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Research Article

Effect of Phosphorus and Potassium Fertilizer Rates on Growth and Yield of Potato (Solanum Tuberosum L.), Northwestern Ethiopia

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ABSTRACT

Potato is one of the most imperative food and nutrition security crops in Ethiopia. Poor soil fertility and nutrient imbalances are the major hindrances of potato production and productivity. In view of this, an experiment was conducted to study the effects of phosphorus and potassium fertilizer rates on growth and yield of potato in Gozamin district during the 2018 rainy season. The experiment consisted of three levels of phosphorus (0, 34.5 and 69 kg P2O5 ha-1) and four levels of potassium (0, 100, 200 and 300 kg K2O ha-1) in a factorial arrangement using RCBD with three replications. Data on phenology, growth, and yield were collected and subjected to analysis of variance using SAS 9.2 statistical software. The result of the study showed that all phenological parameters were significantly affected by the main effects of phosphorus and potassium fertilizer rates but not by their interactions. Growth parameter (plant height), yield components (marketable and total tuber yield); were significantly influenced by the interaction effects of phosphorus and potassium fertilizer rates. The highest marketable (48.32 t ha-1) and total tuber yield (49.14 t ha-1) were attained from treatments received 34.5 kg P2O5 ha-1 with 200 kg K2O ha-1. While, longest plant height (84.80 cm) was recorded on a treatment received, 34.5 kg P2O5 ha-1 and 200 kg K2O ha-1. Likewise, application of 34.5 kg P2O5 ha-1 gave the highest leaf area index (6.86).

Keywords: Fertilizer rates; Phenotypic parameter; Growth parameter; Yield component

INTRODUCTION

The Irish potato [1], is an important food crop in Northwestern Ethiopia. The crop was introduced to Ethiopia by the German Botanist Schimper in 1858 as mentioned by Birtukan Belachew. The annual potato production in Ethiopia was estimated to be 921, 403.9 t harvested from 66, 923.33 ha with average productivity of 13.76 t ha-1. The national average of potato yield on farmer's field in Ethiopia is lower than the yields achieved on experimental plots (38 t ha-1) and the productivity was very low compared to the world average productivity (17.6 t ha-1) [2]. Potato is also suited to smallholder farmers in Ethiopia as the labour required for its production is less than that of cereals. Its shorter growing period makes it possible for smallholder farmers to use this crop in a system where more than one crop is possible on the same land per season [3]. Optimum growth and yield of potato depend on many factors including the supply of a sufficient amount of nutrients [4]. Potato consumes large quantities of nutrients particularly N, P and K [5] and exploits the applied fertilizers better. Moreover, potato is most sensitive to nutrient stress because of its sparse root system [6]. Hence, comprehensive nutrient management program is indispensable for sustaining a healthy potato crop, improving tuber yield and quality, and curtailing impacts on the environment.

Phosphorus plays an irreplaceable role in 16 several key functions, including, photosynthesis, respiration, energy transfer, sugar and starch transformation and nutrient translocation. However, the economically exploitable available phosphorus reserve is depleted with increasing crop production to ensure food security for the growing world population.

Potato takes up significant quantities of potassium for optimal tuber and quality [7]. However, imbalanced fertilizer uses and cropping systems leading to potassium mining that results in

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reduction of crop yield [8]. Hence, there is a need to investigate the role of potassium in balanced nutrient management for sustainable crop production, particularly in high potassium requiring crops like potato have also reported that potato plants require high potassium than many other vegetable crops, as it increases both the rate and duration of tuber bulking and assists in the translocation of carbohydrates from leaves to tubers. Many researchers reported that an increase of potato tubers yield with the increased level of potassium which is explained by either due to the formation of large size tubers or increasing of the number of tubers per plant or both [9].

The beneficial effect of potassium nutrition has also been well known in photosynthesis, enzymatic activities, improving the synthesis of protein, carbohydrates and fats, translocation of photo-assimilates, and increasing resistance to insect pests and diseases [10]. It is a major component of osmotic activities of the plant cell that influences water uptake and root permeability [11]. Potassium is highly mobile within the conductive tissues and aids in the transport of starch and sugars. Besides, adequate potassium levels in the plant help to withstand water stress during periods of drought and also contributes to various aspects of tuber quality.

