YIELD AND GROWTH ANALYSIS OF POTATO (*Solanum tuberosumL.*) VARIETIES UNDER DIFFERENT INTER ROW SPACING AT SILTE ZONE, CENTRAL ETHIOPIA

M.Sc. THESIS

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HAWASSA UNIVERSITY

COLLEGE OF AGRICULTURE

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HAWSSA, ETHIOPIA

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This is to certify that the thesis entitled "yield and growth analaysis of potato (*Solanum tuberosum L.*) cultivars under different inter row spacing, in silte zone, central Ethiopia". Submitted in partial fulfillment of the requirements for the degree of Master of Science with specialization in horticulture the graduate program of school of plant and horticultural sciences, college of agriculture, and has been carried out by Nuredin Rashid Bushira Id. No Gphortr/0004/14, under our supervision and no part of a thesis has been submitted for any other degree or diploma. The assistance and help received during the course of this investigation have been duly acknowledged. Therefore; we recommend that it be accepted as fulfilling the thesis requirements.

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As members of the examining Board of the final master open defense, we certify that we have read and evaluated the thesis prepared by entitled "YIELD AND GROWTH ANALYSIS OF POTATO (Solanum tuberosum L.) VARIETIES UNDER DIFFERENT INTER -ROW SPACING" AT SILTE ZONE, CENTRAL ETHIOPIA and recommend that it can be accepted as fulfilling the thesis requirement for the degree of Master of Science in Horticulture with specialization in Horticulture.

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I here by certify that all the corrections and recommendation suggested by the board of examiners will be incorporated in to the final thesis entitled "" By NUREDIN RESHID BUSHIRA

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DEDICATION

This thesis is dedicated to my beloved wife Zehra Kemal, and genuine friend Nassir Siraj who paved me the way towards education and for nursing me with support and love and for their wholehearted partnership in the success of my life.

DECLARATION

First, I declare that this thesis is my genuine work and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at the Hawassa University College of Agriculture and School of Plant and Horticultural Sciences and is deposited at the University Library to be made available to borrowers under rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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Signature: ___________________

This MSc equivalent thesis has been submitted for examination with my approval as thesis advisor.

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LIST OF ABBREVIATIONS AND ACRONYMS

CASCAPE	Capacity Building for Scaling up of Evidence based best Practices in Agricultural Production in Ethiopia
CGR	Crop Growth Rate
CIP	International Potato Center
CSA	Central Statistical Agency
CV	Convenient Variation
DAP	Day after plant
FAO	Food and Agriculture Organization of the United Nations,Rome, Italy.
FAOSTAT	Food and Agricultural Organizationof the United Nation Statistics
LAI	Leaf area index
LSD	Least Significant Difference
RGR	Relative Growth Rate
USPB	United States Potato Board

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ABSTRACT

YIELD AND GROWTH ANALYSIS OF POTATO (Solanum tuberosumL.) VARIETIES UNDER DIFFERENT INTER ROW SPACING AT SILTE ZONE, CENTRAL ETHIOPIA

BY Nuredin Rashid Bushira

Advisor: Dereje Haile Buko (Phd)

Potato (Solanum tuberosuml.) is a very important food and cash crop in Ethiopia. This experiment was conducted with the objective to increase production of potato through selecting appropriate varieties and determining appropriate spacing at Silte zone, central Ethiopia during belg cropping season.The experiment was arranged in a factorial combination of three inter-row spacing (60 cm , 75cm and 90 cm), and four potato varieties(Belete, Gudene, Chala and Local cultivar) in a randomized complete block design (RCBD) with three replications. Interactive effects of variety and inter-row spacing significantly (P<0.05) influenced most of the parameters considered. Days to flowering, leaf area index, total tuber number, marketable tuber number, total tuber yield, average tuber weight per plant, unmarketable tuber number and tuber yield and harvest index were significantly affected by the interaction effects of variety and spacing. Plant height, dry matter content, 90% plant maturity, crop growth rate and relative growth rate (P<0.05) influenced by the main effect variety and spacing. Days to 50% emergency, Leave number per plant and Stem number per hill were influenced only by the main effect variety. Local cultivar requiring the longest duration (101.22 days). Plant height increased significantly in to increasing inter-row spacing.Gudene varieties produced largest stems number per plant and local cultivar produced smallest stems number per plant. The highest (38.57 t/ha) total tuber yield was recorded from Gudene variety at spacing of 60 cm , whereas the lowest (22.28 t/ha) tuber yield was recorded from local cultivar at spacing 90 cm. The highest marketable (30.48a t/ha) tuber yield was obtained from Gudene variety and lowest was obtained from Local cultivar (18.41t/ha). The Crop Growth Rate values increased progressively with time reaching peak at 45-60 DAP. Therefore, from this study, it can be concluded Gudane and Belete varieties at inter-row spacing of 60 cm and 75 cm resulted in highest marketable tuber yield could be recommended to potato growers in the study area.

Keywords: Potato, Varieties, Inter row spacing, Yield

1. INTRODUCTION

Potato (*Solanumtuberosum* L.) is a root vegetable, belongs to the family Solanaceae that includes about 90 genera and 2800 species. It belongs to the genus Solanum, which presents species with different ploidy levels, varying from diploid (2n = 24) to hexaploid (6n = 72) **(**Tay Buke *et al*., 2021**)**. Rosa et *al*. (2010) noted that *Solanumtuberosum*L., which is tetraploid (4n=48), is the most commonly cultivated species. It is originated in the highlands of the Andes in South America (Asfaw, 2016) and was brought to Europe in the 16th century. The relatively high carbohydrate and low-fat content of potato makes it an excellent energy source for human consumption (Abay Ayalew and Tesfaye Dejene, 2011). In the world today, millions of people particularly, in the developing countries depend on potato production for subsistence (FAO, 2008). As a result, potato is considered as staple food crop in some countries and as vegetable in others (Zamil*et al*., 2010).

Annual world and African production of potato during 2018 about 38368.2 and 26 million tons respectively (FAO, 2020). World total area harvested in 2021 was 18,132,694 hectare (FAO, 2021).the world average production of production of potato 21 tone per hectares (FAO, 2021). In Ethiopia total land area about 70,362.2 hectares covered by potato and over one million tons of potato was produced (CSA, 2020) which average national held 13.14 ton per hectares (CSA, 2020).

Ethiopia is endowed with suitable climatic and edaphic conditions for potato production. About 70% of the available agricultural land is located at an altitude of 1800-2500 meters above sea level and receives an annual rainfall of more than 600 mm, which is suitable for potato production (Gebremedhin *et al*., 2008). Besides; potato is also suited to smallholder farmers in developing countries for the labor requirement. Its shorter growing period makes it possible for smallholder farmers to use this crop in a system where more than one crop is possible on the same land per season **(**TayeBuke *et al*., 2021**)**. Plant growth analysis, a collective technique used to quantify the components of growth such as crop growth rate, relative growth rate and tuber bulk rate . which regulate the crop yield that is a function of total dry matter production and its effective distribution on to economically important plant parts (Mbah and Eke-Okoro, 2015). These growth parameters allow describing the growth of the plant or plant organ and the relationship between the assimilatory apparatus and dry matter production (Olivera, 2000). Potato cultivars show considerable diversity in terms of growth rates, due to their genetic make-up and their interaction with the environment. Therefore, a study of dry matter production and distribution in the various plant organs during development is important to determine a cultivar's growth rate and production. For this purpose, growth analysis has been widely used to study the factors that affect the plant's production and development as the accumulation of photosynthates in time (Ascione et al., 2013).

In Ethiopia, among root and tuber crops potato ranks first in volume produced and consumed followed by cassava, sweet potato and yam (CSA, 2016). It is grown by 1,571,806 farmers, cultivating 74, 935 hectares per season with an annual production of 0.86 million tons (CSA, 2022). Four major potato growing areas (central, eastern, north-western, and southern). Ethiopia comprises approximately 83% of the potato producing farmers (Hirpa*et al*., 2010). It is cultivated by about 21, 3, 23, and 36% of potato producing farmers in central, eastern, north-western, and southern part of the country, respectively with an average yield range from 8-10, 11-13, 14.3-20.3, and 14.1-20.4 t ha^{-1} in the same order (CSA, 2017). Despite high potential production environments and marked growth, the national average potato yield in Ethiopia is 13.9 t ha^{-1} (CSA, 2018), which is lower than the experimental yields of over 38 t ha^{-1}. Many factors influence potato yield and quality such as varieties, plant population, soil type, weather conditions, water management, fertilization, seed piece size, pests and diseases (Khalafalla, 2001).

In Ethiopia, lack of appropriate agronomic techniques is known to be one of the major contributing factors to the existing low tuber yield per unit area despite the existence of highly suitable edaphically and climatic condition for potato productivity (FAOSTAT, 2008). Emerging research outcomes from various parts of Ethiopia demonstrated that plant density per a unit area is important factor that affects the tuber yield and yield components of potato (Bussan *et al*., 2007; Arega*et al*., 2018). Plant density in potato affects some of important plant traits such as total yield, the quantity of marketable tuber numbers, unmarketable tuber numbers and quality of the produced potato (Marguerite *et al*. 2006; Kinde and Asfaw, 2016), seed cost, plant development, yield and the quality of the crop (Bussan *et al*. 2007). Variation in the population causes changes in the light intensities, humidity and temperature within canopies . Too close spacing interferes with normal plants development and increases competition for moisture, mineral nutrients, and light and hinder harvest operations (Ratta*et al*., 1991) resulting in yield reduction and is also similar to decreasing the concentration of growth factors (Norman, 1992). Whereas, too wide spacing may result in excessive vegetative growth of plant and abundant weed population due to more feeding space available.

Under the aforementioned situations the optimization of plant density is one of the most important subjects of potato production management, because it affect seed cost, plant development, yield and quality of the crop (Bussan *et al*. 2007). According to Alemayehu*et al*. (2015), most of the varieties released in Ethiopia were planted at the spacing of 75 cm between rows and 30 cm between plants while CASCAPE project demonstration recommended inter row spacing of 60 cm and intra row spacing of 30 cm for optimum ware potato production (Asresie*et al*., 2015). On the other hand, farmers in Ethiopia are using different spacing below or above the national recommendation many factors including lack of site specific recommended inter and intra row spacing (Arega*et al*., 2018). Gebru*et al*. (2017) also reported that farmers at Silte areas have using low seeding rate (1.5 t/ha) than the recommended amount of seeding rate (2 t/ha) due to inaccessibility of improved seed tubers. Therefore, most of smallholder's farmers in Silte area use local cultivarvarieties in lower seeding rate than the national recommendation.

However, the choice of inter-row spacing is not related to the level of production alone, but also to the choice of potato variety to be grown. Improved potato varieties together with improved management are proved to give three to four-fold yield advantage as compared to Local varieties with traditional production management practices (Mahmood, 2005). Even though, in Ethiopia different research centers and universities have released several high yielding potato varieties, most of smallholder farmers at Silte areas have cultivating local cultivar with higher plant density per unit area. Potato is ideally suited to places where land holding capacity per household is highly limited and labor is abundant (Berga*et al*., 1994).

Alicho Wareda of Silted Zone Central Ethiopia are among the highlands of Ethiopia where potatoes are produced as a staple food and cash crop. In the Wareda, potato is the second staple food crop next to enset. According to the assessment result of Agriculture and Rural Development Office of Alicho Wareda about 30,000 tons of potato was produced in 2023 cropping season. The possibility of securing high yields depends much upon a proper consideration of optimum number of plants per unit area and the pattern in which the given quantity of seed or plant population is arranged in the field (Endale and Gebremedhin, 2001).Thus, it is important to choose and adjust variety with appropriate plant population per unit area, for a better yield, more marketable tuber size, good quality seed tuber and appropriate agronomic practices. Therefore, site specific research to study and recommend optimum inter-row spacing for different potato varieties is required to increase production and productivity.

