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Research Article

Effect of Farmyard Manure and Mineral NP Fertilizers on Yield Related Traits and Yield of Potato (*Solanum tuberosum* L.) at Areka, Southern Ethiopia

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Declining soil fertility is one of the major problems causing yield reduction in Ethiopia. Farmers at Areka apply both organic and inorganic fertilizers to overcome the problem and increase yield of potato. However, information on the application of farmyard manure and chemical fertilizer is inadequate to the area to increase the yield of potato crop. Therefore, an experiment was conducted at Areka, Southern Ethiopia during the 2016 cropping season with the objective of assessing the effect of farmyard manure and mineral NP fertilizers on yield related traits and yield of potato. There were twenty treatments comprising of four levels of FYM (0, 2.5, 5, 7.5 t ha^{-1}) with five levels of combined mineral NP fertilizers [0, 25%, 50%, 75%, 100% of blanket recommended rates of NP (110 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1})] in randomized complete block design in factorial arrangement with three replications. The results showed that the main effect of FYM and mineral NP fertilizers were significant (P<0.01) on tuber number per hill, tuber size category and tuber yield in tha^{-1}. There was significant interaction effect of FYM and mineral NP fertilizers on days to 50% flowering, days to maturity and plant height. The maximum total and marketable tuber yields of 35.11t ha^{-1}, and 33.97 t ha^{-1}recorded at the rate of 7.5 t ha^{-1} FYM respectively while the maximum total and marketable tuber yield of 37.97 t ha^{-1}and 36.78 t ha^{-1}respectively were obtained in response to the application of 100% blanket recommended mineral NP fertilizer rate.

Key words: Combined application, Integrated nutrient management, Organic fertilizer, Soil fertility, Tuber yield.

INTRODUCTION

Potato is an important food and cash crop in eastern and central Africa. It is playing a major role in national food security and nutrition, poverty alleviation and income generation, and provides employment in the production, processing and marketing sub-sectors (Lung'aho *et al.*, 2007).

Ethiopia is endowed with suitable climatic and edaphic conditions for potato production. About 70% of the available agricultural land is located at an altitude of 1800-2500 meters above sea level and receives an annual rainfall of more than 600 mm, which is suitable for potato production (Solomon, 1985).

The total area cropped with potato in Ethiopia is 160,000 ha (Gildemacher *et al.*, 2009), which is very low compared to the existing potential as the crop can be grown on about 70% of the 10 million hectares of arable land in the country (FAO, 2008). The national average yield is 7.2 tons ha^{-1}, which is very low compared to the world's average of 16.4 tons ha^{-1} and to other potato producing countries of the world, such as the Netherlands (40 tons ha^{-1}), Germany (28 tons ha^{-1}), Egypt (17.4tons ha^{-1}) and Burundi (11 tons ha^{-1}) (FAOSTAT, 2012).

On the other hand, the potentially attainable average yields of the crop on research and farmers' fields are 40 and 20 tons ha^{-1}, respectively (MoARD, 2012). The gap between the potential yield and the current average national yield per unit area of land could be attributed to many diverse and complex biotic, abiotic, and human factors. The major ones are shortage of arable land in the high lands (Amede *et al.*, 2006; Tekalign and Hammes, 2005), unavailability and high cost of seed tubers, shortage of adaptable and high yielding varieties (Medihin *et al*., 2006; Gumataw *et al.*, 2013), occurrence of diseases and insect pests (Haverkort *et al*., 2012), insufficient transportation and marketing facilities (Olango, 2008; Bezabih and Mengistu, 2011), little information on agro-ecology based fertilizer rate (both minerals and organic) (Abay and Tesfaye,2011).

The average plant nutrient depletion in East Africa, particularly of Ethiopia is estimated to be around 47–88 kg ha^{-1} $year^{-1}$ in general and 100 kg ha^{-1} $year^{-1}$ in particular on the highlands (Henao and Baanante, 1999). Major factors contributing to such depletion are soil erosion, soil acidity, fixation of phosphorus (P), and leaching in respect of nitrogen (N) and potassium (K), further accelerated by deleterious land use practices resulting from high population pressure. Tamirie (1989) speculated that indiscriminate clearing of forests, complete removal of crop residues, uncontrolled grazing, and low fertilizer inputs, absence of soil and water conservation measures and crop rotations and above all poor soil management practices contribute to accelerated soil erosion.

Most Ethiopian soils are deficit in major nutrients, especially nitrogen and phosphorus (Tekalign *et al*., 2001). Fertilizer application has significantly improved growth and yields of anchote (Girma and Hailu, 2007). However, despite potential for increasing yields and farmers income using fertilizer; most small scale farmers do not have the required resources to make or purchase fertilizer (Haverkort *et al*., 2012). This is mainly due to limited access to modern research-led agricultural technologies, including inputs such as mineral fertilizers and organic manure (Nabhan *et al*., 1999). In Ethiopia, the amounts of fertilizers applied to the potato crop are very low. Gildemacher *et al*. 2009 estimated that the amounts of farmyard manure (FYM), nitrogen, and phosphorus applied to the potato crop by smallholder farmers were only 3 t ha^{-1}, 30.6 kg N ha^{-1}, and 76.5 kg P_2O_5 ha^{-1}, respectively. Moreover, though fertilizer use in Ethiopia has increased notably since 1990 (Mulat *et al*., 1998), there is no concomitant attainable yield increase, especially in potato (Baye and Mehatemwork, 2010; Haverkort *et al.*, 2012). Furthermore, no mineral fertilizers other than those carrying nitrogen (urea) and phosphorus (DAP) are applied in the country (Zelleke *et al*., 2010).