On the other hand, a huge amount of potassium is depleted because of leaching, improper land use and soil erosion every year. Moreover, application of potassium fertilizer for crop production including potato in Ethiopia is not a common practice [12]. These situations led to the mining of native potassium reserves of the soil and results on the reduction of crop yield.

Similarly, in Ethiopia, there is a longstanding information that Ethiopian soils are not deficient with potassium, the use of potassium fertilizer for the production of crops in Ethiopia is entirely neglected. Consequently, the recommendation of potassium fertilizer for the production of crops by smallholder farmers is completely ignored in Ethiopia [13]. Moreover, the information about the requirement of potassium fertilizer and its rates for the production of potato is also scarce in Ethiopia [14]. Although potato requires high potassium, its cultivation is done without application of potassium fertilizer in major potato growing areas of Sub-Saharan Africa including Ethiopia [15]. But some studies have been showed that the response of potatoes to potassium application on highland parts of East Africa is else encouraging [16]. Thus, in sight of the fact that Ethiopian soils are deprived in yield and have problem of soil pH, phosphorus fixation and N and K leaching and appreciating the importance of fertilizers in potato production, the practice of synthetic and natural fertilizers in potato production for ideal yield and quality tuber production is important. Consequently, this research was initiated to evaluate the effects of phosphorus and potassium fertilizer rates on the production of potato under Gozamin condition.

OBJECTIVES

The research was intended to address the following objectives:

To evaluate the effects of different rates of phosphorous and potassium on growth, yield, and quality of potato

To determine the optimum rates of phosphorus and potassium for economical production of potato in the study area

MATERIALS AND METHODS

Experimental site

The experiment was conducted in the Amhara Region of Ethiopia at Gozamin district, Gojjam, which is located at 10°21' N latitude and 37° 43' E longitude with an altitude of about 2450 m above sea level. The area has a mean annual rainfall of 1301.9 mm. The mean minimum and maximum temperatures of the area were 17.76 and 18.83 0C, respectively. The soil of the area is Nitisols, which is characteristically dusky red or dark red in colour. It is acidic having a pH of 5.5 and clay in texture with contents of 22% silt, 14% sand and 64% clay. The soil has total nitrogen, available phosphorus and exchangeable potassium contents of 0.09%, 8.30 ppm, soil and 0.135 cmol kg soils, respectively, at 30 cm soil depth.

Experimental materials

The potato variety called ‘Belete’ (CIP-393371.58) was used as a planting material which has wide-range environmental adaptation in Ethiopia. It requires up to 120 days to reach physiological maturity and considered moderately resistant to the late blight disease.

Fertilizer materials

Triple Superphosphate (TSP) and potassium chloride (KC1) were used as sources of phosphorus (46% P2O5) and potassium (60% K2O), respectively. Urea (CO[NH2]2) (46% N) was used as a source of nitrogen.

Treatments and experimental design

The treatments consisted of three levels of phosphorus (0, 34.5 and 69 kg P2O5 ha-1) and four levels of potassium (0, 100, 200 and 300 kg K2O ha-1). The basis for these levels was the pretesting of the soil nutrient which was medium in available phosphorus (8.30 ppm) and very low in exchangeable potassium (0.135 cmol kg-1 soil) accordingly. The experiment was laid out as a Randomized Complete Block Design (RCBD) in a 3 × 4 factorial arrangements and replicated three times. There were 12 treatment combinations, which were assigned to each plot randomly. The total number of plots was 36 and each plot had a gross area of 11.25 m2 with 3 m length and 3.75 m width. Each plot consisted of five rows with 10 plants each, with a total population of 50 plants per plot. The spacing between rows and plants were 0.75 m and 0.30 m, respectively. The spacing between plots and adjacent blocks were 0.5 m and 1 m, respectively.

EXPERIMENTAL PROCEDURES

Land preparation

The land was prepared manually from May to June, 2018.

Planting

Medium-sized (40-60 g) and well-sprouted potato tubers (6-7 sprouts with 2-3 cm long) were planted on ridges at the specified spacing on the first week of June, 2018.

Fertilizer application

Application of phosphorus and potash fertilizers at the quantified rates were done via banding the granules of the two fertilizers at the depth of 5 cm below and around the seed tuber at planting. All phosphorus was applied at planting while potash was applied in two splits ½ at emergence and ½ at about 40 days after planting, as of the problem of leaching caused by high rainfall. Urea at the rate of 176 kg ha-1 (81 kg ha-1 N) was applied in to two equal splits to all experimental plots where ½ was applied during planting and the remaining ½ at tuber initiation (about 40 days after planting) as recommended by ARARI.

