Response of Irrigated Potato (Solanum tuberosum L.) to Nitrogen Fertilizer at Koga Irrigation Scheme, West Gojam

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Abstract
Poor soil fertility is one of the factors that limit crop productivity both in rainfed and irrigated production systems. Nitrogen fertilizer recommendation for irrigated potato production is lacking for the different irrigation schemes in the Amhara region. A field experiment was conducted to determine the response of potato (Solanum tuberosum L.) to different rates of nitrogen fertilizer at Koga irrigation scheme in 2010 and 2011 irrigation seasons. Treatments were seven nitrogen fertilizer levels (0, 54, 81,108, 135, 162 and 189 kg N ha^{-1}). The experimental design was randomized complete block in three replications. Results showed that application of 189 kg N ha^{-1} followed by 162 kg N ha^{-1} were agronomically high yielding and economically profitable and were, thus, recommended as first and second options for potato production in Koga irrigation scheme.

Key words: Nitrogen fertilizer, Potato, Koga

Introduction

The three major essential plant nutrients namely nitrogen, phosphorus and potassium are found increasingly in short supply in the soils of Eastern, Western and Southern Africa (Rao *et al*., 1998). Nutrient mining in East Africa is among the highest in Sub-Saharan Africa, with an estimated annual nutrient depletion rate of 41 kg nitrogen (N), 4 kg phosphorus (P) and 31 kg potassium (K) per hectare (Bekunda *et al*., 2005). Continuous removal of biomass from crop land without adequate nutrient replenishment can rapidly deplete the soil nutrient reserves and jeopardize the sustainability of agricultural production (Esilaba *et al*., 2000).

Potato is a heavy nutrient feeder crop which often needs addition of plant nutrients for higher productivity. Potatoes respond well to the application of both farmyard manure and inorganic fertilizers. According to Bereke (1988), an application of 150-66 kg N-P_2O_5 ha^{-1} under rainfed conditions resulted in a tuber yield advantage of 32% over the

unfertilized. The amount of nitrogen a potato crop requires varies from 100-200 kg ha^{-1} (occasionally 300 kg) depending on the purpose of production and the soil fertility status. N supply in potato may substantially delay leaf senescence leading to enhanced leaf area duration and increased tuber yield (MacKerron and Heilbronn, 1985).

In Koga irrigation command area from a total of land covered by irrigation 41% is covered by potato production in 2012. However, farmers are growing potato without any fertilizer input and yields are far below the potential of the crop. The objective of this study was, therefore, to determine the optimum rate of nitrogen fertilizer for potato production in Koga irrigation scheme.

Materials and Methods

Description of Study Area

Koga irrigation scheme is found in Mecha district situated at 11° 36 !O! mbujuvef ! 48° 1: ! E longitude and at an altitude of 2020 m asl. The soil at the Koga experimental site is Nitosol. The soil is strongly acidic according to USDA classification with high exchangeable acidity and high exchangeable Al^{3+} content. It has very low organic matter content. Available phosphorus content is very low according to the category by James (2004). This might be due to the acidic nature of the soil. It has medium total nitrogen contents (Table 1). The very low available phosphorus content could be due to the high acidity of the soil.

Table 1. Physicochemical properties of the soils in the Koga irrigation command area.

Parameter	Values
pH	5.18
Total N (%)	0.21
Available p (ppm)	6.28
Organic matter (%)	3.71
Exchangeable acidity (cmol/kg)	2.93
Exchangeable Al^{+3} (cmol/kg)	1.65

Experimental Design and Procedures

Experimental treatments were seven nitrogen fertilizer levels (0, 54, 81, 108, 135, 162, 189 kg N ha^{-1}) arranged in a randomized complete block design with three replications.

Belete, a recently released improved potato variety, was used for the experiment. The gross plot size was 9 m^2 with spacing between rows of 75 cm and plants of 30 cm.

Urea and TSP were used as a nitrogen and phosphorus fertilizer sources, respectively. Nitrogen was applied in split where $^1/_3$ of the N was applied at planting, $^1/_3$ at emergence and the remaining $^1/_3$ at flowering stage. The recommended phosphorus fertilizer rate (69 kg P_2O_5 ha^{-1}) was applied for all the plots uniformly and applied in band at planting at a depth of 5 cm below the tubers. Cultivation was done four times in the cropping season including split application of urea. Irrigation water was applied by furrow application method at weekly intervals. Data on plant height, number of main stem, unmarketable yield, and marketable yield were collected. Composite soil samples to determine the physicochemical properties of the soil were collected prior to implementing the experiment.

Analysis of variance was carried out for yield and yield components using SAS statistical package (SAS Institute, 2008) following statistical procedure appropriate for the experimental design. Whenever treatment effects were found statistically significant, n fbot!x fsf!tfqbsbufe!vt joh!Evodbo t!Nvmujqmf!S bohf!Uftu! bsujbnfuf vehfubobmzt jt!x bt! done using CYMMYT (1988) manual to recommend economically feasible fertilizer rates. Ui f!qsjdf!pg!gfsujmj fs!jo!ui f!gbsn fst !dppqfsbujwf!)vo jpo !ti pq!boe!gbsn !qsjdf!pg! potato in the command area was used for the analysis. Nitrogen fertilizer price used for the analysis was ETB 6.23 kg^{-1} and price of potato was ETB 2.09 kg^{-1}. Marketable yield x bt!bekvtufe!epx o!cz!21 !up!csjoh!epx o!zjfme!up!gbsn fst !qspevdujwjuz!nfwfmboe!dptu! of fertilizer was also adjusted up by 10% to accommodate the rise in hard currency every year.

