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Research Article
Potato (*Solanum tuberosum* L.) Growth and Tuber Quality, Soil Nitrogen and Phosphorus Content as Affected by Different Rates of Nitrogen and Phosphorus at Masha District in Southwestern Ethiopia

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Abstract
Background: Potato (*Solanum tuberosum* L.) was introduced to Ethiopia in 1858 and 70% of Ethiopian land, mainly in the highland is suitable for potato growing. Despite this the national average yield is only 8.2 t ha^{-1}. Low soil fertility especially N and P deficiency is the major constraint limiting potato yield in Ethiopia in general and Southwestern part in particular. Concomitantly, there is insufficient site specific information on how much fertilizer to apply on different soil types with patch of high and low fertility. Therefore, this study was conducted to determine area specific N and P rates for optimum potato growth, quality tuber production and improved N and P content of the soils of the study area. **Materials and Methods:** Four rates of N at 0, 55, 110 and 165 kg ha^{-1} and P at 0, 20, 40 and 60 kg ha^{-1} combined in factorial arrangement and laid out in RCBD with three replications. Data collected on potato growth, tuber quality, TN and available P content of the soil after potato harvest were analyzed using SAS version 9.2. **Results:** The interaction of 165 kg N ha^{-1} and 20 kg P ha^{-1} increased plant height by 51% over the control. Besides, 165 kg N ha^{-1} increased TN contents of the soil by 95% and available P by 42%. Plant height was positively and significantly correlated with soil TN (r = 0.55) and available P content (r = 0.68). Similarly, tuber dry matter content was positively and significantly correlated with tuber specific gravity (r = 0.94) verifying tuber dry matter is an indicator of tuber specific gravity. **Conclusion:** The present results indicated potato growth, tuber quality, TN and available P content of the soil were affected by N and P rates. The lower and medium N and P rates were favoring potato tuber quality parameters while, the higher N and P rates were favoring potato growth, TN and available P content of the soil. Therefore, the combined application of 165 kg N and 60 kg P ha^{-1} is required for optimum growth of Jalene potato variety and improved TN and available P content of the soils of Masha district.

Key words: Critical phosphorus concentration, dry matter, potato growth, nitrogen, specific gravity

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Potato (*Solanum tuberosum* L.) belongs to the family Solanaceae, genus *Solanum* which also includes tomato, eggplant, pepper, etc.[1]. Potato is one of the widely grown root and tuber crops of the world being a rich source of nutrients for human nutrition. It contains about 79% water, 18% starch as a good source of energy, 2% protein and 1% vitamins including vitamin C, minerals including calcium and magnesium and many trace elements[2,3]. Generally, potato is grown for food and feed industry and seed tuber production[4]. It was introduced to Ethiopia in 1858 by a German botanist, Schimper[5] and 70% of Ethiopian land, mainly in highland areas is suitable for potato growing[6]. Despite this potential the national average potato yield is about 8.2 t ha^{-1}, which is very low compared to the world's average production[7] of 17.67 t ha^{-1}. Low soil fertility in general and the deficiency of nitrogen (N) and phosphorus (P) in most Ethiopian soils[8] in particular is the most important constraint limiting potato production in Ethiopia[9]. The soil fertility decline is attributed to continuous cropping, abandoning of fallowing, reduced crop rotation, removal of nutrients together with the harvested crops, reduced use of animal manure and crop residue due to their use as fuel, which should be added to the soil and erosion coupled with low inherent fertility[10,11]. In similar manner, the soils in the Southwestern part of Ethiopia are low in soil organic matter, cation exchange capacity but are high in acidity[12].

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 the region. On top of this since information on soil fertility studies for potato production in the region is limited[13] and hence, there is inadequate site specific experimental information on how much fertilizer to apply on different soil types with patch of high and low fertility for many years. Due to these reasons fertilizer application practices in the region have been mainly based on the experiences of other regions and these could be one of the reasons for low yield of potato in the region. Since N and P are the most important elements among the essential plant nutrients required by the potato plant[8] area specific N and P rates should be identified for optimum potato growth and high quality tuber production as well as improved N and P content of the soil in the study area.