Other cultural practices

Weeds and earthening-up were practiced manually via hoeing as required to prevent exposure of tubers to direct sunlight, to encourage tuber bulking and to ease harvesting. Mancozeb was sprayed at the rate of 50 g per 20 L of water to control late blight disease.

Data collection

Data were recorded on different phenotypic, growth, yield and quality characteristics of potato.

Crop phenotype

Days to 50% flowering was recorded by counting the number of days elapsed from planting until 50% of the plants in the plot flowered as cited on while, days to 50% physiological maturity was noted by counting the number of days elapsed from planting until the haulms of 75% of the plants in the plot became yellow.

Growth parameters

Plant height (cm): The heights of five randomly selected plants grown in the net plot area were measured from the ground level to the tip of the main stem using ruler at 70 days after sowing and the mean values were computed and used for further analysis. Leaf area index: Five photos at different points of each plot of the treatment were taken at a full canopy stage (70 days after planting) using digital camera (Nikon Coolpix Camera). The pictures were subjected to LAI calculator software using the protocol of image processing software as described by and the mean values used for analysis.

Yield components

Total biomass (t ha-1): Aboveground (stems, branches, and leaves) and underground (tubers, roots, stolon's, and part of stems remaining) plant parts from the net plot area were measured by sensitive balance just before senescent (at physiological maturity). It was converted in to hectare and further used for analysis. Marketable tuber yield (t ha-1): It was measured by weighting tubers which were disease free, undamaged and greater than or equal to 25 g in weight, using sensitive balance. The samples were taken from the net plot area and the values were expressed in hectare basis and used for further analysis. Unmarketable tuber yield (t ha-1): Includes tubers, which were diseased, damaged and less than 25 g in weight by using sensitive balance. The samples were taken from the net plot area and the values were expressed in hectare basis and used for further analysis. Total tuber yield (t ha-1): It was obtained by summation of marketable and unmarketable tuber yields.

Parameters		P	K	P x K
Degree of freedom (d.f)		2	3	6
Phenological parameters	Days of flowering (No)	31.69***	11.07***	1.76ns
	Days of maturity (No)	280.78***	202.66***	11.44ns
Growth parameters	Plant height (cm)	675.15***	562.50***	74.59*
	Leaf area index	2.81*	0.07ns	0.33ns
	Total biomass (t)	411.94***	221.19***	53.00*
Yield parameters	Marketable yield (t)	711.68***	405.16***	83.37***
	Unmarketable yield (t)	0.202***	0.115***	0.024***
	Total yield (t)	736.09***	418.83***	86.23***

***, *: Significant differences at 1 and 5% level of significance, respectively; ns = non-significant at 5% level of significance; P = phosphorus (P2O5); K = potassium (K2O).

Table 1: Mean squares of potato phenology, growth parameters and yield components as influenced by phosphorus, potassium and their interaction.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) according to the Generalized Linear Model (GLM) of SAS version 9.2 (SAS Institute, 2008). Significant differences between treatment means were separated based on the ANOVA result, i.e. least significance difference (LSD) test at 5 and 1% significance level.

RESULTS AND DISCUSSION

Influences of P and K on phenological parameters

The analysis of variance showed that days to flowering was very highly significantly ($p<0.001$) affected by the main effects of phosphorus and potassium fertilizers (Table 1) but not significantly ($p>0.05$) influenced by the interaction effects. The longest days to flowering (54.25) was recorded from the application of 69 kg P2O5 ha-1 and it was statistically similar with the results those received 34.5 kg P2O5 ha-1; whereas, the shortest (51.00) was recorded from the control and it was statistically similar with the results received 34.5 kg P2O5 ha-1; in the same way, the longest (53.55) days to flowering was obtained from 300 kg K2O ha-1 and it was statistically similar to the results of those treatments received 100 and 200 kg K2O ha-1; while, the shortest (51.11) days to flowering was recorded from the control and it was statistically similar with results of those receiving 100 kg K2O ha-1 (Table 2). Therefore, by applying 69 kg P2O5 ha-1 (3.25) and 300 kg K2O ha-1 (2.44) extra days were recorded. It might be due to the lack of stress that resulted in extended vegetative growth as stress is a signal for sex hormones that hasten flowering and maturity earlier. Since the research was conducted in the rainy season there was high soil moisture and fluctuated atmospheric condition (temperature and light) in the district and these would prolong the vegetative phases of the crop and delayed flowering and maturity days.

