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Research Article

Response of Potato (Solanum Tuberosum L.) to Nitrogen and Phosphorus Fertilizer Rates on Growth and Yield Components at Debark, Northern Highlands of Ethiopia.

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ABSTRACT

Potato (Solanum tuberosum L.) belongs to the family Solanaceae and genus Solanum. It is native to South America and introduced to Ethiopia in 1859 by a German Botanist called Schimper. In Ethiopia, about 70% of cultivated land is suitable for potato production. The Lowest soil fertility is the major constraints to potato production. Farmers should tackle this problem through the application of inorganic fertilizes, which amend the soil productivity. The application of an appropriate amount of NP fertilizer is a major factor in potato production. A field experiment was conducted in 2018 and 2019 main cropping season to investigate the optimum rate of NP on tuber yield of potato in the Amhara Region, North Gondar at highland Debark districts on farmer's field respectively. The treatments were four levels of nitrogen (0, 46, 92, 138 kg ha-1) and three levels of phosphorus (0, 46, 69 kg ha-1) were combined in factorial arrangements in randomized complete block design with three replications. The founding of the study showed the application of 92kg N ha-1 is recommended at Debark and similar agroecology. Even if application P does not affect potato tuber yield 23 kg ha-1 phosphorus fertilizer should be applied for soil fertility maintenance.

Keywords: Nitrogen, Phosphorus, and potato

INTRODUCTION

In the last ten years, the number of population increased from 76.2 million in 2004/06 to 99 million in 2014/16, the fact that about 22.8 million enlargement. Still, the predominance deficit of food was 55.4% in 2004/06 and 41.3% in 2014/16 displaying a decrease of 14.1% within ten years (FAO, 2016). This indicates that the agricultural sector in Ethiopia must supply an acceptable amount of food for fastly growing population, due to this fixed land and other natural resources are under high pressure. Enhancing the productivity of smallholder farmers is needed to decreasing the problems (WFP, 2016).

Potato (Solanum tuberosum L.) is the major economic importance crop and the number one non-cereal food commodity in the world (Rykaczewska, 2013). It is the major vegetable crops grown in the highlands of Ethiopia. Potato is one of the crops to ensure food security in Ethiopia and the study area also and reducing such types of problems. Although the attainable yield of potato can reach up to 30 t ha-1(Haverkort et al., 2012), but in Ethiopia still the productivity is very low which is below 11.88 t ha-1 (CSA, 2016). This is due to the current potato production practice with inappropriate nutrient management practices (Zelalem et al., 2009).

Nitrogen, Phosphorus, and Potassium are the major essential nutrients to increase the yield of potato (Pervez et al., 2013). Provide an optimum amount of nitrogen encourages root growth and development as well as the absorption of other nutrients (Brady. &Weil, 2008). A sufficient amount of phosphorus nutrient also improve a few aspects of plant physiology, including the fundamental processes of photosynthesis, root growth especially the development of lateral roots and fibrous rootlets (Brady. & Weil, 2008). Different research findings indicated that the combined application of NP fertilizer has a significant effect on the yield of potato. The application of 165 kg N ha-1 and 60 kg P2O5 ha-1 was given the highest marketable yield (35 t ha-1) in southeastern Ethiopia (Israel et al., 2012). Similarly, the highest marketable yield (36.1 t ha-1) was obtained by applying at a rate of 165 kg N ha-1 and 135 kg P2O5 ha-1 and

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the yield has increased 88% with an increasing rate of nitrogen and phosphorus fertilizers (Birtukan ,2016).

In the study area, information for potato production fertilizer rate and other agronomic practices is restricted for the greatest tuber yield. For this reason, determining optimum phosphorus and nitrogen fertilizer for potato production is very important to rise with relevant recommendations that can optimize potato tuber yield. Therefore, this study was conducted to determine the response of phosphorus and nitrogen rate on yield and yield components of potato under rainfed conditions in the northern highlands of Ethiopia.

MATERIALS AND METHODS

Description of study area

The experiment was conducted in the northern highland of Debark district. Debark is located at Longitude 37.22 to 38.51N and 12.82 to 13.5 l E latitude. The altitudes of the area were ranged from 2000 m up to 3000 m above sea level (masl).