The productivity of potato crop is low in Wolaita Zone due in part to poor fertility status of the soil (Abay and Tesfaye, 2011). As in many semi-arid environments where fertilizer use is low and little or no agricultural residues for maintaining soil fertility, the organic-matter content and the fertility status of the soils in Ethiopia is low (Bayu *et al*., 2006). Soil erosion and sole application of low rate of mineral NP fertilizers due to high cost to resource poor farmers of Wolaita Zone, aggravating the decline in soil productivity under the farming community of the area.

In Wolaita Zone, farmers use only blanket recommended fertilizers rate for potato production. However, fertilizer requirement varies across locations due to many reasons such as difference in soil types, nutrient availability of the soil, economic factors of the area, moisture supply and variety (Getu, 1998; IAR, 2000). Besides, it has been reported that most tropical soils are deficient in N and P (Chien and Menon, 1995) and most Ethiopian soils are deficient in N and P (Mesifin, 1998). The P adsorption and fixation is influenced by soil pH, clay type and content, as well as the amount of iron and aluminum oxides (Mesifin, 1998).

The use of organic manure alone may not be enough to maintain the present level of crop production and enhancing soil fertility because of its limited availability, relatively low nutrient content and high labour requirements (Palm *et al*., 1997). Therefore, the integrated use of both manure and chemical (inorganic) fertilizers is the best alternative to provide balanced and efficient use of plant nutrients (Gruhn *et al*., 2000) and increase productivity of soil (Menon, 1992). An experiment conducted at West Shoa Zone of Oromiya Regional State, Central Ethiopia indicated that yield of Potato increased due to application of farmyard manure (FYM) and inorganic mineral NP in combination (Balemi, 2012). A field experiment conducted by Gezahegn *et al*., 2014 at Delbo watershed Wolaita Zone, Southern Ethiopia noticed that the root yield of sweet potato (*Ipomoea batatas* (l.) lam.) increased by the combined effects of inorganic NP and farmyard manure (FYM) fertilizers application. A field experiment carried by Teklu *et al*., 1999-2001 at Debre Zeit on Andosols to evaluate the effects of farmyard manure and inorganic fertilizers application on productivity of horticultural crops (shallot, cabbage and potato) indicated that the yield of the crops increased due to combined application of farmyard manure and inorganic fertilizers.

Although potato is major crop produced in Wolaita Zone, its productivity is less than its potential due to poor fertility of the soil, leaching of major nutrients which enhance production of the crops, fixation of P, shortage of farmyard manure to cover the outfield and high cost of chemical (inorganic) fertilizers to apply at the required rate. Generally, there is little information on balanced use of organic and inorganic fertilizer on potato production in Wolaita Zone. Hence, conducting systematic investigation in this line is vital to come up with conclusive recommendations that would help to increase the yield of the crop in the study area. Thus, this research was initiated with the objective of assessing the effects of rates of FYM and mineral NP fertilizers on yield related traits an yield of potato.

MATERIALS AND METHODS

Description of the Study Site

The experiment was conducted in Boloso Sore Woreda at Areka Agricultural Research Center (AARC) during June to October in 2016, Wolaita Zone, Southern Nations Nationalities and Peoples Regional States (SNNPRS). It is located at 300 km South of Addis Ababa and 3 km from Areka town, found at 7.1°N latitude and 38.2 °E longitude. The altitude of the area is 1830 above sea level (masl). The area receives an annual rainfall of 1520 mm in bi-modal pattern which extends from March to September and the mean annual maximum and minimum temperatures are 24 ^{O}C and 12 ^{O}C, respectively (Abay, 2011).

Experimental Material

Crop: the improved potato variety Belete was used for study (test crop). The variety was released by the Holleta Agricultural Research Center (HARC) in 2009. The adaptation area of the variety Belete was 1600-2800 altitude (m.a.s.l), the variety matures at 110-120 days after planting, the planting date of the variety Belete takes place in the first 10 days of June in the main season. The yield potential of the variety Belete in the research field was 47.19 t ha^{-1} (MoARD, 2012).

Fertilizer (inorganic): nitrogen in the form of Urea (46% N) and phosphorous in the form of triple superphosphate (46% P_2O_5) were used as source of N and P, respectively.

Farmyard manure: well decomposed farmyard manure was used. The manure was analyzed for the pH, N, P, K and organic matter content before application.