1.2. Objective of the Study

1.2.1 General Objective

- ✓ To study the effect of varieties and inter-row spacing on the growth and yield of potato

1.2.2. Specific Objectives

- ✓ To determine optimium growth rate of potato variety under different inter-row spacing

2. LITERATURE REVIEW

2.1. Botanical Description of Potato

Potato is cross-pollinated mostly by insects including bumblebees which carry pollen from other potato plants, but a substantial amount of self-fertilization occurs as well. Potato varieties can be propagated vegetative by planting tubers, pieces of tubers cut to include at least one or two eyes and "true seeds" or botanical seeds. Its tuber is an enlarged portion of an underground steam or stolon. In many contexts, the word potato refers to the edible starchy tuber portion of the plant, but it can also refer to the plant itself. It is an annual plant that produces edible underground mature tubers that are used as vegetable (Struik&Wiersema, 2001).

Potato has a relatively shallow, fibrous root system with the majority of the roots are concentrated in the top soil surface at about 0.3 m. The root system develops rapidly during early growth and achieves maximum development by mid-season. Thereafter, root length, density and root mass decrease as the plant matures. The flowers produced in clusters or cymes are yellow, white, red, blue, pink or purple with yellow stamens, but are rarely produced under conditions in which day lengths are short and temperatures are high. In general, the tubers of varieties with white flowers have white skins, while those varieties with colored flowers tend to have pinkish skins (Winch, 2006). The fruits are globular berries and contain poisonous alkaloids (Solanine).

The stem is angular, branched and bears compound, alternate leaves up to 30 cm long. Its compound leaves manufacture starch that is transferred to the ends of its underground stems (or stolons). The stems thicken to form a few or as many as 20 tubers close to the soil surface. The number of tubers that actually reach maturity depends on available moisture and soil nutrients. Tubers may vary in shape and size, and normally weigh up to 300 g each. At the end of the growing season, the plant's leaves and stems die down to the soil level and its new tubers detach from their stolons. The tubers then serve as a nutrient store that allows the plant to survive the cold and later regrow and reproduce. Each tuber has from two to as many as 10 buds (or "eyes"), arranged in a spiral pattern around its surface. Eyes concentrated near the stolon or basal end. Eye number and distribution are characteristic of the variety . The buds generate shoots that grow into new plants when conditions are again favorable.

2.2. Importance of Potato

Potato is one of the most important food crops in the world after rice and wheat (Vleeshouwers*et al*., 2011). Currently, potato is produced in more than 100 countries and consumed by over a billion people worldwide. Potato is called the hunger breaker crop as it has a short crop cycle (<120 days) compared to cereal crops like maize. It is regarded as a high-potential food security crop because the crop produces large quantities of dietary energy (30 to 35 t/ha starch based produce in 3 to 4 months) and has relatively stable yields under conditions in which other crops may fall (Gebremedhin*etal*., 2008; FAO, 2010).

It represents an important component of human diet, because tubers are able to supply several nutrients, such as essential amino acids, vitamins (as vitamin C) and minerals (Melito*et al*., 2017). Potatoes are approximately 80% water and 20% solids, although this can vary by several percentage points depending on the variety . Of the 20 grams of solids in a 100 gram tuber, about 18 grams are carbohydrate and 2 grams protein. It should become one of the main nutritional components, since it is a rich source of energy and valuable food. Experts of the Food and Agriculture Organization of the United Nations called people's attention to nutritional and wholesome properties of potato, for its proteins are very valuable and one middle-sized potato covers half the daily requirement for vitamin C and one-fifth of the requirement for potassium (Ceglarek and Zarzecka, 2003).

Potato has a very high satiety index compared to foods with an equivalent carbohydrate content and this represents a very positive aspect of potato nutrition. According to FAO report, potato is a staple food for more than 600 million people who live in sub-Saharan Africa . The crop particularly has potential for fertile and waste land where other crops could not survive, to help overcome food shortage (Gebremedhin*et al*., 2013).
The high nutrient content, ability to adapt to marginal environments, relatively ease of cultivation, and low cost and high productivity are attributes that make potatoes one of the principal and most important sources of food and income for underprivileged citizens of developing countries around the world.

Potato is primarily grown for its starchy tuberous root; its flour can be produced for soup, biscuits, bread, and chips. The leaves used as animal feed in the developing countries. In

Ethiopia, potato production could fill the gap in food supply during the hungry months of July to August before the grain crops are being harvested.

2.3. Climatic Requirements for Potato Growth

Knowing about climatic requirements of potato and its physiological responses to the environment is extremely important to help growers produce high yields with good tuber quality under site-specific conditions.

The potato is essentially a "cool weather crop", with temperature being the main limiting factor. In tropical areas, potato should be grown where the climate is tempered by altitude (1500 – 4200 masl) or at lower altitudes provided that the crop is grown during the cool season. The ideal condition for tuberization is a night temperature of around 16°C, while tuber growth is sharply inhibited in temperatures below 10°C and above 30°C, while optimum yields are obtained where mean daily temperatures are in the 18 to 20°C range. The growth rate decreases with increasing temperature above 21°C and finally stops at 30°C.

The potato can be grown almost on any type of soil, except saline and alkaline soils. Naturally loose soils, which offer the least resistance to enlargement of the tubers, are preferred, and loamy and sandy loam soils that are rich in organic matter, with good drainage and aeration, are the most suitable. Soil with a pH range of 5.2-6.4 is considered ideal. Planting on poorly drained soils usually results in a poor plant stand due to seed piece decay and poor-quality potatoes at harvest. Potatoes are less susceptible to scab when soil pH is between 5.0 and 6.5. If pH is too low, apply dolomitic limestone. Better tuber yields have been obtained from potatoes grown at soil reaction ranging from pH 5.0 to 7.0 (AGRISNET, 2010).

The root system of the potato plant is not extensive and ample soil water is necessary whether from rain or supplemental irrigation. Good water penetration and aeration are musts for proper growth and tuber formation. Excessive tillage and land preparation cause compaction and should be avoided. To be effective, the soil should be plowed below any compacted layer within the normal root zone, and then disk harrowed before planting. Spike-tooth harrowing to break up clods and level the soil may be needed just prior to planting.

2.4. Effect of Inter-Row Spacing on Growth of Potato

Potato is heavy nutrient feeder crop and the nutrients have an important role in improvement of productivity and quality of vegetable crops. Inter-row spacing is an important factor determining potato yield and component. The growth rate of a potato crop depends on well supplied with water and nutrients and free from pests and diseases are about proportional to its light absorption (Van Delden, 2001).Plant growth analysis is usually based on total land, plant parts dry matter, size and numbers of different parts per plant or per sample and number of shoots per unit ground area. From these values growth characteristics (various indexes, ratios and coefficients) are calculated. These growth characteristics allow describing the growth of the plant or plant organ and the relationship between the assimilatory apparatus and dry matter production (Sands *et al*., 1983).

More space meant that plants were able to exploit the available nutrients in the soil and the photosynthetic active radiation for growth than plants at close spacing. In other words, the growth rate was increased. Van der Zaag*et al*. (1990) studied the response to plant population under two different sites; one temperate and the other tropical. At the temperate site, closer spacing increased plant height. At the tropical site, closer spacing decreased plant height when canopy cover did not reach 100%.

2.5. Effect of Inter-Row Spacing and Density on Yield of Potato

Plant density is the number of plants per unit area and is inversely related to the distance between plants within a row. Altering plant density and row spacing changes the radiative transport within the canopy (Geremew *et al*. (2010)). In crop production, canopy development is very important to optimize light interception, photosynthesis and dry matter accumulation to harvestable parts. So crop canopy can be managed by alternating row spacing and plant population; as the plant density increases, yield per unit area also increases on onion crop (Silvertooth, 2001).Average tuber weight and tuber number are reported to be an important components determining tuber yield of what? (Elfinesh, 2008). Geremew*et al*. (2010) explained that spacing has effect on different variety as their root and leaf growth habits. The optimum use of spacing or plant density has dual advantage. It avoids strong competition between plants for growth factors such as water, nutrient and light. In addition optimum plant population enables efficient use of available crop land without wastage.

Bussan *et al*. (2007) found that optimizing plant density was one of the most important practices in potato production management, as it affects seed cost, plant development, yield and the quality of the crop. According to Georgakis*et al*. (1997) report, when increasing plant density, the tuber yield was also increased.

Plant density strongly affected yield, both by number and by weight, and more tubers and yield per square meter were expected in higher plant densities (Karafyllidis*et al*., 1997). According to Alvin *et al*.(2007) report with increasing plant density, yield of potato increased. On the other hand, increase in plant density, probably is the reason of the lack of nutrient elements for each plant or production of more tubers per unit area and reduction of their mean size. Increase in plant density decreases mean tuber size probably because of plant nutrient elements reduction, increase in interspecies competition and large number of tubers produced by high numbers of stems (Khajehpour, 2006).

Mauromicale *et al*. (2003) concluded that when reducing plant population the yield was increased. Work by Güllüoglu and Arioglu (2009) revealed that major yield components; mean tuber weight and tuber yield per plant, significantly decreased as planting distance got closer due to increasing inter-plant competition. Increase in plant density enhances the marketable yield than the total yield. Khalafalla (2001) attributed this to increased number of tuber per unit area, more tubers per plant required. In a study by Masarirambi *et al*. (2012), yield was not affected by population density although they did not examine the tuber size distribution which would have shown an increase in smaller tubers with increased plant population. The high number of tubers at high densities may be accounted for by the fact that at low density plantings, fewer sinks are produced per unit area and increase as the planting density increased. This is in contrast with Masarirambi *et al*. (2012); Güllüoglu and Arioglu (2009) who explained that the availability of space had an effect on number of tubers formed, that the greater the space, the higher the number of tubers was formed.

2.6. Response of Potato Varieties of Inter-Row Spacing

Endale and Gebremedhin (2001) stated that the benefits from optimum combination of plant population and spatial arrangement to optimize tuber size, and in turn, revenue and then making appropriate spacing of the seed tubers is an essential factor to economic productivity.

Competition occurs when two or more growing in an environment and the combined demands of the plants exceed the supply of one or more of the limiting factors for growth and development (Winch, 2006). In extreme cases of a crop growing in the absence of competition, its individual yield gives an indication of the maximum yield possible per plant.

Potato varieties do differ in the production of leaves at low temperatures in such a way that horizontal leaves intercept lighter than erect leaves at low lAI, and most varieties differ considerably in this character. According to Damavandi and Asle- Gorgani (2005), the number of stems per plant at maturity, stem and leaf dry weight at maturity, and tuber dry weight compared to shoot dry weight were significant at 0.05 due to variety and plant density. A significant difference has been reported among variety in plant height, number of branches, leaf area, tuber number and tuber weight (Alsharari*et al*., 2007). Abong*et al*. (2010) also reported that specific gravity; dry matter content differed significantly among the different potato variety . Potato crop growth and tuber yields have been linked to the duration of the growth cycle, which depends on climate, variety , and crop management (Kooman*et al*., 1996a, 1996b). Saluzzo*et al*. (1999) also reported that variety with higher average tuber weight in addition to its late maturity might also be more efficient in dry matter partitioning to tubers than variety with lower average tuber weight.