This result is in accordance with who had reported that phosphorus application prolonged days to 50% flowering and it was positively correlated with other growth components. Also stated 100 kg N ha-1 and 92 kg P2O5 ha-1 fertilizer delayed days to 50% flowering. Contrarily, described that phosphorus applications shortened days to flowering.

Potassium has a synergetic effect on most of the macro and micro nutrients because of this the availability of soil nitrogen in the zone was increased and this in turn extends the vegetative growth of the crop and delayed flowering and maturity days. Addition of potassium fertilizer significantly prolonged days to flowering. Disparity to this, Abay Ayalew and Sheleme Beyene have reported potassium fertilization did not influence the time to reach flowering.

Days to maturity was very highly significantly ($p<0.001$) affected by the main effects of phosphorus and potassium fertilizers; whereas, the interaction effect of the two fertilizers didn't show a significant ($p>0.05$) influence on days to maturity (Table 1). Application of 69 kg P2O5 ha-1 gave the longest days to maturity (123.16) and it was statistically similar with results of the treatments those received 34.5 kg P2O5 ha-1, but the shortest (114.33) was recorded from the control. Likewise, application of 300 kg K2O ha-1 attained the longest days to maturity (124.33) and it was statistically similar with the results of those treatments received 100 and 200 kg K2O ha-1; whereas, the shortest (113.22) was recorded from non-fertilized treatment (Table 2). This might be due to the fact that the synergetic effects of phosphorus and potassium with the nitrogen uptake which enhanced the vegetative stage and hence, delayed physiological maturity since its uptake enhanced as the uptake of these nutrients increased.

This result is in agreement with who reported that the longer duration was required for maturity in response to the increased rates of phosphorus and potassium application which could be explained in terms of improved early canopy growth and increased radiation interception for photosynthesis. Consistently, it is harmony with, who reported the major problem in the use of phosphate fertilizer is fixation of applied phosphate by the soil and the efficiency of phosphorus uptake from fertilizer is low. Potassium is well known in photosynthesis, increasing enzyme activity, improving synthesis of protein, carbohydrates, and fats, assimilation translocation, enabling to resist pests and diseases. Potato plants require much more potassium than many other vegetable crops. This result is in contradiction with who reported that phosphorus applications shortened date of physiological maturity.

Treatment	Days to 50% flowering	Days to maturity	LAI
P2O5 (kg ha-1)			
0	51.00b	114.33b	5.95b
34.5	52.58ab	122.16a	6.86a
69	54.25a	123.16a	6.68a
SE (±)	0.44	1	0.3
LSD (1%)	1.67***	3.82***	0.62*
K2O (kg ha-1)			
0	51.11b	113.22b	6.47
100	52.44ab	120.33a	6.43
200	53.33a	121.66a	6.63
300	53.55a	124.33a	6.46
SE (±)	0.5	1.16	0.3
LSD (1%)	1.93***	4.41***	0.72ns
CV (%)	2.05	2.05	11.41

Means with the same letter within a column are not significantly different and; *, ** and *** indicate LSD at P-values of >0.05, <0.05,

<0.01 and <0.001, respectively. SE = Standard errors and CV = Coefficient of Variation, LAI= Leaf area index.

Table 2: Phenological, some growth and quality parameters of potato as affected by phosphorus and potassium fertilizer application.

Influences of P and K on growth parameters

Plant height

Plant height was not-significantly (P>0.05) influenced by the main effects of phosphorus and potassium fertilizers, but significantly (P<0.05) affected by the interaction effects of phosphorus and potassium fertilizers at maturity (Table 1). The tallest (84.80 cm) plant height was recorded from the combined application of 34.5 kg P2O5 ha-1 with 200 kg K2O ha-1; whereas the shortest (51.66 cm) was attained from 0 kg P2O5 ha-1 with 100 kg K2O ha-1 and it was statistically similar with the results of the treatments received 0 kg P2O5 ha-1 with 0, 200 & 300 kg K2O; 34.5 kg P2O5 with 0 kg K2O and 69 kg P2O5 ha-1 with 0 kg K2O ha-1.