Table 1. Results of laboratory analysis of FYM

pH	7.2
Total N (%)	1.71
Available P (%)	0.52
Exchangeable K (%)	2.55
Organic matter (%)	5.57

Treatments and Experimental Design

There were twenty treatments consisting of factorial combinations of five levels of combined mineral NP fertilizer [0, 25% NP (27.5 kg N ha^{-1} and 22.5 kg P_2O_5 ha^{-1}), 50% NP (55 kg N ha^{-1} and 45 kg P_2O_5 ha^{-1}), 75% NP (82.5 kg N ha^{-1} and 67.5 kg P_2O_5 ha^{-1}), and 100% NP (110 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1}) of the blanket recommended NP fertilizer rates)] and four levels of FYM (0, 2.5,5 and 7.5 t ha^{-1}). The treatments were laid out in a randomized complete block design (RCBD) with three replications. Each block and plot within block was spaced 1.5 m and 1 m apart respectively. Each plot consisted of six rows of 75 cm apart between rows and plants were spaced 30 cm apart each other. There were 12 plants per row. The gross plot size was therefore, 3.6 m × 4.5 m (16.2 m^2). In each plot, one plant at both end of each row was left to avoid the border effect and from each plot, the four central rows were considered for determination of yield related traits and yield of potato. Therefore, the net plot size was 3 m x 3 m (9 m^2).

Soil Sampling and Analysis

Pre-plant soil samples were taken diagonally at 0-30 cm soil depth in three replications. The samples were bulked to make one composite sample for the determination of selected physicochemical properties of the experimental soil. Sampled soils were air-dried, ground and then sieved through a 2-mm sieve. These samples were analyzed for pH (1:2.5 soil: water suspension), organic carbon by rapid titration method (Walkley and Black, 1936), soil texture (Bouyoucos, 1962), available P by Olsen's method (Olsen *et al*., 1954), total N by Kjeldahl method (Jackson, 1958). Cation Exchange Capacity (CEC) was measured by ammonium acetate method after saturating the soil with 1N NH_4OAC and displacing it with 1N NaOAC (Chapman, 1965).

Table 2: Physicochemical Properties of the Experimental Site before planting

Soil characters	Value	Rating	Reference
A. Particle size distribution			
Sand (%)	26		
Silt (%)	40		
Clay (%)	34		
Textural class		Clay loam	
B. Chemical analysis			
Soil pH	5.2	Strongly acidic	Tekalign (1991)
Organic carbon (%)	1.52	Medium	Tekalign (1991)
Total N (%)	0.148	Medium	Tekalign (1991)
Available P (mg kg^{-1})	5.3	Low	Olsen *et al*. (1954)
CEC [cmol (+) kg^{-1})	24.11	Medium	Landon (1991)

Experimental Procedures

In order to have a better seedbed for proper root development, the experimental field was ploughed by the tractor. Fifteen days prior to planting, farmyard manure (FYM) was spread in the plots and thoroughly incorporated into the soil. A total of 60 experimental plots were laid out and the required numbers of ridges were marked and ridges were formed manually in each plot with the spacing of 75 cm between the ridges. When there was sufficient soil moisture, well sprouted medium-sized (40 to 60 g) tubers of the potato variety were planted on the ridges at the spacing of 75 cm between ridges and the intra row spacing of 30 cm on June 28, 2016 and harvested on

October 22, 2016. The triple superphosphate (46% P_2O_5) was placed in bands below the seed piece and covered with soil on each ridge. Nitrogen was side-dressed in three splits, i.e. 1/4 at plant emergence; 1/2 at the first earthing up and the remaining 1/4 at 40 days after planting. All agronomic practices such as weed control, and earthing up were done regularly during the growing seasons. When the plants reached physiological maturity (when70% of the haulms dried up) tubers were harvested.

DATA COLLECTION

Phenological parameters

Days to 50% flowering: days to flowering was recorded as the number of days from planting when 50% of the plants in each plot produced flowers.

Days to 90% physiological maturity: was recorded when 70% of leaves from different treatments were turned to yellow.

Growth parameters

Average stems number per hill: the actual numbers of main stems per hill were recorded as the average stem count of five hills per plot at 50% flowering. Only stems that emerged independently above the soil as single stems were considered as main stems. Stems branching from other stems above the soil were not considered as main stems.

Plant height (cm): refers to the height from the base to the apex of the plant. It was measured using a measuring tape at 90% physiological maturity from the main stem originating directly from mother tubers to the apex of the plant by taking five sample plants from each plot.

Yield components and yield

Total tuber numbers/hill: was obtained by adding up the number of marketable and unmarketable tubers. This parameter constituted all tubers: small, medium, large, diseased, deformed etc that were produced by the plants

Marketable tuber number/hill: the number of tubers was counted as marketable which are greater or equal to 25g, free from disease and insect attack in each plot and divided to the respective number of plants harvested.

Unmarketable tuber number /hill: the number of tubers counted as unmarketable which were diseased, insect attacked, deformed and weight less than 25 g.

Tuber size distribution in weight: at harvest, tubers were collected from five randomly selected plants from each plot and were categorized as small (25-38g); medium (39-75g); and large (>75 g) (Lung'aho *et al.,* 2007). The proportion of the weight of tubers in the different tuber size categories were converted to percentages.