2.7 Effects of Varieties and Inter Row Spacing on Growth Rate and Retaltive Growth Rate

Plant growth analysis, a collective technique used to quantify the components of growth such as crop growth rate, relative growth rate and tuber bulk rate . which regulate the crop yield that is a function of total dry matter production and its effective distribution on to economically important plant parts (Mbah and Eke-Okoro, 2015). These growth parameters allow describing the growth of the plant or plant organ and the relationship between the assimilatory apparatus and dry matter production (Olivera, 2000). Research on potato cultivars is usually limited to analyzing differences in tuber yield, yet rarely do such analyses seek to account for the origins of such differences. For an optimum use of natural resources, an explanation for the production differences is important both for physiologists and agronomists (Borrego et al., 2000) to obtain useful information for the choice of genotype and the most appropriate agronomic practices to adopt. Potato cultivars show considerable diversity in terms of growth rates, due to their genetic make-up and their interaction with the environment. Therefore, a study of dry matter production and distribution in the various plant organs during development is important to determine a cultivar's growth rate and production. For this purpose, growth analysis has been widely used to study the factors that affect the plant's production and development as the accumulation of photosynthates in time (Ascione et al., 2013).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The field experiment was conducted under rainfed conditions during the year 2024 main cropping season in Alicho werada, at Silte Zone, Central Ethiopia. The experiment was carried out on a farmer's plot (farm) during belg season. The altitude of alicho district is 2560-3262 meters above sea level and the mean annual rainfall ranges from 750 mm-1350 mm with mean annual temperature of 7.5 ^{o}C-24 ^{o}C.The soil type of the study area is characterized by Nitisol and the soil pH range 4.85-5.89 . with low content of organic carbon (OC) (1.5-3.01 %). The soil types of the study area is 58% clay soil,30% silt soil and 11.8% sand soil.(Eyob *et al*., 2015).

3.2. Experimental Materials

Three improved potato varieties ('*Belete*', '*Gudene*'and '*Chala*') and one local cultivar was used in this study. Seed tuber was one year old having at least five active buds and well prepared for seed purpose. Potato seed tuber used in the experiment was collected from Holata agricultural research center and Haramaya University (Table 1).

Table 1**.** Description of studied varieties

№	Name of variety	Year of release	Yield of Research center	Maturity days	Breeder/ maintainer	Recommended altitude (m.a.s.l)
1	Belete	2010	47.2 t ha^{-1}	110	Holeta research center	1600-2800
2	Gudene	2006	39.85 t ha^{-1}	120	Holeta research center	1600-2800
3	Chala	2004	27.68 t ha^{-1}	96	Haramaya University	1700-2000
4	Local	Na	Na	Na	Farmers	1800

Sources: Habtomu g. et al. (2016), MANR (2016)

3.3. Treatments and Experimental Design

Three levels of inter row spacing (60, 75, and 90 cm) by 30 cm of intra-row spacing, and four potato varieties (Belete, Gudene, Chala and Local) was arranged in 3 x 4 factorial arrangement in Randomized Complete Block Design (RCBD) replicated three times. Each experimental unit was planted on plot area of 3.6 m length and 2.7 m width with a total net area of 9.72 m^2. Each experimental unit length was divided in to four, five and six rows at 90 cm, 75 cm and 60 cm intervals, respectively. The space between plots and block was one.

3.4. Experimental Procedures and Agronomic Practices

The experimental land is well prepared using tractor and manually using human labor. Each row was opened at 20 cm depth (i.e. average plough layer) and seeds were planted as per the treatments in march /2024. All treatments were fertilized with recommended rate of 236 kg NPS ha^{-1}, 194 kg urea ha^{-1} **(**Taye *et al*., 2021**)**. The entire rate of NPS and the half rate of the urea fertilizer were applied at the time of planting, while the remaining half of the urea was applied at flowering stage. Cultural practices such as cultivation, ridging and weeds were carried out as per the research recommendation required for potato production.

3.5. Data Collection and Measurements

3.5.1. Phenology and Growth Related Traits

Date to emergence: -the number of days from planting to 50% tuber seed emergence was recorded each plot.

Days to 50% flowering: - the number of days from planting to 50% flowering was recorded in each plot.

Leaves number per plant:- was counted from the five plant (hill) taken at random in each plot before start tuber Initiation.

Days to maturity: -the number of days from planting to maturity were recorded when 90% of the plants in each plot become ready for harvest as indicated by the senescence of the haulms.

Number of stems/hill: -the average number of five randomly selected plants main stems from the middle rows were counted and recorded from each plot.

Plant height (cm):- the average of five randomly selected plants height from base of the stem to shoot apex was measured and recorded at flowering stage**.**

Growth analysis: -Growth analysis is a mathematical expression of environmental effects on the growth and development of crop plants.It helps is studying the complex interactions between the plant growth and environment. it was carried out by destructive sampling of plant with sequential harvesting at fifteen days interval by random sampling of five potato plant of each plot. The samples were randomly uprooted within the inner rows of the plot at

30, 45, 60, 75, 90, and 105 days after planting (DAP). Total plant biomass was separated in to leave, stem, root and tuber. fresh weight of tuber was taken with electric balance. For dry matter estimation of each biomass group except tuber, the sample was kept in the oven. The temperature of oven was sated at 65 ^{c} and that was dried until a constant weight obtained. The final weight of the dried sample was taken by electric balance. Growth parameters such as crop growth rate (CGR), relative growth rate (RGR) was calculated using the formulae given by Gardner *et al.* (1985).

Crop growth rate**:**It measures the rate at which a crop gains biomass over a specified period. It is expressed as an increase in weight or size per unit area, typically in kilograms per hectare per day (kg/ha/day) or equivalent unit.

Crop growth rate :- $$\mathbf{CGR} = \frac{1}{\mathbf{GA}} * \frac{W2-W1}{T2-T1} gm-2\ day-1$$

Where, W_1 = dry weight (g) at time T_1, W_2 = dry weight (g) at time T_2 and GA = ground area or land area (m^2).

Relative growth rate:- $$\mathbf{RGR} = \frac{LnW2 - Ln\,W\,1\,mg\,g{-}1\,day{-}1}{T2-T1}$$

Where, W_1 = dry weight (g) of plant at time T_1, W_2 = dry weight (g) of plant at time T_2 and Ln = natural logarithm.

It is calculated by dividing the tissue on dry weigt bases over a specific period by its initial dry weight and then dividing the result by the period.

Leaf area index (LAI): - it was recorded from five randomly selected plants in each plot from each plot and the areas of three sample leaves were taken from upper, middle and lower portions of the plant was measured by using a meter for each plant. Leaf area was calculated by W x L x 0.674. Where 0.674 is the correction factor (Djilani and Senoussi, 2013). Leaf area index was calculated by dividing total leaf area to the respective land area occupied by the plants.

3.5.2. Tuber Yield, Yield Components and Quality

Total tuber yield (t/ha): - the total tuber yield were recorded by adding up the weights of marketable and unmarketable tubers and converted to total yield per hectare.

Average tuber yield (g/plant): Mean weight of marketable and unmarketable tubers produced from middle row was recorded after harvest and expressed in gram using a sensitive balance.

Marketable yield (t/ha): -Average of randomly selected five plants of tubers greater than or equal to 20g in weight and healthy were weighed in kg/plot and converted into t/ha.

Non-marketable tubers (t/ha-1): - Average of randomly selected five plants of tubers which are less than 20 g, rotten and greened were measured and recorded at harvest time.

Total tuber number (t/ha-1)): - **T**he total tuber number (marketable and non-marketable) of harvested tubers were counted per plot and converted to total tuber number per hectare were recorded.

Average tuber number per plant: It was measured marketable and unmarketable after harvest and expressed as number of tubers per plant.

Number of marketable tubers randomly selected five plant tubers per plot which are tuber size greater than 20g was measured and counted and converted in to hectare at the harvesting stage.

Number of unmarketable tubers (ha-1): - randomly selected five plant tubers per plot which are under-sized tubers (<20 g) as well as diseased, cracked and rotten were measured and counted at harvest time converted into t/ha.

Dry matter (%): five fresh tubers randomly selected in each plot and weighed. Tubers were sliced and dried in an oven at 70°C until constant weight. Dry weight was recorded and dry matter percent was calculated according to as:

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

Harvest index (HI): It was determined as the ratio of dry weight of the tubers to the dry weight of the total plant biomass measured from five randomly taken plants at harvest, and this can be used as a measure of reproductive efficiency.

3.7. Data Analysis

Data on different parameters were subjected to Analysis of Variance (ANOVA)using SAS Computer software version 9.0 (SAS Institute Inc., 2008).When ANOVA showed significant differences for the measured traits, mean separation was carried out using Least Significant difference(LSD) test at 5% level of significance.

4. RESULTS AND DISCUSSIONS

4.1.Phenological Parameters

4.1.1. Days to 50% Emergency of Seed Potato

Days to 50% emergency of seed potato shown a significant ($P < 0.05$) difference among the varieties but not for inter row spacing and its interaction with potato varieties (Table 2 and Appendix 1).local cultivar took significantly longer days to 50% emergency (18.78 days) while variety Chala took the shortest days to its 50% emergency (13.3days). Variation in seed potato emergency may be governed by genetic factors, the locations where the varieties are grown and the agronomic management such as nutrient supply. Moreover, different varieties had different capacity to store food and to provide an optimal supply of carbohydrate for the emerging seedling of embryo. The result is in agreement with the findings of Abubaker *et al.* (2011) who reported that the genetic variation could be attributed to the differences in emergency percentage among varieties. Variation in days to emergence in potato tubers due to variety difference might be governed by the expression of its genetic factors through its nutrient supply. This suggestion is supported (Taye et al., 2021). reported that a significant difference between varieties for the phenology of potato. also noted that different cultivars had different capacity to store food and to provide an optimal supply of carbohydrate for the emerging seedling.

4.1.2. Stem number per hill

The results of the present study showed that main effect of variety showed highly significant ($P < 0.01$) difference on the stem number of potato whereas inter-row spacing and its interaction with varietys showed no significant difference (Table 2 and Apendix 1). Variety Gudene recorded highest stem number (6.17) and lowest stem number (3.9111) was recorded from local cultivar. Gudene produced 36.30% and 28.06% more stems per plants compared to local cultivar andl Chala varieties, respectively. This difference could be due to the inherent variations in the number of buds per tuber of each variety. The potato crop is usually propagated by using underground storage organs known as tubers. Potato tubers show a wide range of variation and possess a variable number of growing points (buds) arranged in groups (eyes) over their surface. This difference could be due to the inherent variations in the number of buds per tuber of varieties used for the study as reported by Taye et al. (2021). Shayanowako et al. (2015) also stated that the main stem numbers depend on seed bed conditions, planting method and seed tuber characteristics such as number of eyes or sprouts, tuber size, physiological age and varieties. These buds arranged in groups are responsible for emerging sprouts and stem numbers per plant. Different scholars reported that the stem number is the reflection of different factors, such as storage condition (Islam, 2006),. The number of stems per plant had direct relation with the number of sprouts per tuber not on the treatment applied (Abebe *et al*., 2010) and the sprouts are the function of number of eyes on tubers. The result is in agreement with (Frezgi, 2007; Harnet, 2011,) who reported that the number of stems per hill was not influenced by plant density rather it is influenced by variety.

4.1.3. Leave Number Per Plant

The results of the present study showed that the main effect of variety had highly significant ($P < 0.01$) difference on the leave number of potato whereas inter-row spacing had no significant difference on this parameter (Table 2 and Appendix1). The maximum (49.87) and minimum (38.48) leaves number per plant was recorded from the Gudene variety and local cultivar, respectively. The significant differences in leave number per plant due to the varieties may be attributed to genetic differences. Accordingly, Gudene produced 22.8% ,16.3% and 7.8% more leaf number than local, Chala and Belete, respectively variety. Treatment with the highest leaf number produced the highest total tuber yield. This may be attributed to an increased leaf area index they increase in the number of leaves per plant. This result is corroborated by that of Winkler (1971), who reported that leaf numbers of potato influence light interception and season on potato growth and yield. The rate of gross photosynthesis is almost proportional to leaf number per plants. The leaf number per plant was highly significantly and positively associated with total tuber yield and total tuber number. Increase in the number of leaves per plant, increase biomass and increased tuber yield and number in potato production. This indicates that an increase in leaf numbers per plant results in high yield of potato tubers.