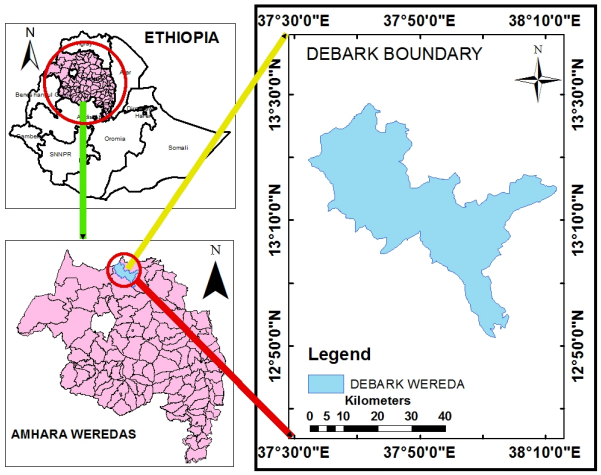

Figure 1: Map of the study area.

The maximum and minimum temperature is 24.5 °c and 4.6°c respectively. The district received about and 1231 to 1254 mm mean annual rainfall. Dominant soil types the area cambisol the tested crop was potato.

EXPERIMENTAL RESEARCH DESIGN AND TREATMENTS

The experiment was laid in factorial RCBD with three replications. Three levels of phosphorus with four level of Nitrogen was used. The levels of P2O5 were (0, 46, and 69) and levels of N were (0, 46, 92, and 138) in kg ha-1. Jaleni potato variety was used as the testing crop. The area of gross plot size was 2.8 m * 2.4 m and the net plot was 2.4.m *1.4 m. The spacing of 1m between plots and 1.5m between blocks were used; and spacing of 70cm and 30cm between row and plant were used respectively.

SOIL SAMPLING TECHNIQUE AND ANALYSIS

Soil samples were randomly collected in a diagonal pattern before sowing from a depth of 0-20cm. The soil samples were air-dried and passed through a 2 mm sieve for physicochemical analysis. The soil was analyzed for texture and soil total nitrogen, available phosphorous, pH, OC, and CEC. The texture of the soil was determined by the hydrometer method according to (Bouyoucos, 1962). Total soil N was analyzed by the Kjeldahl digestion method with sulphuric acid (Jackson, 1962). Soil pH was determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter, a potentiometer (FAO, 2008). Organic carbon content was determined by the volumetric method (Walkley and Black, 1934). The available soil phosphorus was determined by the Olsen method (Olsen et al; 1954). Exchangeable potassium was extracted by ammonium acetate at pH 7 (Sahalmedhin and Taye, 2000) and determined by an Atomic absorption spectrometer. The cations exchange capacity (CEC) of the soil was determined following the 1N ammonium acetate extraction (pH7) method.

LAND PREPARATION AND SOWING

The experimental field was prepared for the conventional tillage practice of the area. It was manually leveled and then divided into blocks and plots; the blocks were separated by a 1.5 meter-wide open space where the plots in the block were 1m apart from each other. Each plot consisted of 4 rows of 2.4 m in length and spaced 0.7 m apart. The selected potato variety (Jaleni) seeds were sown manually at the equal spacing between plants and rows.

FERTILIZER USE AND WEEDING

The full dose of TSP fertilizer was applied during sowing, while urea was applied in the split as a 1/3 urea (i.e. as per treatment) was applied uniformly in rows at planting. The remaining 2/3 of each nitrogen fertilizer treatment was side dressed after 45 days from sowing. The weeds observed in the plots were controlled manually at the same time for all treatments. All other typical agronomic practices of the area were performed uniformly to all plots.

DATA COLLECTED

Days to flowering was recorded when 50 percent of the plant population of each plot produced flowers. Plant height (cm) was measured from ten randomly selected plants per plots at full maturity. The number of stem per hill was recorded as an average stem count of five hills per unit area at full maturity. Days to maturity number of days from emergence to maturity was recorded when 95% percent of the plants of each plot were ready for harvest. The number of tubers per hill was obtained by counting the number of tubers of each hill. Marketable tuber yield (tons/ha) included marketable and healthy tubers with size categories greater than 25 Unmarketable tuber yield (tons/ha) unmarketable tubers included unhealthy tubers as well as

healthy tubers weighing less than 25g. Total tuber yield (tons/ha) total tuber yield was recorded as the sum of all marketable and unmarketable tubers.

STATISTICAL ANALYSIS

Plant data was recorded on a plot basis and extrapolated on a hectare basis. All parameters were determined and calculated from the middle rows. Analysis of variance and treatment means comparisons for the different measured parameters were carried out using SAS software window 9.0. Mean separation for the recorded plant parameters were made using the Least Significance Difference Test (at 0.05 significance level).

ECONOMIC ANALYSIS.

Economic analysis was conducted using partial budget analysis as described by CIMMYT (1988) to find the best treatment which has an economic benefit. The following equations were used:

Gross benefit = economical yield return * price (birr kg-1)

Net profit = gross benefit - total cost that varies.