Marketable tubers yield (t ha^{-1}): these were recorded as the weight of marketable tubers that are free from diseases, insect pests, and greater than or equal to 25 g in weight **(**Lung'aho *et al.,* 2007)**.** These were taken from hills in the net plot area at harvest and converted to t ha^{-1}.

Unmarketable tubers yield (t ha^{-1}): tubers yield recorded as unmarketable which were diseased, insect attacked, deformed and weight less than 25 g

Total tubers yield (t ha^{-1}): it was recorded as the sum of marketable and unmarketable tuber yield from net plot area harvested and converted in to t ha^{-1}.

Statistical Data Analysis

All the measured parameters were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to the General Liner Model (GLM) of the GeneStat 15th edition (GenStat, 2012) and interpretation were made following the procedure described by Gomez and Gomez (1984). Whenever the effects of the treatments were found to be significant, the means were compared using the Least Significant Differences (LSD) test at 5% level of significance.

RESULTS AND DISCUSSION

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Phenological Parameters of Potato

Days to 50% flowering

There were significant ($P < 0.01$) differences in days to 50% flowering of potato due to the main effect of mineral NP fertilizers and farm yard manure (FYM) as well as interaction effect (Appendix Table 1). Increasing the rates of FYM reduced the number of days to 50% flowering across the increased rates of mineral NP fertilizers. Thus, due to the interaction effect of 0 t FYM ha^{-1} and 0 mineral NP kg ha^{-1}, flowering was delayed almost five days as compared with the treatment that received 7.5 t FYM ha^{-1} and 100% blanket recommended mineral NP fertilizers, (Table 3). The delayed flowering in 0 application of FYM and mineral NP fertilizers might be due to lack of essential nutrients for metabolic process and differentiation of buds into flower buds, while in treatment that received 0 rate of FYM and 75% NP earliness in flowering could be attributed to the enhancement of vegetative growth .The result was in conformity of the finding of Daniel *et al*. (2008) who reported that the application of 10 t FYM and 75% NP kg ha^{-1} fertilization enhanced the flowering duration of potato as compared to absolute control.

Table 3: Interaction effect of FYM and mineral NP rates on days to 50% flowering of potato

	NP rate (%)				
FYM (t ha^{-1})	0	25	50	75	100
0	64.67^{h}	60.33^{cdefg}	60.33^{cdefg}	56.00^{a}	59.00^{bcd}
2.5	58.67^{bc}	61.00^{efg}	61.67^{fg}	59.67^{cde}	57.67^{b}
5	59.00^{bcd}	59.67^{cde}	60.00^{cdef}	60.00^{cdef}	60.67^{defg}
7.5	62.00^{g}	59.67^{cde}	57.00^{def}	57.67^{b}	60.00^{cdef}
LSD (5%) FYM× NP = 1.653 CV (%)=1.7					

LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; Means in the table followed by the same letter(s) are not significantly different at 5% level of significance.

Days to 90% physiological maturity

There were significant (P < 0.01) differences in days to maturity of potato due to the main effect of mineral NP fertilizers and farmyard manure (FYM) as well as interaction effect (Appendix Table 1). Increasing the rates of FYM reduced the number of days to maturity across the increased rates of mineral NP fertilizers. Thus, due to the interaction effect of nil t FYM ha^{-1} and nil mineral NP kg ha^{-1}, maturity was delayed almost six days as compared with the treatment that received 7.5 t FYM ha^{-1} and 100% blanket recommended mineral NP fertilizers, (Table 4). The delayed maturity in response to nil application of FYM and mineral NP fertilizers could be due to slow vegetative growth and late formation of reproductive organs, while hastened maturity of the crop with the application of FYM and mineral NP could be due to optimum availability of nutrients in farmyard manure (Ramesh *et al*., 2009; Najm *et al*., 2010) and could also be due to enhanced soil moisture holding capacity as a result of integrated mineral and organic fertilizer application (Srivastava*et al*., 2012). The result of the experiment confirmed the findings of Amir (2014) who reported that the application of 92 kg N ha^{-1} with 15 t ha^{-1} FYM hastened the maturity of potato. As contrary to this result Zelalem *et al*. (2009) reported that the application of N and P fertilizers delayed flowering and prolonged days required to attain physiological maturity of potato.

Table 4: Interaction effect of FYM and mineral NP rates on days to 90 % maturity of potato

			NP (%) rate		
FYM (t ha^{-1})	0	25	50	75	100
0	109.00^{h}	104.70^{efg}	104.30^{defg}	103.70^{bcdefg}	102.70^{abcde}
2.5	103.30^{bcdef}	105.70^{g}	105.30^{fg}	102.30^{abcd}	101.70^{ab}
5	104.30^{defg}	103.70^{bcdefg}	104.00^{cdefg}	104.00^{cdfg}	105.30^{fg}
7.5	105.70^{g}	102.00^{abc}	101.00^{a}	102.00^{abc}	103.00^{abcde}
LSD (5%) FYM× NP_2O_5 = 1.904 CV(%)=1.1					

LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; Means in the table followed by the same letter(s) are not significantly different at 5% level of significance

