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Full Length Research Paper

Response of Irrigated Onion (*Allium cepa* L.) to Nitrogen and Phosphorus Fertilizers at Ribb and Koga Irrigation Schemes in Amhara Region, North western Ethiopia

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Abstract

Nitrogen (N) and phosphorus (P) fertilizer recommendations for irrigated onion production is lacking for the different irrigation schemes in the Amhara region, North western Ethiopia. Two different experiments were conducted at Ribb and Kog irrigation schemes to determine the N and P fertilizer levels for irrigated onion. Experiments were conducted in the years 2010 and 2011. Treatments were comprised of factorial combinations of five N levels (50, 100, 150, 200 and 250 kg N ha^{-1}) and three P levels (20, 40 and 60 kg P ha^{-1}) with one satellite control treatment (0/0 N/P) replicated three times in RCBD. Onion variety used was Bombay Red. Results showed that application of 150 kg N ha^{-1} and 20 kg P ha^{-} at Ribb and application of 100 kg N ha^{-1} and 60 kg P ha^{-1} at Koga are best recommended for onion production under irrigation.

Keywords: Onion, nitrogen, phosphorous, irrigation.

INTRODUCTION

In most irrigable lands, horticultural crops in general and vegetables in particular, play an important role in contributing to the household food security and income. Vegetables being cash crop, with high nutritional value, generate income for the poor households. Higher profits can be achieved by increasing the production of a particular vegetable throughout the year when efficient irrigation system is used. Onion (*Allium cepa* L.) is one of the most popular vegetables in the world. It is fourth in world production of vegetables with a volume of 57.9 million tons (FAO, 2005). In Ethiopia, it contributes substantially to the national economy apart from overcoming local demand. Onion is among the largest production and highly commercialized vegetable crops in Amhara region grown under irrigation. Currently farmers in most irrigable areas of the Amhara region produce large amount of onion bulbs every year. For instance, in 2005/06 production year the region contributed 70,652.6 tons of onion bulb from 5,338 hectares of land covered by the crop (Tadesse, 2008).

In the Amhara region irrigated agriculture is expanding since recent years. Currently, more than 6,200 small scale irrigation schemes of which 95% are traditional exist in the region (Melisew, 2012). Interestingly, the irrigation schemes are owned by more than 330,000 households (or more than 1.9 million people) with an average irrigated land holding of 0.2 ha (Melisew, 2012). Further more, several new and modern irrigation schemes such as Ribb, Megech, Koga, Kobo, Robit, Gumara, etc are under development which will increase the significance of irrigation agriculture in the region. However, farmers are growing most of the irrigated crops with very limited use of improved technologies, which kept the production and productivity of the irrigated

system not better than the rainfed system. For instance in Megech and Ribb areas, only 5 and 4 percent of the households that cultivated during the dry season using irrigation used chemical fertilizers and compost, respectively. The proportion is higher for households in the Megech project area (14% vs 4%) compared with Ribb area (World Bank/DIME, 2012). For the irrigated production system appropriate agronomic technologies have rarely been developed. Therefore, this experiment was conducted with the objective of determining the optimum rates of nitrogen and phosphorus fertilizers for onion production at Rib and Koga irrigation schemes in the region.

MATERIALS AND METHODS

Study Sites

Experiments were conducted at Ribb and Koga irrigation schemes, north western Ethiopia, in the 2010 and 2011 production seasons. Ribb irrigation scheme is found in Fogera district situated at 11^0 41' to 12^0 02' N latitude and 37^0 29' to 37^0 59' E longitude at an altitude of 1800 m a.s.l. On the other hand Koga irrigation scheme is found in Mecha district situated at 11^o25'20'' N latitude and 37^o10'20" E longitude at an altitude of 1960 m a.s.l.

The soil at the Ribb experimental site is fluvisol (an alluvial deposit). According to Bruce and Rayment (1982), the soil has high phosphorus and very low to low total nitrogen contents (Table 1). At Rib the CEC is high according to the category by Pam Hazelton and Brain Murph (2007). The soil at Koga experimental site is Nitosol. However, the soil is strongly acidic with high exchangeable acidity and high exchangeable Al^{3+} content. It has very low organic matter and low available phosphorus content according to the category by Clements and McGowen (1994). It also has medium total nitrogen contents (Table 2).

