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Effect of Planting Depth and Time of Earthing-up on Potato (Solanum Tuberosum L.) Yield and Yield Components at Jimma University College of Agriculture and Veterinary Medicine, South West Ethiopia

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Abstract
Potato (Solanum tuberosum L.) is the fastest growing staple food crop and source of cash income for smallholder farmers in Ethiopia. An experiment was conducted at Jimma, Southwest Ethiopia during 2014/15 cropping season to determine the effect of different planting depth and time of earthing-up on yield and yield components of Jalane potato variety. The treatments consisted of 3 levels of planting depth (10, 12 and 14 cm) and four time of earthing-up (no earthing-up, at 15, 30 and 45 days after plant emergence) were applied to Jalane potato variety. A 3x4 factorial experiment was laid out with 3 replications. Data collected on yield, and yield components were analyzed using SAS Version 9.2 statistical software. Earthing-up at 15 days combined with planting depth of 10 and 12 cm recorded significantly (P<0.01) the highest total tuber number. Planting at 12 cm depth resulted in significantly the highest tuber weight, where as 10cm planting depth gave the highest unmarketable yield. Earthing-up at 15 days produced significantly (P<0.01) the highest main stem number. Moreover, earthing up at 15 days produced average tuber weight of 10.28%, which is higher as compared to the no earthing-up. Earthing-up at 15 days, 30 days and 45 days showed reduced unmarketable tuber yield by 13.62%, 7.51% and 3.52 %, respectively as compared to no earthing-up. Time of earthing-up with depth of planting at (15days x10cm, 15days x12cm, 15days x14cm, 30days x12cm, 30days x14cm and 45days x14cm) recorded the minimum number of green tubers (1.48, 1.16, 0.63, 1.23, 1, 1.56) respectively. Earthing-up at 15 days and at planting depth 12 cm produced the highest marketable yield (23.92 and 23.57ton/ha, respectively),also earthing up at 15 days and planting depth at 12 cm produced the highest total tuber yield (28.28 and 26.72ton/ha, respectively). Even though early earthing-up was superior when compared to very late earthing-up and no earthing-up with regard to different parameters, where as no earthing-up and shallow planting depth performed very poorly. Correlation analysis result showed that the association between all parameters was positive and highly significant. While the number of green tuber and unmarketable yield was negatively and highly significantly (P<0.01) correlated. Therefore, based on the result of this investigation, optimum planting depth at 12cm and earthing up at 15 day is recommended for the potato growers in the study area.. Since, the present study was done only for one season at one location; it would be advisable to repeat the experiment at various agro-ecological conditions to come up with conclusive result leading to a recommendation.
Keywords: Jalane potato, planting depth, Time of earthing-up, Yield, Yield Components.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is an annual, herbaceous, tuber crop of family solanaceae that contains all the essential food ingredients required for maintaining proper health. Potatoes were introduced outside the Andes region four centuries ago, and have become an integral part of much of the world's food supply. It is the world's fourth-largest food crop, following maize, wheat and rice. Wild potato species occur throughout the Americas, from the United States to southern Chile. The potato was originally believed to have been domesticated independently in multiple locations, but later genetic testing of the wide variety of cultivars and wild species proved a single origin for potatoes in the area of present-day southern Peru and extreme northwestern Bolivia (FAO, 2008). The average composition of the potato is about 80% water, 2% protein, and 18% starch. As a food, it is one of the cheapest and easily available sources of carbohydrates and proteins and contains appreciable amount of vitamins B and C as well as some minerals Potato is the world's leading vegetable crop and is grown in 79% of the world's countries (Muhammad et al, 2013). The potato is the world's most important root and tuber crop worldwide. More than a billion people consume it almost daily. Hundreds of millions of people in developing countries depend on potatoes for their survival (FAO, 2008). Potato is one of the most important food crops both in the developing and developed countries of the world. Thirty percent of world's potato production is from developing countries and it is expanding more rapidly than most of the other food crops (Khalid et al, 2002).

Potato is a high potential food security crop in Ethiopia due to its high yield potential and nutritional quality tuber, short growing period, and wider adaptability (Tewodros et al**,** 2014).In Ethiopia the fastest growing staple food crop and source of cash income for small holder farmers. The German immigrant Wilhelm Schimper introduces it to Ethiopia in 1858. Despite its earliest introduction and highest potential than any African country, potato productivity in Ethiopia is too low (7 ton ha-1). Often driven by food security and market forces, farmers in Ethiopia have been innovating for centuries (Berhanu and Getachew, 2014). Potato is grown in diverse soil types from black heavy soils (vertisols) to red soils (nitosols) in the central highlands of Ethiopia. Despite its importance as a food crop, the productivity of this crop is as low as 10 t ha-1 mainly due to poor agronomic practices (Balemi, 2012*)*. In the area, Boneya, degem district, central highlands of Ethiopia, farmers produce even less than the national average (Tesfaye et al, 2012). Despite the suitability of this area for high quantity and quality potato production in the country, there are several constraints, which drastically affect to the low production and productivity of potato crop by smallholder farmers (Tewodros et al*,* 2014).

Identifying the proper planting depth in combination with hill shape, row width and other cultural management practices will become increasingly important (Pavek and Thorthon, 2009). Hilling was provide a good cover for the newly formed tubers and to ensure that the developing tubers covered with an adequate layer of soil. It is important to determine how planting depth and time of hilling up affects the growth and yield of potato. The tuber may be regarding as an enlarged stolen. The pattern of stolon formation i.e. number and size of stolons, and the structure of the stolon system, can be influenced by cultural practices for example planting depth and build-up of the ridges (Darwin, 1991).The knowledge of the farmer in the study site practice time of eathing-up potato and depth of planting is different from farmer to farmer .

Therefore, this study to address effect of agronomic practice planting depth and time of earthing-up on the Jalane potato variety yield and yield components that was due to the following critical problems in general this are: - complexity of the problem, wade range of recommendation planting depth for all potato variety, poor agronomic practices, use of traditional production systems, effect of green tubers on yield, knowledge gap between farmers and low yield from national level.

2. MATERIALS AND METHODS

2.1. Description of the study area

The experiment was conducted at Eladale Research site of Jimma University College of Agriculture and Veterinary Medicine. It is Located in Oromiya Regional State Jimma Zone, 356 km southwest of Addis Ababa at about 7^o, 41^o N latitude and 36^o, 50^o E longitude at an altitude of 1710 m. a. s. l and the annual rainfall ranges from 1250 mm (Mulatu et al, 2011). The mean maximum and minimum temperature are 28^0C and 11^0C, respectively. The mean maximum and minimum relative humidity are 91.4% and 39.92% respectively (Mesret, 2012). The soil type classified as clay soil with a pH of 5.53 (Mulugeta et al, 2014).

2.2. Experimental Material

Jalane potato variety was obtain from Holeta Agriculture Research Center; used for the experiment. In this experiment, three different levels of planting depth include 10 cm, 12 cm and 14 cm and four time of earthing-up such as ;- at 15 days, 30 days and 45 days after complete emergence of potato plants and no earthing up as a control treatment were grown at jimma in 2014/15 cropping season.

2.3. Field Experimental Design, Trail management and Season

The experiment was carried out in 3x4 and 3 replication factorial arrangements in Randomized Complete Block Design. The treatment combinations were grown under uniform rain fed conditions. The size of each unit plot was (3m length x 3 m width), having plant-to-plant and row-to-row spacing 0.3m and 0.75m, respectively. The used similar weight potato tuber (45g) for all treatments. A distance of 0.5m and 1m was maintained between unit plot and replication respectively planting was done by hand on August 02, 2014/15 with number of sprout seed tuber (40 Number/plot).