Growth Parameters of Potato

Plant height

The analysis of variance of plant height showed highly significant (P<0.01) main effects of FYM and mineral NP fertilizers and their interactions (Appendix Table 1). The combination of 7.5 t FYM ha^{-1} and 100% of recommended mineral NP fertilizers gave the maximum plant height (81.6 cm) followed by the application of 7.5 t FYM ha^{-1} and 75% of the recommended mineral NP (79.97 cm) (Table 5). On the other hand shortest plant height (57.8 cm) was observed from nil application of FYM and mineral NP fertilizers. The possible reason for the increment of plant height with the application of FYM and mineral NP might be due to better availability of N and P that come from both FYM and mineral NP fertilizer which enhanced cell division, cell elongation and vegetative growth. The increment in plant height due to combination of fertilizers could clearly indicated the need for adding farmyard manure to the soil in concurrence with mineral fertilizers, which might have increased the availability of nutrients considerably resulting in a positive effect on growth parameters as reported by Yourtchi *et al*. (2013). In accordance with this result, Abou-Hossain *et al*. (2003) found the highest stem height of potato with the application of cattle manure in combination with mineral NP fertilizers.

Table 5: Interaction effect of FYM and mineral NP rate on plant height (cm) of potato

			NP (%) rate		
FYM (t ha^{-1})	0	25	50	75	100
0	57.80^{h}	66.93^{g}	67.67^{g}	77.93^{bc}	77.87^{bc}
2.5	71.00^{f}	72.07^{ef}	73.00^{ef}	73.70^{def}	74.93^{de}
5	72.40^{ef}	73.33^{def}	74.00^{de}	74.92^{de}	75.90^{cd}
7.5	74.53^{de}	74.53^{de}	75.93^{cd}	79.97^{ab}	81.60^{a}
LSD (5%) FYM× NP =2.876 CV(%)=2.3					

LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; Means in the table followed by the same letter(s) are not significantly different at 5% level of significance.

Application of organic manure along with mineral fertilizers could also provide the micronutrients, which might have helped in enhancing of the metabolic activity in the early growth phase which in turn could have increased the overall plant height of potato (Yourtchi*et al*., 2013). The results of this study are in agreement with the findings of

Alam *et al*. (2007) in potato, Alam (2006) and Azad (2000) in cabbage who stated that combined application of manures and mineral fertilizers induced the plants to grow taller. Murakar *et al*. (1998) also showed that application of vermicompost at the rate of 6 ton ha^{-1} led to increase in plant height of mulberry.

Average stem number per hill

Although stems density is one of the most important yield components in potato, the results of the present study showed that main effect of FYM and mineral NP fertilizer rate as well as the interaction of the two had not significant effect on the average stem number per hill (Appendix Table 1). The potato crop is usually propagated by using underground storage organs known as tubers. Potato tubers show a wide range of variation and possess a variable number of growing points (buds) arranged in groups (eyes) over their surface (Allen, 1978). Stem number is not increased with the application of nutrients. This could be due to the fact that stem number is determined very early in the ontogeny of yield (Lynch and Tai, 1989). It could also be due to the fact that this trait is not influenced much by mineral nutrition, as the stem number is the reflection of storage condition (Allen, 1978), physiological age of the seed of the variety (Lynch and Tai, 1989; Dela Morena *et al.*, 1994) and tuber size (Harris, 1978). The number of stems per plant had direct relation with the number of sprouts per tuber not on the treatment applied (Abebe *et al*, 2010 and the sprouts are the function of number of eyes on tubers. Stem density is positively correlated with eye number per tuber (Nielson *et al.,* 1989) and tuber size (Harris, 1978).

Lung'aho *et al.* (2007) stated that stem number is basically determined by the number of eyes present on tubers and the physiological age of the tubers during the storage period rather than by manipulating the supply of fertilizers. Consistent with the results of this study, Assefa (2005) reported that stem number per hill was not significantly affected by the application of nitrogen and phosphorus. It was also reported that seed tubers of different genetic composition are known to differ in stem numbers (Gill *et al.,* 1989, Wurr *et al*., 1992). This study was also supported by the work of Muluberhan *et al.* (2005) who reported that the stem number was not significantly influenced much by mineral nutrients, possibly because stem number may be influence by other factors such as condition of seed tubers and physiological age of the seed tuber.

Yield Components of potato

Total tuber number per hill

Total tuber number per hill was significantly ($P < 0.01$) influenced by the rate of FYM. This parameter was also significantly ($P < 0.01$) influenced by the rate of mineral NP fertilizer application. However, the two factors did not interact to significantly influence this parameter (Appendix Table 2).

