EFFECT OF NITROGEN AND PHOSPHORUS ON YIELD AND YIELD COMPONENTS OF POTATO *(Solanum tuberosum* L.) AT MASHA WOREDA, SOUTHWESTERN ETHIOPIA

M.Sc. THESIS

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EFFECT OF NITROGEN AND PHOSPHORUS ON YIELD AND YIELD COMPONENTS OF POTATO *(Solanum tuberosum* L.) AT MASHA WOREDA, SOUTHWESTERN ETHIOPIA

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By

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APPROVAL SHEET
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As Thesis research advisor, I herby certify that I have read and evaluated this Thesis prepared, under my guidance, by Israel Zewide, entitled "Effect of nitrogen and phosphorus on yield and yield components of potato *(Solanum tuberosum* L.)at Masha Woreda, southwestern Ethiopia"**.** I recommend it be submitted as fulfilling the Thesis requirement.

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As members of the Examining Board of the Final M.Sc Thesis Open Defense Examination, we certify that we have read, evaluated the thesis prepared by Israel Zewide Chino and examined the candidate. We recommend that it be accepted as fulfilling the Thesis requirement for the degree of Master of Science in Horticulture (Vegetable Science).

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DEDICATION

This M.Sc. thesis work is dedicated to my Mother W/ro Almaz Sahele

STATEMENT OF AUTHOR

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BIOGRAPHICAL SKETCH

Israel Zewide Chino was born in August, 1981 at Masha, town, Sheka Zone of Southern Nations, Nationalities, and People's Region. He attended his elementary and junior secondary schools at Masha High School in Masha. Following the completion of his secondary education, he joined Jimma University College of Agriculture and Veterinary Medicine and graduated with B.Sc. Degree in Horticulture in June, 2007. He was employed by Teppi Soil Testing Research Center where he has been working as the head of research section, until he joined the graduate studies program of Jimma University College of Agriculture and Veterinary Medicine to pursue his study leading to a Master of Science degree in Horticulture (Vegetable Science).

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LIST OF ABBREVIATIONS

BD	Bulk Density
BoANRM	Bureau of Agriculture and Natural Resources Management
DA	Development Agent
DAP	Di -Ammonium Phosphate
EARO	Ethiopian Agricultural Research Organization
IAR	Institute of Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
MOARD	Ministry of Agriculture and Rural Development
OC	Organic Carbon
OM	Organic Matter
PBS	Percent Base Saturation
SNNPR	Southern Nations, Nationalities, and People's Region
TSP	Triple Super Phosphate
FAO STAT	Food and Agricultural Organization of the United Nation Statistics
FAO	Food and Agricultural Organization

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ABSTRACT

A study was conducted to determine the response of potato (Solanum tuberosum L.) to different rates of N (0, 55, 110 and 165 kg ha-1) and P (0, 20, 40 and 60 kg ha-1) fertilization at Masha in southwestern Ethiopia from November 2010 to February 2011 main cropping season using randomized complete block design with factorial arrangement (4x4) replicated three times. The plot size was four rows of 3m length each with a spacing of 75 cm between rows and 30 cm between plants. Data collected was on growth yield and quality parameters and analyzed using SAS 9.2 software. The result of the experiment showed that application of 165 kg N /ha highly significantly increased days to flowering by six days, days to physiological maturity by 13 days, above ground biomass by 36%, underground biomass by 29.79%, total tuber yield by 60.33%, marketable tuber number by 56.36% and total tuber number by 31.7% and reduced significantly dry matter content by 21.2%, specific gravity by 1.84% over the control and average tuber weight by 22.43%. Specific gravity and dry matter content showed a highly significant ($P<0.01$) reduction with the increased application of nitrogen and phosphorus over the control. However, N or P did not influence days to emergence, stem number, unmarketable tuber yield and number. Application of P significantly ($P<0.05$) increased days to flowering by three days, above ground and underground biomass by 8.78% and 61.4%, respectively and marketable tuber number by 19.72%, and reduced significantly dry matter content by 10.66%, specific gravity by 0.99%. The interaction effect of 165kg of N with 60 kg P increased marketable tuber yield (36 t/ha) by 122% as compared to control (16.2 t/ha). Application of 165 kg of N and 20 kg P (75.27) increased plant height by 24cm as compared to control (51cm). The phosphorus critical and requirement factors for the site were 12and12.5ppm, respectively. The highest total tuber yield (38.07 t/ ha) was recorded with the maximum N rate of 165 kg N/ ha. The lowest total tuber yield (23.75 t/ ha) on the other hand was recorded with no application of N (control treatment). Correlation analysis showed that total yield per hectare was highly and positively correlated with marketable yield per hectare ($r =0.91^{**}$) total tuber number per hectare ($r =0.81^{**}$) and number of marketable tuber ha^{-1} ($r =0.77^{**}$). Average tuber weight ($r =0.94^{**}$). Partial budget analysis also revealed that application of 165with 60 kg N and P gave the highest return followed by 165 with 40 and 20 kg N and P. The result of this study verified that yield and yield components of potato are influenced by different Nitrogen and Phosphorus rating. From this study, it can be concluded that the higher rating (165 kg Nitrogen and 20Kg Phosphorus) produced higher yield and marketable yield per hectare than other ratings. Thus, potato (Jalenie variety) growers in the study area (Masha) can be benefited if they use these higher rating levels (165 and 60 kg Nitrogen and Phosphorus). However, more such studies need to be conducted at various soils, at different agro climatic conditions and extra rate of nitrogen and phosphorus to generate more reliable information.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) belongs to the family *Solanaceae* and genus Solanum. It also belongs to the Sub-genus *pachstemonum* and section tuberarium which also includes of tomato, eggplant, pepper, tobacco and the wild nightshade (Thomson and Kelly, 1972). It is native to South America (Eskin, 1989). It has been introduced to Ethiopia in 1858 by a German Botanist called Schimper (Berga *et al*., 1994b). For many years, its production was limited to only homesteads (as a garden crop) in Ethiopia.

World annual production of potato is about 330 million metric tons with the area coverage of 51,838 ha. In Africa total production of potato is about 17,625,680 tons with total area coverage of 1,765,617ha. However, land acreage under potato production in Ethiopia is estimated to be only about 69,784 ha and the national average yield is about 8.2 tons/ha, which is very low as compared to the world's average production of 17.67 tons/ha .It is one of the major world food crops in its ability to produce high food per unit area per unit time. Developing countries are now the world's biggest potato producers, importers and consumers. Demand is shifting from fresh tubers to processed products. Potato production in the developing countries exceeded the industrial states for the first time in 2005. China is the largest potato producer and nearly one third of all potato is harvested in China and India. (FAO STAT, 2009).

Potato production has substantially increased from 280,000 tons in 1993 to 525,000 tons in 2007 .Ethiopia has the greatest potential for potato production. 70% of Ethiopian land, mainly in highland areas, is suitable for growing the potato (FAO, 2008).

Potato requires a variety of mineral elements for growth and development. Nitrogen and phosphorus are the most important among the elements that are essential for potato growth. It has been reported that Nitrogen and Phosphorus are deficient in most of Ethiopian soils and application of this fertilizer has significantly increased yields of crops (Tekalign *et al.*, 2001).

Inconsistent recommendations have been reported by different researchers at different locations as stated by Bereke (1988). Application of 150 kg N and 66 kg P_2O_5/ha under rain fed conditions resulted in a yield advantage of 32 % over the unfertilized control. Getu (1998) found that the optimum fertilizer rates for potatoes were 87 kg N and 46 kg P_2O_5 on clay soil of Haromaya. Another fertilizer trials conducted at Holeta Research Center in 1999 resulted in the recommendation of 110 kg N and 90 kg P_2O_5 /ha (IAR, 2000). According to Mulubrhan (2004), an application of 165 kg N/ha and 90 kg P_2O_5 /ha is needed for optimum potato production on vertisols of Mekelle area. Zelalem *et al*. (2009) studied the response of potato to different rates of fertilizers under rain fed highland situation at Debre Berhan area and as a result 207 kg N/ha and 90 kg P_2O_5/ha gave the optimum tuber yield.

Low soil fertility is one of the most important constraints limiting potato production in Eastern Africa. Accelerated and sustainable agricultural intensification is required for suitable potato production (Muriithi and Irungu, 2004). Fertility of most Ethiopian soils have already declined due to continuous cropping, abandoning of fallowing, reduced use of manure, crop rotation and removal of nutrients together with the harvested crops. The use of residues as fuel, which should be added to the soil and erosion coupled with low inherent fertility are among the main causes for decreasing soil fertility (Taye *et al.,* 1996; Tilahun *et al.,* 2007).

In Ethiopia, national yield and variety trials data over several locations on different crop species clearly indicated that soil nutrient stress is the most significant parameter controlling crop yield (Tamirie, 1989). Farmers should tackle this problem through the application of both organic and inorganic fertilizes, which amend the soil environment. Nutrient and soil fertility management is also becoming more accepted by development and extension programs in Sub Saharan Africa (SSA) and most importantly, by smallholder farmers (Place *et al.,* 2003).

Soils in western Ethiopia are low in soil organic matter, Cation Exchange Capacity but are high in acidity (Wakene, 2001). Low level of soil organic matter combined with poor land coverage have resulted in many production problems accounted for the low yield of potato in Ethiopia. These are lack of proper planting material, inappropriate agronomic practices, absence of proper pest management practices and unavailability of proper transport, storage and marketing facilities are the prominent ones (Tekalign, 2005). In addition, there are a number of production constraints such as soil types, low nutrient availability in the soil, cropping season, inadequate moisture supply, and lack of improved crop variety. Without considering the fertility status of the soil and the types of crop cultivars, blanket type of national fertilizer recommendation that is 165 kg urea and 195 kg DAP/ha is being used for potato production in Sheka Zone. Furthermore, available information regarding soil fertility studies with regard to potato production in SNNP region is limited (Taye, 1998). Due to these reasons fertilizer application practices in the region have been mainly based on the experiences of other regions.

Therefore, systematic investigations for the response of potato to applied nitrogen and phosphorus fertilizers under this specific Agro-ecology is required to come up with relevant fertilizer recommendations and to help farmers increase the productivity of their potato crop in the area. In view of this the present study was conducted at Masha, with the following objective.

- To determine the effects of rates of nitrogen and phosphorus and their interaction on yield and yield components of potato.

2. LITERATURE REVIEW

2.1. Potato Crop

The chromosome number of wild potato is 2n = 24, while the cultivated has 2n = 48. It is a dicotyledonous, herbaceous perennial plant that is treated as annual, since the edible portion of the plant is uprooted and used each year. It has pinnately compound pattern alternate leaves on its above ground stem and specialized underground storage stems or tubers (Decoteau, 2005).

It is widely grown in tropical and subtropical regions (Beukema and Van der Zaag, 1990). The potato crop is usually propagated by using underground storage organs known as tubers. This may be planted whole or after cutting into small pieces (Thompson and Kelly, 1972; Harris, 1992). Potato tuber is shortened, swollen, starchy stem or it is a modified stem with shortened (and broadened) axis and rather poorly developed leaves (Wien, 1997). The importance of the tubers is indicated by the fact that most of the total dry mater produced by the plant accumulates there and the difficulties as well as time spent in the finding of a new potato cultivars are compensated for by the fact that once the seedling has been chosen, the new cultivars can be maintained, made genetically stable by asexually multiplication (Santos and Gilreath, 2004). Propagation of the tubers obviously plays a significant role in potato cycle (Nonnecke, 1989).

2.2. Economic Importance of Potato

Potato is fourth most important food crop of the world after, wheat rice and corn in human diet among the root and tuber crops, it ranks first followed by cassava, sweet potatoes and yams next to maize in terms of the number of producer countries (FA0, 2008). It is an important crop and it can supplement the food requirements of the country in a considerable way as it produces more dry-matter food, has proportionate protein and produces more calories from unit area of land and time than other main food crops (Romero-Lima *et al.,* 2000; Pandey, 2007).