Table 2. Main effect of variety and inter-row spacing on days to 50% emergence, stem number and leave number per plant of potato ilte zone centeral Ethiopia 2024 cropping season

Treatment/ Variety	Days to 50% Emergence	Stem member per plant	Leaf number per Plant
Belete	16.78^{b}	5.97^{a}	45.96^{b}
Gudene	16.45^{b}	6.17^{a}	49.87^{a}
Chala	13.34^{c}	4.45^{b}	41.74^{c}
local cultivar	18.78^{a}	3.91^{c}	38.48^{d}
LSD(0.05)	**1.0104**	**0.27**	**0.95**
CV%	**6.32**	**5.51**	**2.56**

Means with the same letter(s) within a column are not significantly different at 5% level of significance. LSD (5%) = Least significant difference at P=0.05, and CV (%) = Coefficient of variation percentage

4.1.4. Plant Height

Analysis of variance showed plant height was significantly ($P<0.05$) affected by the main effects variety and spacing. But their interaction was not significantly affected the plant height (Table 3 and Appendix, 4). Significantly ($P< 0.05$) the highest plant height was recorded from variety Gudene (81.78 cm) and Belete (80.15 cm) with statistical parity while the lowest plant height was recorded from local cultivar (62.43 cm). The significant differences in plant height due to the varieties may be attributed to genetic differences. This suggestion is in accord with Singh and Singh (1973) who reported that plant height is a quantitative trait controlled by many genes. Plant height increased significantly in response to increasing inter-row spacing.

Wider planting space encouraged longest plant height and narrower planting spacing resulted in shortest plant height . Plant height was decreased as plant density increase. This decreasing in plant height with increased plant density is consistent with the results of Zamil et al. (2010) who reported that the wider spacing enhances growth and height of the plant. Frezgi (2007) also noted that increasing inter-row spacing resulted in significant increase in pant height. The result was also agreed with the finding of Kantona et al., (2003) on onion and Wolde Mariam (2009) on ginger. This is could be due to that plants at wider spacing practiced less competition for growth resources such as water, light and nutrients and grow more vegetatively whereas, plants that exhibit intense competition decreased in heigh.

4.1.5. Days to 50% Flowering

Interactive effects of variety and inter-row spacing significantly ($P<0.05$) influenced the days to flowering (Table 4 and Appendix 1). All varieties had taken long days to flowering at wider inter-row spacing (90 x 30 cm). In all the varieties, the days to flowring increases as plant interrow spacing increase from 60 – 90 cm . The longest days (65.67) to followiring was recorded from local cultivar inter-row spacing of 90 x 30 cm followed by variety Belete (62.00), and Gudene variety (60.34), respectively. The shortest days (53.34 days) to flowering was obtained from Chala variety (90 cm) inter-row spacing. This might be due to the difference in environmental adaptability among varieties and their genetic factors. The variation in days to flowering of potato varieties were reported by many studies**.** Vreugdenhil (2007) stated that days required to flowering is highly dependent on genotypes and governed by many environmental factors (mainly temperature and light). Similary results was reported by Arega et al. (2007) who also suggested the variation between varieties in respect to days to 50% flowering this is due to gene factors and environmental factors. Variation among varieties might be due to the fact that flowering is controlled by various factors including genetic and environmental factors.

The current result is compatible with the findings of Chala & Dechasa (2015). On the other hand, as planting density increased, the date of 50% flowering decrease/shortened.. This might be due to the fact that at higher planting density, plants compete for available resource, which enhance early flowering compared to lower density. The result of this finding was in line with the findings of Takele et al. (2017) who reported that the closer intra- and inter-row spacing leads the plants to stress and ultimately the plants early flowering instead of prolonged vegetative growth. On the contrary, Bikila et al. (2014) reported that plants at closer spacing compete for the available light and may remain in a vegetative stage for a longer period of time than plants grown in a wider spacing. This might be due to the difference in environmental adaptability among varieties and their genetic factors. Vreugdenhil (2007) stated that days required to flowering is highly dependent on genotypes and governed by many environmental factors. The mean longest days to flowering obtained for all varieties is (90 cm) at wide spacing (90 x 30 cm), whereas the mean shortest days to flowering is (60 cm) obtained at narrower spacing (60 x 30 cm)   inter-row spacing. This is probably due to tuber planted a wider space got sufficient light and nutrient that hinder the transition of vegetative stage to the reproductive stage than those planted in a closer spacing. Plants in a closer spacing may compete for the available light and nutrients this might be lead them to transacted rapidly to reproductive stage than plants that does not compute for light and nutrients. This result in-agrees with (Sadik *et al*., 2018; El-Naim, 2003) who reported that closer spacing could reduce vegetative growth and enhances flower formation on potato and shorten days to 50% flowering.

4.1.6. Days to 90% Maturity

The main effects of variety and inter row spacing showed highly significant ($P < 0.01$) effect on days to maturity of potato while its interaction was not significant. (Table 3 and Appendix Table 1). The mean shortest and longest days to maturity was 86.11 days and 101.22 days after planting for all the varieties studied.

The longest days to maturity (101.22) was recorded from local cultivar while the shortest (86.11 days) was from Chala. This might be due to the fact that maturity period is dependent on the variety and climatic conditions. This is in agreement with the report of Musa *et al*. (2007) who noted that the maturity is a varietal characteristic which of course can be influenced by planting date, climatic condition and adopted cultivation practices. The results of this study also agrees with report of Tekalign (2005), who reported that potato growth depends on varieties and environmental factors. EARO (2004) also stated that days to maturity of potato varieties varied from 90 to 120 days and the variation is accounted for by variety, growing environment and cultural practices. The number of days to reach maturity is the important parameter for potato producers in that, it enables the growers to develop a suitable production calendar, as well as the marketing plan (Khalafalla, 2001). Variation in days to maturity among varieties could be due to genetic and environmental factors. Bekele (2018) also reported that maturity is a varietal characteristic that can be influenced by planting date, climatic conditions, and adopted cultivation practices. In relation to planting density, 90% of physiological maturity dates increase with decreasing planting density. This result is also in agreement with the finding of Tesfaye et al. (2012) who obtained the shortest days to maturity from closer intra-row spacing.

On the other hand, the earliest days (92.91) to maturity was recorded at closer spacing (60 x 30 cm) whereas prolonged days (97.33) to maturity were recorded from wider spacing (90 x30 cm). Increasing inter-row spacing delayed the time required to reach maturity. Rapid maturity in response to closer planting space is an indicator of competition for growth factors while at wider spacing the competition is less which favor growth and extend days to maturity. The current finding is in agreement with Mengistu and Yamoah (2010) and Birhanu *et al*. (2016) who reported that increasing plant density had shortened days to maturity. Similarly, Harnet (2011) reported that wider inter-row spacing not only delayed maturity but also caused total yield reduction in broad area of land.

4.1.7. Leaf Area Index

Interactive effects of variety and inter-row spacing significantly ($P<0.05$) influenced the leaf area index (Table 4 and Appendeix 2). For all the varieties tested, the highest leaf area index was obtained spacing of 60 x 30 cm. The highest (5.16) leaf area index were recorded from Gudene variety at inter-row spacing (60 x 30) and the lowest leaf area index (1.79) were recorded by local cultivar at planted at spacing of 90 x 30 cm. Leaf area index indicates the level of photosynthesis and accumulation of starch for partitioning to tuber at the end of the growing season. Leaf area index can vary widely according to growing conditions and variety which is in agreement with the report of Allen *et al*. (1992). Ronald (2005) who revealed that the highest density increased leaf area index, possibly indicating potential partitioning of assimilates for vegetative growth. According to Ravichandran and Singh (2003), LAI in potato increased with decreasing inter-row spacing.

Table 2. Main effect of variety and inter-row spacing on, plant height and days to 90% maturity (DM) in at Silte zone centeral Ethiopia 2024 cropping season.

Variety	Plant height(cm)	Days to 90% maturity
Belete	80.15^{a}	97.23^{b}
Gudene	81.78^{a}	94.78^{c}
Chala	69.25^{b}	86.12^{d}
Local	62.43^{c}	101.22^{a}
LSD(0.05)	1.8208	2.001
Spacing		
60*30	71.4375^{b}	92.9167^{b}
75*30	72.9292^{b}	94.25^{b}
90*30	75.84255^{a}	97.3333^{a}
LSD(0.05)	**1.5769**	**1.7329**
CV %	**2.5372**	**2.1583**

Note. *Means with the same letter(s) within a column are not significantly different at 5% level of significance. NS = non-significant difference, LSD (5%) = Least significant difference at P=0.05, and CV (%) = Coefficient of variation in percent. PH,DM*

Table 3.The interaction effect of variety and inter-row spacing on days to 50% of flower and leaf area index at Silte zone, central Ethiopia in 2024 cropping season.

Variety	Spacing in (cm)	days to 50% of flowering	LAI
Belete	60*30	53^{e}	5.03^{a}
	75*30	56^{c}	4.05^{b}
	90*30	62^{b}	3.40^{dc}
Gudene	60*30	48.34	5.16^{a}
	75*30	56.34^{dc}	4.18^{b}
	90*30	60.34^{b}	3.47^{c}
Chala	60*30	43.34^{g}	3.23^{d}
	75*30	47.34^{f}	2.68^{e}
	90*30	53.34^{e}	2.24^{f}
Local	60*30	54.67^{de}	2.44^{f}
	75*30	61^{b}	2.4^{f}
	90*30	65.67^{a}	1.79^{g}
LSD(0.05)		1.992	0.2178
CV%		2.092	3.898

4.2. Crop Growth Rate (g m^{-2} Day^{-1}) .

The CGR explains the dry matter accumulated per unit land area per unit time (g m-2 day-1).Defined as the increase of dry matter in grams per unit area per unit time. The main effects of variety and inter row spacing showed highly significant ($P < 0.01$) effect on crop growth rate while its interaction was not significant (Figure 1,). Significant variation in CGR value was observed among the varieties at all the growth stages and inter-row spacing. The CGR values increased progressively with time reaching peak at 45-60 DAP. The maximum (10.85) CGR was obtained from variety Gudene at 45-60 DAP followed by Belete (9.09) and local cultivar (7.3388) respectively. Chala variety which recorded the highest value of CGR only at 30-45 DAP (7.51).

At 30-45 DAP, the highest CGR was obtained by Chala variety (7.51 g m-2 day-1) followed by Gudene variety (6.67 g m-2 day-1) and Belete (6. g m^{-2} day^{-1}), while the lowest was obtained from local cultivar (5.15 g m-2 day-1). Chala variety CGR was started to decrease at 45-60 DAP stages. But all other variety CGR was started to decrease at 60-75 DAP. At 60-75 DAP growth stage, Gudene variety gave highest CGR, followed by variety Belete and local cultivar (9.32), (8.95) and (6.71) respectively. Chala variety gave the lowest CGR values (5.26 g m-2 day-1) at 60-75DAP growth stage. The decrease in CGR at the early of growing season indicates that the crop had an early maturing tendency. From this it may be interpreted that variety Chala had early maturing tendency, but the rest three Varieties Gudene, Belete and local had late maturing. Similar results were reported by Mahmud (2012) and Esfahai et al. (2012). At later stages, CGR value slowed down because of reduction in absorption of solar radiation and leaf falling (Borrego et al, 2000). Tthe early maturing varieties reached maximum during the early growth.