2.4. Statistical Analysis

The data was collect per plot basis checked for meeting all the ANOVA assumptions and subjected to analysis of variance Randomized Complete Block Design (RCBD) of SAS Version 9.2 statistical software (SAS Institute Inc., 2002). Treatment means was separate by using LSD value at 5% significance level (Montgomery, 2005) and correlation analysis was included.

2.4.1. Analysis of variance (ANOVA) Structure /Model

The Mathematical Model for Randomized Complete Block Design (RCBD) is:- $y_{ijk} = \mu+\alpha_i+\beta_j+ (\alpha\beta)_{ij}+ €_{ijk}$, where Y_{ijk}= the value observed for the plot in the kth replication containing the treatments α_i = the effects of i^{th} planting depth i = 1-3, β_j = the effects of the j^{th} time of earthing-up j = 1-4, $(\alpha\beta)_{ij}$ = the interaction effects between depth of planting and time of earthing-up, $€_{ijk}$ = the random error compared for the whole factor and k = number of replication.

3. RESULT AND DISCUSSION

3.1. Growth Parameters

The results of the current investigation obtained in terms of growth parameters including days to 50% emergence, days to 50% flowering, days to 50% maturity, main stem number/hill , plant height and plant spread are presented (Table 3 and 7) and discussed as follows.

Table 3. Mean squares for potato growth parameters

Source of variation	Df	Mean Squares					
		Days to50% Emergence	Days to50% Flowering	Daysto 50% maturity	Main stem number/hill	Plant Height(cm)	Plant Spread(cm)
Replication	2	38.74	42.18	3.122	0.48	3.84	6.50
Planting depth	2	60.60**	40.72**	14.67**	2.38**	68.46**	245.27**
Timeof Earthing-up	3	0.06^{ns}	39.07**	6.83**	1.98**	38.82**	44.78**
Planting depth*Timeof Earthing- Up	6	0.005^{ns}	4.37^{ns}	0.04**	0.16^{ns}	0.23^{ns}	1.18*
Error	22	0.84	0.79	0.99	0.75	0.96	0.99
SE±		1.26	1.87	0.08	0.43	0.63	0.49
CV(%)		8.46	2.95	10.07	12.81	1.07	1.13

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

4.1.1. Days to 50% emergence

The analysis of variance indicated that there was highly significant (P<0.01) variation in respect of days to emergence on planting depth. But, there is no significant (P>0.05) variation effect was observed at time of earthing-up on days to 50 % emergence. However, no significant (P>0.05) interaction effect was observed between planting depth and time of earthing-up on days to 50 % emergence (Table 3 and Appendix Table 6). The result revealed that planting depth at 14 cm took significantly longer days to 50% emergence (16.98) than depth at 10cm and depth at 12cm which took 12.54 and 15.35 days, respectively (Table 7). The fact that emergence was typically delayed as planting depth increased due to temperature variability across the field and soil depth likely contributed to the unexpected values (Pavek and Thornton ,2009). The difference soil depths are difference soil temperature that delay or hasten the emergency. Adersn and Cliston, ,(2010) the result show that, the rate of development of sprouts from planted seed pieces depends on soil temperature. Very little sprout elongation occurs at 6°C. Elongation is slow at 9°C and is maximized at about 18°C. The time between planting and emergence depends on soil temperature. Hanber *et al.*, (2013), the result show that Proper planting depth may be the emergence, seedling establishment and survival suits and each stage of growth with favorable environmental conditions to be met.

The results are also in agreement with findings of Sultana and Rabbani, (2001) who result show that, this might be due to the fact that in case of deep planting, the potato sprouts had to come across a long distance of the ground to emergence than the shallow planting. The results are also in agreement with findings of Sultana and Rabbani, (2001) who reported this might be due to the fact that in case of deep planting, the potato sprouts had to come across a long distance of the ground to emergence than the shallow planting. Similarly, reported by James and Allemann, (2013) each potato cultivar has its own accumulated heat units for eye and sprout development and if there is enough moisture available. Abdulla *et al.*,(1993) percentages of plant emergence were affected by planting depth, seed tuber placed deeper resulted in lowering the plant emergence.

Time of earthing-up after of full emergency there is no relationship with emergence sprouts develop from eyes on seed tubers and grow upward to emerge from the soil, roots begin to develop at the base of emerging sprouts, and the seed piece is the sole energy source for growth during this stage (Adersn and Cliston, 2010).

Table 4. Effect of planting depth on days to 50% emergence.

Treatments	Daysto50% emergence
Planting Depth (cm)	
10	12.54^{c}
12	15.35^{b}
14	16.98^{a}
LSD (5%)	1.87
CV(%)	8.10

Means sharing the same superscript letter do not differ significantly at P = 0.05 according to the LSD test.

4.1.2. Days to 50% flowering

Days to 50 % flowering was highly and significantly (P<0.01) affected by planting depth and time of earthing-up. However, no significant (P>0.05) interaction effect was observed between planting depth and time of earthing-up on days to 50 % flowering (Table 3 and Appendix Table 9). It was observed that planting depth took longer days to 50% flowering (65.62) which was significantly longer period than planting depth at 10cm and planting depth at 14 cm that required 62.14 and 62.84 days to flower, respectively (Table 7). The planting depth at 10cm was the earlier to flower (62.14 days) than planting depth at (12cm and 14 cm), however, this value was statistically similar with days planting depth took to reach its 50% flowering. The observed variation in terms of flowering date could be attributed to the soil Moisture at 10 cm suggesting that additional factors such as evaporation, air temperature, and canopy coverage could be influencing soil moisture at this depth (Fernando and chand, 2006). This due to plants un optimum level of soil moisture, temperature and soil air in the deep and Shallow planting depth that lead the plants to stress and ultimately the plants flower early instead of prolonged the growth. This result agreement to (Almekinders and Struik, 1996; Sleper and Poehlman, 2006) indicated that Flowering in potato is best when abundant moisture, and cool temperatures prevail). Similar Result showed by Adersn and Cliston, ,(2010) show that tubers form at stolon tips but are not yet appreciably enlarged and in most cultivars the end of this stage coincides with early flowering this is may be due to unfavorable condition for potato growth that cause the difference soil moisture, aeration and temperature. Also Jane *et al.,* (2012) indicated that flowering and fruiting are mainly affected by genotype, day length, and temperature. Genotype, day length and temperature are the main factors that determine flowering and fruiting in potato.

The other result is indicate that increased planting depth has decreased the number of stem and reducing the number of stem tuber is reduced thus reducing the number of gland function is decreased (Hanbar,2012). Depending on this result also similar result was indicated by, (Almekinders and Wiersema, 1991) stated that increasing stem density (number of steam) has been decrease the number of flowers per plant, berry set and seed production from every inflorescence. Increasing plant density was shown to increase the proportion of primary flowers in the total number of flowers per plant and reduced the proportion of flowers on lateral stems also reported by, (Almekinders, 1991). The tips of the solons, which produce no new tubers, this is due to un proper planting depth, This promotes vigorous stem growth and enhances flowering (Gopal, 1994). This is due to tubers in dry soil moisture lost and most of the buds of may the buds with normal moisture in the soil after planting was carried out and the soil around the roots with water to produce buds and stems are earned. Hanbar ,(2012) also reported tubers grown in deep, often causing the plant to a single stem and much lower density per unit area if planting is done and the surface gland production out of the soil .However, the date of flowering was depend on the number of steam (steam density) produce that per plant that affected by depth of planting seed potato tuber that the interaction between soil depth with stolon tuber formation, Tuber formation with steam number and steam number with flowering date. When un optimum soil depth that lead problem of soil temperature, soil moisture and soil air this cause stolen low tuber formation and small number of steam with vigor's growth finally lead early flowering.