It is a very important food and cash crop in Ethiopia, especially in the high and mid altitude areas. It has a promising prospect in improving the quality of the basic diet in both rural and urban areas of the country (Berga *et al.*, 1994).

As a food crop, it has a great potential to supply high quality food within a relatively short period and is one of the cheapest sources of energy. In addition to the high nutritive value and lysine content of potato protein, it is a valuable supplement to cereal proteins. Potatoes thus serve as a significant source of proteins (10 to 15% of total protein requirements), cheep source of energy due to its large content of carbohydrate and containing significant amount of vitamin B, C and mineral. Moreover, it is used in many industries for starch production and an important source of energy for industrial communities of the developed countries it is a non-fattening, nutritious and wholesome food that supplies many important nutrients to the diet. Potatoes contain approximately 80% water, 20% dry matter (specific gravity) and fat-free. About 60-80 percent of dry matter is carbohydrate, mainly starch, with some dietary fiber and small amounts of various simple sugars. Although potatoes contain only relatively little protein balanced proportionate of proteins to calories, their nutritional quality is better than that of cereals or soybeans (Abdel *et al.*, 1977; Tacio**,** 2009; Ekin. 2011).

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

2.3. The Role of Nitrogen and its Major Sources

the element nitrogen as an ingredient for the manufacture of protein plants cannot make use of free diatomic nitrogen (N_2) in the air the nitrogen in the air must be combined or fixed with other elements which can be used by the plant . In the nitrogen cycle nitrogen is taken in from the atmosphere by nitrogen fixing bacteria in root nodule of leguminous plant such as clover, beans , chick peas and alfalfa nitrogen can also be added to the soil industrially by man organism combine with other element and form ammonia is changed to nitrite by nitrate bacteria change it to nitrate by nitrifying bacteria nitrogen which is fixed by lighting is also converted to nitrate (Boddey *et al.*, 2006).

Nitrogen has been identified as being the most often limiting nutrient in plant growth. It is found to be an essential constituent of metabolically active compounds such as amino acids, proteins, enzymes, co-enzymes and some non-proteinous compound. Plants absorb nitrogen in the form of ammonium (NH_4^+) or nitrate ($N0_3^-$), and to a lesser extent as urea and ammonia (NH_3). Plants obtain readily available nitrogen forms from different sources. The major sources include biological nitrogen fixation by soil microorganisms, mineralization of organic nitrogen, industrial fixation of N-gas and fixation as oxides of N by atmospheric electrical discharge (Scialabba and Lindenlauf, 2010). Soil pH and its mineral nutrient status, photosynthesis, climate and crop management influence the availability of N through biological N-fixation. Similarly, mineralization of organic N to inorganic forms depends on temperature, level of soil moisture and supply of oxygen (Dawit, 2007).

Nitrogen is needed to form chlorophyll, proteins and it is a major part of all amino acids and many other molecules essential for plant growth and other critical nitrogenous plant components such as the nucleic acids. It is also essential for carbohydrate use within plants. A good supply of nitrogen stimulates root growth and development as well as the uptake of other nutrients (Brady and Weil, 2002).

Potato crop takes nitrogen up from the soil mostly in the form of nitrate. The nitrate is transported to the leaf, where it is reduced to ammonium and incorporated into organic nitrogen compounds. Nitrate concentration in the petiole reflects the balance between recent nitrate uptakes by the potato root system, and nitrate reduction in the leaf in response to crop growth (Sopher and Baird, 1982).

Physiological processes and morphological traits of the potato crop are affected by nitrogen these include the rate of canopy development, the rate of leaf appearance, the rate of individual leaf growth, final leaf size, and the life span of individual leaves, the integral of light interception by the crop over time, the rate of photosynthesis, the number of lower and sympodial branches and the onset of tuberization, final tuber yield and final harvest index (Vos and MacKerron, 2000).

The rate of nitrogen fertilization is a key consideration in managing soil fertility, because excessive applications delay maturity and reduce the partitioning of dry matter to the tubers, not to mention possible adverse effects on processing quality and on the environment (Hirel *et al*., 2007). Vitosh (2005) reported that under conditions of good plant growth, NH_4^+ is rapidly converted toNO_3^- by bacteria. Both forms of nitrogen can be taken up and utilized by plants. However, crops such as tobacco, potatoes and tomatoes prefer NO_3^- as their source of Nitrogen. Since nitrate is much more mobile than ammonium, ammonium forms of Nitrogen are recommended when the application is made prior to the time of greatest need. This practice minimizes potential loss by leaching (Tisdale *et al.,* 1995). Urea (46%N) is the most widely used dry nitrogen fertilizer. Once applied the soil, urea is converted to ammonia which reacts with water to form ammonium with- in two or three days.

2.4. The Role of Phosphorus in Potato Production

Phosphorus is essential in many plant functions and is needed in a stable supply in order to avoid disruptions in plant growth. Soil in which potatoes are grown generally contains large quantities of phosphorus, around 1000-2000 kg/ha (Joakim, 2007).

However, most of it is bound to the soil to the extent that it becomes unavailable to plants. Plants need about 1/5 to 1/10 as much phosphorus as they do nitrogen and potassium but the concentration of phosphates in soil solution is only about 1/20 or less of those of nitrogen and potassium (Westermann and Bosma, 1994). Moreover, the potato plant has a relatively small nutrient exploration area because of its limited tolerance to drought is shallow root system, light root hairs and low root to foliage ratio (Nigussie, 2001).

Applications of Phosphorus recommended to potato crops and are believed to increase yield, quality, and tuber set and early leaf development the crop has traditionally been regarded as having a large requirement for phosphorus with the results that substantial applications of phosphate fertilizer are frequently made in anticipation of significant economic yield responses. Numerous studies have revealed relationships between phosphorus availability and yield (Jenkins and Ali, 2000).

Jenkins and Ali (1999) also demonstrated the beneficial effect of phosphate fertilizer on growth could be explained in terms of enhanced early canopy growth and increased radiation interception. The work presented here examined in field grown crops the effects of phosphorus supply on progeny tuber numbers, a relationship widely recognized but rarely documented in the literature, and considers the consequences for tuber size grading. Relatively large amounts of fertilizer Phosphorus are frequently applied to potato crops and economic responses occur where phosphorus is essential for numerous metabolic processes.

Among the significant functions and qualities of plants phosphorus has most importantly enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, reproduction, nitrogen fixation, flowering, fruiting (including seed production) and maturation. Root growth, particularly development of lateral roots and fibrous rootlets, is encouraged by phosphorus. In cereal crops, good phosphorus nutrition strengthens structural tissues such as those found in straw or stalks, thus helping to prevent lodging (falling over). Improvement of crop quality, especially in forages and vegetables, is another benefit attributed to this nutrient (Hue and Fox, 2010). Phosphoruscan be present in soils in two forms, inorganic and organic. In most agricultur al soils30-60% ofthe phosphorus is present in inorganic forms, although this fraction can vary from 5-95%.Itsavailability is controlled by solubilization and precipitation of phosph ate in inorganic formand through the mineralization and immobilization of the organic fra ction (Sims *et al.*, 2005).

Crop yields and quality have been limited due to many factors proposed by many researchers. According to Downs and Hellmers (1975) and Tisdale *et al*. (1995), these can be categorized in to four major headings: the soil up on which the crop grows, the genetic makeup of the crop, the climatic conditions during the growth of the plant and the management practices. Maintaining adequate level of soil fertility has been recognized as one of the management

The deficiency or excess amount of Nitrogen and Phosphorus change the normal function of plants (Glass *et al*., 2002; Mahmud *et al*., 2003; Taghavi *et al*., 2004; Montemurro *et al*., 2007).

Application of nitrogen and phosphorus fertilizers have shown good yield responses, for different crops across different locations indicating low nitrogen and phosphorus status of these soils (Berga *et al*., 1994a**:** Yohannes, 1994). This situation would become more critical in potato production in view of the fact that the potato crop is known to be a heavy feeder of plant nutrients (Powon, 2005).

As cited in Asseffa (2005) under normal condition potato crop may remove an estimated 90 to 192 kg of N/ha, 13.8 to 25.8 kg P/ha and 150 to 250 kg K/ha from the soil. Owing to its shallow root system and short crop duration, the nutrient requirement of potato is very high. Depending on the type of variety, crop rotation, moisture supply and management practices (Sikka, 1982).

The yield response to mineral nutrient application in potato, as in other crops, was found to be determined by soil, plant management and climate (Bereke, 1994). It is a well-established fact that the soil nutrient affects the maturation and fruiting of plants.

2.5. Yield Components of Potato

2.5.1. Stem number

Many investigators reported the absence of close relationship between mineral nutrition and the number of stems per plant (De la Morena *et al.*, 1994; Mulubrhan, 2004; Asseffa, 2005; Zelalem *et al.,* 2009). From their studies on yield development of potato as influenced by nitrogen and phosphorous fertilizer, observed that the yield difference due to nitrogen and Phosphorous treatment was not attributed to its effect on stem density as the number of stems was not significantly influenced by nitrogen and phosphorous nutrition. However Getu (1998) observed a significant difference in mean stem number of potato (per hill) as nitrogen rate was increased.

2.5.2. Number of tubers

Zelalem *et al*. (2009) who found that application of 207kg N/ha resulted in a significantly higher total tuber number in Potato. In addition, Mulubrhan (2004) and Daniel (2006) noted that the application of Nitrogen and Phosphorus increased the number of tubers per unit area. By contrast, Sharma and Arora (1987) observed absence of strong association between tuber number and increased application of mineral nutrients.

2.5.3. Average tuber weight

Average tuber weight has been reported to be the third most important yield component of potato after two, stem and tuber number, contributing to the total tuber yield, Sharma and Arora (1987); Bereke (1994) and Mulubrhan(2004) also stated significant increase in average tuber weight in response to Nitrogen application. Similarly Asseffa (2005) observed that nitrogen treatment (0, 50, 100, 150 kg N/ha) significantly increased average tuber weight at all levels of nitrogen application. In addition, 150 kg N/ha gave the highest Average tuber weight. Zelalem *et al*. (2009) reported a reduced average weight of tubers when nitrogen level was increased above 138 kg/ha. On the other hand Bereke (1994) reported no significant response in average tuber weight was obtained when Phosphorus application rates were increased.

2.6. Effect of Nitrogen and Phosphorus on Yield and Yield Components of Potato

Zelalem *et al.* (2009) in his study application of nitrogen increment N (0, 69, 138 and 207 kg/ha) on potato resulted in a significantly increase in, days to flowering, days to physiological maturity, plant height, above ground biomass, underground biomass, marketable tuber yield, marketable tuber number, total tuber number and average tuber weight however reduction in harvest index was noted due to nitrogen rate increasing.

Similarly, to nitrogen increasing phosphorus application (0, 20, 40, and 60 kg/ha) increases significant days to flowering, plant height, above ground biomass, underground biomass, marketable Tuber yield and marketable tuber number.

Mulubrhan (2004) in a study on the influence of Nitrogen Phosphorus and Potassium On yield, and yield components of potato at Haramaya University, found that application of Nitrogen and Phosphorus significantly increased, total and marketable tuber yield, tuber numbers (per hill).

Lakachew (2007) noted excess Nitrogen or imbalance of Nitrogen results in excessive vegetative growth and foliage, high shoot to root ratio, poorly developed root system, reduced flowering, and delayed maturity. Frezegi (2007) also reported that high available Nitrogen levels in soil at planting delayed potato tuber growth period by 11 days as compared to no nitrogen fertilization.

Similarly, Robert and Cheng (1988) high rate of Nitrogen on potatoes at planting, delayed tuber maturity and further extra Nitrogen fertilizer slowed the early bulking rate. Contrary to the Nitrogen, it is observed that plants mature earlier when there is an abundance of Phosphorus in the root zone by reducing the Nitrogen balance of the plant.