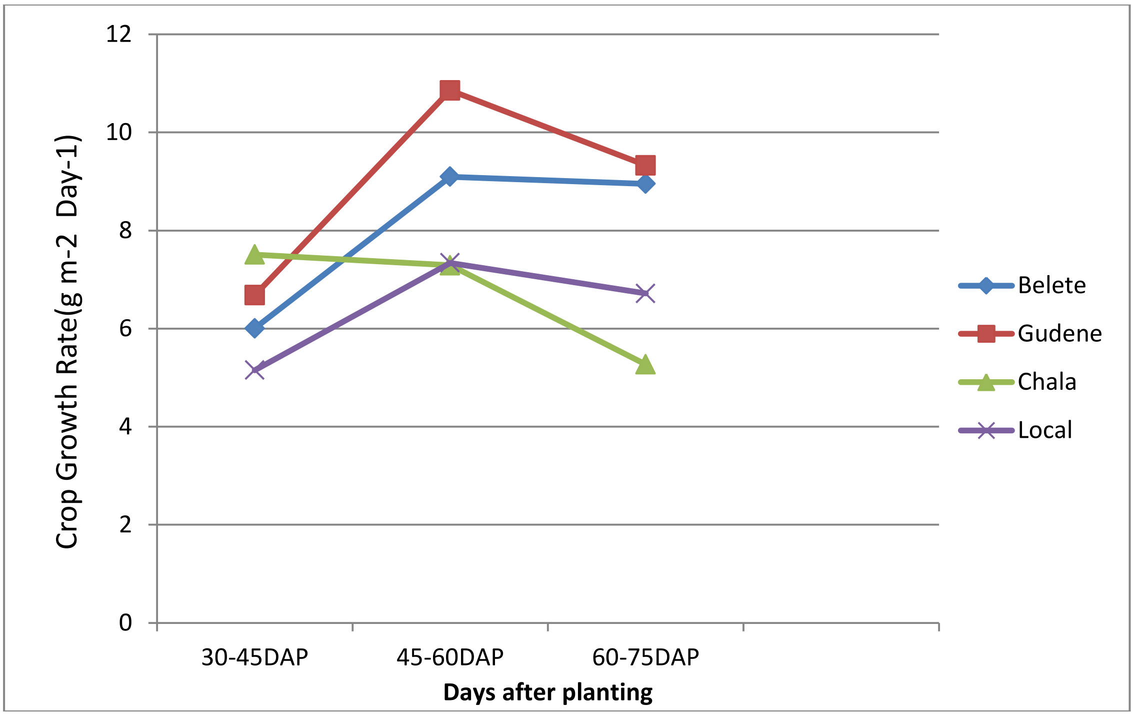

Figure 1. Crop growth rate of four potato varieties at different days after planting

Crop growth rate of potato increased with decreasing inter-row spacing (Figure 2). The highest crop growth rate was recorded by narrow inter-row spacing(60cm) at all growth stage and lowest crop growth rate was obtained by wider inter-row spacing (90cm) at all growth stage .

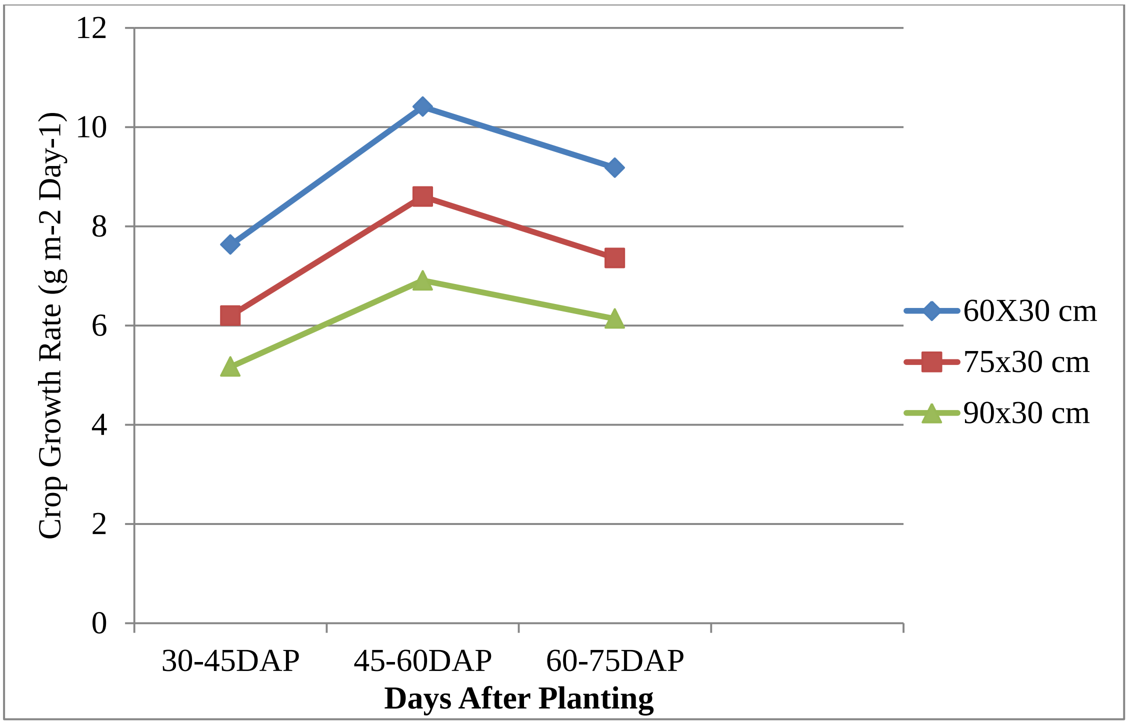

Figure 2. Crop growth rate at different inter-row spacing at different days after planting

4.3. Relative Growth Rate (Mg G- Day-1) .

Relative Growth Rate (RGR) expresses the total plant dry weight increase in a time interval in relation to the initial weight.Defined as dry matter increment per unit biomass per unit time. Expressed as unit dry weight / unit dry weight / unit time (g /g /day).

The main effects of variety and inter row spacing showed highly significant ($P < 0.01$) effect on relative growth rate while its interaction was not significant (Figure 3). The relative growth rate (RGR) of four potato varieties were studied during the growth stages from 30 to 75 DAP. Significant variation was observed in RGR value among the varieties at all the growth stages from 30 DAP to 75 DAP, respectively. The RGR values were higher in earlier season and showed a decreasing trend as the crop advanced in age. The values of RGR were attained maximum at 30-45 DAP stage for all the varieties. At this stage the highest RGR value was obtained from local cultivar (44.75 mg g-1 day-1) followed by variety Gudene variety (41.16 mg g-1 day-1) and variety Belete variety (33.93 mg g-1 day-1), while the lowest was from Chala variety (33.5 mg g-1 day-1).

This may be interpreted local cultivar as the most efficient variety in utilization of dry mass for further growth as relative growth rate expresses growth in terms of a rate of increase in size per unit of dry mass basis (Hunt, 2003). Variety Gudene was recorded highest RGR (36.97 mg g-1 day-1) at 45-60 DAP and followed by local cultivar (35.08 mg g-1 day-1) the lowest RGR was recorded at 45-60 DAP by Chala variety (21.67 mg g-1 day-1). local cultivar, Gudene and Chala the RGR values declined started from 45-60 DAP. RGR value decreased with plant age due to the fact that an increasing of the plant is structural rather than metabolically active tissue and as such does not contribute to growth.The decline in RGR value was also due to the decrease in net assimilability rate. Our present findings were in agreement with Mahmud (2012) and Begum et al.(2011), similar decreasing trend of RGR in potato varieties and the highest RGR value was calculated at 30-45 DAP. According to Abbas (2011), the variation in the RGR in the respective varieties might be due to difference in temperature or weather during the crop seasons.

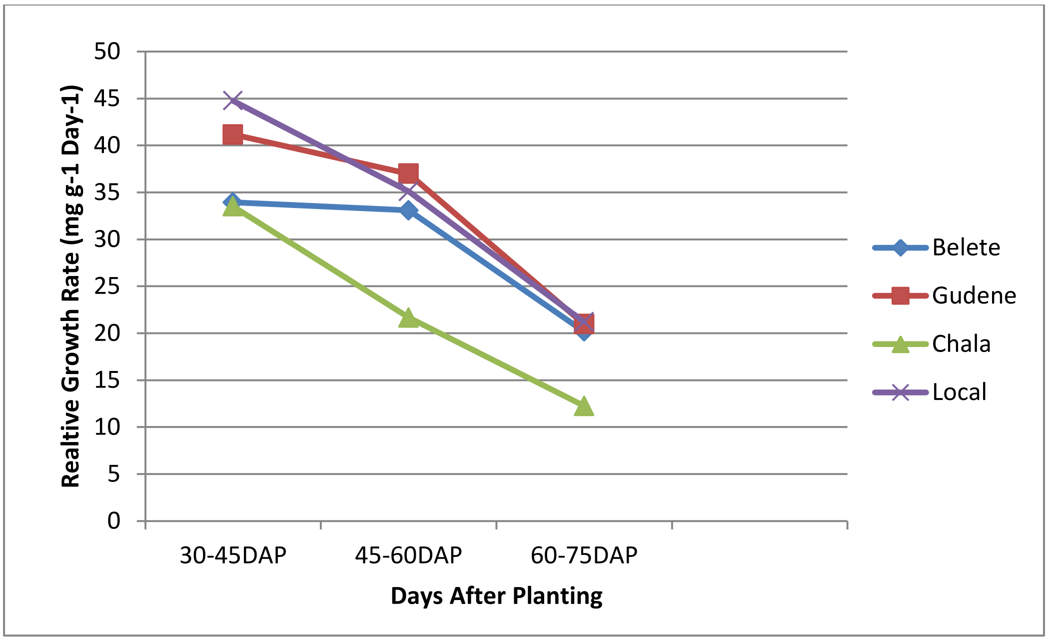

Figure 3. Relative growth rate of four potato varieties at different days after planting

No significant variation among the among inter-row spacing at all the growth stages from 30-45 DAP to 60-75 DAP.The highest relative growth rate was recorded at 30-45DAP at three inter-row spacing.The lowest relative growth rate were observed at 60-75 DAP growth stage.

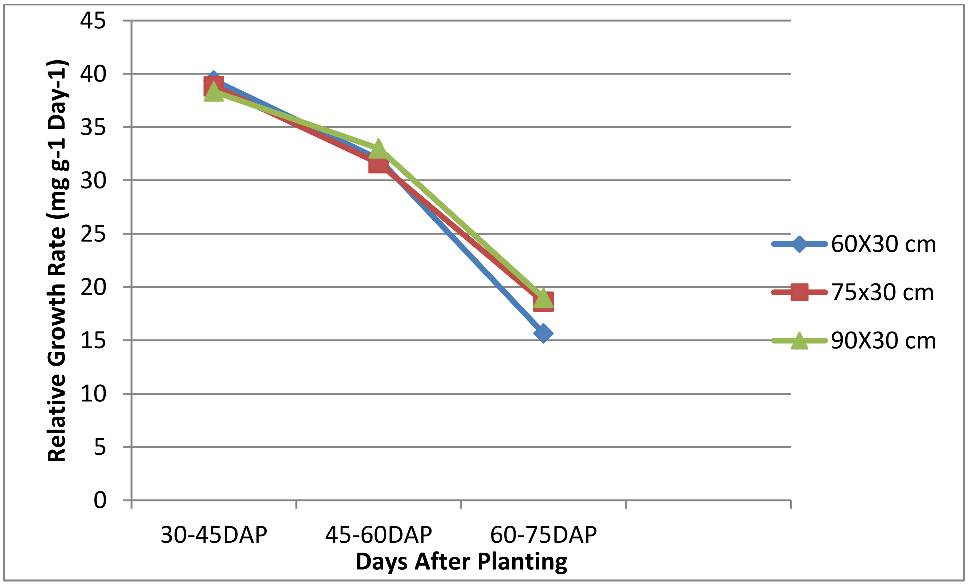

Figure 4 Relative growth rate of at different inter-row spacing at different days after planting

4.4. Total Fresh Tuber Yield (T/Ha)

Interactive effects of variety and inter-row spacing significantly ($P<0.05$) influenced the total fresh tuber yield of potato (Table 5 and AppendixTable 3). Form all the studied varieties, the highest fresh tuber yield was obtained from Gudane planted at inter-row spacing of 60 x 30 cm. The highest (38.57 t/ha) and lowest (25.71 t/ha) fresh tuber yield was obtained at inter-row spacing of 60 x 30 cm from variety Gudene and local cultivar respectively. And also the highest yield was obtained by Gudene variety at inter-row spacing of 75 x 30 cm and whereas, the lowest tuber yield was from local cultivar planted at at inter-row spacing 75 x 30 cm.