Results and Discussion

Results indicated that there were signific bou) 1/16 !usfbun fou e jggfsfodft! jo!qmbou height, marketable tuber yield and total tuber yield of potato (Table 2). Plant height was significantly higher with the application of 189 kg N ha^{-1} (Table 3). The highest marketable tuber yield was found at the rate of 189 N ha^{-1} followed by 162 kg N ha^{-1}

while the lowest marketable tuber yield was recorded for the unfertilized or control plot (Table 3). Total tuber yield was significantly higher with the application of 108 kg N ha^{-1} and beyond, however applying nitrogen fertilizer beyond 108 kg N ha^{-1} did not bring significant increase in total tuber yield (Table 3). This result agrees with the results of Tesfaye *et al*. (2008) who recommended 108 and 81 kg N ha^{-1} as first and second economically profitable recommendation for South Gondar zone and 81 kg N ha^{-1} for Adet and Injibara areas.

Table 2. Combined ANOVA for the effect of nitrogen fertilizer on the yield and yield components of potato at Koga irrigation scheme (2010/11 and 2011/12)

		Means square			
Sources of variation	df	Plant height	Marketable yield	Unmarketable yield	Total yield
Rep	2	79.270**	2638..487*	1692.538**	1801.751*
N rate	6	143.680**	26811.377**	103.304ns	27510.260**
Year	1	24.259**ns**	1960.302ns	7590.097**	1835.768*
N_rate*Year	6	24.576*	2888.851**	57.755ns	2542.088**
Error	12	5.577	509.630	117.198	326.202

Table 3. Response of irrigated potato to nitrogen fertilizer combined over years (2010/11 and 2011/12) at Koga irrigation scheme

N_rate (kg ha^{-1})	Stand count	PH (cm)	MTY (t ha^{-1})	Total TY (t ha^{-1})
0	15.33	46.35d	13.877e	15.636d
54	14.83	50.27c	17.548d	19.3364c
81	15.83	51.48c	23.978c	25.746b
108	14.83	56.23b	27.964b	30.727a
135	15.33	56.27b	29.130ab	30.9460a
162	15.67	56.36b	29.950ab	32.040a
189	15.50	61.02a	31.142a	32.598a
CV (%)	8.69	4.37	8.51	6.89

**Means within a column followed by the same letter are not significantly different at P≤ 0.05. PH =Plant height, MTY = Marketable tuber yield, TY = Tuber yield.*

The partial budget analysis result showed that applying 189 kg N ha^{-1} had the highest net benefit and marginal rate of return followed by 162 kg N ha^{-1} (Table 4). These rates are agronomically high yielding and economically profitable, thus, are recommended as the first and second options for potato production in Koga irrigation scheme.

Table 4. Partial budget analysis for the effect of nitrogen fertilizer on the yield of potato at Koga irrigation scheme.

N rate (kg ha^{-1})	Adjusted marketable yield (t ha^{-1})	Gross benefit (ETB ha^{-1})	Total variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	Marginal rate of return (MRR) (%)
0	12.49	23479.3	0	23479.3	
54	15.79	29692.7	807.2	28885.5	669.70
81	21.58	40570.4	1210.9	39359.5	2595.01
108	25.17	47315.8	1614.5	45701.4	1571.22
135	26.22	49295.5	2018.1	47277.4	390.47
162	26.96	50675.4	2421.7	48253.7	241.88
189	28.02	52692.6	2825.4	49867.3	399.78

Conclusion and Recommendations

Results indicated that irrigated potato responded well to application of nitrogen fertilizer. Adding nitrogen fertilizer for irrigated potato at Koga increased the marketable yield of potato. For each application of additional 1 kg of N there was a yield advantage between 130 kg ha^{-1} to 67 kg ha^{-1} marketable tuber yield at the rate of 108 to 54 kg ha^{-1} nitrogen rate. The result indicated that application of each kg N can give at least 67 kg ha^{-1} additional tuber yield as compared to the control. The result of economic analysis also revealed that applying 189 kg N ha^{-1} and 162 kg N ha^{-1} gave the highest net benefit. Therefore, applying 189 kg N ha^{-1} which is 385 kg urea ha^{-1} along with the recommended phosphorus fertilizer rate (69 kg P_2O_5 ha^{-1} or 150 kg DAP ha^{-1}) is recommended for potato production in Koga irrigation command area and as a second option applying 162 kg N ha^{-1} which is 325 kg urea ha^{-1} along with the recommended phosphorus fertilizer rate (69 kg P_2O_5 ha^{-1} or 150 kg ha^{-1} DAP) is recommended. Further studies on Phosphorus-Nitrogen interaction and organic fertilizer should be conducted for Koga area to develop holistic and integrated soil fertility management technologies.

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