Days to 50% flowering was significantly delayed by after full emergence 15 days time of earthing- up. After full emergence 15 days time of earthing- up delayed flowering by 5 days than non earthing-up (control). no earthing-up (control) was none significant difference from earthing-up at 45 days after full emergence (61 and 62.45) respectably. In general, time of earthing-up the number of days to flowering was significantly decreased. However, this result is agreement to Getachew *et al.,*(2012) this is due to lowering was prolonged when potatoes was earthed-up at 15 days after complete plant emergence , absence of earthing up created stress on the plant due to lack of aeration and mechanical barrier of soil colloids during its active growth stage that affected the plant growth and brought early flowering. This early flowering is also related with days to emergence; potatoes which emerged earlier did also flower earlier than those emerged later. The physiological condition of potato seed tuber affects emergence and growth of potato crop (Wiersema, 1987).

4.1.3. Days to maturity

Days to 50% maturity was highly and significantly ($P<0.01$) affected by both planting depth and time of earthing -up. This parameter was also significantly ($P< 0.01$) affected by the interaction planting depth and time of earthing-up (Table 3 and appendix Table 10). The soil type condition of Jimma zone, the vegetation period for potato varied from 112.58 to 116.05 days depending planting depth and time of earthing -up. The longest days to maturity was recorded from depth of planting 12 cm with at 15 days earthing up after full emergency while the planting depth combination with time of earthing-up after complete plant emergency 10 cm x 0 and 10cm x 45 were recorded (112.58, 113.38) respectively matured early (Table 5). The plant extended crop cycle of each growth stage when it's get favorable condition. The is lined with the result of Tesfaye *et al.*(2012) that earthing-up at 15 days after complete plant emergency, matching with the active growth stage of the plant, created favorable soil environment and enhanced further vegetative growth that extended days to maturity.

The correct choice of time of earthing-up critical as far as crop yields and quality achieved are concerned. Soil temperatures play a major role in determining the length the of season that is related to depth of planting in the soil. Early maturity in this experiment was observed to be related with early emergence and flowering. The results line with findings of Caruso *et al.* (2010), who the result show that planting led to crop cycle shortening and faster emergence of more mature seeds. The same result show.

Table 5. Day to maturity of potato as affected by the interaction depth of planting and time of earting-up

Depth of planting(cm)	Days to maturity				
	Time of earthing-up(days)				
	0	15	30	45	Mean
10	112.58^{I}	115.30C^{DE}	114.08^{GH}	113.38^{HI}	113.84
12	115.00^{DEF}	117.21^{A}	116.05^{B}	115.30^{CDE}	115.89
14	113.61^{GH}	116.05^{BC}	114.75^{EFG}	114.17^{FGH}	114.65
Mean	113.73	116.17	114.96	114.29	
LSD(5%)	0.87				
CV(%)	10.07				

Means sharing the same superscript letter do not differ significantly at P = 0.05 according to the LSD test.

4.1.4. Number of main stems per plant

Number of main stems per hill was highly and significantly (P<0.01) affected by depth of planting and time of earthing-up. However, the interaction effect between depth of planting and time of earthing-up was found to be non significant (Table 3). The highest number of main stems was 3.90 recorded for depth of planting (12cm) on average per plant and this value was statistically significant with main stem numbers obtained from both planting depth at 10 and 14, while the lowest was obtained from planting depth at 10 cm (3.49) and this was statistically not significant with number of stems produced from planting depth at 14 cm.

Production of higher main stem number per hill by planting depth at 12 cm was probably due to the all the sprouts are grow found at planting depth 12 cm might have resulted from favorable environmental condition like soil moisture ,temperature, free from soil born disease and soil air and healthier plants .Agreement with Hanbar *et al.,* (2012) the number of stems per plant decreased with increased planting depth the relationship between planting depth and number of stems per plant was reduced as negative. Similarity, Hansen, (2005) mentioned the produced steam number in bush is determined in the environmental condition and the variety regardless the seed. The experiment conducted by Hamid *et al.,* (2001) show that the result of this research indicated that larger number of stems at 20 cm depth compared to 30 cm caused exceeded competition for light absorption in crops. Pavek and Thornton (2009) studies further strengthen the argument that the effects of planting depth on stem and stolon growth appear to be cultivar dependent. Seed pieces can produce more stems when planted into warmer soils, which may explain why Burbank stem number increased when seed pieces were planted closer to the soil surface. As cited by Pavek and Thornton, (2009) despite the fact that warmer temperatures have also been shown to increase stolon number (Bodlaender *et al*. 1964), The smaller the tuber and the deeper it is buried in the soil, the smaller the chance that the stem will emerge (James and Allemann, 2013). Iritani *et al*. (1983) demonstrated that seed pieces can produce more stems when planted into warmer soils, which may explain why Burbank stem number increased when seed pieces were planted closer to the soil surface. Throughout emergence and stolon development the shallowest planted seed pieces were exposed to warmer average soil temperatures than those planted deeper. As it can be seen maximum depth of was cut The reason is that with increased planting depth has decreased the number of stem (Hanbar *et al.,* 2013), results shown that increasing the planting depth of 12 cm, the number of stem and air operations increased and increased planting depth to 14 cm - feet and more, reducing the number of stems air and yield .

It was observed that earthing-up at days after full emergence resulted in increased number of main stem per plant. Earthing-up at 15 days after full emergence increased main stem number per hill 4.06. while the lowest number of main stems was recorded for earthing-up at 45 days after full emergence (3.04) on average per plant and this value was statistically not significant with stem numbers obtained from no erthing-up (3.09).

Tesfaye *et al.,* (2012) reported that cultural practice, given to the plant during active growth stage, enhanced the growth and development to plant steam. This result confirm with Majid and Roza, (2001) reported that the soiling in the height of 15 cm, because the plants are not growing well, so could not properly use the environmental resources and for this reason the number of stems per tuber was reduced. However, when the plant height was 25 to 35 cm, the soiling with controlling the vegetative growth and encouraging the underground growth (or development) cause to inhibition of longitudinal growth and will increase the number of stems. Strongly agree to Muhammad *et al.,*(2013) the analysis showed that minimum number of stems per plant (1.9) was recorded in plants planted haphazard on un leveled land, followed by tubers when planted in furrows without ridges. Potato planted on plain wide beds and covered from one side gave maximum number of stems per plant (3.5). It may be due to aeration and earthing-up that were provided to the tubers in this planting system. This parameter is of great importance because it is directly related with the total production of tubers.

4.1.5. Plant height

Plant height was highly and significantly (P<0.01) affected by depth of planting and time of earthing-up. However, the interaction between depth of planting and time of earthing-up was not significant (P>0.05) (Table 3). The depth of planting at 12 cm had significantly the tallest (61.24 cm) plant height, while depth of planting at 10 cm (56.46 cm) was the shortest. Recorded plant height of depth of planting at 12 cm was higher by 4.78cm and 2.26cm than depth of planting at 10 and depth of planting at 14, respectively. This could be attributed to light availability it is report that increase of steam number will lead to increase of bush height due to light availability and its effect on increase of length number of node, (Dawers, 2006).