Decreasing planting spacing increases total fresh tuber yield of all potato varieties tested including local cultivar. Significantly higher (31.76 t ha^{-1}) total tuber yield scored from closer inter row spacing (60 cm x 30), intermediate inter row spacing (75 cmx 30 cm) showed fairly high yield to narrower inter row spacing while the wider inter row spacing (90cm) reveled the lower (26.91 t ha^{-1}) total tuber yield. The possible reason might be due to variation between varieties in efficient utilization of nutrients applied, earlier in season ground coverage might be hurt weed growth and reduced its competition for nutrients and other growth factor, could be enhanced the light interception that used in assimilation, fewer lateral branches are being formed and tuber formation starts earlier. In other words, narrowing inter row space increase plant population that could be increasing total tuber yield per unit area of land. This is may be attributed with enhanced leaf area index and trapping of optimal radiation for production of photo assimilate. This result in consistence with Rajasekaran *et al*.(2006); Silva *et al*. (2008); Harnet (2011); Zebenay (2015) who reported plant density strongly affected yield, both by number and by weight, and more tubers numbers and yield per square meter were obtained in higher plant densities. This shows that wider spacing results in underutilization of growth factors such as moisture, nutrients, and light resulting in the production reduced total tuber yields. This suggestion is consistent with that of Sharpe and Dent (1968) who reported that narrower inter-row spacing resulted in significantly higher total tuber yield than wider inter-row spacing . The increased yield at closer inter-row spacing may be due to the higher canopy coverage of the ground with green leaves earlier (earlier in the season, light is intercepted and used for assimilation), as well as the formation of fewer lateral and the possible early start of tuber growth and bulking. For production of small-sized tubers, higher plant densities are needed than for the production of large tubers. In other words, increased plant population density increased yield due to more tubers being harvested per unit area of land as reported by Beukema and Vander Zaag (1990). However, decreases in total yields as a result of wider spacing may be compensated for in part by an increase in large-size tubers and decrease in small tuber yields. This is apparently a result of reduced inter plant competition which may result in an increase in the total number of tubers per plant and average tuber size with wider seed piece spacing (Rex et al, 1987).

This is may be attributed with enhanced leaf area index and trapping of optimal radiation for production of photo assimilate. . In other words, narrowing inter row space increase plant population that could be increasing total tuber yield per unit area of land. Şanlı et al. (2015) also reported the highest mean TTY from the closest inter-row spacing than from the wider interrow spacing. Similarly, Getie et al. (2015) found that the maximum TTY from high planting density.This is may be attributed with enhanced leaf area index and trapping of optimal radiation for production of photo assimilate. Total tuber number and the number of seed-size tubers (smaller-tuber) increased with closer spacing. In contrast the number of ware potatoes (larger potatoes) was greater with wider spacing as it can be seen from larger average tuber weight. Even though the wider spacing gave relatively higher yield than the closer spacing, as compared to the higher tuber yield per individual plant base, the lower spacing gave higher yield per ha. This is due to the compensation effect of plants per hectare than the wider spacing, which results in higher yields of tuber per hectare (Burton, 1980).

The increased yield was attributed to more tubers produced at the higher plant population per hectare although average tuber size was decreased because of increased inter-plant competition at closely spaced plants leading to more unmarketable tuber yield. This result is in agreement with Mahamood (2005) who reported that the yield increments were attributed to more tubers produced at the higher plant population per hole although average tuber size was decreased because of increased inter-plant competition with close spacing. Rex et al. (1987) also reported that yield increment is attributed to more tubers being produced at the higher plant population per hectare although average tuber size is decreased because of increased inter-plant competition with closer spacing. The highest yield recorded from the wider spacing could be explained by the presence of large sized tubers than the closer spaced because of the absence or limited competition among plants.

4.5. Fresh Tuber Yield Per Plant (G)

The main effect of variety and inter-row spacing and their interaction significantly (P < 0.05) affected fresh tuber yield per plant (Table 5 and Appendix table 2) .All varieties produced maximum tuber yield per plant at 90 x 30 cm spacing. variety Gudene produced highest tuber yield per plant at wider inter-row spacing (838.06g) followed by Belete variety (803.4g) and the lowest (619.13) fresh tuber yield per plant was from local cultivar planted at 90 x30. Variety Gudene produced highest fresh tuber yield per plant (630.34 g) at narrowest inter row spacing and followed by Belete variety (602.53g). The narrowest inter row spacing tested (60 cm) by all varieties produced minimum fresh tuber yield per plant. The highest tuber yield per plant produced by wider inter-row spacing.

The maximum mean tuber fresh yield per plant of 773.58 and 720.89 g form variety Gudene and Belete respectively was recorded. The lowest (524.87 g) fresh tuber yield per plant was obtained from the local cultivar. The variation may be associated to that variety with long growth period have more leisure to complete tuber initialization and storage of photo synthetically matter in the tubers and also may be due to the variety have inherent genetic variation on tuber bulking among potato varieties. This result is also agrees with the work of Levy (2007) who suggested that the duration and rate of tuber bulking vary among varieties and depend on environmental conditions. Tuber size is affected by the length of growth period of potato time of tuber initiation (Ankumah *et al*., 2003).

The potato varieties also produced significantly different on average tuber weight per plant. The highest tuber weight 743.27g was recorded from inter row spacing of 90 x 30 cm followed by 682.48 g from the spacing of 75 x 30 cm whereas a closer spacing of 60 x 30 cm gave the lowest (555.20 g) average tuber yield per plant. This could be attributed to the fact that plots at higher plant densities were at intense competition among plant for growth resources as a result it gave less yield per plant as compared to plots with less plant densities, where resources were not limited to support better growth and partitioning of assimilates. And also at wider spacing better plant exposure for high radiation interception that increased the photosynthetic efficiency of the plant and finally increase the average tuber weight. This result is similar with those of Sultana and Siddique (1991) who stated the yield of tubers per hill increased significantly with increase in inter-row spacing but the yield of tuber per hectare did not follow the same trend.

4.6. Fresh Marketable Tuber Yield (Fmty) (T/Ha)

The main effect of variety and inter-row spacing had significant ($P < 0.05$) effect on mean marketable yield of potato and the interaction effect of varieties with spacing did not showed significant effect on this parameter (Table 6 and appendix 2). Gudene and Belete variety gave the highest FMTY of 30.48 (t $ha^{-1)}$ and 27.18 t ha^{-1}, respectively compared with other varieties whereas, the local cultivar howed the lowest (18.41 t ha^{-1}) marketable tuber yield. These differences could have been attributed to the difference in the genetic makeup of the varieties to exploit more resources and develop its growth and development.

Marketable tuber yield decreased with increasing inter row inter-row spacing. For instance, at closer spacing 60 x 30 cm, the highest mean marketable tuber yield (26.07 t ha^{-1}). Conversely, the lowest yield of marketable tuber (22.96 t ha^{-1}) was recorded from wider planting spacing (90 X 30 cm). Increasing inter row spacing from 60 to 75cm decreased mean marketable tuber yield per hectare by 7.8%, and similarly, increasing inter row spacing from 75 to 90cm deceased the mean tuber yield per hectare by 4.4%. The possible reasons for the increasing yield per hectare might have been due to having the greater number of the tubers so used the seedling to establish which leads high population density per hectare and, these contributes the ability to produce more tuber number. The results of the study are similar to the findings of Kumar *et al*. (2007) who investigated that marketable yield was significantly varied by variety, location and genotypes x environment interaction.

In addition, Tesfa (2012) reported that an increasing number of rows per unit area increase total yield per hectare and widening inter row spacing also decreased total yield per hectare. The production of higher marketable tuber yield in response to planting the seed tubers at wider or increased spacing may be attributed low competition between plants for growth factors such as moisture, nutrients, and light and the optimal utilization of the growth factors for photosynthesis and assimilation of carbohydrates to tubers. This finding is in agreement with that of Wurr (1992) who reported that narrower spacing led to the production of many small-sized tubers that were not marketable.The decrease in MTY at the lower planting density was attributed to the lower number of tubers produced at the low planting density than at the higher planting density. This result is in agreement with Binalfew et al. (2015) who reported higher MTY at high planting density. Dagne et al. (2018) also recorded higher MTY at closer spacing.

4.7. Unmarketable Tuber Yield (T/Ha)

The main effect of variety and inter-row spacing and their interaction significantly ($P < 0.05$) affected unmarketable tuber yield. Presented (Table 8 and Appendix table) .all varieties produced unmarketable tuber yield maximum at 60 cm inter row spacing. Chala variety produced highest unmarketable tuber yield (6 t/ha) at narrowest inter row spacing and followed by local cultivar (5.87).The lowest unmarketable tuber yield produced by wider inter-row spacing. At wider inter-row spacing the highest unmarketable tuber yield produced by local cultivar (4.89) and followed by Chala variety (4.24) .The lowest unmarketable tuber yield at wider inter-row spacing produced by Gudene variety (2.85).

At all inter-row spacing Chala and local cultivar was recorded highest unmarketable tuber yield and followed by Belete variety whereas the lowest was recorded at the variety Gudene. The variation in non-marketable tuber yield of the genotypes may be due to adaptability, crop maturity, and inherent ability of potato genotypes in producing unmarketable tubers. Bekele (2018) showed that variation among genotypes of non-marketable yield could be attributed to their genetic make-up. And also Haile *et al*. (2015), who pointed out the effects of genotype that significantly influence unmarketable tuber yield. Planting potato closely leads to the production of relatively higher proportion of unmarketable tubers such as small and misshaped tubers than planting the crop at a wider spacing. This suggestion is corroborated by the results of Beukema and Vander zaag (1990) who reported that inter-row spacing had a marked effect on unmarketable tuber yield and the highest unmarketable tuber yield was recorded from closely-spaced potato plants due to higher inter-plant competition.

Unmarketable tuber yield per hectare was significantly affected by plant density. Among the spacing level, 60 x 30 cm shows maximum unmarketable potato yield (5.68) followed by 75 x 30 cm and 90 x 30 cm (5.13) and (4.01) respectively. From the three spacing the wider inter-row spacing 90 x 30 cm gave the lowest unmarketable yield of potato. From this parameter it show us that potato planted with narrow spacing gives maximum unmarketable yield while the spacing was increased the unmarketable yield become decreased.