Potato tuber yield is a function of three major processes: radiation interceptions conversion of intercepted radiation to dry matter and the partitioning of dry matter between tubers and the rest of the plant (Harris, 1985). It is most easy to reveal the effects of nutrient supply, radiation interception and dry matter partitioning where the nutrient in question is in short supply.

2.7. Effect of Nitrogen and Phosphorus on Quality of Potato

2.7.1. Tuber dry matter content

Kanzikwera *et al.* (2001) and Lakachew (2007) reported a reduced percentage of dry matter of potato tuber as nitrogen rates were increased. This is attributed high rates of nitrogen that delay tuber initiation and maturity. As a result, tubers tend to be harvested immature with low dry matter percentages. Asseffa (2005) indicated that increasing nitrogen and phosphorous application rate significantly decreased specific gravity and dry matter content of potato tuber.

Regarding phosphorus, Zelalem *et al.* (2009) reported non-significant differences in dry matter contents of the tubers in response to increased phosphorus application. According to Storey and Davies (1992), the tuber dry matter content was influenced by a wide range of factors that affected the growth and development of the crop including most importantly, environmental factors such as intercepted solar radiation, soil temperature, available soil moisture and cultural treatments. That tuber dry matter failed to increase with an Increase in nitrogen application. This may be attributed to the fact that high rates of N stimulate top growth more than tuber growth thereby delaying tuber formation and maturity.

2.7.2. Tuber specific gravity

Specific gravity of raw potatoes is generally accepted by the potato processing industry as a measure of total solids, starch content and other qualities. High consistent specific gravity in potato tubers is important to the grower and the processor. Timm and Flocker (1966) reported a reduced specific gravity of tubers when nitrogen level was increased above 136 kg /ha. Similarly Asseffa (2005) reported that the specific gravity of tubers decreased with increasing rates of nitrogen fertilizer. Daniel (2006) also reported that increasing the rates of mineral fertilizer tend to reduce tuber specific gravity in addition Gezachew (2006) higher Nitrogen doses reduce the specific gravity of tuber. Excessive nitrogen can reduce tuber quality by lowering specific gravity or dry matter content, promotes internal blackening of the tuber (after bruising), while ‘reducing sugar', protein and nitrate contents are increased. Susceptibility potato to secondary plant nutrients and excess salt create burning to young seedlings. On the other hand Roberts and Cheng (1988) reported that there is no difference in specific gravity of tubers due to nitrogen application.

Conflicting results have been reported about the effect of phosphorus on the specific gravity of potato tubers. As the rate of phosphorus fertilizer increased, while specific gravity of tubers decreased (Asseffa, 2005; Daniel, 2006). However, Tyler *et al*. (1961) observed increased specific gravity with increased phosphorus application. As opposed to the above findings, Zelalem *et al*. (2009) reported non-significant effect of Phosphorus on the specific gravity of tubers. As stated by Maier *et al*. (1994), at sites deficient in phosphorus, banding of phosphorus fertilizer at planting might increase specific gravity.

The specific gravity is a measure of quality in potato tuber which is related to the dry matter contents in the tubers. Variety, location and type and amount of fertilizer used are some of the factors that affect the specific gravity of potato tubers, (Khan *et al.,* 2010). The specific gravity is also associated with starch content, total solids and mealiness of potato tubers (Teich and Menzres, 1964). They also reported a reduction in specific gravity due to fertilizer treatment and its influence on crop quality. Higher the specific gravity the higher will be the quantity of dry matter and the greater the yield of produce.

Potatoes with high specific gravity are preferred for preparation of chips and French fries. While with low specific gravity are used for canning. However, potatoes with very high specific gravity (1.10) may not be suitable for French fries production because they become hard or biscuit like. Based on specific gravity value tubers are categorized as low (< 1.077), intermediate ($1.077 \leq X \leq 1.086$), and high (>1.086) (Fitzpatrick *et al.,* 1964).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted at Yena Keble, Masha Woreda, and Sheka Zone of SNNPR on A land owned by farmer plot during 2010/2011 main cropping season. The area is located about 677km south-west of Addis Ababa at 7°44N 35°29E longitude and 7.733°N latitudes with an elevation of 2223 m.a.s.l. The site receives an average annual rainfall between 1800 and 2200 mm with multimodal distribution and experiences annual mean temperature ranging between 15.1 and 27^0C. The length of potato growing period extends from November 2010 to February 2011 (Bedru, 2007).

The Woreda is classified into three agro-ecological zones, namely, highland, midland, and lowland. The midland covers the largest part which accounts about 80% of the total 15,716.4ha while both the highland and lowland covers the rest 20% (BoANRM, 2008).

As per the FAO/UNESCO system of classification, the soils of the area is characterized as Acrisol (soils with sub surface layer of accumulated Kalonitic clay in the order Oxisol) (Berhane and Sahlemedhin, 2003).

In the western, south western and southern highlands, Acrisol are characterized by high Kaolintic clays, low Cation Exchange capacity, low base saturation and low pH values. This may be due to high rainfall and hot climate, which result in intensive leaching. They are deep, well-drained and reddish brown when moist and dark red when dry (Berhane and Sahlemedhin, 2003).

3.2. Physical and Chemical Properties of the Experimental Site

Surface soil samples (0-30 cm) were collected randomly using auger from 10 spots of the experimental area after final land preparation but before planting. The surface soil samples collected from the study area were composted, bagged, labeled and transported to the laboratory for selected physico-chemical soil analysis and analyzed after the soil samples were air-dried and passed through a 2mm mesh sieve all analysis were made using the procedure manual for soil and plant analysis by Sahlemedhin and Taye (2000) and all the laboratory analysis were done in Teppi Soil Testing Laboratory

The results of the laboratory analysis of some selected physiochemical properties of the soil of experimental site are presented in the (Appendix Table 1). According to Landon (1991) the experimental soil results before planting showed that the soil is sandy loam in texture (%sand= 60, %silt=30, %clay=10) and it was found to be strongly acidic in reaction with a pH of 5.1 high in total N (0.314%), medium organic matter (3,52%). Medium C:N(1;12), generally good in C:N ratio there may be release of nitrogen low in Cation Exchange Capacity (12.5meq/100) medium K (0.6meq/100), and Medium Ca (6.5meq/100) low Mg(0.5meq/100) medium percent base saturation of 60.8 is considered to be good soil low Electrical Conductivity (2.65ms/cm) which indicate that the soils of the study area is salt free slightly compacted bulk density low in soil available P such findings further signify that soils require external application of nutrients according to recommendation for the crops grown (10.5ppm). The low P content of the soil is probably attributed to high P fixing capacity of the Acrsol (Berhan and Sahlemedhin, 2003). These properties indicate that the experimental soil has some limitations with regard to its use for crop production.

3.3. Experimental Material

A potato variety Jalene obtained from Holeta Agricultural Research Center was used for the experiment. Among the improved varieties Jalene is one of the potential potato cultivars for south west Ethiopia such as Masha Woreda. It is being cultivated widely and has got acceptance by farmers due to its high yielding ability, acceptability by consumer, wider adaptation, better cooking ability and relatively resistance to late bight as compared to local and improved varieties growing in the area (Table 1).

Table 1. Characteristics of Jalene potato variety

Variety	Year of Release	Researc h Station	Altitude (m.a.s.l)	Rainfall (mm)	Maturity (days)	Yield (t/ha)	
						Research	Farmers
Jalene	2002	Holleta	1600-2800	750-1000	90-120	44.8	29.13

Source: EARO(2004)

3.4.Treatments and Experimental Design

The experiment consisted of two factor namely, Nitrogen at four levels (0, 55, 110 and 165 kg N/ha) and phosphorus at four levels (0, 20, 40, and 60 kg P/ha). The rates for both nitrogen and phosphorus were fixed by considering the national recommendation as a bench mark.(EARO, 2004) Therefore, treatments were arranged in a 4 x 4 factorial arrangements in a Randomized Complete Block Design (RCBD) with three replications.

3.5. Experimental Procedures

Land preparation was done in late September, 2010. Using draft animals and human labor Medium sized and well-sprouted tubers were planted on November 20, 2010. The whole field was divided into three blocks each containing 16 plots. Each plot size has an area of $9m^2$ (3m length and 3m width) and each with a spacing of 75cm between rows and 30cm between plants. The number of potato plants per row was 10 plants (40 plants per plot). The entire rate of Phosphorus and half the rate of the nitrogen fertilizers were applied at the time of planting. The remaining half of the Nitrogen was applied 45 days after planting. Urea (46% N) and triple super phosphate (TSP) (46% P_2O_5) were used as fertilizer sources for Nitrogen and Phosphorus, respectively. Management practices such as weeding; cultivation and ridging were practiced as per the recommendation (Gebremedihin *et al.*, 2008). No major diseases and insect pest incidence were encountered.

3.6. Data Collected

3.6.1. Growth parameters

1. The actual number of stem per plant: was recorded only by counting the main stem which came out from the tuber (Zelalem *et al*., 2009).

2. Days to 50% flowering: Days to 50% flowering was recorded by counting the number of days, in which 5 plants flowered out of 10 plants (Janagrad *et al.*, 2009).

3. Plant height (cm): Plant height was determined by measuring the height of the plant from the base of the main shoot to the apex at full blooming stage (Zelalem *et al*., 2009).

4. Days to 50% maturity: It was recorded when the haulms (vines) of 50% of the plant population have yellowed or in each plot they showed senescence.

5. Shoot biomass (g): biomass of the haulm was recorded; and dry weight was noted after air drying the samples and further oven-drying at 65^0C for 72 hours until constant weight was obtained (Mulubirhan, 2004).

6. Root biomass (g): biomass of roots and withered stolon were recorded; and dry weight was noted after air drying the samples and further oven-drying at 65^0C for 72 hours until constant weight was obtained (Mulubirhan, 2004).

3.6.2. Yield parameters

1. Total tuber number (count/hill): It was arrived at by taking the sum of both marketable and unmarketable tubers.

2. Marketable tuber number (count/hill): Number of tubers was counted as marketable based on their size category (more than 50 g considered as marketable) (Tekalign, 2005).

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

4. Marketable tuber yield (ton/ha): It was recorded by considering and weighing only the healthy tubers with a size greater than or equal to 50 g (Zelalem *et al*., 2009).

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

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

3.6.3. Quality parameters

1. Specific gravity of tubers (g/cm^3): Specific gravity of the potato tubers was determined using the method described by Dinesh *et al*. (2005).

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

2. Tuber dry matter content (%): Tubers from randomly chosen five plants per harvestable plot were washed, chopped and mixed. 200g of sample was taken and pre-dried at a temperature of 60°C for 15 hrs and further dried for 3 hrs at 105°C in a an oven until constant weight was attained. It was calculated as

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

3.6.4. Soil parameters

1. Soil particle size distribution (texture): It was analyzed by Bouyoucos hydrometric method following the procedure described by (Day, 1965).

2. Soil pH: the composited soil sample was analyzed for and determined potentiometrically in 1:2.5 ratio soil water mixtures using a glass electrode attached to a digital pH -meter as described by (Van Reeuwijk, 1992).

3. Soil Organic matter content (%): It was estimated from soil organic carbon (OC) using wet oxidation method where the carbon was oxidized under standard conditions with potassium dichromate ($K_2Cr_2O_5$) in sulfuric acid solution. Finally, the organic matter (OM) content of the soil was calculated by multiplying the percent organic carbon (% OC) by 1.724 standard procedures outlined by Sahlemedhin and Taye (2000).

4. Total N content of the soil(%): It was recorded before and after planting was determined using Micro Kjeldahl method by oxidizing the OM with sulfuric acid (through sulfuric acid digestion and distillation) and converting the N into NH_4^+ as ammonium sulfate as modified by Sahlemedhin and Taye (2000).

5. Soil available P (mg/kg soil): It was determined before and after planting. calorimetric measurements was taken after extraction of soil samples by sodium bicarbonate ($NaHCO_{3)}$ solution at P^H 8.5 following the procedure outlined by (Olsen and Dean, 1965).