Sultan *et al.,* (2001) reported that plant height at maximum vegetative growth stage, plant height obtained from 7.5cm depth of planting were found maximum and the lowest height was recorded from Surface planting. This indicate when planting the near to the surface the plant height is decreased relatively similar trend was observed in this study. Abbasifar *et al.* (1995) reported that stem length was shortened as planting depth was increased.

On the other hand, earthing-up at days after full emergence resulted to difference in plant height. significantly the tallest plant height (61.46cm) was recorded at earthing-up at 15 days after full emergence followed by the earthing-up at 30 days after full emergence (59.67cm), while the shortest (54.46cm) from the last planting at earthing-up at 45 days after full emergence and this value was statistically not significant with the fourth planting at no earthing-up. At earthing-up at 15 days after full emergence increased plant height by 7cm than at earthing-up at 45 days after full emergence. Generally, as earthing-up delayed decreasing trend on plant height was observed. This might be due to moisture and nutrient use efficiency at late earthing potatoes. Tesfaye *et al.,* (2012) reported that this might be due to that early soil cultivation (earthing-up) facilitated the nutrient absorption though enhanced microbial processes and increased soil aeration.

4.1.6. Plant Spread

As depicted in Table 3 The Plant Spread was highly and significantly ($P<0.01$) affected by both planting depth and time of earthing-up. This parameter was also significantly ($P< 0.05$) affected by the interaction of planting depth and time of earthing-up. In the soil condition of Jimma, the plant spread for potato varied from 35.79 to 50.40 cm depending to planting depth used and time of earthing-up. The higher to plant spread was recorded from planting depth 12cm with at time of earthing-up at 15 days after full emergence while the shallow planted 10 cm with at no earthing-up narrowest plant spread.

As shallow planting increased, the length of plant spread decreased in all tested time of earthing-up. This result the same to Muhammad *et al.,* (2013) the result show that, the data analyzed for plant spread after 60 days of planting showed that maximum plant spread (45.5 cm) was recorded in tuber planted on covered with soil.

One reason may be due to earthing-up, which provided enough nutrients in the roots zone of the plants and also due to the favorable environment this method provided to the plants leading to good emergence and healthier plants. On the other hand potato tubers planted following the local farmers method, showed poor plant spread (29.9 cm). It might be due to poor emergence, weaker plants less nutrients and water available to all the plants due to haphazard plantation. And as no earthing-up was practiced in this method, therefore some plants fill down due to less support and bare roots on soil surface. This result line with the study of Tesfaye *et al.,*(2012) is significantly the widest plant spread was observed at days 15 earthing-up. This could be due to the reason that earthing-up at 15 days after complete plant emergency early in the growing season of the potato plant coincide with the proper time of soil workability and optimum soil moisture level. This made the soil porous and aerated and the plant receive the advantaged of proper growth and development than the plant on the control and lately managed plots. At time of 15 days earthing-up after complete plant emergence was observed at all level of planting depth the maximum plant spread. Similarly, planting depth at 12 cm at all level of time of earthing-up the maximum recorded of plant spread.

Table 6 .Plant spread of potato as affected by the Interaction depth of planting and time of earthing-up

Depth of planting(cm)	Plant Spread				
	Time of Earthing-up(days)				
	0	15	30	45	Mean
10	35.79^{i}	42.55^{ef}	39.98^{g}	38.00^{h}	39.08
12	46.33^{c}	50.40^{a}	48.36^{b}	47.37^{bc}	48.11
14	41.53^{f}	46.61^{c}	44.04^{d}	43.36^{de}	43.88
Mean	41.22	46.52	44.12	42.91	
LSD(5%)	1.47				
CV(%)	1.13				

Means sharing the same superscript letter do not differ significantly at P = 0.05 according to the LSD test.

Table 7. Effect of planting depth and time of earthing-up on main stem number/hill, days to 50% emergence, days to 50% flowering and plant height

Treatments	Main Steam Number /Hill	Daysto50% Flowering	Plant Height(cm)
Planting Depth (cm)			
10	3.11^{b}	62.14^{b}	56.46^{c}
12	3.90^{a}	65.62^{a}	61.24^{a}
14	3.16^{b}	62.84^{b}	58.98^{b}
LSD (5%)	0.35	1.61	0.50
Time of earthing-up after Full emergence (Days)			
0	3.09^{b}	61.39^{c}	56.97^{c}
15	4.06^{a}	66.17^{a}	61.46^{a}
30	3.38^{b}	64.11^{b}	59.67^{b}
45	3.04^{b}	62.45^{bc}	54.46^{c}
LSD (5%)	0.41	1.85	0.58
CV(%)	12.81	2.95	1.07

Where,Time of Earthing-up; 0 = no Earthing-up; 15 = Earthing-up at 15 days after full emergency ; 30 = Earthing-up at 30 days after full emergency ;45=Earthing-up at 45 days after full emergency and Depth of Planting;10=Planting Depth at 10 cm;12=Planting Depth at 12 cm;14 = Planting depth at 14 cm. Means sharing the same superscript letter do not differ significantly at P = 0.05 according to the LSD test.

4.2. Yield Parameters

This experiment show that the results obtained in terms of the following yield Parameters such as number of tubers per plant, marketable tuber yield, unmarketable tuber yield, total tuber yield, average tuber weight and number of green tuber are presented (Table 7 and 10) and discussed as follows.

Table8. Mean squares for potato yield parameters

		Mean Squares					
Source of variation	Df	TotalTuber Number (count/hill)	Unmarketable Tuber yield(ton/ha)	Marketable Tuber Yield (ton/ha)	TotalTuber Yield (ton/ha)	Average Tuber Weight (g)	Number of Green Tuber(count/hill)
Replication	2	0.65	5.34	5.71	1.52	24.08	4.02
Planting depth	2	3.37**	10.22**	80.59**	36.33**	44.50**	0.45**
Time of earthing-up	3	7.17**	0.95**	96.64**	78.99**	41.75**	3.28**
Planting depth x Time of earthing-Up	6	0.37**	0.05^{ns}	3.39^{ns}	3.32^{ns}	2.79^{ns}	0.33**
Error	22	0.93	0.98	0.87	0.87	0.79	0.99
SE±		0.31	0.17	1.50	1.44	1.79	0.07
CV(%)		3.70	4.28	7.04	5.83	3.88	4.66

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

4.2.1. Total number of tubers

In table 7 and appendix table 5 total tuber number count per hill was highly and significantly (P<0.01) planting depth and time of earthing-up. This parameter was also significantly (P<0.01) affected by the interaction of depth of planting and time of earthing-up. Total tuber number count per hill varied from 6.75 to 10.13 numbers depending to planting depth and time of earthing-up. The large number of total tuber number count per hill was recorded from at time of earthing-up at 15 days of after full complete plant emergency combined with planting depth at 10 cm and 12 were recorded (9.52 and 10.13), respectively. While, the minimum number of total tuber number count per hill was recorded from no earthing-up combined with planting depth at 10cm observed 7.52, this is statically none significant to time of earthing-up 45 days after full complete plant emergency combine with depth of planting at 10 cm and 14cm (7.78 and 8.32) ,respectively (Table 9).