Therefore, the present study was conducted with the objectives of determining the response of potato to different N and P rates in terms of potato growth and tuber quality as well as the N and P content of the soil after potato harvest.

MATERIALS AND METHODS

Description of the study area: The experiment was conducted at Masha district in Sheka zone in Southwestern Ethiopia during 2010/2011 main cropping season. The area is located 677 km Southwest of Addis Ababa at 7°44'N latitude 35°29'E longitude and altitude of 2223 m a.s.l. The site is with an average annual rainfall of 1800-2200 mm with bimodal distribution and annual mean temperature of 15-27°C[14].

The soil type of the area is acrisol and the low available phosphorus content of the soil is attributed to high phosphorus fixing capacity of acrisol[15].

Planting material: Potato variety Jalene, released by Holeta Agricultural Research Center in 2002 was used for this experiment as a planting material. Among the improved varieties, Jalene is one of the potential potato cultivars for Southwestern Ethiopia including Masha district. It is well performing at altitude range of 1600-2800 m a.s.l and requires rainfall of 750-1000 mm per season. It is being cultivated widely and has got acceptance by farmers due to its high yielding ability, acceptability by consumers, wider adaptation, better cooking ability and relatively its resistance to late bight compared to the local and improved varieties growing in the area. Actually it gives an optimum yield of 29.13 t ha^{-1} on farmers field and 44.8 t ha^{-1} at research station[16].

Experimental treatments, design and procedures: Four levels of nitrogen: 0, 55, 110 and 165 kg ha^{-1} and four levels of phosphorus: 0, 20, 40 and 60 kg ha^{-1} were combined in 4×4 factorial arrangements in randomized complete block design with three replications. All management practices, such as weeding, insect and disease control were applied as per the general recommendations of potato[17]. The experimental field was divided into three blocks each containing 16 plots and a plot size of 9 m^2 (3 m length×3 m width) was used. A distance of 0.75 m was maintained between the plots within a block and 1 m distance was maintained between blocks and 75 cm row spacing was uniformly used and medium sized and well sprouted potato tubers were planted. The entire rate of phosphorus and half the rate of nitrogen was applied at the time of planting and the remaining half nitrogen was applied 45 days after planting. Urea with 46% N and Triple Super Phosphate (TSP) with 46% P_2O_5 were used as sources of nitrogen and phosphorus.

Data collection and analysis: Data was collected on potato growth and tuber quality parameters: Plant height, harvest

Table 1: Physical and chemical properties of the soil of the experimental site

Parameters	Value
Soil texture	Sandy loam (60% sand, 30% silt and 10% clay)
Soil pH	5.1
Available phosphorus	10.5 ppm
Total Nitrogen (TN)	0.314%
Organic Matter Content (OMC)	3.52%
C:N ratio	12: 1
Cation Exchange Capacity (CEC)	12.5 meq/100 g
Exchangeable K	0.6 meq/100 g
Exchangeable Ca	6.5 meq/100 g
Exchangeable Mg	0.5 meq/100 g
Percent base saturation	60.8%
Electrical Conductivity (EC)	2.65 mS cm^{-1}

index, tubers specific gravity and dry matter content. Harvest index was determined as the ratio of fresh weight of tubers to the total biomass fresh weight at harvest[18], tuber specific gravity was determined using the method described by Kumar *et al.*[19] and tuber dry matter content was measured on tubers taken from randomly chosen five plants per harvestable plot. Tubers were washed, chopped, mixed and 200 g sample was taken and pre-dried at a temperature of 60°C for 15 h and further dried for 3 h at 105°C in a an oven until a constant weight was attained. The dry weight was divided by the initial fresh weight to give percentage tuber dry matter content[20]. Similarly data on soil physical and chemical properties: Soil texture[21], pH[22], organic matter and total nitrogen[23], available phosphorus[24], exchangeable cations[25], cation exchange capacity[26] and bulk density[27] were determined and used to describe the study area (Table 1). Critical phosphorus concentration was determined using Cate-Nelson diagram method[28] and phosphorus requirement factor was also calculated using available soil phosphorus value in samples collected from fertilized and unfertilized plots[29]. Data were checked for normality and subjected to analysis of variance using SAS version 9.2 statistical software[30]. Treatment means for nitrogen, phosphorus and their interaction effects were compared using LSD value at 5% significance level[31].