The higher amounts of unmarketable tuber yield at higher planting density could be due to the fact that at the narrower spacing there is strong inter-plant competition for growth factors, which result in the production of more numbers of undersized tubers. According to Zebenay, (2015) report closer inter-row spacing increased competition of plants for growth factors due to high number plant per unit area than wider inter-row spacing which led to producing high number of under size tubers which was high unmarketable tuber yield. Other factor this result shows us that at closer spacing absence of air circulation resulted in development of disease and associated diseased plants which contribute more for un-marketability. Beukema and Van der zaag (1990) according to them, planting density had a marked effect on unmarketable tuber yield and the highest unmarketable yield recorded from the closer spacing due to higher inter-plant competition and associated small sized tubers.

Table 4. The interaction effect of variety and inter-row spacing on total fresh tuber yield and Average fresh tuber yield per plant of potato varieties**,** site zone central Ethiopia 2024 cropping season

Variety	Inter row spacing in (cm)	TFTY (t/ha)	AVTY/plant (g)
Belete	60*30	34.29[b]	602.53[d]
	75*30	32.21[c]	756.73[bc]
	90*30	29.83[ed]	803.40[ba]
Gudene	60*30	38.57[a]	630.34[d]
	75*30	34.97[b]	852.34[a]
	90*30	30.51[d]	838.06[a]
Chala	60*30	28.45[e]	546.4[e]
	75*30	26.40[f]	606.9[d]
	90*30	25.03[f]	712.46[c]
Local	60*30	25.71[f]	441.53[e]
	75*30	23.31[g]	513.93e
	90*30	22.28[g]	619.134[d]
LSD(0.05)		1.6189	53.681
CV%		3.5	4.6

Note: *Means with the same letter(s) within a column are not significantly different at 5% level of significance. NS = non-significant difference, LSD (5%) = Least significant difference at P=0.05, and CV (%) = Coefficient of variation in percent. TFTY,* AVTY

4.8. Total Tuber Number Per Ha

Interactive effects of variety and inter-row spacing significantly (P<0.05) influenced the total tuber number (Table 7,and Appendix table 3). All varieties gave highest tuber numbers at inter-row spacing of narrowest inter- row spacing tested (60 x 30 cm). The highest total tuber numbers were obtained at narrowest inter- row spacing (60 x 30 cm) in Gudene variety (659464.6.) followed by Chala variety (548696.34 and lowest were recorded by local cultivar (349794).And also the lowest total tuber numbers (330932 were counted from the local cultivar at spacing 75 x 30 cm.

The increase in the tuber number produced per hectare in response to narrow spacing is due to a strong competition among tubers for growth factors, which restricts expansion in size and increases the tuber number Taye et al. (2021). Also it might be due to both genetic and environmental factors that play a vital role in stolon development and tuberization process. According to Subarta and Upadhya (1997), the numbers of tubers per plot depend mainly on the number of stems per plot, total number of stolons and stolons which tuberize. Similar to the result of this study, Patel *et al*, (2002); Tesfa (2012) reported that total number of tubers per unit area increased linearly with increasing density). In general, decreasing the seed tuber spacing led to a significant increase in the number of total tubers produced. This could be attributed to the production of lager numbers of tubers per unit area at the narrower spacing than at wider spacing, owing to stiffer competition among tubers for resources, which would limit their expansion in size. The results of this study are in agreement with the findings of other authors (Beukema and Van der Zaag, 1990), who reported that high planting densities should be used to produce relatively large numbers of seed-sized tubers.

4.9. Marketable Tuber Number

The main effect of variety and inter-row spacing and their interaction significantly (P < 0.05) affected marketable tuber number presented (Table 7 Appendix table 3). Variety Gudene in all inter-row spacing was recorded maximum marketable tuber number per hectare (596708) was recorded at interaction of narrowest inter-row spacing (60 x 30 cm), (517489) was recorded at spacing of 75 x30 cm. and (470850) was recorded wider inter-row spacing 90 x 30 cm). followed by variety Belete. Whereas, the lowest marketable tuber number per hectare in all inter-row spacing observed from local cultivar. The results showed that variety Gudene produced two fold more yield over local cultivar at the closest inter row spacing. The result indicates that narrowing inter-row spacing increases marketable tuber numbers per hectare. This might be payable to the increased plant density per hectare which produced higher tuber numbers per hectare.

The result of the current investigation also supported by the findings of various authors, Khajehpour (2006) reported that with increasing plant number, numbers of stems grown from the planted tuber, and consequently, number of produced tubers per stem are increased. Thus, increase in plant density leads to increase in produced tubers. increase in plant density leads to increase in produced tubers. Thus, increase in plant density leads to increase in produced tubers. Similarly Kantona *et al*. (2003); Harnet *et al*., (2014) were pointed out that where number of marketable yield increased significantly as plant density and tuber yield increased.

4.10. Average Tuber Number Per Hill

Both main effect of variety and inter-row spacing had showed highly significant ($P < 0.01$) effect, whereas, the interaction didn't show significant effect on average tuber number per hill (Table 6 and Appendix 3). Higher average tuber number per hill (13.5) was obtained at Gudene variety and the lowest average tuber number per hill (8.088) was recorded from the local cultivar. The variation may be attributed to that the difference in genetic potential among potato varieties. Stolen and tuberilization processes is affected by genetic makeup and environmental factor (Bekele, 2018). Significantly varied average tuber numbers per plant were recorded from different inter-row spacing of potato. The result revealed that when the plant space decreasing, the average number of tuber per plant also decrease but total tuber number per hectare increase. The highest (12.86) tuber number per hill was obtained at wider inter-row spacing (90 X 30 cm) followed by 75 X 30 cm (10.80) whereas the lowest (9.033) was obtained at closer inter-row spacing (60 X 30 cm). Decreasing inter row spacing from 90 to 75cm average tuber number plant decreased by 16.9%, and again, decreasing inter row spacing from 75 to 60cm deceased the average tuber number per plant by 15.5%. At lower plant densities, competition is less, which results in a greater number of tubers per plant, but also in a smaller number of tubers per unit area.

On the other hand, when plant densities increase, the number of tubers per plant decreases, but the number of tubers per unit area generally increases. This probably due to the number of tubers produced depends on the competition among the plant for growth factors such as nutrients, water and light. The results of the study is in line with findings of Zebenay (2015) who reported that the higher number of plants produced at closer inter-row spacing than plants at wider spacing which led to the production of highest number of total tubers per hill. In addition, genetic and other macro and micro environmental factors might play a vital role in stolons' development and tuberization processes. The current result is in agreement with the findings of Arab et al. (2011) who reported that increase in plant density reduced the number of tubers per plant, But, it is in contradiction with the findings of Arega et al. (2018) who reported that production of the total number of tubers per plant increased as plants were grown at narrow spacing and decreased at wider plant spacing.

4.11. Unmarketable Tuber Number

The main effect of variety and inter-row spacing and their interaction significantly ($P < 0.05$) affected unmarketable tuber number presented (Table 8 and Appendix 4) .all Varieties produced maximum unmarketable tuber number at 60 cm inter row spacing and local cultivar produced highest unmarketable tuber number(63785.67) at narrowest inter row spacing and followed by variety Gudene (62759). The lowest unmarketable tuber number produced by wider inter-row spacing .The highest unmarketable tuber number produced at wider inter-row spacing (90x30) by local cultivar (55898.) and followed by Chala variety (48353.34) .The lowest unmarketable tuber number at wider inter-row spacing produced by belete variety (26748.34). Maximum unmarketable number tuber (58813.58) observed at the spacing 60 x 30 cm and minimum unmarketable tuber number (42609.6) at spacing 90 x 30 cm.The result indicates that widening inter-row spacing decreases the numbers of unmarketable tuber number per hectare. This might be due to the fact that at wider spacing the plants face less competition and resulted in big sized tubers which are marketable. Whereas, at closer spacing, due to more number of plants per unit area, the plants get severe competition and resulted in small sized and diseased tubers and associated high unmarketable tuber per hectare. Consistent with the results of this study, Frezgi (2007) also indicated that closer seed tuber spacing resulted in a significantly higher yield of small-sized tubers as the consequence of higher competition between plants. Similarly, Tesfa (2012); Birhanu *et a*l. (2016) reported that the narrower spacing resulted in the production of large numbers of undersized unmarketable tubers compared to the wider spacing.

4.12. Dry Matter Content

The dry matter content was significantly ($P < 0.05$) affected by variety and inter-row spacing but not by their interactions (Table 6 and Appendix 4). Gudene and Belete had showed significantly ($P < 0.05$) highest tuber dry matter (25.11% and 22.6833% respectively with statistical parity; while the lowest tuber dry matter (12.89%) was recorded from Local cultivar. This result is consistent with that of Soltanpour (1969) who reported that tuber dry matter yields vary significantly with variety.

Higher dry matter percentage recorded at variety that had maximum LAI, it might be the capacity to prepare more photosynthesis and able to produce more assimilates and it is the channeled to sinks and also the inherent genetic differences among the potato varieties in the production of dry matter (total solids) contents of tubers. The present result is in concurred with the finding of Tekalign and Hammes (2005) who reported that significant variation among potato varieties with respect to total dry matter content was observed. In this study, the results showed that increasing inter-row spacing could result in decreasing dry matter content. Thus, the highest tuber dry matter yield (22) was recorded at the spacing of 60 x 30 cm. Conversely, the lowest yield of dry matter (17) was obtained at the spacing of 90 x 30 cm. Hence, increasing inter row spacing from 60 to 75cm reduced percentage of tuber dry matter from 9.8%. The result agreed with the finding of Alvin *et al*. (2007), who reported when plant density increasing, plant dry matter was decreased in each plant but increased per unit area. This finding also in conformity with those reported by Frezgi (2007) that tuber dry matter percentages decreased with increased inter row spacing.

4.13.Harvest Index

The main effect of variety and inter-row spacing and their interaction significantly (P < 0.05) affected harvest index presented (Table 9 and Appendix 4) . Variety Gudene at inter-row spacing (60x30) was recorded highest harvest index(0.9034) and the second highest harvest index was recorded variety Belete (0.80667) at inter-row spacing (60x30 cm).the lowest harvest index was recorded in local cultivar (0.6367) at wider inter-row spacing (90x30). Narrow inter-row spacing of 60 x 30 cm resulted high harvest index over the other spacing (75 x 30 cm and 90 x 30 cm). That means most of the .time its efficiency related with spacing, there was decreasing trend in harvest index in response to decreasing planting density. According to Beukema and Van der Zaag (1990) study in temperate zone harvest indices of 0.75 -0.85 are quite common but in warmer climates, the harvest index tend to be lower and often a wider variation is also observed between varieties or growing conditions.

Table 6. The interaction effect of variety and inter-row spacing on harvest index at Silte zone centeral Ethiopia 2024 in cropping season.

Variety	Spacing in (cm)	HI
Belete	60*30	0.80667^{ba}
	75*30	0.78867^{bc}
	90*30	0.74^{de}
Gudene	60*30	0.857^{a}
	75*30	0.80^{b}
	90*30	0.7167^{de}
Chala	60*30	0.7934^{bc}
	75*30	0.75134^{dc}
	90*30	0.72134^{de}
Local	60*30	0.71^{de}
	75*30	0.6934^{e}
	90*30	0.6367^{f}
LSD(0.05)		0.0488
CV%		3.8225

Note. Means with the same letter(s) within a column are not significantly different at 5% level of significance. LSD (5%) = Least significant difference at P=0.05, and CV (%) = Coefficient of variation in percent.

Table 7 . Main effect of variety and inter-row spacing on Avrege tuber number per plant, marketable yield and Dry matter content in potato at Silte zone centeral Ethiopia 2024 in cropping season.