This result agrees with that Gholipour (1996) who reported that number of produced tubers per plant and unit area decreased as planting depth increased and mentioned the reduction of stem number as its reason. Due to soil depth difference tuber initiation and formation vary. Agreement to the result of Adersn and Cliston (2010) reported that tuber initiation is slower at temperatures over 20oC. The optimum soil temperature for initiating tubers ranges from 16 to 19°C .Under high soil temperatures, stolonization was substantially compromised and there was no underground tuber development. Tuber development declines as soil temperatures rise above 20°C and tuber growth practically stops at soil temperatures above 30°C. The number of tubers set per plant is greater at lower temperatures than at higher temperatures. May be due, to soil depth difference, increased duration of water stress before tuber initiation reduces tuber set per stem.

The result line with Krystyna (2013) result show that soil moisture favorable for plants led to an increase of the number of tubers. The stolon number are affected the tuber number formed. Agreement with the work of Darwin (1991) result showed that planting depth had an effect on the stolon length and the stolon position and hence on the position of the tuber in the soil. The stolon length varied with the planting depth and with deeper planting the stolons was very short. The stolon numbers here not affected by the planting depth, but at 0 cm very few stolons formed tubers. Due to this reason number of tuber decrease in the shallow planting depth.

Covering nodes by hilling stiroulated the rate of stolon formation during active growth stage of the plant. This study lined with Harder et al. (2013) result show that totally planting depth and method of farming, soil temperature and humidity around the tubers grown on the land has significant effect in this regard, the planting depth and soil conditions should be set. This result similar to Lorenz (1945) result show that, the number of tubers per hill became smaller as the depth of planting was increased. Time of earthing-up significantly affect the tuber number due to the critical active stage of the growth and development of potato favorable soil conditions in terms of soil moisture and temperature enhance potato growth. James and Allemann (2013) reported that, as soon as the sprout breaks through the soil surface, leaves and branches starts forming on the nodes.

The plant is now reliant on sunlight for photosynthesis and the underground sprouts starts forming stolons. The optimum temperature for the successful formation of above ground parts and stolon development is 25°C. Potatoes grow very quickly under warm and moist conditions. When they are 10cm tall, the leaf shoots can be mounded around with soil to their full height. This increase the length of underground stem that will bear potatoes (Tafi et al.,2010).

Agreement to Tafi et al. (2010) result show that adding soil could increase tuber numbers per bush .The root system develops rapidly during early growth and thereafter, root length, density, and root mass decrease as the plant matures. Leaves and branches develop on emerged sprouts; roots and stolons develop below ground, and photosynthesis begins. Potato development in stages lasts from 30 to 70 days, depending on planting date, physiological age of the seed tubers, cultivar, soil temperature, and other environmental factors Adersn and Cliston (2010) may be due to this reason early stage earthing-up can create favorable condition for potato large number of tuber formation.The colder the soil temperature, the more rapid the initiation of tubers and the greater the number of tubers formed.

The optimum soil temperature for tuber initiation is 59 to 68˚F (15 to 20˚C). May be, due to active growth stage of plant and favorable environment condition. This work line with Majid and Roza (2011), the result show that, according to the number of tubers per unit area, the effects of time and depth of soling the plant foot has had a significant effect. So, that when the plant height reached 25 or 35 cm the maximum number of tubers per unit area. Due to the plant's severe need of the soil moisture and nutrients at this stage, and soil are forming, food and moisture around the plants collected is with less evaporation, thus, creates a suitable environment for growth of rhizomes.

Table 9.Total Tuber Number of Potato as affected by the Interaction Depth of Planting and Time of Earthing-up

Depth of planting(cm)	Total Tuber Number				
	Time of Earthing-up(days)				
	0	15	30	45	Mean
10	7.52^{f}	9.52^{ab}	8.81^{cd}	7.78^{ef}	8.41
12	8.78^{cd}	10.13^{a}	9.00^{bc}	8.32^{de}	9.06
14	6.75^{g}	9.17^{bc}	8.60^{cd}	7.51^{f}	8.00
Mean	7.68	9.61	8.03	7.87	
LSD(5%)	0.64				
CV(%)	3.70				

Means sharing the same superscript letter do not differ significantly at P = 0.05 according to the LSD test.

4.2.2. Unmarketable tuber yield

Unmarketable tuber yield was highly significant at ($P < 0.01$) affected by planting depth and time of earthing-up, however interaction effect between planting depth and time of earthing-up was none significant ($P>0.05$) (Table 7 and Appendix Table 2). Higher non-marketable yield was registered by planting depth at 10 cm, while the minimum non-marketable yield was produced by planting depth at 12 cm. planting depth at 12 cm and planting depth at 14 cm showed reduced unmarketable tuber yield by 37.07% and 17.86 %, respectively as compared to planting depth at 10 cm. Tubers in the field exposed to sunlight through cracks in the soil or protruding from the trill that turn green before harvest and increase in undersized are graded out as unmarketable (William and Stephen, 2005). Porter *et al*., (2005) the result was show the incidence of infection of tubers at the soil surface was 54% when all surface tubers were combined over all experiments. Sunburned or green tubers harvested from fields with late blight during the growing season are high-risk tubers due to their surface location. Tubers located deep in the soil are better protected from infection than surface or shallow tubers. Tuber infection decreased with increasing soil depth in all soils tested. Concentrations of sporangia and zoospores are reduced at greater soil depths due to the filtering capabilities of the soil. The pore size in soil decreases as the moisture level increases, but increased soil moisture provides a continuous water medium which benefits the movement of sporangia and zoospores through soil. Similarly, Nyankanga *et al,*.(2008) studies have shown that movement of fungal propagules is influenced by soil moisture, soil type and soil temperature. Stem number and plant height can strongly influence non-marketable yield of many potato cultivars (Arsenault and Christie, 2004).

Adersn and Cliston, ,(2010) result show that in proper soil depth that cause deficiency soil moisture increase the attack of cutworms (Spodopteralitura) and mites (Tetranychusspp and Tenuipalpidaeespp). Low soil moisture also increases formation of cracks in the soil, which allow the entry of potato tubermoth and its larvae. The misshaped tuber formed due to soil depth temperature difference. Krystyna (2013) high temperatures during early stages of tuber development caused lower the percentage of misshapen tubers.

Soil moisture favorable for plant growth in the first periods of heat stress was significantly more conducive to the physiological defects of tubers the soil moisture difference due to soil depth difference related to temperature cause of physiological disorder of tuber. Similarly, Selman *et al*., (2008) reported that growth cracks and secondary growth tuber cracking occurs when the potato splits while still growing. These cracks generally start at the bud or apical end of the potato and extend lengthwise secondary growth refers to knobs that grow from lateral buds the cause: Both of these physiological problems are related to fluctuations in soil moisture and rapid, uneven uptake of water. This is the same the result of Majid and Roza, (2011), result show that, the largest impact to marketable yield and gross income came from green tubers. Planting deeper appears unnecessary and it may increase the risk of disease and seed piece rot from delayed emergence during colder years (Pavek and Thornton, 2009).

With regard to time of earthing-up, recorded unmarketable tuber yield from plots planted on earthing-up at 15 days after full emergence was lower by 16.55% and 10.65 % than unmarketable tuber yield from plots planted earthing-up at 45 and 30 days after full emergence respectively. Treatment no earthing-up and at 45 days of after full emergency statically none significant. Results of this experiment revealed that the delaying and no earthing-up at resulted in higher percentage of green tuber deformed disease attacked and small sized tubers as a result of which high unmarketable tuber number. Moreover, higher number of affected tubers by disease, size, malformedand tubers green color and pre harvest sprouting on tubers was observed in none earthing-up and late of earthing-up. This work agreement with Tafi *et al*., (2010) reported that soil adding to the bush affects on the potato product structure. This is due to appropriate time of the soil adding for active physiological growth stages that create favorable soil environment for that plant growth and development plant. Hilling can be an effective late blight management strategy as long as intact soil is present over the surface of the tubers (Arsenault and Christie, 2004).