Consequently, by applying 34.5 kg P2O5 ha-1 with 200 kg K2O ha-1, the plant height was maximized by 33.14 cm (Table 3). Phosphorus and potassium nutrients are very limiting for potato production and the requirements of the potato crop are higher than cereals.

In line with this, Irfan stated that phosphorus and potassium fertilizers increased extent of nitrogen and other micronutrients distribution and they are part of essential amino acid, vitamins, and other compounds and also provides resistance against insects, insect pests and diseases in plants which may be certainly associated with plant height. Shunka have also pointed out that plant height was significantly affected by fertilizer application and positively correlated with yield parameters which contributed higher to potato yield.

Contrary to this, stated that increasing phosphorus and potassium rates had no associated effect on plant height at all the stages of plant growth, also reported that an increase in the level of phosphorus and potassium had no effect on plant height. Instead, nitrogen application results in vigorous growth of the plant.

Leaf area index

The main effect of phosphorus fertilizer showed statistically significant difference (p<0.05) but not-significant (p>0.05) effect for potassium and their interaction on leaf area index (Table 1). The highest leaf area index (6.86) was attained from 34.5 kg P2O5 ha-1 over the control (5.95) (Table 2). Leaf expansion is the growth parameter that can be used to optimize phosphorus fertilizer management in agro-ecological practices. The higher leaf area index contributes to meristematic tissue growth, nutrient synthesis, and assimilation. The growth components of potato (plant height, leaf area index, leaf and stem weight) will be increased with the increasing dose of phosphorus fertilizer. Phosphorus is a part of nucleic acid used for tuber initiation, formation and setting that may indirectly contribute a lot for the expansion of leaf area index, leaf sizes, leaf expansion, canopy size and diameter, leaves appearance.

The values obtained was consistent with Marschner who stated that leaf area index for optimum yield ranges between 3 and 6. Also reported that potato crop received phosphorus fertilizer was greatly responsive. Reported that leaf area index increased steadily up to a recommended rate of phosphorus fertilizer, after that it started to decline. Hence, slow increase at early and rapid at the middle and decreasing trend at the later growing periods up to harvest was estimated and it increased with the increasing of nutrient.

The leaf area index also depends on species composition, developmental stage, existing site conditions, seasonality and the supervision practices. Likewise, itemized that leaf area index is a dynamic factor; it might be changed from day to day (frequently in spring and autumn) and determined by diverse features from year to year. Contrarily, have reported that the application of phosphorus fertilizer did not affect the leaf area index of the potato crop.

Total biomass

Total biomass was not-significantly (p>0.05) influenced by the main effects of phosphorus and potassium fertilizers, whereas it was significantly (P<0.05) affected by the interaction (Table 1). The highest total biomass (44.52 t ha-1) was recorded from the combined application of 34.5 kg P2O5 with 200 kg K2O ha-1; whereas the lowest (20.05 t ha-1) was from the control and it was statistically similar with the results those received 0 kg P2O5 ha-1 with 100, 200 & 300 kg K2O ha-1; 34.5 kg P2O5 ha-1 with the absence of K2O; and 69 kg P2O5 ha-1 with no K2O fertilizer (Table 3).

The positive interaction of nutrients in soil and plants is an important factor in determining the yield of the potato crop and they are required for the formation of chlorophyll, cell division, and elongation activities. Since the chemical energy of organic compounds is sourced from the biomass in the ecosystem, it is a permanent storage of solar energy on the earth and used to feed both the people and animals. So, applying phosphorus and potassium fertilizers on potatoes may enhance its biomass content and provides more energy both for humans and animals. Similarly, biomass can also be used for soil fertility improvement after incorporation with the soil and supply essential minerals for the soil microbe's which are important for decomposition processes in the soil. Finally, phosphorus and potassium are important for all aspects of the plant growth and development and maximizes the biomass through promoting the phenology, growth, yield and quality components of the potato crop.

In line with this result, reported that macro nutrients have significant influences on growth, yield and quality of potatoes, predominantly nitrogen, phosphorus and potassium fertilizers have important stimuli on production of biomass at all growth stages of the crop.

Disparate to this effect, Sharma and Arora have described that increase in phosphorus and potassium had no prominent interaction effect on fresh weight of leaves, stems and other growth components of the potato crop. Likewise, Puskarnath and Taya have stated that the rate of increase in top growth and leaf weight is directly related to the level of N applied. Hence, an increase in phosphorus and potassium had no visible effect on biomass weight of potato crop.