RESULTS AND DISCUSSION

Effects of nitrogen and phosphorus rates on potato growth and tuber quality: The results of the present study showed highly significant ($p<0.01$) and significant ($p<0.05$) effects of nitrogen (N) and phosphorus (P) rates, respectively on potato growth and tuber quality parameters (Table 2).

Plant height: Plant height was significantly ($p<0.05$) affected by the interaction effect of N and P, highly significantly ($p<0.01$) affected by N and significantly ($p<0.05$) affected by P application rates alone (Table 2). The highest plant height (75.27 cm) was recorded at the combined application of 165 kg N ha^{-1} and 20 kg P ha^{-1}, which was significantly increased by 51% over the control treatment. It was also statistically similar with the plant height recorded at the application rate of 165 kg N ha^{-1} combined with 40 and 60 kg P ha^{-1} (Fig. 1).

In contrast, the shortest plant height (51 cm) was recorded from the control treatment with no N and P which was statistically similar to the result obtained from plots those received the combination of 0 kg N ha^{-1} and 20 kg P ha^{-1}, 55 kg N ha^{-1} and 0 kg P ha^{-1}. This might be due to the effect of N on plant height that was enhanced in the presence of P. Moreover availability of N is increasing the availability of P, where N and P could synergistically increase plant height. In agreement with this, Singh and Singh[32] also reported the increase in N levels led to vigorous vegetative growth and high dose of P also enhanced plant height.

Harvest index: It was highly significantly ($p<0.01$) affected by N but not significantly ($p>0.05$) affected P and its interaction effect with N (Table 2). The highest harvest index (0.87) was obtained at 0 kg N ha^{-1}, which was not significantly different from the harvest index obtained at 55 kg of N ha^{-1} but the lowest harvest index was obtained at 165 kg N ha^{-1} indicating that application of 165 kg N ha^{-1} significantly reduced potato harvest index by 14% compared to the control treatment (Table 3).

This reduction in harvest index could be due to the effect of N in encouraging more above ground biomass production of potato than the tuber growth. Nitrogen is also known in extending the vegetative growth period and the plant continue active growth afterward in the season, which makes the vegetative part a competing sink against the tubers and resulting in lower dry matter accumulation which could be

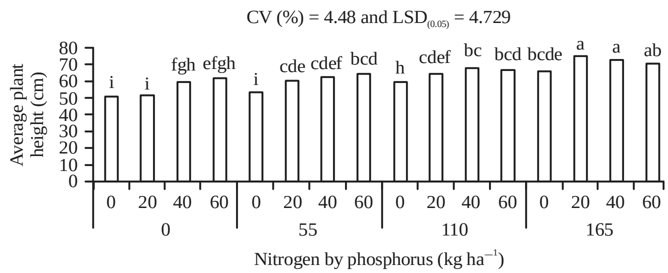

Fig. 1: Interaction effect of nitrogen and phosphorus on potato plant height

Table 2: Mean square values of potato growth and tuber quality parameters as affected by N and P application rates

		Mean square values			
Source of variation	Df	Plant height (cm)	Harvest index	Dry matter content (%)	Specific gravity (g cm^{-3})
Block	2	6.90	0.034	3.04	0.00001
Nitrogen (N)	3	496.27**	0.015**	34.44**	0.0009**
Phosphorus (P)	3	201.09*	0.0003^{ns}	12.77*	0.00031872*
N×P	9	21.37*	0.0004^{ns}	3.02^{ns}	0.0.00005864^{ns}
Error	31	2.83	0.029	2.06	0.00005076
CV (%)		4.48	0.029	6.65	0.66

Df: Degree of freedom, *,**Significant at 5 and 1% probability level and ns: Non-significant

Table 3: Harvest index of potato as affected by N and P application rates

Treatment	Harvest index
Nitrogen (kg ha^{-1})	
0	0.87^{a}
55	0.85^{ab}
110	0.83^{b}
165	0.78^{c}
LSD (5%)	0.024
Phosphorus (kg ha^{-1})	
0	0.84
20	0.84
40	0.83
60	0.83
LSD (5%)	ns
CV (%)	0.029