4.2.3. Marketable Tuber Yield

Marketable tuber yield was highly significant at ($P < 0.01$) affected by planting depth and time of earthing-up, however interaction effect between planting depth and time of earthing-up was none significant ($P>0.05$) (Table 7 and Appendix Table 3). Higher marketable yield was registered by planting depth at 12 cm, while the minimum marketable yield was produced by planting depth at 10 cm (17.23) and 14 cm (17.77) this are statically none significant. planting depth at with regard to time of earthing-up 12 cm and planting depth at 14 cm showed maximum marketable tuber yield by 38.82% and 23.39 %, respectively as compared to planting depth at 10 cm. The marketable yield reduction was presumably due to an increase in green tuber yield at the shallow planting depth. Pavekand Thornton, (2009) result show that marketable yield and gross income typically declined when seed pieces were planted shallow (10 cm). The largest impact to marketable yield and gross income came from green tubers. Tuber greening was reduced as seed pieces were planted deeper. Multiple studies indicate that green or sunburned tuber yield can be significantly reduced by increasing planting depth. Infected with Phytophthora infestans as the season progresses (Lacey, 1966). Drawbacks of deeper planting depths may include marketable yield reduction a likely increase in soil volume that harvesters would have to lift. Concerns regarding shallow planting depth include reduced early-season moisture to plants and occasionally, lower marketable yields due to an increase in undersized, green, and surface-exposed tubers Pavek and Thornton, (2009). Intermediate planting depth critical for marketable tube like tuber size depending on soil type of soil moisture and soil temperature. This study agreement with the work of William and Stephen, (2005) the investigation result show that there was a significantly higher average tuber size at the optimum planting depth, there was approximately one less tuber per plant at the 15-cm depth compared with the 8- and 23-cm planting depths. This result indicate that tubers were set at intermediate depth in the soil is very important that increase the performance of potato. Planting deeper appears unnecessary and it may increase the risk of disease and seed piece rot from delayed emergence during colder years (Pavek and Thornton, 2009).

Other factors influencing stolon and tuber growth include photoperiod, irradiance, temperature, moisture, mineral nutrient supply, physiological and chronological mother tuber age, and date of planting (O'Brien *et al.* 1998). Little research is available on the effect of soil temperature during tuber growth on potato grade and quality Adersn and Cliston, ,(2010) Higher temperatures favor development of large tubers (Western Potato Council, 2003). Also, moisture gradient in the soil depth affects plant top growth, tuber yield, and tuber grade. Agreement to Anderson and Cliston, ,(2010) reported that, fluctuations in water that stress the potato plant during tuber development can result in greater proportions of misshapen tubers of lower market grade. Similarly, tuber physiological disorders such as brown center, hollow heart, and translucentend, as well as secondary growth, growth cracks, bruise susceptibility, and heat necrosis have been associated with water stress and/or wide variations in soil moisture content (Eldredge *et a*l., 1992).This result similar to, Majid and Roza (2011), result show that Marketable yield and gross income typically declined when seed pieces were planted shallow (10 cm).

With regard to time of earthing-up recorded, recorded marketable tuber yield from plots planted on earthing-up at 15 days after full emergence was maximum by 38.82% and 34.6 % than marketable tuber yield from plots planted no earthing-up and earthing-up at 45 days after full emergence respectively. no earthing-up and earthing-up at 45 days after full emergence are statically none significant. Results of this experiment revealed that the no earthing-up and delaying of earthing-up at resulted in higher percentage of small sized tubers as a result of which high unmarketable tuber number.

Moreover, the seed potato is surrounded by soil of a high ,moisture content, a necessary condition for sprout and root growth. The favorable results obtained when earthing-up early, may be caused by higher moisture content in the ridge and a part of the subsoil brought about by a reduction of the number of cultivations (Kouwenhoven, 1970). Similarly , agreement with the work of Tesfaye *et al*.,(2012) result showed that this could be due to plant improved the soil conditions for proper root growth and nutrient absorption that facilitate the above ground part for better growth and development ultimately resulted for the better marketable tuber yield.

4.2.4. Total tuber yield

Total tuber yield was highly significant at ($P < 0.01$) affected by planting depth and time of earthing-up, however interaction effect between planting depth and time of earthing-up was none significant ($P>0.05$) (Table 7 and Appendix Table 4).Mean comparison of different planting depths indicates that 12 cm depth possessed greater yield in comparison with 10 and 14 cm depths (Table 7). Planting the tubers at the depth of 14 cm led to the least yield. Findings of this research revealed that larger number of stem at 12 cm depth compared to that of 14 cm depth. Would result in exceeding competition for environmental factors among crops. On the other hand, this situation improves crop capability of producing photosynthetic matters and increases every tuber's portion from the photosynthetic products (Hamid *et al.,* 2011). Pavek and Thornton, (2009) despite changes to the belowground stem, planting depth did not affect total yield of either cultivar. Under high soil temperatures, stolonization was substantially compromised and there was no underground tuber development. The induction of tuberization by the leaves was affected mainly by air rather than soil temperature, but the signal to tuberize might be blocked by high soil temperatures Adersn and Cliston, ,(2010). This result is in line with the finding of Mahmood *et al,*. (2002) reported that mulch at Islamabad, Pakistan, decreased daily maximum soil temperature at a 15 cm-depth by 1.5 to 4.5oC, resulting in faster emergence, earlier canopy development, and higher tuber yields. Stalham *et al.,* (2005) reported that, potato crops planted into soil with a resistance greater than the threshold for root penetration will develop shallow, restricted rooting systems with a limited capacity for exploiting reserves of water and nutrients in the soil. Water uptake in such crops will almost certainly be limited and, as a consequence, canopy growth, light interception, water use and ultimately yield will be reduced. Similarly, Planting depth had varies effect on total tuber yield (Abdulla *et al*., 1993). This Work line with Hanbar *et al*., (2013), result reported that proper planting depth is usually the most will lead to achieve maximum product performance

With regard to time of earthing-up recorded, line with the study of Tafi *et al*., (2010) result show that that the mutual effect of the soil adding is significant from the yield characteristic view, which it indicates the varieties different reaction toward the appropriate time of the soil adding from the limits of philological growth stages view.

That adding soil could increase tuber yield significantly compared to non adding soil which led to improvement of total yield. Don and James, (1990) the result show that the late hilling treatments appeared not to affect soil temperatures effects of hilling treatments on tuber yield and quality did not appear to be related to soil temperature, all hilled treatments yielded significantly more than the treatment that was not hilled. This work line with Majid and Roza (2011), the result show that, time and depth of soiling of the plant foot had a significant effect on the percentage of potato yield per unit area. So, that when the plant height reached 25 or 35 cm the maximum number of tubers per unit area. Due to the plant's severe need of the soil moisture and nutrients at this stage, and soil are forming, food and moisture around the plants collected is with less evaporation, thus, creates a suitable environment for growth of rhizomes. All of these factors increase the potato yield.

4.2.5. Average tuber weight

The results pertaining to average tuber weight per hill statistically displayed highly significant (P<0.01) difference among potato planting depth and time of earthing-up (Table 7 and Appendix Table 1). On the other hand, the interaction effect of planting depth and time of earthing-up was found to be not significantly (P>0.05). recorded average tuber weight per hill planted at shallow planting depth was (43.91) minimum by 9.29% (47.40) and 8.37 % (47.07) than average tuber weight per hill planted 12 cm and 14 cm depth of planting respectively. planted 12 cm and 14 cm depth of planting are statically none significant. Results of this experiment revealed that the shallow planting depth resulted in minimum average tuber weight per hill as a result of which lower number of tuber gland.