Experimental Design and Procedures

At Ribb the trial was conducted on farmers' field whereas at Koga it was conducted inside the research station. The treatments constituted factorial combinations of five N fertilizer levels (50, 100, 150, 200 and 250 kg N ha^{-1}) and three P levels (20, 40 and 60 kg P ha^{-1}) with one satellite control treatment (0/0 N/P) for comparison. The experimental design was randomized complete block in three replications. Onion variety, Bombay Red was used. After raising seedlings on seedbed for 50 days, healthy and uniform seedlings were transplanted to the experimental plots. Spacing between furrow, rows and plants were 40cm, 20cm and 10cm, respectively in a net plot size of 1.2 m^2. Distances between plots and blocks were 1m. Urea and TSP/DAP were used as a source of nitrogen and phosphorus fertilizers, respectively. Phosphorus was band-applied at planting in rows 2 cm below seedlings. While nitrogen was applied in split, half at transplanting and the remaining half at 45 days after transplanting on both sides of the rows of 2-3cm away from plants. Plants were cultivated four times in the cropping season. Irrigation water was supplied weakly using furrow irrigation method.

Data were subjected to analysis of variance using SAS statistical package (SAS Institute, 2002) to assess treatment effects. Whenever significant treatment differences were detected, means were separated using LSD at 5% probability.

In order to identify economically feasible recommendations partial budget and sensitivity analysis was done based on the manual developed by CIMMYT (1988). The analysis was based on data collected from respective district office of Trade and Transport, Cooperatives and from onion fields. At Rib, the mean price of onion, urea and DAP from 2009-2011 was 3.40, 7.74 and 8.90 ETB kg^{-1}, respectively. While at Koga, the mean price of onion, urea and DAP were 2.62, 7.41 and 8.60 ETB kg^{-1} respectively. For the purpose of partial budget analysis, yields were adjusted downward by 10% from the exact yield. Sensitivity analysis was conducted to see the worst economic situations by increasing the current fertilizer cost by 10% for both urea and DAP. The acceptable minimum rate of return was set as 100%.

RESULTS AND DISCUSSION

Results of Ribb Irrigation Scheme

Results at Ribb indicated that nitrogen has significant ($P<0.01$) effect on the marketable and total yields of onion and bulb diameter, but phosphorus and the interaction of N and P did not show significant effect on the stated parameters (Table 3). As compared to the control (0/0 N/P_2O_5), application of 20 kg ha^{-1} P has 3.89 ton ha^{-1} marketable yield advantage. This result shows that application of 20 kg/ha P fertilizer contributes 19.55% yield increment over the zero fertilizer around Rib .This may have positive implication to boost the yield of onion at those Woredas. Application of N fertilizer indicated that significantly higher marketable and total bulb yields were recorded at the application of 100 kg N ha^{-1} and beyond, although high yield was recorded with the application of 250 kg N ha^{-1}(Table 4). However, applying N fertilizer beyond 100 kg N ha^{-1} did not significantly increase marketable and total bulb yields (Table 4). The increase in onion bulb yield with the application of N fertilizer could be due to the fact that nitrogen increases the rate of metabolism where more carbohydrate is

Table 1. Chemical properties of the soils of Ribb irrigation command area, 2011

Sample	Available Phosphorus (ppm)	Total Nitrogen (%)	CEC (cmol kg^{-1})
Farmers' field	24.32- 36.71.	0.003-0.18	33.40-36.25

Table 2. Chemical properties of the soils of Koga irrigation command area, 2011

pH	Exchangeable Al3+ (cmol kg^{-1})	Exchangeable H^+ (cmol kg^{-1})	Exchangeable acidity (cmol kg^{-1})	Total N (%)	Available P (ppm)	Organic matter (%)
5.1-5.3	0.92-2.88	0.62-2.35	1.54-5.23	0.18-0.24	3.54-8.69	2.34-4.44

Table 3. Combined ANOVA for the effect of N and P fertilizers on the marketable and total yields of onion at Ribb irrigation schemes

Sources of variation	Df	Mean square values							
		Marketable bulb yield	Pr > F	Total bulb yield	Pr > F	Bulb diameter	Pr > F	Bulb length	Pr > F
Rep	2	4047.30	0.0143	4162.41	0.0114	18.08	<.0001	0.42	0.002
N	4	4826.35	0.0009	4882.36	0.0007	4.20	0.022	0.089	0.200
P	2	133.42	0.8592	74.51	0.9165	1.098	0.424	0.021	0.680
Year	1	292419.60	<.0001	289736.79	<.0001				
N x P	8	846.76	0.4728	816.35	0.4796	1.52	0.3176	0.044	0.602
Error	52	874.17		850.78					

Table 4. Effect of nitrogen fertilizer on the marketable and total yield of onion at Ribb combined over two years (2010 and 2011).