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

Table 4: Tuber dry matter content of potato as affected by N and P application rates

Treatment	Tuber dry matter content (%)
Nitrogen (kg ha^{-1})	
0	23.61^{a}
55	21.75^{b}
110	21.35^{b}
165	19.48^{c}
LSD (5%)	1.196
Phosphorus (kg ha^{-1})	
0	23.48^{a}
20	21.75^{b}
40	21.01^{b}
60	20.31^{b}
LSD (5%)	1.196
CV (%)	6.65

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

responsible for reduced harvest index[33]. In agreement with the present finding[34] also reported variation in harvest index between growing conditions. According to the present result the effect of P on harvest index was not significant (p>0.05). Similarly Zelalem *et al*.[35] also reported none significant differences (p>0.05) in harvest index of potato in response to increased P application, from their study conducted on response of potato to different rates of N and P fertilization.

Dry matter content: Tuber dry matter content was highly significantly (p<0.01) affected by N and significantly (p<0.05) affected by P but not significantly (p>0.05) affected by their interaction effect (Table 2). The highest dry matter content (23.61%) was recorded at the rate of 0 kg N ha^{-1}, the control treatment while, the lowest tuber dry matter content (19.48%) was recorded at the rate of 165 kg N ha^{-1} and similarly the highest dry matter content (23.48%) was recorded at the rate of 0 kg P ha^{-1}, the control treatment while, the lowest tuber dry matter content (20.31%) was recorded at the rate of 60 kg P ha^{-1} and this showed application of both N and P significantly reduced tuber dry matter content of potato by 17 and 14%, respectively below the control treatment (Table 4).

The reduction in tuber dry matter content with increased N fertilization could be attributed to production of high quantity of gibberellins hormone induced by high N application, which in turn reduced partitioning of photo assimilates to the tubers. This is in agreement with the study of many researchers[18,35,36] who reported reduced tuber dry matter content of potato with increased N rate. Similarly, increased P application rate reduced tuber dry matter content of potato from 22.48-20.3%. The highest tuber dry matter content obtained at the rate of 0 kg P ha^{-1} was none significantly different from that obtained at the rate of 20 kg P ha^{-1}. On the other hand, the lowest tuber dry matter content obtained at the rate of 60 kg P ha^{-1} was none significantly different from that recorded at the rate of 40 kg P ha^{-1}. In line with the present finding, Assefa[37] observed significant reduction in tuber dry matter content of potato due to increased P application rate and similarly Daniel[38] observed reduction in tuber dry matter with increased rate of P.

Specific gravity: It was highly significantly ($p<0.01$) and significantly ($p<0.05$) affected by N and P but not significantly ($p>0.05$) affected by their interaction (Table 2). The highest tuber specific gravity (1.095 g cm^{-3}) was obtained at 0 kg N ha^{-1} (control treatment) but the lowest specific gravity (1.074 g cm^{-3}) was recorded at 165 kg N ha^{-1}, highest N rate (Table 5).

This reduction in specific gravity might be due to the fact that nitrogen was not enhancing dry matter accumulation in the tuber. This is in agreement with the findings of many researchers[18,36,37,39] who reported reduced tuber specific gravity with increased application rate of N. With the exception of the tuber specific gravity obtained at the rate of 165 kg N ha^{-1}, all the tuber specific gravity results recorded with the remaining N application rates are in the acceptable range of specific gravity required for processing, which is greater[40] than 1.077 g cm^{-3}. In case of phosphorus, the highest tuber specific gravity (1.09 g cm^{-3}) was obtained at the rate of 0 kg P ha^{-1}, which was also at par with the tuber specific gravity obtained at the application rate of 20 kg P ha^{-1}. In contrast, the lowest tuber specific gravity (1.079 g cm^{-3}) was obtained at 60 kg P ha^{-1}, which was none significantly different from the result obtained at the application rate of 40 kg P ha^{-1}. These values are greater than 1.077 g cm^{-3} for all phosphorus levels hence it is within the acceptable range for processing[40].