The gland weight increased with increasing planting depth, the production of seed tubers should be given to attribute the number of stems per plant. Because the increased number of stem gland may also increase the number tuber, because the production of seed tubers, the tuber is the weight of the gland. May be the depth is greater total gland weight less but increased. But, what he under line that as it can be seen maximum depth of was cut the reason is that with increased planting depth has decreased the number of stem and reducing the number of stem tuber is reduced thus reducing the number of gland function is decreased (Hanbar *et al.,,* 2013). The deeper planted potatoes had higher average tuber weights than those planted shallow.

With regard to time of earthing-up recorded, recorded average tuber weights per hill planted on earthing-up at 15 days and 30 days after full emergence was maximum (48.78g) and (46.98g) than average tuber weights per hill planted no earthing-up and earthing-up at 45 days after full emergence (44.23g) and (44.52g) respectively. no Earthing-up and earthing-up at 45 days after full emergence are statically none significant. Results of this experiment revealed that the no earthing-up and delaying of earthing-up at resulted in lower average tuber weights per hill.

Soil adding significant average tuber weight the potential average tuber weight that can be successfully produced by time of earthing-up with the tuber numbers per bush, tuber yield, number of stems per hill (stem population) and environmental conditions during the initiation phase of growth Tafirt *et al*.,(2010).

4.2.6. Number of Green Tuber

As depicted in table 10 number of green tuber was highly and significantly (P<0.01) planting depth and time of earthing-up. This parameter was also significantly (P<0.01) affected by the interaction of depth of planting and time of earthing-up (Table 8 and Appendix 12). In the local agro-ecological condition of jimma, the number of green tuber potato varied from 0.63 to 2.88 depending to planting depth and time of earthing-up. The large number of number of green tuber potato was recorded from no earthing-up with planting depth at 10cm, 12cm and 14cm was (2.88, 2.36 and 2.11) respectively, while time of earthing-up after full emergency with depth of planting at (15days x10cm, 15days x12cm, 15days x14cm, 30days x12cm, 30days x14cm and 45days x14cm) were recorded the lowest number of green tubers (1.48, 1.16, 0.63, 1.23, 1, 1.56) respectively (Table 10). The lowest number of green tuber per hill on deep planting was probably due to the deep planting potato its, very low chance to exposed to sun light and the large volume of soil hilling effect that protect potato from expose direct sun light. Numbers of green tuber depend on time and condition of earthing-up. Early earthing-up is important, during potato growth in the first active growth tuber initiation stage and required timely earthing-up. After tubers changed to green tuber, late earthing-up potato there is no chance to change the original pigment (potato once it can be developed the toxic Compound).

Result Selman *et al.* (2008) and Majid and Roza (2011) result show that, potato tuber exposure to light in the field causes the formation of a green pigmentation on the potato. This occurs when sunlight directly contacts tubers growing at or near the soil surface or reaches tubers through cracks in the soil surface. This result is line with that of Pavek and Thornton (2009) who reported that during harvest when some tubers displayed a well defined green strip across their surface which presumably came from a sunlight-saturated soil crack. Additionally, the longer stolons found on stems of the shallowest-planted seed pieces may have exacerbated tuber greening by positioning tubers nearer the sides of the hill. No single planting depth will optimize grower revenue across all situations. Potatoes should be planted deep enough to avoid tuber greening, surface-exposed tubers, soil moisture deficits, and to accommodate the predicted yield.

Similarly, William and Stephen (2005) it seems logical to think that planting seed pieces deeper should help to minimize tubers growing out of the top of a hill, thus reducing field tuber greening. The Highest number of green tubers was observed for the shallow planting depth for no earthing-up used in the experiment. Number of green tubers are increased only when the chance of tubers exposed to direct sun light as decrease the depth of planting and no earthing-up, Agreement with the work of Don and Games (1990) result show that significantly more no hill treatment tubers were green than in all other treatments

However, produced many green tubers when plants were not hilled, significantly more than any of the hilled treatments. The results coincide with the findings of Muhammad *et al.* (2013) who reported that ridging significantly improved yield and reduced tuber greening.

Table 10 .Number of green tuber of potato as affected by the interaction depth of planting and time of earthing-up

Depth of planting(cm)	Number of Green Tuber				
	Time of Earthing-up(days)				
	0	15	30	45	Mean
10	2.88[a]	1.48[bcde]	1.65[bcd]	1.98[abcd]	1.99
12	2.36[ab]	1.16[cde]	1.23[cde]	1.73[bcd]	1.62
14	2.11[abc]	0.63[e]	1[de]	1.56[cbde]	1.76
Mean	2.45	0.75	1.29	1.76	
LSD(5%)	0.98				
CV(%)	4.66				

Means sharing the same superscript letter do not differ significantly at P = 0.05 according to the LSD test.

Table 11 .Effect of Planting Depth and Time of Earthing-up on Unmarketable Tuber yield (ton/ha) Marketable Tuber Yield (ton/ha), Average Tuber Weight (g)

Treatments	Unmarketable Tuber yield (ton/ha)	Marketable Tuber Yield, (ton/ha)	TotalTuber Yield (ton/ha)	Average Tuber Weight (g)
Planting Depth (cm)				
10	4.99[a]	18.69[b]	23.68[b]	43.91[b]
12	3.14[c]	23.57[a]	26.72[a]	47.40[a]
14	4.10[b]	19.62[b]	23.72[b]	47.07[a]
LSD (5%)	0.15	1.29	1.28	1.47
Time of Earthing-up After Full emergence (Days)				
0	4.26[a]	17.23[c]	21.94[c]	44.23[c]
15	3.68[c]	23.92[a]	28.28[a]	48.78[a]
30	3.94[b]	21.26[b]	25.99[b]	46.98[b]
45	4.41[a]	17.77[c]	22.64[c]	44.52[c]
LSD (5%)	0.18	1.47	1.47	1.70
CV(%)	4.28	7.04	5.83	3.88

Means sharing the same superscript letter do not differ significantly at P = 0.05 according to the LSD test

4.4. Correlation Analysis among Growth, Yield and Quality Parameters

The result of Correlation analysis showed that total tuber number per plant (r = 0.766), average tuber weight (r = 0.577), marketable tuber yield (r =0.975), Steam Number (r = 0.798), plant Height (r = 0.789), Day of Flowering (r= 0.564), Days of Maturity (r=761) and Plant Spread (r=0.648) correlated significantly and positively (P<0.01) with total tuber yield. These result showed that any positive increase in such characters had boasted total tuber yield (Table 11). On the other hand, negative and significant (P<0.01) correlations were determined between Unmarketable Yield (r = -0.508) and Number of Green Tuber (r = -0.520).

Plant characters also showed significant association with one another. Marketable tuber yield associated positively and significantly (P<0.01) with average tuber weight (r = 0.642), Total tuber number (0.784), steam Number (r=0.784), plant height (r=0.873), days to Flowering (r = 0.656), days of maturity (r=0.847), and plant spread (r = 0.759). Steam number associated positively and significantly with marketable tuber yield (r = 0.808, P<0.01), while unmarketable tuber yield (r = -0.522) and number of green tuber (r = -0.418) were negatively correlated with marketable tuber yield (P<0.01) and (p<0.05). Highly significant (P<0.01) negative correlation between stem number (r = -0.522), plant height (r = -0.803) and total tuber number (r = -0.534,),total tuber Yield (r=-0.508),day to emergency (r= -0.607), days to flowering (r = -0.701), days to maturity (r = -0.795), plant height (r = -0.69), average tuber weight (r = -0.75), and plant Spread (r = -0.822) were observed. Average tuber weight Associated positively and significantly (p<0.01) with plant height (r=0.716), day of flowering (r=0.590), days of maturity (r=0.786) and plant spread (r=0.713).