N rate (kg ha^{-1})	Marketable bulb weight (t ha^{-1})	Total bulb weight (t ha^{-1})	Bulb diameter (cm)	Bulb length (cm)	P rate (kg ha^{-1})	Marketable bulb weight (t ha^{-1})	Total bulb weight (t ha^{-1})	Bulb diameter (cm)	Bulb length (cm)
0	19.74^{c*}	19.91^{c}	17.92^{ab}	4.37^{a}	0	19.74^{a}	19.91^{a}	17.92^{a}	4.37^{a}
50	21.87^{bc}	21.95^{bc}	17.06^{c}	4.41^{a}	20	23.63^{a}	23.75^{a}	17.71^{a}	4.43^{a}
100	22.54^{ab}	22.55^{abc}	17.5^{bc}	4.32^{a}	40	24.04^{a}	24.06^{a}	18.45^{a}	4.39^{a}
150	24.76^{ab}	24.86^{a}	18.68^{a}	4.54^{a}	60	23.93^{a}	23.96^{a}	17.65^{a}	4.46^{a}
200	24.30^{ab}	24.33^{a}	17.52^{bc}	4.33^{a}					
250	25.87^{a}	25.93^{a}	18.41^{ab}	4.51^{a}					
LSD (0.05)	**	**	*	NS		NS	NS	NS	NS
CV (%)	14..07	13.72	6.25	5.32		14..07	13.72	6.25	5.32

*Means followed by the same letters are not significantly different at P≤0.05.

synthesized which increases the bulb weight and then total yield. This result was in agreement with the finding of Shaik et al, (1987). Lack of response for phosphorus application at Ribb could be due to the high available phosphorous content of the soil (Table 1). Fogera plain soils are fluvisols which are deposited from upper Catchments. This finding is in agreement with the general truth that fluvisols have good nutrient content (MOW, 2009). This result is similar with findings of Baye et al. (2010), where the effect of phosphorus and its interaction with nitrogen was found statistically non significant for all of the onion yield parameters.

The partial budget analysis for Ribb showed that applying 250 kg N ha^{-1} had the highest net benefit (41611.92 ETB ha^{-1}) and MRR of 201% followed by 150 kg N ha^{-1} with net benefit of 41491.62 ETB ha^{-1} and MRR of 325.8% (Table 5). For one kg nitrogen fertilizer investment the farmer can get 2.10 ETB and 3.25 ETB return by using 250 and 150 kg ha^{-1} respectively. Since the net benefit is more or less same (nearly 120 ETB ha^{-1} difference) for the two rates, thus 150 kg ha^{-1} followed by 250 kg ha^{-1} N fertilizer in combination with 20 kg ha^{-1} P are recommended for onion production at Ribb irrigation scheme as first and second option, respectively. The

Table 5. Partial budget analysis for the effect of nitrogen fertilizer on the yield of onion at Ribb irrigation scheme.

N level (kg ha^{-1})	Un adjusted yield(t ha^{-1})	Adjusted yield (t ha^{-1})	Gross benefit (ETB ha^{-1})	Total variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	MRR (%)
0	19.74	17.766	35309.93		35309.93	D*
50	21.87	19.683	39119.96	932.61	38187.35	308.5
100	22.54	20.286	40318.43	1865.22	38453.21	D
150	24.76	22.284	44289.45	2797.83	41491.62	325.8
200	24.3	21.87	43466.63	3730.435	39736.19	D
250	25.87	23.283	46274.96	4663.043	41611.92	201.1

Table 6. Combined ANOVA for the effect of N and P fertilizers on the marketable and total yields of onion at Koga irrigation schemes.

Sources of variation	Df	Mean square values							
		Marketable bulb yield	Pr > F	Total bulb yield	Pr > F	Bulb diameter	Pr>F	Bulb length	Pr>F
Rep	2	2.30	0.998	318.57	0.813	1.54	0.69	6.391	<.0001
Nitrogen (N)	4	2487.82	0.160	2929.22	0.123	3.58	0.49	0.238	0.70
Phosphorus (P)	2	46812.6	<.000	48816.28	<.0001	8.09	0.16	0.066	0.86
Year	1	207526.5	<.000	325141.08	<.0001				
N x P	8	5005.93	0.002	5595.25	0.001	6.96	0.14	0.370	0.57
Error	52	1448.15		1534.19		4.11		0.436	

farmers at Fogera and libokemkem woredas did not apply fertilizer at all for onion production; however this finding revealed that application of fertilizer has contributed much to boost yield. This has positive implication for onion production increment in woreda as well as national level.

Results of Koga Irrigation Scheme

According to Pam Hazelton and Brain Murph (2007), suitable pH range for onion is 6-6.5 however the soil pH at Koga (5.09 to 5.3) is far below the optimum range which indicates that the performance of onion at Koga irrigation scheme could be affected by soil acidity, especially with Al^{3+} toxicity. Onion is very sensitive to soil acidity, especially for Al^{3+} toxicity. Exchangeable Al^{3+} becomes significant at pH levels less than 5.5 in water or about 4.7 in CaCl2. The critical level of Al^{3+} for onion is 0.4-0.8 extracted by $CaCl_2$ (Pam Hazelton and Brain Murph, 2007) while exchangeable Al^{3+} at Koga is 0.92-2.88 which is above the critical level. This result indicates that onion production was affected by aluminum toxicity at Koga irrigation scheme. The soil at Koga has very low organic matter content. Available phosphorus content is also low according to the category by Clements and McGowen (1994). Since the soil is acidic and its organic matter is depleted phosphorus unavailability is most likely for onion.