Treatment	Avrege tuber number	Marketable tuber yield (t/ha)	Dry matter Content
Variety			
Belete	11.55[b]	27.18[b]	22.68[b]
Gudene	13.5[a]	30.48[a]	25.11[a]
Chala	10.31[c]	21.43[c]	17.86[c]
Local	8.08[d]	18.41[d]	12.89[d]
LSD(0.05)	0.646	1.1591	0.4125
Spacing			
60*30	9.03c	26.07[a]	22[.a]
75*30	10.69[b]	24.09[b]	19.84[b]
90*30	12.86[a]	22.96[c]	17.05[c]
LSD(0.05)	0.5594	1.0038	0.3677
CV %	**6.111**	**4.924**	**2.159081**

Note. *Means with the same letter(s) within a column are not significantly different at 5% level of significance. NS = non-significant difference, LSD (5%) = Least significant difference at P=0.05, and CV (%) = Coefficient of variation in percent.*

Table 8. The interaction effect of variety and inter-row spacing on total and marketable tuber number per hectare at Silte zone centeral Ethiopia 2024 in cropping season**.**

variety	Spacing in (cm)	Total tuber number	Marketable tuber number
Belete	60*30	537744.33[cb]	489026.00[c]
	75*30	490740.33[d]	449588.00[de]
	90*30	422153.33[e]	398147.66[f]
Gudene	60*30	659464.66[a]	596708.00[a]
	75*30	557955.33[b]	517489.66[b]
	90*30	510287.66[cd]	470850.00[dc]
Chala	60*30	548696.33[b]	488682.66[c]
	75*30	497942.00[d]	444786.66[e]
	90*30	481824.33[d]	433470.00[e]
Local	60*30	349794.00[f]	286002.00[g]
	75*30	330932.66[f]	274005.00[g]
	90*30	328788.66[f]	269889.66g
LSD(0.05)		28836	24667
CV%		3.698	3.52

***Note.** Means with the same letter(s) within a column are not significantly different at 5% level of significance. NS = non-significant difference, LSD (5%) = Least significant difference at P=0.05, and CV (%) = Coefficient of variation in percent.*

Table 9. The interaction effect of variety and inter-row spacing on Unmarketable tuber yield and unmarketable tuber number per hectareat Silte zone centeral ethiopia 2024 in cropping season.

Variety	Spacing in (cm)	UMTY	UMTN
Belete	60*30	5.68[ab]	48696.67[d]
	75*30	5.07[d]	42523.67[gf]
	90*30	4.04[g]	26748.34[h]
Gudene	60*30	5.21[dc]	62759[ab]
	75*30	4.55[ef]	40466.67[g]
	90*30	2.85[h]	39437.67[g]
Chala	60*30	6.00[a]	60013.34[bac]
	75*30	5.35[c]	53154[edc]
	90*30	4.24[gf]	48353.34[f]
Local	60*30	5.87[a]	63785.67[a]
	75*30	5.55[bac]	57612[bac]
	90*30	4.89[d]	55898[bdc]
LSD(0.05)		0,4549	7207.8
CV%		5.241	9.793

Note. Means with the same letter(s) within a column are not significantly different at 5% level of significance. LSD (5%) = Least significant difference at P=0.05, and CV (%) = Coefficient of variation in percent.

5. SUMMERY AND CONCLUSION

Potato (*Solanum tuberosum* L.) is one of the most important food crops as it is the source of food, employment and income in developing countries. Ethiopia has the greatest potential for potato production and 70 percent of the arable land mainly in highland areas above 1500 m which is believed suitable for potato production. Since the highlands are also home for about 90 percent of Ethiopia's population, the potato could play a key role in ensuring national food security. The study area is suited in the central high land and the most densely populated with very small land holding per household. Potato is the main staple and food security crop next to enset in the study area. Even though the study area is characterized as the potential potato producing area, using the low yielding local cultivars without standardized inter-row spacing led the growers to be ineffective in properly using their scanty land holding which consequently resulted in inferior productivity. Potato is main food for about three to four months in a year, May to August. Therefore, to utilize the small land intensively and to exploit the potential of the crop there was a need to develop proper agronomic packages such as optimum plant spacing and introduction of better performing varieties to the study area. Optimum plant spacing and selection of high yielding variety are important economic considerations in potato production. These factors influence tuber yield and quality especially in terms of marketability, which may negatively affect the final income of the growers. The selection of best performing variety with suitable intra-row spacing helps to utilize the small land efficiently and intensively not only for higher tuber yield but also for quality tuber seed. The field experiment were carried out at Alicho in Silte zone central Ethiopia during belg c ropping season to to determined of potato varieties and inter -row spacing .

Recommend optimum inter-row spacing for good potato production in the area. A factorial arrangement consisting of four potato varieties (Gudenie, Belete, Chala and Local) and three inter-row spacing (60 x30 cm, 75 x 30 cm, and 90 x 30 cm) was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data were collected on phenology, growth, yield and yield components and tuber quality related traits and subjected to appropriate statistical analysis. The result showed that the main effect of variety and inter-row spacing and their interaction significantly ($P < 0.05$) affected most parameters such as days to flowering, leaf area index, total tuber number, marketable tuber number, total tuber yield, average tuber weight per plant, unmarketable tuber number, unmarketable tuber yield and harvest index.Other parameters such as plant height, dry matter conten, 90% plant maturity, crop growth rate, marketable tuber yield,tuber number per plant and relative growth rate were significantly ($P<0.05$) influenced only by the main effect variety and inter-row spacing spacing. Days to 50% emergency, leave number per plant and stem number per hill were influenced only by the main effect variety.

All four varieties significantly differed in the duration required to reach physiological maturity, with local cultivar requiring the longest duration but varieties chala requiring the shortest duration to reach physiological maturity. Gudane produced the tallest plants whereas the local cultivar produced the shortest plants. Plant height increased significantly in response to increasing inter-row spacing.Gudene varieties significantly differed in the number of stems from Chala and Local cultivar they produced. At 60-75 DAP growth stage, The highest tuber yield was obtained from Gudene variety (38.57 t/ha) at inter-row spacing (60 x 30 cm) , which also gave (34.97 t/ha) at spacing (75 x 30) and followed by variety Belete (34.29t/ha) at spacing 60 x 30 cm and 75 x 30.The lowest tuber yield was recorded by local cultivar (22.28 t/ha) at spacing 90 x30 cm. Highest marketable tuber yield was obtained by Gudene variety 30.48 t/ha and followed by Belete variety (27.71t/ha) and lowest marketable tuber yield was obtainded by Local cultivar (18.41t/ha). Variety Gudene produced 39.59%, 29.69% and 9.08 % more MTY over Local, Chala and Belete respectively. Increasing inter-row spacing significantly decreased the amount of unmarketable tuber yields produced. Thus, plants grown at the wider spacing produced lower unmarketable tuber yields.

Therefore, planting potato closely leads to the production of relatively higher proportion of unmarketable tubers as well as higher total tuber yields. On the other hand, decreasing inter-row spacing significantly increased the yield of very small-sized tubers but decreased yield of medium and large-sized tubers. Increasing or widening inter-row spacing significantly reduced total as well as unmarketable tuber yields whereas decreasing or narrowing it significantly increased this yield parameter. On the other hand, increasing inter-row spacing significantly increased marketable tuber yields. the result was statistically significance difference between variety Gudene and Belete marketable tuber yield. produced more than one fold MTY over Local cultivar . Regarding spacing, the highest total tuber and marketable tuber yield recorded from 60cm inter row spacing and the lowest from 90cm and 75cm inter row spacing resulted intermediate yield. Therefore, from this study, it can be concluded Gudane and Belete varieties at a inter-row spacing of 60 x 30 cm and 75 x 30 cm resulted in highest marketable tuber yield could be recommended to potato growers in the study. Therefore, from this study, it can be concluded Gudane and Belete varieties at a inter-row spacing of 60 cm and 75 cm resulted in highest marketable tuber yield could be recommended to potato growers in the study.

However, it is premature to make a final recommendation since the experiment was conducted at one location for only one season using four varieties. Hence, studies involving more varieties should be conducted at several locations over seasons to arrive at a conclusive recommendation.

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APPENDIX

Appendice table 1. Means squares for days to emergency, stem number per plant, leave number per plant, days to 50% flowering and days to 90% maturity **.**

Source of variation	Means squares					
	DF	Days to emergence	Stem number per plant	Leave number per plant	Days to 50% flowering	Days to 90% maturity
Replication	2	0.2500	0.021111	2.0312	0.77779	6.5834
Cultivars	3	45.555556***	11.316***	221.503***	245.6574***	367.814815***
Spacing	2	0.5833334ns	0.05444ns	4.25445ns	325.6944***	61.5834***
Cultivar x Spacing	6	1.3611111ns	0.09888ns	2.65834ns	3.546296*	6.175926ns
Error	22	1.06818181	0.085353	1.27308	1.383839	4.189394
Cv%		6.327727	5.697464	2.563691	2.131313	2.158314

*and *** = = Significant and very highly significant difference at 5% and 0.1% probability levels respectively. Ns = Non-significant

Appendice table 2. mean square for total tuber yield ha-1,marketable tuber yield ha-1,average tuber yield per plant and leaf area index.

Source of variations	Means squares				
	DF	total tuber Yield ha-1	Marketable tuber yield ha-1	Average tuber yield per plant	Leaf area index
Replication	2	2.5727218	2.7225402	31.9803	0.02200
Cultivars	3	223.6844***	268.1186978***	108953.7277***	9.609996 ***
Spacing	2	70.389388***	29.783312***	110527.2469***	4.622594 ***
Cultivar x Spacing	6	3.8639051*	2.5925426ns	4687.04*	0.231917 99*
Error	22	0.9140729	1.1268973	1005	0.016554 654
Cv%		3.262882	4.354523	4.80106	3.845874

** And *** = highly significant and very highly significant difference at 1% and 0.1% probability levels, respectively. Ns = Non-significant

Appendice table 3. Means squares for un marketable tuber yield ha-1 , Total tuber number ha-1, average tuber number per plant and marketable tuber number ha-1.

Source of variation	Means Squares				
	DF	unmarketable tuber yield ha-1	Total tuber number ha-1	Average tuber number per plant	Marketable tuber number ha-1
Replication	2	0.0124767	529783890.03	0.7869444	368897599.19
Cultivars	3	2.57592***	92692902911***	46.3010185***	102140522723***
Spacing	2	8.816491***	24121538826***	44.350277***	15792165884***
Cultivar x Spacing	6	0.268060*	2521224157.5*	0.9865741ns	1781869235.6*
Error	22	0.07215471	290006948.48	0.4093687	212214476.68
Cv%		5.431560	3.576817	5.889413	3.415177

** And *** = highly significant and very highly significant difference at 1% and 0.1% probability levels, respectively. Ns = Non-significant

Appendice 4. Means squares for unmarketable tuber number, dry matter content, Plant height and harvest indx.

Source of variations	Means squares				
	DF	Unmarketable tuber number	Dry matter content	Harvest index	Plant height
Replication	**2**	87892923	0.2239528	0.00038811	137.9536
Cultivars	**3**	652526813***	263.5406741***	0.02653244***	759.764706***
Spacing	**2**	808392222***	74.0055361***	0.02989378***	60.233211***
Cultivar x Spacing	**6**	83852649*	0.2578657ns	0.00275511*	1.108915ns
Error	**22**	18118678	0.1757558	0.000767	3.46873
Cv%		8.521028	2.134826	1.546402	2.537296

and* = highly significant and very highly significant difference at 1% and 0.1% probability levels .respectively. Ns = Non-significant

14 to 2002. He pursued secondary school education at werabe Senior Secondary School from 2003 to 2006 in Silte Zone.He joined Mizan-Tep University College of Agriculture Department of Horticulture in 2007. and graduated with BSc in Horticulture in 2009. After graduation, Starting from 2011, He Joined employed Werabe University College of Agriculture Department of Horticulture. He joined Hawassa University to pursue a master of science Degree in plant and Horticultural sciences in 2014 E.C.