Total tuber number per hill increased significantly and linearly in response to increasing the rate of FYM application from nil up to the highest rate of the fertilizer. Thus, the lowest number of tubers per hill was obtained for the nil FYM treatment whereas the highest was obtained from treatment that received 7.5 FYM t ha^{-1} (Table 6). Total tuber number per hill is also increased significantly and linearly in response to increasing the rate of mineral NP fertilizer application from nil up to the highest rate of the fertilizer. Thus, the lowest number of tubers per hill was obtained for the nil mineral NP fertilized treatment whereas the highest was obtained from treatment that received the highest mineral NP fertilizer (Table 6). The possible reason for the increment of tuber number at the highest rate of mineral NP fertilizer might be attributed to an increase in stolon number in response to mineral N and P application, which is known to influence the rate of gibrillic acid biosynthesis in the potato. The involvement of gibberellins in regulating stolon number through stolon initiation was reported by Kandil *et al*. (2011). According to Amir *et al*. (2014), N and P influenced tuber formation in potato by influencing the activity and phytohormone balance in the plant, especially, on the levels of gibberellic and abscissic acids and cytokinins. This is related to gibberellins enhancing stem organ elongation thus stimulate potato stolon initiation, growth and branching. Abscissic acid controls stolon growth. So the ceassation of stolon in apical growth in potato is accompanied by the increase of the ABA/GA ratio. Cytokinin is related to when potato plants transited to tuber formation activity of endogenous cytokinin increased substantially in stolons and developing tubers. These cytokinins are known in plants in stimulating cell division. Similar to the results of this study, Sommerfeld and Knutson (1965), Sparrow *et al.* (1992), Israel *et al*. (2012) and Zelalem *et al.* (2009) reported that the increasing the rates of phosphorus and nitrogen increased the number of potato tubers set per hill.

Marketable tuber number per plant

Marketable tuber number was highly significantly ($P<0.01$) affected by the main effects of FYM and mineral NP fertilization rates, however, their interaction was not significant (Appendix Table 2). The marketable tuber number increased linearly for both FYM and mineral NP fertilizers application. The highest marketable tuber number per plant was recorded in the treatment that received the highest FYM t ha^{-1} and also for the highest mineral NP fertilizers respectively. While the lowest marketable tuber number was recorded in treatment that received no fertilizers for FYM and mineral NP. From the findings of Daniel *et'al,* 2008, the possible reason for increased marketable tuber number might be due to applied fertilizer increased the size of the tuber and there by increased the weight of the tuber and also phosphorus fertilization increased the interception of solar radiation at low soil phosphorus conditions so it might have a positive effect on tuber set at certain conditions. The increased marketable tuber number in FYM fertilization might be related to increment of soil micro and macro nutrients and its availability to the crop for ease of absorbation. The result was in agreement with finding Habtam (2012) who reported that marketable tuber numbers per hill increased by about 26, 51 and 98% as the level of potassium was increased from nil to 100, 200 and 300 kg ha^{-1}, respectively. The result was in agreement with the finding of Gezahegn *et al*. (2014) who reported that application of 46 kg N ha^{-1} and 5 t ha^{-1} FYM increased marketable root yield on sweet potato by 48.55% as compared to non-fertilized treatment.

Table 6: Main effect of FYM and mineral NP fertilizer rate on marketable, unmarketable and total tuber number per hill of potato**.**

FYM (t ha^{-1})	MTN per hill	UNMTN per hill	TTN per/hill
0	5.18^{c}	4.09	9.27^{d}
2.5	6.30^{b}	3.9	10.20^{c}
5.0	6.63^{b}	4.05	10.68^{b}
7.5	8.38^{a}	3.31	11.69^{a}
LSD (5%)	0.52	0.78	1.09
NP (%)			
0	5.94^{c}	4.23	10.17^{c}
25	6.08^{c}	4.24	10.32^{c}
50	7.21^{b}	3.44	10.65^{bc}
75	7.26^{b}	3.79	11.05^{b}
100	8.42^{a}	3.25	11.67^{a}
LSD (5%)	1.24	0.44	0.62
CV (%)	8.80	21.04	10.32

LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; NS= Non-significant. Means in the column followed by the same letter(s) are not significantly different at 5% level of significant.

Tubers size distribution in weight

The size distribution of tuber was highly significantly (P<0.01) affected by FYM and mineral NP fertilizer for medium sized and small sized tubers in main effect and significantly affected for large sized tuber (P<0.05) however their interactions was not significant on tuber size distribution (Appendix Table 3).

The highest proportion of large and medium sized tubers were recorded in response to the application of highest amount of FYM (7.5 t ha^{-1}) and mineral NP fertilizers which might be due to the nutrient utilization efficiency of the crop, and the applied fertilizer pronounced better nutrient availability to increase the tuber size. The increase in tuber size was also correlated to FYM at increased rate which might have enhanced the available nitrogen and phosphorus to the soil which was immediately usable to the crop. Tuber size distribution varies with many factors among which soil fertility and population density are the major ones (Haverkort *et al*., 2012). The more populated potato plants result in the more number of tubers which result in small tuber size or weight of tuber. Soil which is fertile with optimum nutrient content for potato plant growth that is well structured, good drainage to allow and proper root aeration, result in tuber development. The result of this study was in agreement with that of Haase *et al*. (2007) who reported that decomposed cattle manure increased the number of tubers with diameters > 65 mm as a result of N mineraliation. Taheri *et al*. (2010) also found the highest ratio (13.07%) of number of large tubers as a result of application of 20 t ha^{-1} of compost combined with 225 kg ha^{-1} phosphorus × 50 kg ha^{-1} zinc.