Marketable yield

The analysis of variance revealed that marketable yield was not-significantly ($p>0.05$) affected by the main effects of phosphorus and potassium fertilizers, but it was very highly significantly ($p<0.001$) influenced through the interaction effects (Table 1). The highest marketable yield (48.32 t ha-1) was attained from the combined application of 34.5 kg P2O5 ha-1 and 200 kg K2O ha-1, and it was statistically similar with the yield of the treatments received 69 kg P2O5 ha-1 and 200 kg K2O ha-1; whereas, the lowest marketable yield (20.47 t ha-1) was recorded from 34.5 kg P2O5 ha-1 with 0 kg K2O ha-1 and it was also statistically similar with the treatments received 0 kg P2O5 ha-1 at all levels of K2O fertilizer; and 69 kg P2O5 ha-1 with 0 kg K2O ha-1 fertilizer (Table 3). Thus, combined application of 34.5 kg P2O5 and 200 kg K2O ha-1 improved the marketable yield by about 27.85 t ha-1. This result proved that application of optimum rate of phosphorus and potassium fertilizers have strong response for optimum yield of marketable and total yield of potato crop. Fertilization of potato is important in increasing the carbohydrates and protein contents of tubers and which are reflected on potato quality and its yield production. NPK fertilizers had significant effect on nutrient composition and also improved both yield and quality of potato tubers.

In line with this result, have reported that phosphorus and potassium fertilization markedly increased the production of potato and improved tuber quality.

Fertilizer application has important effects on the quality and yield of potatoes but the response of potato to NPK varies with variety, soil characteristics and geographical slope.

Consequently, Israel have reported that Nitrogen, phosphorus and potassium in the soil and from inorganic sources could influence the yield of potato crop and organic fertilizers have also been found to have a direct effect on potato yields (total and/or marketable tuber yields). Constantly, have also confirmed that nutrition of potato with phosphorus and potassium fertilizers significantly affected tuber diameter, marketable and total tuber yield of potato compared with the non-applied one.

Complementary to this result, have reported that phosphorus and potassium have no interaction effects on marketable and total tuber yield of potatoes. In the same way, the combined application of phosphorus and potassium fertilizers didn't influence the marketable and total yield of potatoes instead the main effect significantly affected the yield of potatoes.

Unmarketable yield

Unmarketable yield was not-significantly ($p>0.05$) affected by the main effects of phosphorus and potassium fertilizers, whereas it was statistically and very highly significantly ($p<0.001$) influenced through the interaction effects (Table 1). The maximum unmarketable yield (0.82 t ha-1) was recorded from the application of 34.5 kg P2O5 ha-1 with 200 kg K2O ha-1, and it was statistically similar with the results of the treatments received 34.5 kg P2O5 ha-1 with 300 kg K2O ha-1; and 69 kg P2O5 ha-1 with 200 kg K2O ha-1, whereas, the lowest (0.34 t ha-1) was recorded from 34.5 kg P2O5 ha-1 with 0 kg K2O ha-1 and it was also statistically similar with the results of the treatments received 0 kg P2O5 ha-1 at all levels of K2O fertilizer; and 69 kg P2O5 ha-1 with 0 kg K2O ha-1 fertilizer (Table 3).

Application of phosphorus and potassium fertilizers above and below the recommended rate may increase the number and the extent of unmarketable tubers.

Also, unmarketable tuber yield could be met due to over application of NPK fertilizers on the potato that tubers may disintegrate their cellular organization and may drop their size and weight.

Likewise, has reported that poor adaptation of cultivars, poor agronomic practices, poor fertilization, pest, and diseases interference could also have influenced potato yield and maximizes unmarketable tuber number and yield.