To identify the best treatments from the experiment the dominance analysis was used. The marginal rate of return (MRR) was calculated by considering a pair of non-dominated treatments listed. MRR denotes the return per unit of investment for the different managements tested in the field. Following the analysis, treatments with the highest MRR were recommended to farmers.

MRR =change in NB/change in TCV

Where MRR is the marginal rate of return, NB is the net benefit ha-1 for each treatment, and TCV is the total variable costs ha-1 for each treat

RESULT AND DISCUSSION

The results of composite soil samples for the cropping seasons used in determining the physicochemical properties of the experimental sites are presented in Table 1. The PH value of the soil was range 5.58-5.65 which indicated that moderately acidic. As per the classification set by London (1991), the organic contents of all the study sites rated under very low. The available P content of the composite surface soil sample of the experimental sites could be rated as very high. The exchangeable potassium of the soil was optimum (Berhanu Debele, 2008). According to Murphy (2007), the cation exchange capacity of the soil was very high.

		Year 1		Year 2	
Soil property	**Unit**	**Site 1**	**Site 2**	**Site 1**	**Site 2**
Total nitrogen	%	0.18	0.25	0.22	0.28
Available P	P/PPM	34.61	33.27	25.29	14.37
pH	H2O	5.6	5.65	5.58	5.58
OC	%	1.87	1.79	2.53	2.46
CEC	Cmol/kg Ammon. Acet.	47.48	42.45	39.57	35.82
Ex.K+	Cmol/kg Ammon. Acet.	0.95	1.12	0.55	0.29
Textural class	%	Clay loam	Clay loam	Clay	Clay

Table 1; physicochemical properties of the experimental sites

GROWTH PARAMETERS

Days to flowering and maturity

The analysis of variance showed that the application of nitrogen and phosphorus has a significant effect on days to flowering and maturity (Table 2). Application of 138 kg N ha-1 delayed days to flowering and maturity by almost 9 and 14 days, respectively when compared to control plots. Also, the application of phosphorus takes a long time to flowering and maturity when the rate increasing from 0 to 69. The present study coherent with Zelalem et al. ;(2009) and Israel et al.; (2016), they obtained that the application of high nitrogen levels delayed flowering and maturity.

Plant height

nitrogen levels. Analysis of variance revealed that the application of N has significantly affected the plant height of potato while P did not influence. The fertilization of nitrogen at a rate of 138 kg N ha-1 increased plant height by about 22 cm compared to the control. This result similar to Zelalem et al.; (2009) they reported that N fertilization increased potato plant height when increasing at the rate from 0 to 207 kg N ha-1 and makes the difference about 24 cm over the control plot. The current finding support previous studies with Israel et al.; (2016), Fayera (2017), and Alemayehu et al. (2015) they obtained that the application of nitrogen fertilizer has a significant effect on plant height. They also found that the plant height of potato increasing with an increase in

Number of stem per hill

The application of nitrogen did significantly influence the number of stems per hill. Increasing the application of nitrogen from 0 to 138 kg ha-1 increased stem number per hill from 5.6 to 7.3. The highest (7.3) and the lowest (5.6) number of stem per hill was obtained on the rate of 138 kg N ha-1 and control plot, respectively. On the contrary, P fertilization did not significantly affected but, increasing phosphorus application from 0 to 69 kg

ha-1 increased stem number per hill from 6.6 to 6.9. The present finding in line with, Hassanpanah et al. (2009) and Alam et al. (2007) have described that the lowest stem number of potato was obtained from the control plot (0/0 N/P).

N kg ha-1	DF	DM	SNH	PH (cm)
0	60.78d	106.33d	5.6b	51.9d
46	65.89c	110.78c	6.8a	63.9c
92	68.22b	115.56b	7.3a	69.7b
138	69.89a	120.67a	7.3a	73.5a
LSD(0.05)	**	**	*	*
P kg ha-1				
0	65.58b	111.25b	6.6	65.3
46	65.67b	113.5a	6.8	64.4
69	67.33a	115.25a	6.9	64.3
LSD(0.05)	**	*	ns	ns
CV (%)	1.31	2.05	20.6	11.6

Table 2: Effects of nitrogen and phosphorus fertilizer on growth parameters of potato.