6. Exchangeable Cations (Ca, Mg, and K): Were determined by the ammonium acetate method (Chapman, 1965) whereby K was read by flame photometer and Ca and Mg by atomic absorption spectrophotometer.

7. Soil Cation Exchange Capacity (CEC): It was determined by ammonium acetate method after leaching the ammonium acetate extracted soil samples with 10% NaCl solution. Determined from ammonium acetate saturated samples through distillation and measuring the ammonium using the modified Kjeldahl procedure as described by (Jacson, 1958).

8. Bulk Density (g/cm^3): It was determined by the core method described by Ghildyal and Gupta (1998) a cylindrical metal sampler of 5 cm diameter and 15 cm long was used to sample undisturbed soil. The core was driven to the desired depth and the soil sample was carefully removed to preserve the known soil volume as existed in situ. The soil was then weighed, dried at 105^{o}C for two days.

9. Electrical Conductivity (*ms*/cm): The soil was analyzed for EC by using Ec meter before planting.

3.6.5. Determination of critical P concentration

For the determination of critical value of phosphorus the Cate-Nelson diagram method (Nelson and Anderson, 1977) was used where soil phosphorus value were put on X axis and relative yield value on Y axis and scatter point were divided into two population this was achieved by overlay of clear plastic sheet having a pair of perpendicular lines drawn on it to produce four quadrant roughly of the same relative size the overlay was then positioned on the graph in such way that the maximum number of points fell in the positive quadrant while the lowest number fell in the negative quadrant the vertical line defines the responsive and non responsive range the observation in the upper left quadrant overestimate the fertilizer phosphorus requirement while the observation in the lower right quadrant underestimate the fertilizer requirement the optimum is indicated by the point where vertical line crosses the X-axis data from a site and all the treatments with their replication were used for such analysis.

3.6.6. Determination of Phosphorus Requirement Factor

This factor enables the quantity of phosphorus required taken to raise the soil test by (1ppm) it was calculated using available soil Phosphorus above the critical level it was calculated using available soil P value in samples collected from fertilized and unfertilized plot (Abreha and Yesuf, 2008).

3.7. Statistical analysis

The data were checked for normality and meeting all ANOVA assumptions and analysis of variance and correlation was done using SAS Version 9.2 statistical software (SAS Institute, 2008). When the ANOVA showed significant differences means for nitrogen, phosphorus and interaction effects were compared by using List Significant Difference (LSD) value at 5% significance (Montgomery, 2005). All the graphs and tables were generated by using excel computer program. The following model for factorial RCBD was used.

Model for the Experiment

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + €_{ijk} \quad \begin{cases} i = 1, 2\ldots \text{ nitrogen} \\ j = 1, 2\ldots \text{ phosphorus} \\ k = 1, 2\ldots \text{ number of replication} \end{cases}$$

Where, μ = the overall mean effects

αi = the effects of i^{th} level of nitrogen

i = 1-4

βj = the effects of the j^{th} level of phosphorus

j = 1-4

$(\alpha\beta)$ ij = the effects of the interaction effects between nitrogen and phosphorus

€ijk = the random error compared for the whole factor

k = number of replication

3.8. Economic Analysis

To estimate the economic significance of the different treatments, partial budget analysis (CIMMYT, 1988) was employed to calculate the marginal rate of return (MRR) and economic analysis was done on nitrogen by phosphorus factorial treatments. Before economic analysis, tuber yield was adjusted down by 10% to minimize the effect of researcher managed small plots that may differ from the yield level on farmers' fields. Current price of 500 EB (Ethiopian Birr) per 100 kg potato tuber was used. This was the actual price during year 2010/2011 harvesting season (based on personal varied from 1100 to 1142 EB for 100 kg DAP and from to 850 to 904 kg EB for 100 kg urea depending on the proximity of the DA center to the main road to Addis Ababa (personal observation). The maximum price of fertilizer (i.e., 1142birr for 100 kg DAP and 904 EB for 100 kg urea) was considered for the economic analysis the sites. For the experiment, we used TSP (Triple Super Phosphate) and urea as source of phosphorus and nitrogen, respectively. Since, TSP is not available in local markets in the country, the price of DAP was considered as a base for the price of TSP for economic analysis. However, the nutrient content of DAP is 18% N and 46% P_2O_5 (a total of 64%) and that of TSP is only 46% P_2O_5. Therefore, the price of TSP was assumed to be 72% of the price of DAP (72%

of 1142 EB), i.e., 822 EB/100 kg TSP for economic calculation leaving the remaining 28% to be the price of N. Fertilizer transport and cost of broadcasting was assumed to be 15.00 and 10.00 EB for 100 kg TSP or urea fertilizer. Similarly, the cost of harvesting and bagging were assumed to be 15.00 and 10.00 EB /100 kg tuber, respectively, summing up to 25.00 EB/100 kg potato tubers. And cost of tuber seeds is not considered in the budget to use the marginal rate of return (MRR) as a basis for fertilizer recommendation the minimum acceptable rate of return (MARR) was set to 100%. Treatments with lower net benefit than treatments of lower cost are dominated, and are not included in the partial budget analysis.

4. RESULTS AND DISCUSSION

The effect of different combinations of nitrogen and phosphorus rates on yield and quality of potato were evaluated with respect to potato growth, tuber yield and quality attributes and the results obtained are presented and accordingly discussed in light of the available literature.

4.1.Growth Parameters

The results of the current investigation obtained in terms of growth parameters including days to flowering and maturity, plant height, Shoot dry weight, Root dry weight are discussed as follows.

4.1.1. Days to 50 % flowering

Days to 50 % flowering was highly significantly *($P<0.01$)* affected by nitrogen and significantly *($P<0.05$)* affected by phosphorus. However, no significant *($P>0.05$)* interaction effect was observed between nitrogen and phosphorus on days to 50 % flowering (Appendix Table 2). Increasing nitrogen application resulted in delaying the time required to reach 50% flowering from 55 to 62 days and the earliest time to flower was observed at 0 level of nitrogen and phosphorus application (Fig. 1). However, this value is statistically similar with 55 kg of nitrogen and the latest time to flowering was observed at 165 kg of nitrogen. This could be due to the fact that application of excessive nitrogen prolonged vegetative growth of the potato plant. This result is in consistency with the findings of Lauer (1986); Frezgi **(**2007) and Zelalem *et al.* (2009) who reported that high nitrogen level promotes excessive vegetative growth and delays flowering.

Similarly, the effect of increased phosphorus application from 0 to 60 kg P /ha prolonged the days to 50% flowering from 56 to 59 days (Fig.1). However, as in the case of nitrogen, an increase in phosphorus application did not result in highly significant effect on days to 50% flowering. The earliest time to flower was observed at no phosphorus (0kgP/ha) application and the latest time to flowering was observed at phosphorus application of 60 kg/ha. This value is statistically similar with the application of 20 and

40 kg/ha of phosphorus. The increase in days to flowering due to applied phosphorus was significant only at the level of (0 kg P /ha) this may be due to immobile nature and slow availability of phosphorus the effect of phosphorus is suppressed by nitrogen In agreement with the findings of the present investigation, phosphorus application had been found to prolong days required to 50% flowering (Harris, 1978 and Mulubrhan, 2004).

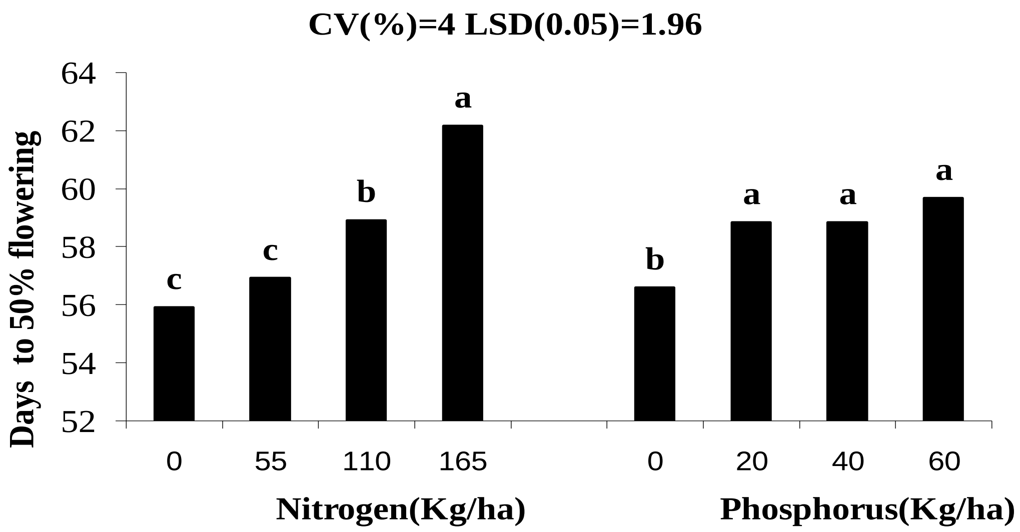

Fig 1. Effect of nitrogen and phosphorus on days to 50% flowering of potato.

4.1.2. Days to 50% maturity

Days to 50% maturity was highly significantly *(P<0.01)* affected by both nitrogen and phosphorus. However, no significant *(P>0.05)* interaction effect was observed between nitrogen and phosphorus on days to 50% maturity (Appendix Table 2). Days to 50% maturity was prolonged with increased nitrogen rates (Fig. 2). Hence, increased rate of nitrogen from zero to 165 kg /ha delayed days to 50 % maturity from 99 to 112 days. This could be due to the fact that the increased rate of nitrogen stimulated haulm growth; prolonged the growing period and delayed tuber formation (crop maturity). Therefore, a crop with more nitrogen will mature later in the season than a crop with less nitrogen because later growth (maturity) is related to excessive haulm development but early tuber growth (maturity) is related to less abundant haulm growth (Mulubrhan, 2004).

In case of phosphorus, in contrast to that of nitrogen, increased rates of phosphorus reduced the days to 50 % maturity. The reduction in days to 50% maturity due to applied phosphorus was significant only at the level of 40 and 60 kg P/ha (Fig. 2). This might be due to the role of phosphorus in facilitating tuber bulking stage of potato. The results of the present investigation support earlier studies on the effect of phosphorus on days to maturity (Klein Kopf *et al*., 1987and Mulubrhan, 2004) where in phosphorus nutrients was reported to be related with shortening maturity.

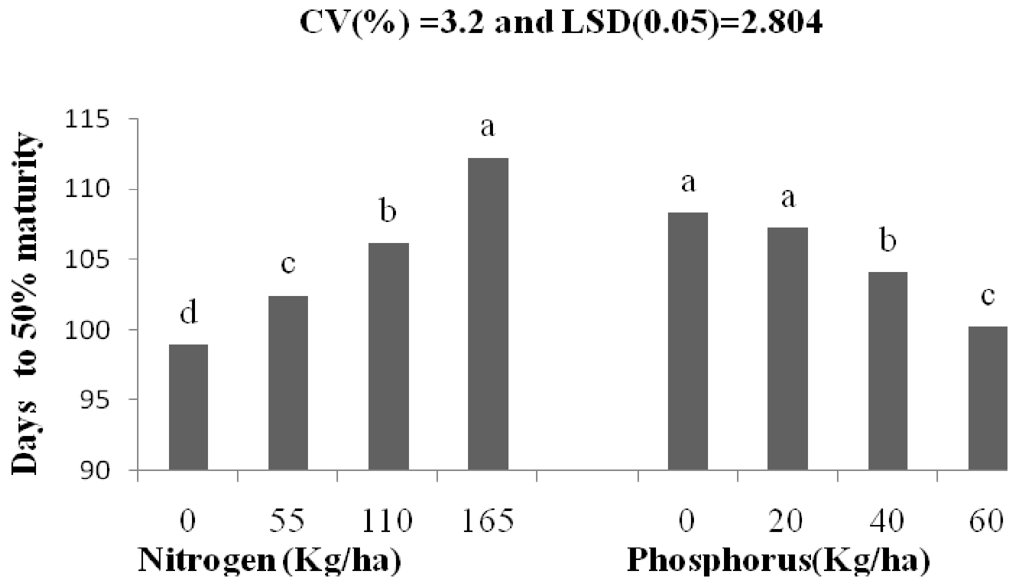

Fig 2. Effect of nitrogen and phosphorus on days to 50% maturity of potato.