Total tuber yield

The analysis of variance exhibited that total tuber yield was not-significantly ($p>0.05$) affected by the main effects of phosphorus and potassium fertilizers, however, it was statistically and very highly significantly ($p<0.001$) influenced by the interaction effects (Table 1). The highest total tuber yield (49.14 t ha-1) was achieved from the combined application of 34.5 kg P2O5 ha-1 and 200 kg K2O ha-1, and it was statistically alike with the results of those treatments received 34.5 kg P2O5 ha-1 with 300 kg K2O ha-1 and 69 kg P2O5 ha-1 with 200 kg K2O ha-1; while, the lowest total tuber yield (20.81 t ha-1) was recorded from 34.5 P2O5 ha-1 with 0 kg K2O ha-1, and it was statistically similar with the results of those treatments received 0 kg P2O5 ha-1 at all levels of K2O ha-1, 69 kg P2O5 ha-1 with 0 kg K2O ha-1 fertilizer. Thus, the combined application of 34.5 kg P2O5 and 200 kg K2O ha-1, enhanced the total potato yield by about 28.33 t ha-1 (Table 3). This result proved that application of optimum rate of phosphorus and potassium fertilizers have a strong response for optimum yield of the marketable and total yield of the potato crop.

The increase in total yield due to phosphorus and potassium fertilization may be due to the stimulating effect of phosphorus and potassium on photosynthesis, phloem loading, and translocation as well as the synthesis of large molecular weight substances within storage organs. Also, tuber yield was influenced by the great extent of growth, nutrient and moisture supply. The increase in yield with the application of fertilizers could be attributed to the corresponding increase in leaf area, which was responsible for synthesizing food and increase in number and weight of tubers.

The highest yield (45.14 t ha-1) of potato (Belete var.) was recorded in 2018 from the surrounding (Debre Markos) which is very close to the experimental area. And the average productivity of potato (Solanum tuberosum L.) in Amhara region and national level was 14.90 and 13. 92 or near to 15 and 14 t ha-1, respectively (CSA, 2018). Optimum rate of fertilizer application may have resulted in unmarketable tuber yield reduction and which is too economical and cost-effective.

P2O5	K2O	PH	TBM	MY	UY	TY
(kg ha-1)	(kg ha-1)	(cm)	(t ha-1)	(t ha-1)	(t ha-1)	(t ha-1)
	0	51.86e	20.05f	21.19e	0.36d	21.55e
0	100	51.66e	21.59ef	22.49e	0.38d	22.87e
	200	59.93de	22.23ef	24.96e	0.42d	25.38e
	300	59.20de	22.93ef	22.04e	0.37d	22.41e
	0	57.20de	22.20ef	20.47e	0.34d	20.81e
34.5	100	69.13bc	31.79bcd	38.57bc	0.65b	39.22bc
	200	84.80a	44.52a	48.32a	0.82a	49.14a
	300	69.06bc	33.25bc	39.92abc	0.67ab	40.59abc
	0	54.26e	25.08def	25.70de	0.43cd	26.13de
69	100	64.06cd	27.94cde	33.89cd	0.57bc	34.46cd
	200	73.93b	36.48b	42.37ab	0.71ab	43.08ab
	300	73.93b	31.25bcd	38.12bc	0.64b	38.76bc
SE (±)		4.2	0.2	2.2	0.03	2.2
LSD (1%)		8.79*	7.22*	8.41***	0.14***	8.85***
CV (%)		8.1	15.09	8.85	9	8.85

Means with the same letter within a column are not significantly different and; *, ** and *** indicate LSD at P-values of >0.05, <0.05, <0.01 and <0.001, respectively. SE = Standard errors and CV = Coefficient of Variation, PH= Plant height, TBM=Total biomass, MY= Marketable yield, UY= Unmarketable yield, TY=Total yield.

Table 3: Some growth and yield parameters of potato as affected by phosphorus and potassium fertilizer application.

Effect of Fertilizer Application on available Phosphorous and exchangeable Potassium levels of the Experimental Soil

A comparison of soil analysis before and after cropping shown that application of phosphorus fertilizer (34.5 kg ha-1) increases the concentration of exchangeable potassium up to a certain level (0.26 cmol) in the soil but the concentration declines when the rate of phosphorus was maximized (Figure 1), whereas application of potassium fertilizer increases the level of available phosphorus in the soil (Figure 2).

Application of phosphorous fertilizer improved the exchangeable K+ over the control, although the increment was only in one treatment (Figure 1). The highest (0.26 cmol (+) kg-1) exchangeable K+ was acquired from the application of 34.5 kg P2O5 ha-1, whereas the lowest (0.21 cmol (+) kg-1) was gained from the control. However, application of P2O5 above the rate of 34.5 kg ha-1, substantially reduced of the level of exchangeable K+ in the soil.