Effects of nitrogen and phosphorus rates on soil nitrogen and phosphorus: The results of the present study showed that application of N and P significantly increased the concentration of N and P in the soil after potato harvest compared to concentration of N and P in the soil before planting in general (Table 6).

Total nitrogen: It was highly significantly ($p<0.01$) affected by N but not significantly ($p>0.05$) affected by P and its interaction effect with N (Table 6). The highest TN content of the soil (0.554%) was recorded at the application rate of 165 kg N ha^{-1}, which was not significantly different from the TN content of the soil recorded at the application rate of 110 kg N ha^{-1} but the lowest TN was recorded at 0 kg N ha^{-1} (control treatment). Application of 165 kg N ha^{-1} significantly increased the TN content of the soil by 95% over the control (Table 7).

The TN content of the soil before planting, 0.314% was reduced to 0.284% in the control plot after potato harvest but it was in the range of 0.464-0.554% in the plots those received different N application rates. This could be due to the application of higher rate of N (165 kg N ha^{-1}) compared to the blanket N recommendation rate (54 kg N ha^{-1}) widely used in the region, that is at the rate 100 kg urea (46% N) and 100 kg DAP (18% N+46% P_2O_5) ha^{-1} for all crops and soil

Table 5: Tuber specific gravity of potato as affected by N and P application rates

Treatment	Tuber specific gravity (g cm^{-3})
Nitrogen (kg ha^{-1})	
0	1.095^a
55	1.087^b
110	1.086^b
165	1.074^c
LSD (5%)	0.006
Phosphorus (kg ha^{-1})	
0	1.090^a
20	1.089^a
40	1.082^b
60	1.079^b
LSD (5%)	0.006
CV (%)	0.66

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

Table 6: Mean square values of total nitrogen and available phosphorus contents of the soil as affected by N and P application rates

	Mean square values		
Source of variation	Df	Total nitrogen (%)	Available phosphorus (ppm)
Block	2	0.02499222	8.27
Nitrogen (N)	3	0.19331270**	43.11**
Phosphorus (P)	3	0.00185407^{ns}	53.18**
Nitrogen×Phosphorus	9	0.01075858^{ns}	10.64^{ns}
Error	31	0.006004	4.83
CV (%)		16.7	17.20

Df: Degree of freedom,**Significant at 1% probability level and ns: Non-significant

Table 7: Total Nitrogen (TN) content of the soil after potato harvest as affected by N and P application rates

Treatment	Total soil N after harvest (%)
Nitrogen (kg ha^{-1})	
0	0.284^c
55	0.463^b
110	0.550^a
165	0.554^a
LSD (5%)	0.064
Phosphorus (kg ha^{-1})	
0	0.454
20	0.455
40	0.481
60	0.465
LSD (5%)	ns
CV (%)	16.7

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

Table 8: Available phosphorus content of the soil after potato harvest as affected by N and P application rates

Treatment	Available phosphorus (ppm)
Nitrogen (kg ha^{-1})	
0	10.39^c
55	12.04^{bc}
110	13.67^{ab}
165	14.72^a
LSD (5%)	1.832
Phosphorus (kg ha^{-1})	
0	10.31^c
20	11.88^{bc}
40	13.40^{ab}
60	15.23^a
LSD (5%)	1.832
CV (%)	17.2

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

types. In agreement with the present result, Endalkachew[41] reported postharvest of potato, TN content of the soil was increased by the application of N fertilizer.

Available phosphorus: Available phosphorus content of the soil was highly significantly (p<0.01) affected by both N and P but none significantly affected by the interaction effect of N and P application rates (Table 6). The highest available phosphorus content of the soil (14.72 ppm) was obtained at the application rate of 165 kg N ha^{-1}, which was in par with the available phosphorus obtained at the application rate of 110 kg N ha^{-1} but the lowest available soil phosphorus (10.39 ppm) was obtained at the application rate of 0 kg N ha^{-1}, which is similar to the result obtained at the application rate of 55 kg N ha^{-1}. Application of 165 kg N ha^{-1} significantly increased the available P content of the soil by 42% over the control (Table 8).