4.1.3. Plant height

Plant height was significantly *(P<0.05)* affected by the interaction effect between nitrogen and phosphorus (Appendix Table 2). The highest plant height (75.27 cm) was recorded for nitrogen applied at the rate of 165 kg/ha and phosphorus 20 kg/ha which was statistically similar with 165 kg of nitrogen and 40 and 60 kg of P/ha (Fig. 4). In contrast, the shortest plant height (51 cm) was recorded from plots that received no nitrogen and phosphorus, which was statistically similar with the result obtained from plots that received no nitrogen and 20 kg of phosphorus, 55 kg of nitrogen/ha and zero phosphorus per hectare. This might be due to the effect of N on plant height was enhanced due to the presence of phosphorus. This may probably be due to the fact that these two important plant nutrients have complementary metabolic and physiological functions, thereby affecting the height of plant. In agreement with this, Singh and Singh (1973) reported that the increase in nitrogen levels which led to vigorous vegetative growth and high dose of phosphorus that enhanced the height of plant.

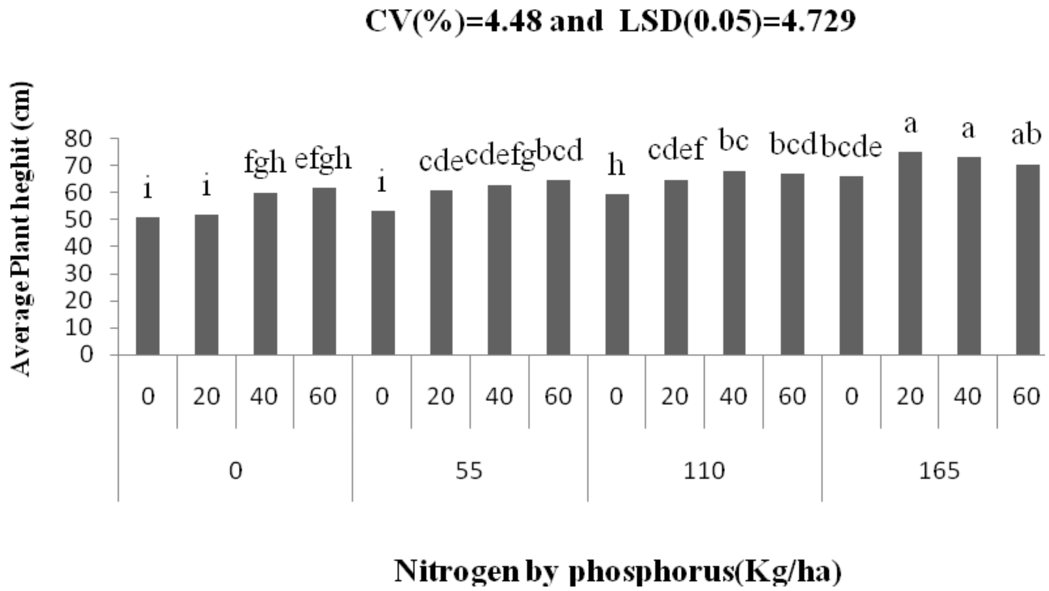

Fig 3. Interaction effect of nitrogen and phosphorus on plant height of potato

4.1.4. Dry Biomass Yield

4.1.4.1. Shoot dry weight

Shoot dry weight was highly significantly *(P<0.01)* affected by both nitrogen and phosphorus. However, the interaction effect of nitrogen and phosphorus did not significantly *(P>0.05)* influenced shoot dry weight (Appendix Table 2). The shoot dry weight increased from 52.75 to 72.25 gram per hill as the rate of nitrogen increased from 0 to 165 kg/ha. Shoot dry weight increased by 36.9% as compared to the control (Table 4). A similar result was obtained for shoot dry weight, wherein it showed highly significant differences in relation to the rate of nitrogen fertilizer as shoot dry weight increased significantly and linearly with increasing the nitrogen rate using different concentrations. This could be due to the fact that, increased concentration of nitrogen fertilizer can increase availability and subsequently promotes nitrogen uptake. This increase has a positive effect on the chlorophyll concentration, photosynthetic rates, leaf expansion, total number of leaves and ultimately the dry matter accumulation. Consequently, nitrogen fertilizer plays an important role in canopy development which is especially related with shoot dry matter (Najm *et al*., 2010).

Regardless of nitrogen applied, phosphorus significantly *(P<0.05)* affected shoot dry weight of potato (Table 3 and Appendix Table 7). The shoot dry weight increased from 59.67 to 64.91g per hill as the rate of phosphorus increased from 0 to 60 kg/ha(Table 4). Application of phosphorus increased shoot biomass by 8.78% as compared to control treatment this might be the favorable effect of P application on Shoot dry weight could be attributed to its importance in cell division, in turn more number of root production and this increases water use efficiency and in turn shoot dry weight increases. This is in harmony with the work of Gabriel (2010) who reported application of phosphorus fertilizer increases shoot dry weight

4.1.4.2. Root dry weight

Root dry weight was highly significantly *(P<0.01)* affected by nitrogen and phosphorus. However, the interaction effect of nitrogen and phosphorus was not significant (*P>0.05)* on root dry weight (Appendix Table 2). Maximum root dry weight (11.56 g/hill), was obtained with application of nitrogen at rate of 165 kg/ha while the minimum (8.90 g/hill) was obtained without (zero) nitrogen application (Table 4). This might be associated with application of nitrogen which stimulates the growth and development of roots. Similarly (FAO, 2000) reported that this might be due to the fact that application of nitrogen enhanced the availability of phosphorus and facilitates the division of cells this in turn causes the development of roots particularly lateral and fibrous root lets. Regarding the effect of phosphorus, the maximum root dry weight (12.2 g/hill) was obtained from plants that were fertilized with phosphorus at rate of 60 kg P/ha and this value was statistically at par with the effect obtained with application of 40 kg P/ha and the minimum value (7.58 g/hill) was recorded from plots without (zero) phosphorus application (Table 4). A good supply of phosphorus is associated with increased root growth. When phosphorus is available, plant roots proliferate extensively and encourage extensive exploitation of immobile nutrients and increase root dry weight. Similarly, Brady and Weil (2002) reported that phosphorus is required in large quantities in young cells, such as root tips, where metabolism is high and cell division and development of roots is rapid.

Table 2. Effect of nitrogen and phosphorus on number of stem/hill, shoot and root dry weight of potato

Treatments	Number of stem/hill	Shoot dry weight (g/hill)	Root dry weight (g/hill)
Nitrogen(kg/ha)			
0	4.46	52.75[d]	8.90[c]
55	4.46	58.33[c]	9.97[bc]
110	4.35	65.00[b]	11.43[ba]
165	4.68	72.25[a]	11.56[a]
Phosphorus(kg/ha)			
0	4.15	59.67[b]	7.59[c]
20	4.63	61.25[ba]	10.37[b]
40	4.58	63.00[ba]	11.70[a]
60	4.6	64.92[a]	12.21[a]
LSD *(P<0.05)*	ns	2.785	1.541
CV (%)	15	5.37	17.64

formed by different letters per column differ significantly *(P<0.05)* as established by LSD test

4.2. Yield Parameters

According to the current investigation the results obtained in terms of the following yield and Yield components such as marketable tuber number per hill, unmarketable tuber number per hill, total tuber number per hill, marketable tuber yield, unmarketable tuber yield, total tuber yield, and average tuber weight and harvest index are presented (Table5) and discussed as follows

4.2.1. Marketable tuber number

With respect of marketable tuber number, highly significant *(P<0.01)* effect was observed for both nitrogen and phosphorus. However, non significant *(P>0.05)* interaction effect was observed between nitrogen and phosphorus on marketable tuber number (Appendix Table 3).Increasing rate of nitrogen application from 0 to 165 kg N/ha increased marketable tuber number from 5.68 to 8.85/hill without affecting the unmarketable tuber number (Table 3). This increased rate of nitrogen from 0 to 165 kg N/ha increased marketable tuber number by 56.36%. The trend depicted that marketable tuber number increased with increased nitrogen rate. This could be probably due to the fact that marketable tuber number increases with higher nitrogen rate because nitrogen can trigger vegetative growth and development. The increase in terms of the number of marketable tubers in relation with the increase in applied nitrogen was associated with decrease in the number of the small size tubers owing to the increase in the weight of individual tubers. This result is in line with the finding of Hanley *et al* (1965), who confirmed that application of nitrogen increased the number of tubers produced per hill in a study conducted for three consecutive years. Similarly, increasing the level of applied phosphorus also increased marketable tuber number per hill from 6.44 to 7.76. However, there was no apparent difference between application of 40 and 60 kg P/ha (Table 3).

4.2.2. Total tuber number

Total tuber number was highly significantly *($P<0.01$)* affected by nitrogen and significantly affected by *($P<0.05$)* phosphorus. However, the interaction effect was non significant *($P>0.05$)* for total tuber number (Appendix Table 3). Increasing the application ofnitrogen increased total tuber number per hill from 9.78 to 12.2 (Table 3). In the presentstudy, increasing the rate of applied nitrogen from 0 to 165 kg/ha increased total tubernumber by 31.7%. This is may be due to increased Nitrogen increased tuber number perplan that could have resulted from higher interception of light, more assimilate productand partitioning of assimilates to tubers as a consequence of better vegetative growth and division of cells this in turn increases tuber number. The current result is in conformity with the works of different researchers (Reddy and Rao, 1968; Herlihy and Carroll, 1969; Sommerfeld and Knutson, 1965; Hanley *et al*., 1965 and Mahmoodabad *et al., 2010*) who had reported that increase in rates of nitrogen application increased vegetative growth of the aerial parts and hence, promoted the activity of photosynthesis and cell division this in turn increases number of tubers per plant.

Similarly, increasing the level of applied phosphorus significantly increased total tuber number per hill from 10.68 to 11.55 (Table 3). Increasing the applied rate of phosphorus from 0 to 60 kg P/ha increased total tuber number by 8.19% as compared to the control treatment. This might be role of phosphorus in facilitating rapid cell division in line with this Sommerfeld and Knutson (1965) and Sparrow *et al.* (1992) the application of phosphorus increased the number of potato tubers set per unit.

Table 3. Effect of nitrogen and phosphorus on marketable tuber number, unmarketable tuber number, total tuber number, unmarketable tuber yild, total tuber yield, average tuber weight, and harvest index of potato

Treatments	Marketable tuber number/hill	Unmarketable tuber number/hill	Total tuber number /hill	Unmarktabletuber yield(t/ha)	Total tuber yield (t/ha)	Average tuber weight(g)	Harvest Index
Nitrogen (kg/ha)							
0	5.68[c]	4.09	9.77[d]	6.01	23.75[d]	54.48[c]	0.87[a]
55	6.80[b]	3.9	10.70[c]	5.98	30.17[c]	63.00[b]	0.85[ab]
110	7.13[b]	4.07	11.20[b]	6.92	34.64[b]	67.54[ab]	0.83[b]
165	8.88[a]	3.39	12.19[a]	6.42	38.08[a]	70.23[a]	0.78[c]
LSD (5%)	0.523	Ns	0.456	Ns	1.270	5.499	0.024
CV (%)	8.80	21.4	4.95	18.86	10.32	10.33	3.47
Phosphorus(kg/ha)							
0	6.44[b]	4.23	10.67[c]	6.27	27.10[c]	56.8[c]	0.84[a]
20	6.58[b]	424	10.82[bc]	6.55	28.83[c]	59.68[c]	0.84[a]
40	7.76[a]	3.39	11.15[ab]	6.84	33.11[b]	65.93[b]	0.83[a]
60	7.71[a]	3.84	11.55[a]	5.76	37.56[a]	72.85[a]	0.83[a]
LSD (5%)	0.523	Ns	0.456	Ns	1.270	5.499	Ns
CV (%)	8.80	21.4	4.95	18.86	10.32	10.33	3.47

Means followed by different letters per column differ significantly*(P<0.05*) as established by LSD test

4.2.3. Total tuber yield

Total tuber yield was highly significantly *(P<0.01)* affected by both nitrogen and phosphorus. However, there was no significant *(P>0.05)* interaction effect observed between nitrogen and phosphorus on total tuber yield (Appendix Table 3). Nitrogen and

Phosphorus application independently resulted in highly significant variation in terms of Total tuber yield of potatoes.