Based on the results of the present study, the greatest reduction of exchangeable K+ was occurred in the control treatment, whereas the lowest reduction was recorded from the application of 69 kg P2O5 ha-1. The exchangeable K+ content in untreated experimental soil was only 0.21 cmol (+) kg-1 soil which is extremely low for better crop production. According to Mengel and Kirby and Murphy and Brain, the exchangeable K+ content of a given soil should be near to 0.3 cmol (+) kg-1 for sufficient growth and optimum yield of crops.

Mengel and Kirby also stated that the reduction of exchangeable K+ could be recognized to the fact that the amount and type of charges on the soil colloids govern the ability of a soil to hold essential plant nutrients against the forces of water moving through the soil profile. According to this statement, the ability of a soil to retain potassium and other cations increased with the increase in negative charges in soil. Khan and Zameer also reported that excessive use of nitrogen and phosphorus fertilizer might aggravate the situation of potassium deficiency in different cropping system as no potassium fertilizer is used. Continuous use of nitrogen and phosphorus would accelerate the depletion of native soil potassium reserves. It will not only impoverish soil potassium but also adversely affect crop yields.

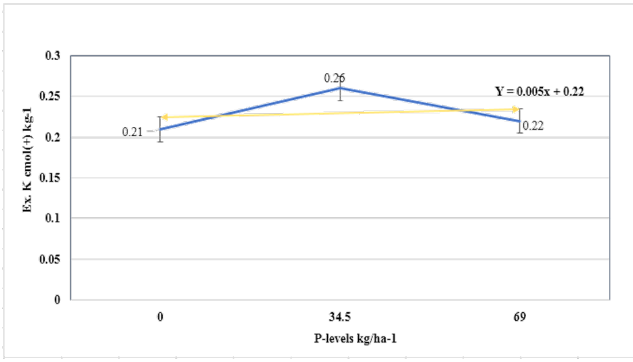

Figure 1: Exchangeable potassium as influenced by phosphorus fertilizer application after potato harvest.

After harvesting of potato, the available phosphorus content was ranged between 6.30 and 7.38 ppm. But '5-8 ppm or lower range' of critical values of phosphorus nutrient was reported by Frank (1990) as cited by Birtukan Belachew (2016). The highest (7.38 ppm) and the lowest (6.3 ppm) available phosphorus were obtained from the application of 300 and 0 kg K2O ha-1, respectively. Application of potassium increased the level of available phosphorus and the trend was linear with the rate of the fertilizer.

Horrer D have reported, crops responded to higher potassium levels when N is sufficient. Correspondingly, potassium interacts with phosphorus and that together may interact with other nutrients in the soil. Khan and his colleagues (2012) also pointed out that, despite massive soil reserves of potassium minerals, potassium chloride (KCl) fertilization has long been promoted as building up the exchangeable K+ of soils to ensure against yield and quality loss. Likewise, they found that KCl fertilization anticipated to build up soil potassium. In general, the soil fertility has been built up to the optimum level of the nutrient application rate and it can be accomplished by applying nutrients at a rate that closely contests the rate of nutrient removal in the harvested crop.

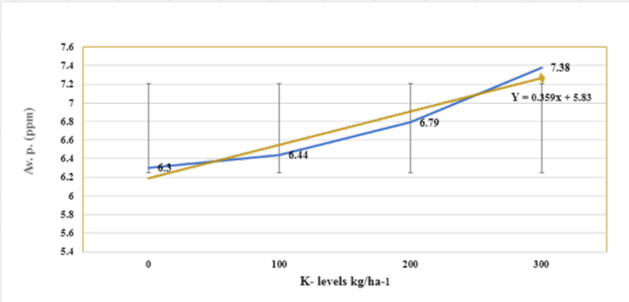

Figure 2: Available phosphorous as influenced by potassium fertilizer application after potato harvest.

CONCLUSION

Separate application of phosphorus and potassium fertilizers significantly affected phenological and some growth components (leaf area index) of potato. Whereas, combined application of phosphorus and potassium influenced growth component (plant height) and yield parameters including, total biomass, marketable and total tuber yield. The highest marketable (48.32 t ha-1) and total tuber yield (49.14 t ha-1) was attained by the combined application of 34.5 kg P2O5 ha-1 with 200 kg K2O ha-1.

CONFLICT OF INTERESTS

The writers have not stated any conflict of interests.

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