Application of N and P increased the available phosphorus content of the soil after potato harvest. It was

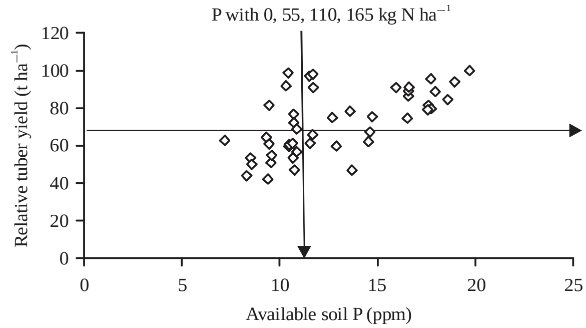

Fig. 2: Scatter diagram of the relative tuber yield of potato in relation to available P in soils and each point represents independent measurement

10.5 ppm before planting and highly significantly (p<0.01) increased to 12.04 and 14.72 ppm after application of N at the rates of 55 and 165 kg N ha^{-1}, respectively. This could be due to the reason that N increased the availability of P in the soil[42]. Similarly, the highest available phosphorus content of the soil (15.23 ppm) was obtained at the application rate of 60 kg P ha^{-1}. The initial concentration of soil available phosphorus (10.5 ppm) increased in the rage of 11.88-15.23 ppm after application of P rate from 20-60 kg P ha^{-1}. The result showed consistent increment of available phosphorus of the soil with increased application rates of P. On the other hand, the initial level of available phosphorus of the soil, 10.5 ppm decreased to 10.31 ppm in the control plot and indicated some available soil P could be lost through either plant uptake or fixation in the soil. The increased available P content of the soil in this study could be due to the replacement of the already fixed P by the current P fertilization, particularly the higher rates in the labile forms that can release phosphorus in to the soil solution. The current result is in consistent with the finding of Tisdale *et al.*[42] who reported that as the quantity of P added in to the soil was increased, the corresponding available soil phosphorus in the soil solution was also linearly increased after it exceeded the quantity of available P content of the soil lost through crop removal and undesirable P soil fixation.

Critical phosphorus concentration and phosphorus requirement factor: Application of P increased the available phosphorus level in the soil as per Olsen method and thus creating phosphorus value ranges from 10.52-25.15 ppm. For assessing the association among the response of tuber yield and the soil phosphorus test value, relative tuber yields were plotted against the corresponding test values of soil phosphorus[43] for all P treatments (Fig. 2).

The critical soil test level (point on the x-axis) is below which the probability of a response to added fertilizer is high

Table 9: Phosphorus requirement factor as affected by P application rates

Phosphorus Applied (kg ha^{-1})	Available soil P (ppm)	Phosphorus increase over the control (ppm)	Phosphorus requirement factor
0	10.31		
20	11.88	1.57	12.74
40	13.40	3.09	12.94
60	15.23	4.92	12.20
Mean for P Olsen	3.19		12.63

Rate of P fertilizer to be applied = $(P_c-P_o)xP_F$, P_c: Critical P concentration, P_o: Initial p-values of the site and P_F: P requirement factor

Table 10: Person correlation coefficient among potato growth and tuber quality parameters and some soil physico-chemical properties

	PH	HI	TNA	APA	DMC	SG
Plant Height (PH)	1	-0.38**	0.55**	0.68**	-0.62**	-0.61**
Harvest Index (HI)		1	-0.38**	-0.27	0.46**	0.48**
Total N after harvest (TNA)			1	0.5**	-0.51**	-0.64**
Available P after harvest (APA)				1	-0.43**	-0.53**
Dry Matter Content (DMC)					1	0.94**
Specific Gravity (SG)						1