NB; Days to 50% flowering(DF),Days to maturity(DM),Stem number per hill(SNH),Plant height(PH),Least significance difference(LSD), and Coefficient of variance(CV)

Number of stem per hill

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YIELD CHARACTERS

Number of tubers per hill

Results showed that the application of nitrogen and phosphorus fertilizer has a significant effect on the number of tubers per hill. The maximum (13.9) and minimum (10.5) tubers were obtained at the rate of 138 kg N ha-1 and control plot, respectively. Different levels of phosphorus application has also significantly influence on potato tuber. The highest (13.5) and lowest (12.2) tubers were recorded at the rate of 69 kg ha-1 and the control plot, respectively.

Nitrogen	Av.no. of tuber/hill	Marketable yield	Total yield
(kg ha-1)		(ton ha-1)	(ton ha-1)
0	10.5b	20.3c	22.0c
46	13.0a	27.8b	29.8b
92	13.7a	33.3a	35.6a
138	13.9a	33.7a	36.3a
LSD(0.05)	1.1.	2.8	2.7
P2O5 (kg ha-1)			
0	12.2b	28.7	30.8
46	12.6ab	29	30.9
69	13.5a	28.7	31.2
LSD(0.05)	0.9	ns	ns
CV (%)	18.3	2.4	18.6

Table 3: Effect of N and P on the combined mean value of growth and yield of potato at Debark district over two years NB; Least significance difference (LSD), and Coefficient of variance (CV)

Marketable yield (t ha-1)

Nitrogen levels showed a significant effect on marketable yield (t/ha) while phosphorus levels were found to be non-significant. The maximum 36.3 t/ha and 31.2 t/ha were obtained from the plot received at the rate of 138 kg N ha-1 and 69 kg P ha-1 respectively. At the application of nitrogen at the rate of 92 kg N ha-1 and 138 kg N ha-1was given the highest yield but statistically nonsignificant. The yield of potato increasing with an increase in nitrogen levels. This result in line with the finding of Zelalem et al.; (2009), Fayera (2017), and Isreal et al. ; (2012) who reported that the application of high levels of nitrogen increases marketable yield. The opposite result was found by Desalegn et al.;(2016) the reported that the yield of potato is not increasing with an increase of nitrogen levels.

Total yield (t ha-1)

The analysis of variance showed the application of different levels of N fertilizer significantly affected the total tuber yield (P≤0.05). The maximum 36.3 t ha-1 and minimum 22 t ha-1 total tuber yield were obtained at the application of 138 N ha-1 and 0 N ha-1, respectively.

PARTIAL BUDGET ANALYSIS

Treatment arrangement(P2O5, N) respectively	Marketable yield (ton ha-1)	Adjusted yield (ton ha-1)	fertilizer Application Cost (ETB)	fertilizer Cost (ETB)	Total variable cost (ETB)	Gross benefit (ETB)	Net benefit (ETB)	dominance analysis	MRR
(0,0)	21.1	19	0	0	0	151920	151920		
(46,0)	19.5	17.5	0	1558.5	1558.5	140162	138604	D	
(0,46)	25	22.5	700	1456.6	2156.6	180302	178146		12.2
(69,0)	20.5	18.4	0	2337.8	2337.8	147362	145025	D	
(46,46)	29.5	26.5	700	3015.1	3715.1	212342	208627		19.6
(0,92)	34.3	30.8	900	2913.2	3813.2	246600	242787		348.2
(69,46)	28.8	25.9	700	3794.4	4494.4	207360	202866	D	
(46,92)	33.1	29.8	900	4471.7	5371.7	238262	232891	D	
(0,138)	34.3	30.9	1100	4369.8	5469.8	246902	241433	D	
(69,92)	32.6	29.3	900	5251	6151	234418	228267	D	
-46,138	34.1	30.7	1100	5928.3	7028.3	245398	238369	D	
-69,138	32.8	29.5	1100	6707.6	7807.6	236282	228475	D	

Table 4: Partial budget analysis of the experiment.

The result of the partial budget analysis is shown above (Table 4) financial profitability is the ultimate measures to recommend the rate of inorganic fertilizer. The partial budget analysis showed that treatment 8 (nitrogen 92 kg ha-1 and 0 phosphorus) is economically and biologically profitable as it gives a marginal rate of return above 100% acceptance rate of return. So the application of 98 kg ha-1 for northern highlands and similar areas is recommended for obtaining a higher yield of potato

CONCLUSION AND RECOMMENDATION

According to this finding, the application of nitrogen fertilizer, the economic analysis is approving with the agronomic result at Debark district. So, that in Debark district and similar agroecology 92 kg ha-1 nitrogen is recommended. Even if the application of phosphorus fertilizer has no significant effect on potato tuber yield at Debark district 23 kg ha-1 phosphorus fertilizer should be applied for soil fertility maintenance.

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