An increase in the rate of nitrogen application resulted in an increment of the total tuber yield of potatoes from 23.75 to 38 t/ha (Table 6). Accordingly the maximum total tuber yield was obtained from the application of 165 kg N/ha while the minimum was obtained from the control treatment (no nitrogen application). The increase in the rate of nitrogen application from 0 to 165 kg N/ha increased the total tuber yield by 60.33%. This may be due to nitrogen increases vegetative growth increases the plant uptake of other of plants nutrients and translocation of this assimilate in to useful part this all contributes to increment of tuber yield. This is in line with the finding of Mulubrhan (2004) and Zelalem *et al*. (2009) who reported that application of nitrogen increased total tuber yield

In similar manner, increasing the rate of phosphorus application from 0 to 60 kg P/ha, resulted in an increase of the total tuber yield of potato from 27.1 to 37.6 t/ha. The maximum total tuber yield (37.6 t/ha) was obtained with the application of phosphorus at the rate of 60 kg P/ha, while the minimum (27.1 t/ha) was obtained in the control treatment, which is statistically identical with the result obtained with application of 20 kg of phosphorus per ha. An increase in the rate of phosphorus application from 0 to 60 kg P/ha, increased the total tuber yield by 38.6% compared to the control treatment (zero level of phosphorus) (Table 6). This might be due to the role phosphorus in root development and cell division energy translocation contributes towards the increment of tuber yield This is supported by the results of Yibekal (1998) and Mulubrhan (2004) who found that increasing P levels from 0 to 60 kg/ha increased total tuber yield per hill.

4.2.4. Marketable tuber yield

The interaction of nitrogen and phosphorus significantly *($P < 0.05$)* influenced marketable tuber yield during the growing season (Appendix Table 3). The maximum marketable tuber yield was recorded from plots that received the combination of nitrogen at 165 kg/ha with phosphorus 60 kg/ha (36 t/ha) and this value was statistically non significant with application of 165 kg/ha of nitrogen and 40 kg/ha of phosphorus and this value is statistically similar with application of 165kg/ha of nitrogen and 20 kg of P/ha. On the other hand, the minimum yield (16.2 t/ha) was obtained from zero nitrogen and phosphorus and this value is statistically similar with application of zero nitrogen with 20 and 40 kg P/ha, respectively and 55 kg N/ha with 20 kg P/ha. This result could be due to positive interaction and complementary effect between nitrogen and phosphorus in affecting marketable tuber yield. Similarly (FAO, 2000) reported a decline in nitrogen efficiency in the absence of phosphorus application, thereby indicating interaction between these nutrients.

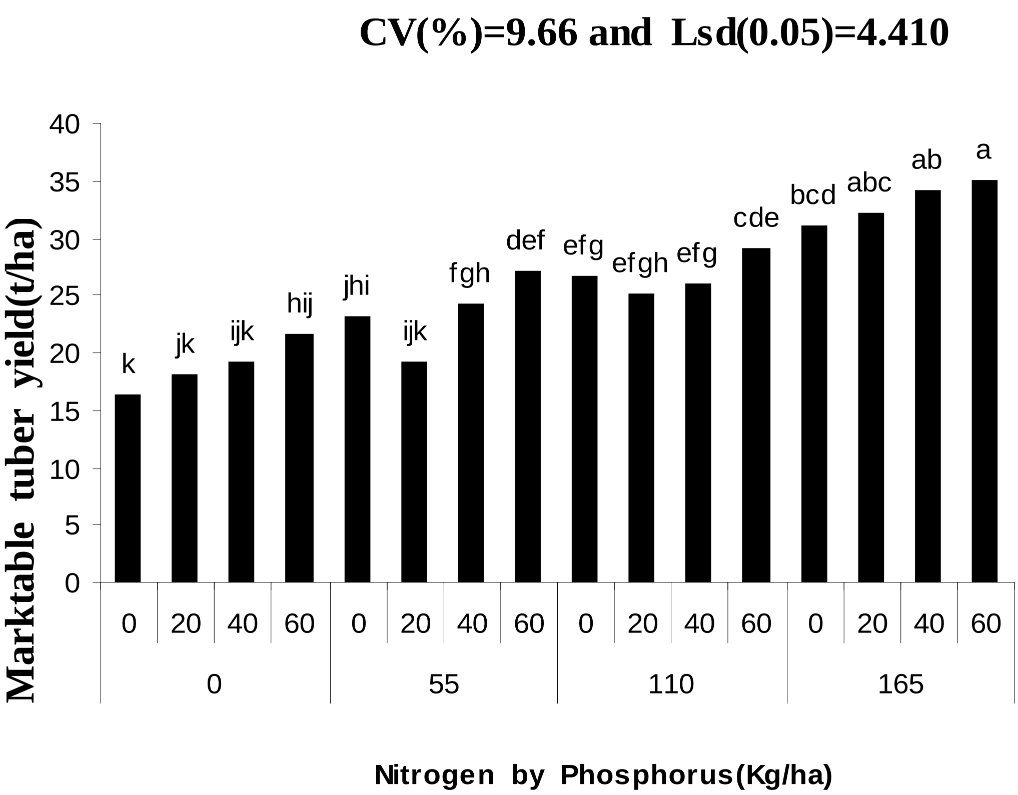

Fig 4. Interaction effect of nitrogen and phosphorus on marketable tuber yield of potato.

4.2.5. Average tuber weight

The variation among tubers in respect of their average weight was found to be highly significant *($P<0.01$)* as influenced by nitrogen and phosphorus. However, the interaction effect of nitrogen and phosphorus was not significant *($P>0.05$)* for average weight of tubers (AppendixTable 3). The highest average weight of tubers (70.23 g) was found in the treatment that received 165 kg of N/ha and this value was statistically similar with application of 110 kg of N/ha and the lowest average weight of tubers (54.47g) was obtained in the treatments that received no nitrogen (Table 6). The increase in rate of application of nitrogen from 0 to 165 kg N/ha increased average tuber weight by 22.43% as compared to the control. this might be due to increased application of nitrogen fertilizer average weight of tubers increased thus in turn can results more foliage and leaf area this also gives in higher supply of photosynthate which helped in producing bigger tubers resulting in higher yield (Mulubrhan, 2004).

Likewise, increasing application of phosphorus increased average tuber weight and showed a consistent increasing trend with increasing dose of phosphorus fertilizer rate. Raising the rate of phosphorus application from 0 to 60 kg P/ha increased the average tuber weight by 22.49% as compared with the control. The increase in average tuber weight in response to the increased supply of mineral nutrient could be due to more luxuriant growth, more foliage and leaf area and higher supply of photosynthates which may have induced formation of bigger tubers thereby resulting in higher yields (Patricia and Bansal, 1999).

4.2.6. Harvest index

The effect of nitrogen on harvest index was found to be highly significant *($P<0.01$)* while no significant *($P>0.05$)* effect was obtained from phosphorus application and its interaction with nitrogen (Appendix Table 3). The highest harvest index was observed in treatments that received zero nitrogen and this value was statistically non significant with the result obtained from 55kg of N/ha and while the lowest harvest index was obtained at 165 kg N/ha (Table 6). This might be due to the effect of nitrogen on biological yield increment which was noted to be greater than the harvestable yield and hence harvest index was decreased. The yield advantage obtained through the use of nitrogen fertilizers might not be accredited to its effect on increment of harvest index; rather a parallel increase in both useful and non economical parts was visible. In general, harvest index is commonly used as a key plant parameter which may not necessarily compare with high yield. This is probable where the applications of mineral nutrients enables the potato crop to exhibit a high rate of assimilate production (high total biomass) and continue active growth afterward in the season (Gawronska *et al*., 1984).

Harvest indices of 0.75 -0.85 are more common in temperate zone but in hotter climates, the harvest index tends to be lower and often a wider variation is also observed between cultivars or growing conditions (Beukema and Vander Zaag, 1990). The resulting extensive shoot growth and the increased period of a canopy for light interception usually produces a much higher final yield of tubers than in plots that receive no nitrogen fertilizer. This is in spite of the fact that the unfertilized plants have a much higher harvest index than the fertilized (Wien, 1997).

Regarding phosphorous its effect on harvest index was found to be non significant (*P>0.05*) so that with increasing or decreasing phosphorous application this trait is not affected. Effect of phosphorus has little impact on biological or economical yield and this reason harvest index is not affected (Appendix Table 3and Table 6).

Similarly Zelalem *et al.* (2009) reported non-significant differences *(P>0.05)* in harvest index of the tubers in response to increased phosphorus application.

4.3. Quality Parameters

The results obtained in the current investigation in terms of potato quality parameters tuber dry matter content (%) and specific gravity (g/cm^3) are presented in Table 4 and discussed as follows.

4.3.1. Dry matter content

Dry matter content of tubers was highly significantly *(P<0.01)* affected by nitrogen and significantly affected by phosphorus (P<0.05) but no significant *(P>0.05)* effect imparted by the interaction effect observed between nitrogen and phosphorus for dry matter content (Appendix Table 4). The highest dry matter content (23.60%) was recorded with zero nitrogen application while, the lowest dry matter content (19.48%) was recorded from 165 kg N/ha (Table 4). Reductions in dry matter content of tubers was noticed when the rate of nitrogen fertilization was increased. The decrease in percent dry matter could be attributed to high production of gibberellins hormone due to high Nitrogen application this in turn reduces partioning of assimilate to tubers. This is in line with the work of many researchers (Mulubrhan, 2004; Frezgi, 2007and Zelalem *et al.*, 2009) who reported that high nitrogen level reduces the dry matter content of potato tubers

Similarly, increased phosphorus application reduced dry matter content of potato tuber from 22.47 to 20.3%. The highest dry matter content was obtained with no phosphorus application which was not statistically different with application of 20 kg/ha of phosphorus. The lowest dry matter content was obtained from application of 60 kg phosphorus /ha and this value was statistically at par with the application 40 kg P/ha. In line with the present finding, Asseffa (2005) observed significant reduction in percent dry matter of potato tubers due to increased phosphorus application. In addition Daniel (2006) noted reduction in tuber dry matter content when application of phosphorus fertilizer increases.

4.3.2. Specific gravity of tubers

The average specific gravity of tubers was highly significantly *($P<0.01$)* affected by nitrogen and significantly by phosphorus *($P<0.05$)*. However, there was no significant *($P> 0.05$)* effect from the interaction of nitrogen and phosphorus application (Appendix Table 4). The maximum Tuber specific gravity (1.096) was obtained without nitrogen application whereas the minimum tuber specific gravity (1.074) was recorded from the highest nitrogen application rate (165 kg N/ha) (Table 4). This might be due to the fact that nitrogen decreases the solid constituent of tuber and increases the water content of tubers. This is in agreement with work of many researchers (Teich and Menzres, 1964; Mulubrhan, 2004; Asseffa *et al*. 2005; Frezgi**,** 2007) who reported a reduction in specific gravity of tubers due to application of nitrogen fertilizer treatment and this in turn reduced the quality of tubers.

The higher the specific gravity the higher will be the quantity of dry matter and the greater the yield of produce. Potatoes with high specific gravity are preferred for preparation of chips and French fries. With exception of the effect registered from application of 165 kg N/ha, all the levels produced acceptable range of specific gravity for processing which is greater than 1.077 (Fitzpatrick *et al.*, 1964).