**Significant at 1% probability level

and above which the probability of such a response is low[43]. Accordingly, from this curves the critical phosphorus concentration value in the intersection point was 12 ppm for the Olsen method[28,44]. This implies that under the rain-fed condition of Masha district potato planted on soils having available phosphorus greater than 12 ppm would not respond to phosphorus fertilization. However, if the soil available phosphorous is below the critical level, additional information is needed on the quantity of phosphorus required to elevate the available phosphorus value of the soil to the required level and it would be imperative to establish the phosphorus requirement factor (Table 9), which is a measure of the quantity of phosphorus required per hectare to raise the soil available phosphorus test level by 1 ppm. For the study site, Masha district this value was computed from the difference between available phosphorus value and phosphorus value of samples collected from plots which received fertilizer and the value is used to calculate the total amount of phosphorus fertilizer[29]. The average phosphorus requirement factor (Pf), calculated from soil test phosphorus values of all treatments for the study area was 12.63. To protect a potential loss of potato yield, at least a maintenance application of 15 ppm P ha^{-1} is needed for responsive sites that had soil test phosphorus levels above the critical level[43].

Correlation analysis among potato growth and tuber quality parameters as well as TN and available P content: The correlation analysis revealed positive and negative associations among the studied potato growth and tuber quality parameters as well as TN and available P content of the soil (Table 10). Accordingly, plant height was positively and highly significantly correlated with soil TN (r = 0.55) and available P (r = 0.68) after potato harvest.

The positive association between plant height and TN content of the soil could be due to the increase in plant height in response to the N fertilization treatment which could be attributed to stem elongation of the potato plant. Although there was differential response of plant height between the different rates, generally N fertilization increased potato plant height[45]. But plant height was also negatively and highly significantly correlated with harvest index (r = -0.38), tuber dry matter content (r = -0.62) and tuber specific gravity (r = -0.61). On the other hand, harvest index was negatively and highly significantly correlated with soil nitrogen (r = -0.38) and phosphorus (r = -0.27) after harvest but positively and highly significantly correlated with tuber dry matter content (r = 0.46) and tuber specific gravity (r = 0.48). In agreement to the present study, Tekalign and Hammes[46] also verified that specific gravity was strongly and positively correlated with dry matter content indicating that the harvest index is an excellent indicator of tuber dry matter content. Total N after harvest was positively and highly significantly (r = 0.5) correlated with available P after harvest but it was negatively and highly significantly correlated with tuber dry matter content (r = -0.51) and specific gravity (r = -0.64) and similarly available P after harvest was negatively and highly significantly correlated with tuber dry matter content (r = -0.43) and specific gravity (r = -0.53). Tuber dry matter content of potato was positively and highly significantly (r = 0.94) correlated with tuber specific gravity[47], indicating that tuber dry matter is an excellent indicator of tuber specific gravity of potato.

CONCLUSION

Soil fertility and nutrient management are among the key factors affecting crop productivity and soil nutrient depletion.

Accordingly, the response of potato to different application rates of N and P was significantly different in potato growth and tuber quality parameters. Correlation analysis also showed positive and negative associations among the studied parameters. The results of the present study indicated potato growth, tuber quality, TN and available P content of the soil are affected by N and P application rates. Accordingly, the lower and medium N and P rates were favoring tuber quality while the higher N and P rates were favoring potato growth, TN and available P content of the soil. Hence, considering the improvements in potato growth, TN and available P content of the soil, the combined application of 165 kg N ha^{-1} and 60 kg P ha^{-1} is found to be the appropriate rates for optimum growth of Jalene potato variety and improved TN and available P content of the soil at Masha district in Southwestern Ethiopia under rain fed conditions. Therefore, the use of 165 kg N ha^{-1} and 60 kg P ha^{-1} could be recommend for the optimum growth of Jalene potato variety as well as improved TN and available P content of the soil and hence save the valuable soil nutrients, money and time of the resource poor small holder farmer's of the study area.

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SIGNIFICANCE STATEMENTS

The purpose of this study was to provide area specific recommendation of N and P for optimum potato growth and tuber quality as well as improved soil N and P content for Masha district in Southwestern Ethiopia. The results of this study can be used as N and P recommendations for smallholder potato farmers in the study area, as a reference for research centers, academic institutions such as Colleges and Universities and farmers training centers, development oriented NGOs and large scale private farms for optimum productivity of the crop and sustainable soil fertility management. Alongside, it is used to improve the food security and hence the diet of the society for better nutrition, health and quality of life.

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