
Total	44	2465.24			

R-Square	Coeff. Var.	Root MS	DF Mean
0.87	5.63	3.41	60.49

Appendix Table 4. Days to maturity

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	2265.38	1132.69	81.41	.007
Date of planting	4	1940.98	485.24	34.88	.0061
Variety X Date of planting	8	270.62	33.83	2.43	0.04
Error	28	389.56	13.91		
Total	44	4880.98			

R-Square	Coeff. Var.	Root MS	DM Mean
0.92	3.73	3.73	101.58

Appendix Table 5. Average stems number per hill

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	0.48	0.24	2.87	0.04
Date of planting	4	14.56	3.64	43.35	<.0001
Variety X Date of planting	8	0.56	0.07	0.84	0.57
Error	28	2.35	0.08	0.12	
Total	44	17.99			

R-Square	Coeff. Var.	Root MS	SN Mean
0.87	8.01	0.29	3.62

Appendix Table 6. Average plant height

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	1209.06	604.53	52.49	.002
Date of planting	4	820.85	205.21	17.82	.0003
Variety X Date of planting	8	91.94	11.49	1.00	0.46
Error	28	322.47	11.52	12.08	
Total	44	2547.94			

R-Square	Coeff. Var.	Root MS	SN Mean
0.87	4.79	3.39	70.77

Appendix Table 7. Disease incidence

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	1538.81	769.41	44.81	.0001
Date of planting	4	9104.85	2276.21	132.56	.004
Variety X Date of planting	8	1463.67	182.96	10,66	.0021
Error	28	480.79	17.17		
Total	44	12635.43			

R-Square	Coeff. Var.	Root MS	DI Mean
0.96	19.57	4.14	21.17

Appendix Table 8. Total tuber number

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	10.87	5.43	15.58	<.0001
Date of planting	4	5.18	1.29	3.71	0.015
Variety X Date of planting	8	3.89	0.49	1.39	0.242
Error	28	9.76	0.35		
Total	44	34.05			

R-Square	Coeff. Var.	Root MS	TTN Mean
0.71	7.78	0.59	7.59

Appendix Table 9. Average tuber weight

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	2761.78	1380.89	30.63	.004
Date of planting	4	1868.18	467.04	10.36	.0061
Variety X Date of planting	8	545.86	68.23	1.51	0.197
Error	28	1262.13	45.08		
Total	44	6815.25			

R-Square	Coeff. Var.	Root MS	ATW Mean
0.81	8.95	6.71	75.04

Appendix Table 10. Total tuber yield

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	481.89	240.94	150.82	.0014
Date of planting	4	430.30	107.57	67.34	<.0001
Variety X Date of planting	8	149.41	18.68	11.69	.0023
Error	28	44.73	1.60		
Total	44	1125.82			

R-Square	Coeff. Var.	Root MS	TTY Mean
0.96	5.00	1.26	25.26

Appendix Table 11. Marketable tuber yield

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	663.95	331.98	72.54	<.0001
Date of planting	4	613.62	153.40	33.52	<.0001
Variety X Date of planting	8	140.68	17.59	3.84	0.004
Error	28	128.14	4.58		
Total	44	1588.30			

R-Square	Coeff. Var.	Root MS	MTY Mean
0.92	10.29	2.14	20.79

Appendix Table 12. Unmarketable tuber yield

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	56.48	28.23	44.95	<.0001
Date of planting	4	19.46	4.86	7.75	0.002
Variety X Date of planting	8	2.16	0.27	0.43	0.89
Error	28	17.58	0.63		
Total	44	95.69			

R-Square	Coeff. Var.	Root MS	UMTY Mean
0.82	17.58	0.79	4.51

Appendix Table 13. Harvest index

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	0.05567	0.02783	8.08	.0017
Date of planting	4	0.05569	0.01392	4.04	.0104
Variety X Date of planting	8	0.08494	0.01061	3.08	.0127
Error	28	0.09646	0.00344		
Total	44	0.30151			

R-Square	Coeff. Var.	Root MS	HI Mean
0.68	7.87	0.06	0.75

Appendix Table 14. Large tuber Percentage

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	338.05	169.02	47.50	.0021
Date of planting	4	178.22	44.55	12.52	<.0001
Variety X Date of planting	8	56.52	7.06	1.99	.051
Error	28	99.64	3.56		
Total	44	784.04			

R-Square	Coeff. Var.	Root MS	LTP Mean
0.87	16.77	1.89	11.25

Appendix Table 15. Medium tuber Percentage

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	502.01	251.01	50.44	<.0001
Date of planting	4	91.91	22.98	4.62	.0055
Variety X Date of planting	8	47.44	5.93	1.19	.34
Error	28	139.35	4.98		
Total	44	869.44			

R-Square	Coeff. Var.	Root MS	MTP Mean
0.84	3.49	2.23	63.99

Appendix Table 16. Small tuber percentage

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	1539.02	769.51	99.69	.004
Date of planting	4	383.52	95.88	5.36	<.0001
Variety X Date of planting	8	76.87	9.61	1.27	.0102
Error	28	64.05	2.29		
Total	44	2066.32			

R-Square	Coeff. Var.	Root MS	STP Mean
0.97	6.12	1.51	24.69

Appendix Table 17. Tuber specific gravity

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	0.000744	0.000372	12.67	.001
Date of planting	4	0.002596	0.000649	22.11	.0106
Variety X Date of planting	8	0.000387	0.0000484	1.65	0.16
Error	28	0.000822	0.000029		
Total	44	0.004574			

R-Square	Coeff. Var.	Root MS	DMC Mean
0.82	0.50	0.005418	1.0813

Appendix Table 18. Tuber dry matter content

Source of variation	Df	SS	MS	F Value	Pr > F
Variety	2	5.17	2.28	5.77	0.008
Date of planting	4	47.52	11.88	26.54	<.0001
Variety X Date of planting	8	2.82	0.35	0.79	.62
Error	28	12.53	0.45		
Total	44	74.37			

R-Square	Coeff. Var.	Root MS	DMC Mean
0.83	3.06	0.67	21.87