In case of phosphorus, Similar to the effect of nitrogen, the highest tuber specific gravity (1.09) was obtained with no phosphorus application and this value is statistically at par with the application of 20 kg/ha of Phosphorus. In contrast, the lowest tuber specific gravity (1.089) was obtained with 60 kg P/ ha which to be is statically non significant with application of 40 kg P/ha. This value is greater than 1.077 for all phosphorus levels hence it is within the acceptable range for processing (Fitzpatrick *et al.*, 1964).

Table 4. Effects of nitrogen and phosphorus on dry matter content, and specific gravity, of potato tuber

Treatments	Dry matter content (%)	Specfic gravity (g/cm^3)
Nitrogen(kg/ha)		
0	23.61[a]	1.095[a]
55	21.75[b]	1.087[b]
110	21.35[b]	1.086[b]
165	19.48[c]	1.074[c]
Phosphorus(kg/ha)		
0	22.48[a]	1.0904[a]
20	21.75[b]	1.089[a]
40	21.01[b]	1.083[b]
60	20.31[b]	1.089[b]
LSD (5%)	1.196	0.006
CV (%)	6.65	0.66

Means followed by different letters per column differ significantly *($P<0.05$)* as established by LSD test

4.4. Soil Parameters

The results obtained in the current investigation in terms of potato total soil nitrogen after harvest (%) and available soil phosphorus (ppm) are presented in (Table 5).

4.4.1. Total soil nitrogen

Total soil nitrogen was highly significantly *($P<0.01$)* affected by nitrogen but not significantly *($P>0.05$)* affected by phosphorus and the interaction between the two nutrients (Appendix Table 5). The highest total soil nitrogen was obtained from the application of 165 kg N/ha which nonetheless was not significantly different from result recorded from the application of 110 kg N/ha. On the other hand, the lowest total soil nitrogen was obtained from plots that received no fertilizer application (Table 5). This might be due to the application of enough amount of nitrogen (165 kg N/ha) to the experimental field in the form of urea. In line with this Endalkachew (2006), reported that post harvest soil nitrogen was increased by the application of fertilizer nitrogen.

The concentration of total nitrogen (0.314) of the soil recorded before planting (Appendix Table 1) was decreased after harvest to 0.284 in the control plot and it was in the range of 0.464 to 0.554 % in plots those received nitrogen. This reduction in total nitrogen in the soil after harvest may be due to either the consumptive use of the crop or loss of soil nitrogen due to different soil and environmental factors (Table 5).

4.4.2. Available soil phosphorus

Available soil phosphorus was highly significantly *(P<0.01)* affected by both nitrogen and phosphorus, however the interaction effect was non significant (Appendix Table 5). The highest available soil phosphorus (14.71ppm) was obtained from nitrogen application of 165 kg N/ha and this result was not significantly different from the application of 110kg of nitrogen. The lowest available soil phosphorus (10.39ppm) was obtained at no nitrogen application and the result obtained was statistically the same as application of 55kg N/ha (Table 4).The available phosphorus concentration of soil showed an increment with the application of nitrogen and phosphorus fertilizer. The available phosphorus concentration of the soil before planting (10.50 ppm) (Appendix Table 1) was highly significantly (P<0.01) increased from 12.04 to 14.71ppm due to application of nitrogen at the rates of 55 and 165 kg/ha, respectively. This might be nitrogen increases the availability of other nutrient such as P similarly (Tisdale *et al*., 2002). Confirmed that Nitrogen promotes P uptake by plants by Increasing top and root growth, altering plant metabolism and increasing the solubility and availability of P. Increased root mass is largely responsible for increased phosphorous

Similarly, the initial concentration of soil available phosphorus increased to 15.23 ppm with the application of 60 kg P/ha, but available phosphorus concentration at this phosphorus fertilization rate was not significantly different from fertilization at 40 kg P/ha. The result showed consistent increment of available phosphorus of the soil with increased application of phosphorus fertilizer rates. On the other hand, the initial level of available phosphorus of the soil decreased to 10.31 ppm in the control plot indicated that some of the soil phosphorus was lost though either plant uptake or fixation in the soil.

The phosphorus fertilization resulting in increment of available phosphorus in the soil in this study might be due to its replacement of already fixed phosphorus and increased the levels in the soil and particularly its level in the labile forms that can release phosphorus to the soil solution. The current result is compatible with (Tisdale *et al.,* 2002). Who reported that as the amount of fertilizer soil P added to the soil the corresponding increment in available soil phosphorus in soil solution also increases linearly when it exceeded removal by the crop

Table 5. Effects of N and P on total soil nitrogen (%) and available phosphorus (ppm) After harvest of potato

Treatments	Total soil Nitrogen (%)	Available Phosphorus (ppm)
Nitrogen(kg/ha)		
0	0.284^{c}	10.39^{c}
55	0.463^{b}	12.04^{bc}
110	0.550^{a}	13.67^{ab}
165	0.554^{a}	14.72^{a}
LSD (5%)	0.064	1.832
CV (%)	16.69	17.29
Phosphorus(kg/ha)		
0	0.454	10.31^{c}
20	0.455	11.88^{bc}
40	0.481	13.40^{ab}
60	0.465	15.23^{a}
LSD (5%)	ns	1.832
CV (%)	16.69	17.29

Means followed by different letters per column differ significantly *($P<0.05$)* as established by LSD test

4.4.3. Critical phosphorus concentration and phosphorus requirement factor

Application of Phosphorus fertilizer increased the level of available phosphorus in the soil as per Olsen method thus creating ranges of phosphorus value from 10.52 to 25.15 for assessing the relationship between tuber yield response to nutrient rate and soil test phosphoru**s** value relative tuber yield (%) to nutrient rate and soil test phosphorus value relative tuber yield in percent (Yield/maximum Yield) X100 were plotted against the corresponding soil test value analyzed by Olsen method for all P treatment (Fig. 5).

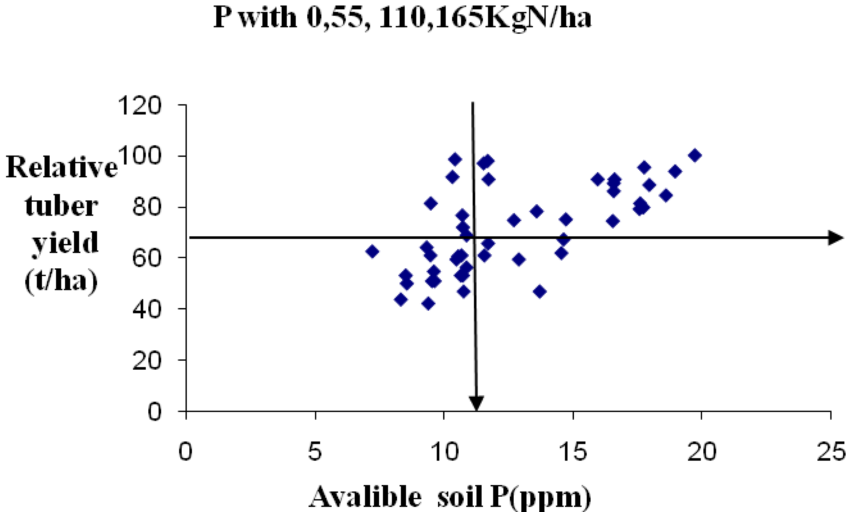

Fig 5. Scatter diagram of the relative tuber yield of potato in relation to available P in soils (each point represents independent measurement).

From this curves the critical value in the intersection point was found to be 12 ppm for the Olsen method This implies that under the rain-fed condition of Masha woereda potato planted on soils having greater than 12 ppm would not respond to phosphorus fertilization, however, if the soil phosphorous is below the critical level additional information is needed on the quantity of phosphorus required to elevate the phosphorus of the soil to the required level and for it would be imperative to establish the phosphorus requirement factor which is a measure of the quantity of phosphorus required per hectare to raise the soil test level by 1ppm. This value for the studied site was computed from the difference between available phosphorus value and phosphorus value of samples collected from plots which received fertilizer and value is used to calculate the total amount of phosphorus fertilizer.

Table 6. Phosphorus requirement factor calculated based on soil test P from different fertilizer treatment on potato in Masha werda, Sheka Zone

P Applied (Kg/ha)	Average soil P (ppm)	P increase Over the control (ppm)	P requirements factor
0	10.31		
20	11.87	1.56	12.82
40	13.40	3.09	12.94
60	15.23	4.92	12.19
Mean for Olsen		3.19	12.65

Rate of P fertilizer to be applied = $(P_c - P_o) \times P_F$

Where:
P_c = critical P concentration
P_o = initial P values for the site
P_F = P-requirement factor

4.5. Correlation Analysis among Growth and Yield Parameters

Correlation analysis showed that marketable tuber yield significantly and strongly and positively related with days to flowering (r=0.64**), after harvest soil nitrogen (r =0.56**), after harvest soil phosphorus (r=0.72**), plant height (r=0.79**), marketable tuber number (r =0.74**), and total tuber number (r=0.80**), Moreover, all yield parameters revealed significantly strong and negative relationship with specific gravity and dry matter content. On the other hand, shoot dry weight was found to be strongly and significantly correlated with root dry weight (r=0.74**). On the contrary, the majority of yield parameters happened to be significantly and positively correlated with total tuber yield including total tuber number (r=0.82**), marketable tuber number (r=0.77**) marketable tuber yield (r=0.91**) and average tuber weight (r =0.93**) indicating that tuber yield increase as a result of nitrogen and phosphorus application was due to tuber number and tuber weight increase (Table 7).

Table 7. Person correlation coefficient of growth, yield and quality parameters of potato

	DF	DM	PH	MTN	TTN	MTY	TTY	AVG	SDW	RDW	HI	TNA	APA	DMC	SG
DF	1	0.35**	0.71**	0.64**	0.65**	0.63**	0.64**	0.53**	0.37**	0.45**	-0.4**	0.46**	-0.52**	-0.17	-0.28
DM		1	0.42**	0.39**	0.45**	0.17	0.27	0.14**	0.16	0.48*	-0.41	0.44**	-0.04	-0.04	-0.26
PH			1	0.78**	0.75**	0.92**	0.75**	0.64**	0.24	0.46**	-0.38**	0.55**	0.68**	-0.62**	-0.61**
MTN				1	0.79**	0.74**	0.77**	0.63**	0.40**	0.47**	-0.47**	0.57**	0.53**	-0.68**	-0.65**
TTN					1	0.80**	0.81**	0,59**	0.43**	0.48**	-0.47**	0.66**	0.56**	-0.65**	-0.65**
MTY						1	0.91**	0.82**	0.27	0.41**	-0.33*	0.56**	0.72**	-0.77**	-0.77**
TTY							1	0.94**	0.3*	0.45**	-0.39**	0.59**	0.61**	-0.77**	-0.77**
AVG								1	0.17	0.36*	-0.28*	0.47**	0.55**	-0.7**	-0.75**
SDW									1	0.74**	-0.79**	0.37**	0.34*	-0.32*	-0.39**
RDW										1	-0.65**	0.27	0.47**	-0.38**	-0.38**
HI											1	-0.38**	-0.27	0.46**	0.48**
TNA												1	0.5**	-0.51**	-0.64**
APA													1	-0.43**	-0.53**
DMC														1	0.94**
SG															1

**, ** indicate significant at 5% and 1% probability level respectively DF = days to flowering, DM = Days to Maturity, PH = Plant Height, MTN = Marketable Tuber Number, TTN = Total Tuber Number, MTY = Marketable Tuber Yield, TTY = Total Tuber Yield, SDW = Shoot Dry Weight, RDW = Root Dry Weight, HI = Harvest Index, TNA = Total Nitrogen After harvest, AVP= Available Phosphorus after harvest, DMC =Dry Matter Content, SG = Specific Gravity*

4.6. Economic Evaluation

Economic analysis also revealed that economically most advantageous tuber yield of potato was obtained with application of 165/60 kg N/P/ha (Table 8). Under price assumption of potato, MRR of 382.25% was achieved over the control treatment. The highest net return of birr 139834/ha was recorded in the treatment that received 165 kg N/ha in combination with 60 kg P/ha followed by 165 kg N together with 40kg P/ha (Birr 132700/ha). These interpretations are in harmony with those obtained in central Kenya by Makoha *et al.* (2000**)** and Bangladesh by Bhuiyan (2001).