Table 7: Main effect of FYM and mineral NP fertilizers application on large, medium and small sized tubers of potato.

FYM (t ha^{-1})	Large Size (%)	Medium Size (%)	Small Size (%)
0	59.10^{c}	28.72^{a}	12.18^{a}
2.5	62.03^{b}	27.14^{a}	10.83^{ab}
5.0	61.48^{bc}	28.30^{a}	10.22^{b}
7.5	69.21^{a}	23.15^{b}	7.64^{c}
LSD (5%)	2.643	1.994	1.615
NP (%)			
0	58.06^{c}	30.28^{a}	11.67^{a}
25	58.18^{c}	30.27^{a}	11.55^{a}
50	62.63^{b}	27.51^{b}	9.86^{ab}
75	67.13^{a}	23.24^{c}	9.64^{b}
100	68.79^{a}	22.83^{c}	8.38^{b}
LSD (5%)	2.955	2.23	1.806
CV (%)	5.7	10.1	21.4

LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; Means in the table followed by the same letter(s) are not significantly different at 5% level of significance.

Small sized tuber proportion significantly (P<0.01) affected by the main effect of application of FYM and mineral NP fertilization (Appendix Table 3). Large amount of small sized tubers were obtained from plots which received lowest application of FYM and mineral NP while, low quantity of small sized tubers contributed by the high application of FYM and NP fertilizers (Table 7). It was observed that as the rate of FYM and mineral NP fertilizers increased, the proportion of small sized tubers reduced. The result was in line with the work of Hossain *et al*. (2007) who found maximum tuber size with combined application of organic and inorganic fertilizers.

Tuber Yield Parameters of Potato

The main effects of FYM and mineral NP fertilizers highly significantly affected marketable and total tuber yields. However, their interaction did not significantly influence these parameters and the main effects as well as their interaction did not significantly influence the unmarketable tuber yields (Appendix table 4).

Total and marketable tuber yield increased significantly and linearly in response to increasing the rate of FYM application from nil up to the highest rate of the fertilizer. Thus, the lowest total (27.11 t ha^{-1}) and marketable (25.47 t ha^{-1}) tuber yield were obtained for the plot that received nil FYM rate whereas the highest total and marketable (35.11 t ha^{-1}, and 33.97 t ha^{-1}) tuber yield were obtained from treatment that received 7.5 FYM t ha^{-1} respectively (Table 8). Total and marketable tuber yield were also increased significantly and linearly in response to increasing the rate of mineral NP fertilizer application from nil up to the highest rate of the fertilizer. Thus, the lowest total (24.02 t ha^{-1}) and marketable (22.66 t ha^{-1}) tuber yield were obtained for the nil mineral NP fertilized treatment whereas the highest was obtained from treatment that received the highest mineral NP fertilizer (Table 8).

The possible reason for the increment in marketable and total tuber yield of potato by the application of either FYM along with mineral fertilizer could be attributed to their favorable effects on yield components, like average number of tubers per hill, and dry matter production. This might be due to FYM fertilizer along with in mineral fertilizer enhance all nutrient requirement of the plant. This clearly showed that, the applied nutrients increased tuber quality and weight. From the findings of Israel *et'al,* 2012, this can be attributed to increased vegetative growth of the aerial parts and hence, prolonged the duration of photosynthesis. The marketable tuber yield was increased with increased rates of both FYM and mineral NP fertilizer. This could be probably due to the fact that marketable tuber yield increased at highest nitrogen rate because nitrogen can trigger the vegetative growth and development. The increase in number of marketable tuber with increase in applied nitrogen was associated with decrease in the number of the small size tubers due to increase in the weight of individual tubers, thus increase marketable tuber yield.

Total tuber yields also followed similar trend and it was also highest in response to high rate of application resulted in highest marketable yield. This result corroborates with the study of Habtam Setu (2012) who reported that increase in yield of crop might be due to increased dry matter production and its distribution in plant parts. Tekalign and Hammes (2005) also reported that the assimilation of dry matter and its distribution within the plant are important processes determining crop productivity. The results of this experiment also confirmed the observations of Sanchez and Jam (2002) who reported that integration of organic and mineral NP fertilizers sustains crop production due to positive interaction and complementarities between them.

The result, therefore, clearly showed that the yield of potato could be maximized by the combined application of FYM and mineral NP fertilizer. The above results are in agreement with the observation by Amir *et al*. (2014) who reported that highest tuber yield of potato was obtained from the combined application of 20 t ha^{-1} cattle manure with 150 kg N ha^{-1}. Similarly, Nyiraneza and Snapp (2007) reported that the combined application of 179 kg N ha^{1} fertilizer and 5.6 t ha^{-1} poultry manure consistently increased tuber yield by 20% over the use of inorganic N alone at 224 kg ha^{-1}. The result was also in agreement with the finding of Teshome and Nigussie (2012) who reported that the application of 20 t farmyard manure ha^{-1} and 180 kg P_2O_5 ha^{-1} resulted in production of highest marketable root yield of sweet potato.