The relationship between marketable tuber yield and total tuber yield with average tuber weight and total tuber number per plant was positive and highly significant. This means that tuber number and tuber weight have more effect on total tuber yield. The correlation coefficients between days to flowering days to maturity ,plant spread and steam number with average tuber weight, marketable tuber yield, plant height total tuber number and total tuber yield were positive and significant= (P<0.01).

The result indicated that the above mentioned parameters can be increased by Available yield early earthing-up and with optimum planting depth in which the plant can high yield due to the critical management activity in the active vegetative growth stage of the plant. But, plant spread and days to maturity associated negatively with number of green tuber (P<0.05).

Line with the work of Hanbar *et al.,*(2013) result show that as it can be seen maximum depth of 20 cm was cut the reason is that with increased planting depth has decreased the number of stem and reducing the number of stem tuber is reduced thus reducing the number of gland function is decreased, Correlation between the average weight of the entire gland (r=0.72*)and the total number of tubers per plant (r=0.67*)is also positive and significant at the level of five percent of the significant .Similarly, Kouwenhoven, (1970).The depth of soil cover on the seed tuber is determined by the ridge size, planting depth and time earthing up. Earthing up, corresponding with a deep soil cover has become possible by chemical weed control increase yield.

Therefore, in the production of tubers should be given to attribute the number of stems per plant. Because the increased number of stem Gland may also increase the number because the production of tubers, the tuber is the weight of the gland, the debate should be modified according to the attribute besides the increasing number of stems. This is same as the results of Majid and Roza, (2011) time and depth of soiling of the plant foot had a significant effect on the percentage of potato yield per unit area. The soiling in the height of 25 to 35 cm and depth of one second of the plant height has produced the highest yield according to the results of the number of stems per unit area and the number of tubers (or glands) per unit area which are the two main components in the yield of potato.

The total yield depends on the length of the tuber growing gland the average growth of the tubers per day. The number of tubers per m2 depends on the number of main steins per m2 and on the number of tubers per main stein, which, in turn, decreases with the number of main sterns. (van der Zaag,1992).

Table 12. Correlation analysis among yield and yield components

	Awt	Unmy	My	Tty	Ttn	Sn	Ph	Df	De	Dm	Ps	Ngt
Awt	1	-.600**	.642**	.577**	.571**	.424**	.716**	.590**	.353*	.786**	.713**	-.336*
Unmy		1	-.686**	-.508**	-.534**	-.522**	-.803**	-.701**	-.607**	-.795**	-.822**	.003
My			1	.975**	.784**	.808**	.873**	.656**	.231	.847**	.759**	-.440**
Tty				1	.766**	.798**	.789**	.564**	.088	.761**	.648**	-.520**
Ttn					1	.639**	.726**	.695**	.042	.783**	.595**	-.325
Sn						1	.722**	.534**	.175	.643**	.618**	-.418*
Ph							1	.729**	.439**	.907**	.900**	-.506**
Df								1	.266	.820**	.717**	-.110
De									1	.288	.426**	-.092
Dm										1	.924**	-.348*
Ps											1	-.399*
Ngt												1

*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level. DE= Days to Emergence, DF=Days to Flowering, DM=Days to Maturity, SN=Main Stem Number, PH= Plant Height, PS= Plant Spread, TTN=Total Tuber Number, ATW = Average Tuber Weight, MTY=Marketable Tuber Yield, UMTY=Unmarketable Tuber Yield, TTY=Total Tuber Yield, NGT= Number of Green Tuber.

5. SUMMERY AND CONCLUSION

This study was conducted to evaluate different planting depth and time of earthing-up after full plant emergency for potato production in south west Jimma, Ethiopia. Three different potato planting depth in centimeter (10, 12 and 14) and four different time of earthing-up after full plant days emergence (0,15, 30, and 45) were used.

The result of the investigation showed that most of the parameters considered were significantly affected by the by both factors. Planting depth significantly affected days to 50% emergence, days to 50% flowering, days to 50% maturity, plant spread, stem number per plant and plant height.

Deep planting of potato resulted delayed emergence, flowering and maturity. The maximum plant height was recorded at 12cm planting depth. The longest days to maturity was obtained from depth of planting at 12 cm combined with at 15 days earthing-up after full emergency. The number of main stems per plant generally increased with planting depth optimum and earthing-up on the time of earthing-up at 15 days to after complete plant emergency. The wide plant spread and maximum total tuber per plant recoded (50.40 cm and 10.3) respectively from time of earthing-up at 15 days to after complete plant emergency. as compare with other treatments at this treatment lead large number of total tuber per plant (10.13). The highest marketable yield was obtained from planting depth (12 cm) which was 23.57 ton ha^{-1} and at time earthing-up 15 days after full plant emergency obtained 23.92 ton ha^{-1}. The lowest marketable yield was in planting depth (10 cm) (18.69 ton ha^{-1}) and no earthing-up gave 17.23 ton ha^{-1}.

The interaction effect of planting depth and time of earthing-up showed a significant variation on total tuber number, number of green tuber on number of tuber of potato. The large number of total tuber number count per hill was recorded from at time of earthing-up at 15 days of after full complete plant emergency combined with planting depth at 10 cm and 12 (9.52 and 10.13), respectively. Time of earthing-up after full emergency with depth of planting at (15days x10cm, 15days x12cm, 15days x14cm, 30days x12cm, 30days x14cm and

45days x14cm) recorded the minimum number of green tubers (1.48, 1.16, 0.63, 1.23, 1, 1.56) respectively.

Time of earthing-up at 15 days to complete plant emergency was superior in the heaviest tuber weight with at optimum planting depth (12cm). Earthing-up at 15 days to complete plant emergency resulted in increased average tuber weight by 10.29% as compared to the no earthing-up. Similarly, earthing-up at 15 days to complete plant emergency showed reduced unmarketable tuber yield by 13.62 %, as compared to no earthing-up. Concerning to depth of planting, recorded unmarketable tuber yield from plots planted at optimum depth (12 cm) and deep planting (14cm) was lower by 36.87 and 16.49% respectively than obtained from shallow planting depth (10 cm).

The correlation coefficients between days to flowering and days to maturity with average tuber weight, marketable tuber yield, total tuber yield, tuber number, steam number and plant height and plant spread were positive and highly significant (P<0.01), were as unmarketable yield and number of green tuber were negatively and highly significant (p<0.01).The results of correlation show that most yield and yield components can be a good performance by early earthing-up when the plant reach active growth stage and tuber imitation period with, without go to the cut point above or below optimum planting depth which the plant can use the recourse efficiently and effectively due to the extended vegetative growth of the plant. The result indicated that increased planting depth decreased the number of stem and reducing the number of stem tuber.

Planting depth (12cm) and time of earthing-up at 15 days after complete plant emergence showed superior performance with regard yield and yield component parameters. Therefore, according to the current study, depth of planting (12cm) and the time of earthing-up at 15 days after complete plant emergence can be used for better of Jalane potato variety at Jimma area.

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