High net return from the foregoing treatments could be attributed to the high yield whilst the low Net returns to low yield. From the economic point of view, it was apparent from the above results that 165 kg N/ha plus 60 kg P/ha is more profitable than the rest of treatment combinations.

Table 8. Partial budget analysis of fertilizer rate trial on potato using the price in Masha (year 2003)

Treatments (N:Pkg/ha)		TY (t/ha)	ATY (t/ha)	GFB (EB/ha)	TAC (EB/ha)	HBC (EB/ha)	FC (EB/ha)	TCTV (EB/ha)	NB (EB/ha)	MRR (%)
0	0	16.2	14.58	72900	3645	3645	0	7290	65610	
0	20	18.07	16.263	81315	4065.75	4065.75	822.24	8953.74	72361.3	405.788
55	0	19.06	17.154	85770	4045.5	4045.5	1080.87	9171.87	76598.1	1942.36
0	40	21.52	19.368	96840	4286.25	4286.25	1644.48	10217	86623	959.219
55	20	23.15	20.835	104175	4495.5	4495.5	1903.11	10894.1	93280.9	983.248
110	0	19.06	17.154	85770	4842	4842	2161.74	11845.7	73924.3	D
0	60	24.07	21.663	108315	5206.5	5206.5	2466.72	12879.7	95435.3	108.5
55	40	27.98	25.182	125910	5415.75	5415.75	2725.35	13556.9	112353	2498.47
110	20	26.62	23.958	119790	5676.75	5676.75	2983.98	14337.5	105453	D
165	0	25.6	23.04	115200	5989.5	5989.5	3242.61	15221.6	99978.4	D
55	60	26	23.4	117000	6462	6462	3547.59	16471.6	100528	D
110	60	29	26.1	130500	6525	6525	4628.46	17678.5	112822	11.3642
110	40	31	27.9	139500	7031.25	7031.25	3806.22	17868.7	121631	4630.37
165	20	32	28.8	144000	7200	7200	4064.85	18464.9	125535	654.869
165	40	34	30.6	153000	7706.25	7706.25	4887.09	20299.6	132700	390.533
165	60	36	32.4	162000	8228.25	8228.25	5709.33	22165.8	139834	382.253

Market rates (5birr/kg) as per local market price, Ty (10%) =Adjusted tuber yield (t/ha), TCTV=total cost that vary, GFB=Gross Field Benefit, HBC=Harvesting and Bagging Cost, TAC=Transport and Application Cost NB=Net Benefit (EB/ha), MRR=Marginal Rate of Return (%), EB=Ethiopian Birr, D=DominatedTreatment

5. SUMMARY AND CONCLUSIONS

Potato *(Solanum tuberosum* L.) is the most important food crop after, wheat rice and corn in human diet. Information on fertility status of soils and crop response to Nitrogen and Phosphorous soil fertilizers is one of the most important factors for production of quality and yield of potato. In Ethiopia fertilizer is accepted as an important input to obtain high yields and overcome the low production of potato However there is inadequate site specific experimental information on how much fertilizer to apply on different soil type with patch of high and low fertility for many years there was one blanket rate of application 165kg/ha urea and 195kg/ha DAP for all potato Varieties and soil types throughout the country Hence to make appropriate and site specific fertilizer recommendation, a relationship must be developed between soil test parameters and crop.

In view of this, the present study was conducted at Masha werda to assess the effects of N and P fertilizer on the yield, and yield components of potato. A potato variety 'Jalene' was used with four levels of N (0, 55, 110, and 165 kg/ha) and four level of P (0, 20, 40 and 60 kg/ha) fertilizer during the year 2010/2011 main cropping season using RCBD.

Considering the growth of plants, the maximum plant height was observed at the highest level of nitrogen (165kg/ha) with the second level of phosphorus (20kg/ha). The longest days to 50% flowering was achieved with the application of (165kgN/ha), which had a similar effect with application of (60kgP/ha). Similarly delay in maturity from treatments of plants with 165kg N/ha while, with phosphorus the delay in maturity of plants was due to absence of phosphorus application (0kg/ha). The highest dry weight of shoot and root of potato was obtained at 165kg/ha nitrogen and 60kg/ha of phosphorus.

Considering of the yield of potato, the highest marketable tuber yield was obtained from the combined application of 165kg N/ha with 60kg P/ha. Pertaining to yield, the highest total and marketable tuber yield was obtained from the potato plants which were fertilized with (165kgN/ha) and (60kgP/ha). The higher rating levels of N and P gives the maximum yield This shows that there is opportunity for additional gain in tuber yield through further application of more N and P fertilizers above 165 kg N /ha and 60 kg P/ha, respectively.

The higher rating levels of N and P gives the maximum yield This shows that there is opportunity for additional gain in tuber yield through further application of more N and P fertilizers above 165 kg N /ha and 60 kg P/ha, respectively. However, the highest harvest index was obtained at first level of nitrogen (0 kg/ha).

Acceptable range of specific gravity and dry matter content for processing is obtained at all levels of nitrogen and phosphorus except at fourth level of nitrogen (1.074). The highest specific gravity and dry mater content of potato was obtained at the lowest level of nitrogen (0 kg/ha) and phosphorus (0 kg/ha), respectively. The highest average tuber weight was obtained at 165 kg/ha of nitrogen and 60 kg/ha of phosphorus. The critical and phosphorus requirement factor for the site was 12.65 and 12 ppm, respectively.

Correlation coefficient values also displayed different directions and associations within potato yield, yield components and physical quality. Marketable tuber yield was highly significantly and positively correlated with days to 50% flowering (r=0.63**), plant height (r=0.92**), marketable tuber number (r=0.74**), total tuber number (r=0. 80**), after harvest soil nitrogen (r=0.56**), after harvest soil Phosphorus (r=0.72**) and total tuber yield was highly significantly and positively correlated with marketable tuber number (r=0.77**), total tuber number (r=0.81**), marketable tuber yield (r=0.91**), average tuber yield (r=0.82**), after harvest soil Nitrogen (r=0.59**), and after harvest soil Phosphorus (r=0.61**). Plant height was highly and significantly positively correlated with days to 50% flowering (r=0.71**) and significantly and positively correlated with 50%days to maturity (r=0.42**). Dry weight of roots was highly significantly and positively correlated with dry weight of shots (r=0.74**). Dry matter content was highly significantly and positively correlated with specific gravity (r=0.94**) and negatively correlated with all yield and growth parameters.

In conclusion, the result of this study showed that different nitrogen and phosphorus level and their interaction have sound and promising impact on marketable tuber yield and quality of potato. Therefore, on the basis of the results of the present study, it is indicative that potato can grow well in the Masha area and farmers can benefit more by using 165 kg/ha of nitrogen with 60 kg/ha phosphors, respectively.

Economic analysis also revealed that application of 165 /60 kg N/P, 165/40 kg N/P and 165/20 kg N/P more profitable than the rest of the treatment however 165/60 kg N/P gave highest MRR, 382.25 % which is above the minimum acceptable MRR of 100% against the control this suggests that farmers at Masha and its surroundings can produce potato by applying 165 kg N/ha with 60 kg P/ha more benefited.

Future line of work

Since the yield obtained from the potato variety used in the present study is lower than what has been reported from research centers, there is a need to conduct extensive research on the following aspects:

- Determination of exchangeable acidity (Fe and Al) and development of appropriate Practices for managing soil acidity.
- Studies on phosphorus fixation in soils of the area.
- Evaluation of soil fertility status and plant nutrient requirements based on nutrient status of the soils and plants.

However, significant responses in yield and quality traits were observed in response to rates of nitrogen and phosphorus. It is too early to reach conclusive recommendation since the experiment was conducted only in one location for one season using four levels of nitrogen and phosphorus. Hence, further study on multi-location and season with more levels of N and P for different potato growing regions of southwest Ethiopia should be continued to reach at sound and precise conclusion.

6. REFERENCES

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7. APPENDICES

Appendix Table 1. Soil physical and chemical properties of the experimental site

Sampling Auger depth 30cm

Soil parameters	Result
p^h	5.1
O.M	3.52%
Total N	0.314%
C/N	1:12
Available P	10.5ppm
Eletrical conductvity	2.65(ms/cm)
Exchangeable K	0.6 meq/100g
Ca	6.5 meq/100gsoil
Mg	0.5meq/100gsoil
Cat ion exchangecapacity	12.5 meq/100g soil
PBS	60.8%
B.D	1.25g/cm^3
Soil texture	Sandy loam

Appendix Table 2. Mean squares for potato growth parameters

Source of Variation	Mean squares						
	Df	Num berof steam /hill	Days to 50% Flowering	Days to 50 % Maturity	Pant height (cm)	Shoot dry weight (g/hill)	Root dry weight (g/hill)
Block	2	2.46	2.79	20.27	6.90	803.16	171.37
Nitrogen	3	0.23	95.82**	384.7**	496.27**	837.91**	19.48**
Phosphorus	3	0.67	30.37*	158.3**	201.09*	61.36**	51.88**
Nitrogen X Phosphorus	9	0.42	2.79^{ns}	15.33^{ns}	21.37*	2.90^{ns}	1.08^{ns}
Error		0.46	5.47	3.36	2.83	11.16	3.41
SE±		0.68	2.34	3.36	1.37	3.34	1.84
CV (%)		15	4.00	3.20	4.48	5.37	17.64

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

Appendix Table 3. Mean squares for yield and yield component parameters potato

Source of Variation	Df	Mean Squares: Marketable tuber number/hill	Unmarketable tuber number/hill	Total tuber number /hill	Marketable tuber yield (t/ha)	Unmarketable tuber yield (t/ha)	Total tuber yield (t/ha)	Average Tuber Weight (g)	Harvest index
Block	2	1.00	0.01	0.92	7.86	0.56	0.05	29.31	0.034
Nitrogen	3	21.15**	2.63**	13.17**	334.54**	2.12ns	459.51**	571.44**	0.015**
Phosphorus	3	6.03**	1.94ns	1.80*	291.62**	2.50ns	264.29**	609.69**	0.0003ns
Nitrogen.X Phosphorus	9	0.46ns	0.25ns	0.37ns	15.84*	3.01ns	20.11ns	52.62ns	0.0004ns
Error	30	0.4	0.7	0.3	6.16	1.44	10.69	43.50	0.029
SE±		0.63	0.82	0.54	2.48	1.20	3.27	6.59	3.47
CV (%)		8.80	21.04	4.95	9.66	18.87	10.33	10.33	0.029

Appendix Table 4.Mean squares for potato quality parameters

Source of Variation	Df	Mean Squares: Dry matter content (%)	Specific Gravity (g/cm^3)
Block	2	3.04	0.00001
Nitrogen	3	34.44**	0.0009**
Phosphorus	3	12.77*	0.00031872*
Nitrogen x Phosphorus	9	3.02ns	0.0.00005864ns
Error	30	2.06	0.00005076
SE±		1.43	0.007125
CV (%)		6.65	0.65

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

Appendix Table 5. Mean square values for total nitrogen and available phosphorus after harvest

Source of Variation	Df	Mean Squares	
		Total Nitrogen (%)	Available Phosphorus (ppm)
Block	2	0.02499222	8.27
Nitrogen	3	0.19331270**	43.11**
Phosphorus	3	0.00185407ns	53.18**
Nitrogen.X Phosphorus	9	0.01075858ns	10.64ns
Error		0.006004	4.83
SE±		0.077485	2.2
CV (%)		16.7	17.2

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