Table 8: Main effect of FYM and mineral NP fertilizers application on total and marketable tuber yield (t ha^{-1}**)** of Potato.

FYM (t ha^{-1})	Marketable tuber yield (t ha^{-1})	Total tuber yield (t ha^{-1})
0	25.47[c]	27.11[c]
2.5	28.46[b]	29.76[b]
5.0	29.89[b]	31.00[b]
7.5	33.97[a]	35.11[a]
LSD (5%)	2.086	2.267
NP (%)		
0	22.66[d]	24.02[c]
25	25.10[c]	26.41[c]
50	28.12[b]	29.38[b]
75	34.59[a]	35.96[a]
100	36.78[a]	37.95[a]
LSD (5%)	2.332	2.534
CV (%)	9	9.4

LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; Means in the column followed by the same letter(s) are not significantly different at 5% level of significance

SUMMARY AND CONCLUSION

Potato production is widely practiced in southern Ethiopia. The existing potato productivity in the area is very low despite the high potential for increased production and yield of the crop in the area. This is due to constraints such as poor agronomic practice, poor soil fertility, poor cultural practices, diseases and pests. The crop requires a variety of elements for growth and development of which N, P, and K are the most important of the essential nutrients because they are required in large quantities.

Sustaining soil and soil fertility in intensive cropping systems for higher yields and better quality of crops could be achieved through optimum levels of fertilizer application and fertilizer management. Thus, information on fertility status of soils and crop response to different soil fertility management is very important to come up with profitable and sustainable crop production. Therefore, this experiment was carried out with the objective of assessing the effect of farmyard manure and mineral NP fertilizers on yield related traits and yield of potato (S*olanum tuberosum* L.) at Areka, Southern Ethiopia. The experiment consisted of four levels of FYM (0, 2.5, 5, 7.5 t ha^{-1} and five levels of mineral NP fertilizers [0, 25%, 50%, 75%, 100% of the blanket recommended rate (110 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1})] in factorial combination in RCBD with three replications during 2016 'Meher'cropping season. The improved potato variety Belete was used as a test crop.

The results showed that the main effect of FYM and mineral NP fertilizers were significant
($P < 0.01$) on total tuber number per plant, marketable tuber number per plant, tubers size category, marketable tuber yield (t ha^{-1}), and total tuber yield (t ha^{-1}). Thus, the highest total and marketable tuber number per plant was obtained for the treatments that received the highest rate of both FYM and mineral NP fertilizers. There were significant interaction of FYM and mineral NP fertilizers on days to 50% flowering, on days to maturity and plant height.

The highest total and marketable tuber yields were obtained in response to the application of 7.5 FYM t ha^{-1} and 100% of blanket recommended mineral NP fertilizer, but the optimum total and marketable tuber yield obtained from the application of 7.5 FYM t ha^{-1} and 75% of blanket recommended mineral NP fertilizer.

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APPENDIX

Appendix Table 1.Mean squares of ANOVA for phenological and growth parameters of potato as affected by FYM and NP rate.

		Mean Squares			
Source	Df	DF	DM	PH	SN
Block	2	0.950	0.117	5.176	1.10
FYM	3	8.956**	12.417**	153.233**	1.358ns
NP	3	6.558**	12.733**	151.209**	0.473ns
FYM*NP	12	10.858**	8.444**	36.869**	1.783ns
Error	38	1.00	1.327	3.028	2.456
CV (%)		1.7	1.1	2.3	2.4

*= significant, ** = highly significant, ns = non significant, Df = degree of freedom, DF = days to flowering, DM = days to maturity, PH = plant height, SN=Stem Number per hill, %, CV=co-efficient of variation in percent.

Appendix Table 2. Mean squares of ANOVA for tuber number per plant as affected on FYM and NP rate.

		Mean squares		
Source	Df	MTN/hill	UMTN/hill	TTN/hill
Block	2	1.00	0.012	0.92
FYM	3	21.15**	2.63ns	13.17**
NP	4	6.03**	1.94ns	1.80*
FYM*NP	12	0.46ns	0.25ns	0.37ns
Error	38	0.4	0.7	0.3
CV (%)		8.80	21.04	4.95

Where, Df=degree of freedom, MTN/hill=Marketable tuber number per hill, TTN/hill=Total tuber number per hill, UNMTN/hill= unmarketable number per hill CV= coefficient of variation; *=significant, **=highly significant, ns=not significant

Appendix Table 3. Mean squares of ANOVA for tuber yield parameters as affected on FYM and NP rate

		Mean squares	
Source	Df	MTY(t ha^{-1})	TTY(tha^{-1})
Block	2	1.748	4.62
FYM	3	187.416**	166.371**
NP	4	440.790**	434.983**
FYM*NP	12	4.126ns	4.350ns
Error	38	7.964	9.403
CV (%)		9	9.4

Where, Df=degree of freedom, MTY=Marketable tuber yield (t ha^{-1}), TTY=Total tuber yield (t ha^{-1}); SG (cm^{-3})=specific gravity ,DM(%9)=percent dry matter content, CV= coefficient of variation; *=significant, **=highly significant, ns=not significant.

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