The interaction effect of N and P fertilizers had significant (P<0.01) effect on the marketable and total yield of onion at Koga (Table 6). However, there was no interaction effect of N and P fertilizer (P<0.05) on bulb diameter and length. Significantly higher marketable bulb yields were recorded with the application of 100 kg N ha^{-1} with 60 kg P ha^{-1} followed by application of 150 kg N ha^{-1} with 40 or 60 kg P ha^{-1}. This result shows that application of 60 kg ha^{-1} P with 100 kg ha^{-1} N fertilizer contributes (9. 48 t ha^{-1}) 48 % yield increment over the zero fertilizer around Koga. Similarly, significantly higher total bulb yields were recorded with the application of 250 kg N ha^{-1} with 40 kg P ha^{-1} followed by application of 100 kg N ha-1 with 60 kg P ha-1 (Table 7). This result indicated that application of N and P fertilizer has highly significant influence on the bulb yield and vegetative growth of onion which is in harmony with the findings of Rizk (1997) and Baloch *et al (1991),* who concluded that increasing the application rate of N increased yield of onion. In addition the result indicates that higher bulb diameter was recorded by applying 150 kg ha^{-1} N.

According to Rizk (1997), in irrigated agriculture use of chemical fertilizer can increase the yield of onion more

Table 7. Effect of N and P fertilizers on the marketable bulb yield of onion at Koga over two years (2010 and 2011)

P / N rates (kg ha^{-1})	Marketable bulb yield (t ha^{-1})	Total bulb yield (t ha^{-1})	N rate (kg ha^{-1})	Bulb diameter (cm)	Bulb length (cm)	P rate (kg ha^{-1})	Bulb diameter (cm)	Bulb length (cm)
0/0	19.74^{f}	20.00^{g}	0	18.21^{b}	6.53^{a}	0	18.21^{b}	6.53^{a}
20/50	24.41^{def}	25.48^{ef}	50	21.32^{a}	6.97^{a}	20	20.84^{a}	6.74^{a}
20/100	24.30^{cde}	27.68^{def}	100	22.02^{a}	6.91^{a}	40	22.21^{a}	6.84^{a}
20/150	23.34^{de}	25.90^{ef}	150	20.75^{a}	6.67^{a}	60	21.99^{a}	6.87^{a}
20/200	24.46^{cde}	34.79^{abc}	200	22.03^{a}	6.62^{a}			
20/250	25.89^{bcd}	33.93^{bc}	250	22.28^{a}	6.92^{a}			
40/50	21.86^{ef}	22.33^{f}	LSD (0.05)	1.96	0.63		1.52	0.49
40/100	24.13^{cde}	29.58^{de}	CV (%)	9.36	9.68		9.36	9.68
40/150	27.74^{ab}	27.84^{ef}						
40/200	26.04^{bcd}	33.89^{bc}						
40/250	24.93^{bcd}	38.04^{a}						
60/50	25.68^{bcd}	28.91^{def}						
60/100	29.22^{a}	35.09^{ab}						
60/150	26.79^{abc}	29.04^{def}						
60/200	26.18^{abcd}	30.91^{cd}						
60/250	25.39^{bcd}	29.03^{def}						
LSD (0.05)	3.05	3.42						
CV (%)	13.64	12.97						

**Means followed by the same letters are not significantly different at P<0.05.*

Table 8. Partial budget analysis for the effect of N and P fertilizers on the yield of onion at Koga irrigation scheme.

N (kg ha^{-1})	P (kg ha^{-1})	Unadjusted yield (t ha^{-1})	Adjusted yield (t ha^{-1})	Gross benefit (ETB ha^{-1})	Total variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	MRR (%)
0	0	19.74	17.77	46546.92	0	46546.92	
50	20	24.41	21.97	57558.78	1513.35513	56045.42	690.41
50	40	21.86	19.67	51545.88	2140.21787	49405.66	D
50	60	25.68	23.11	60553.44	2838	57715.44	1309.973
100	20	24.3	21.87	57299.4	2399.847522	54899.55	706.9403
100	40	24.13	21.72	56898.54	3026.710261	53871.83	D
100	60	29.22	26.30	68900.76	3653.573	65247.19	1996.114
150	20	23.34	21.01	55035.72	3286.339913	51749.38	4043.096
150	40	27.74	24.97	65410.92	3913.202652	61497.72	1710.609
150	60	26.79	24.11	63170.82	4540.065391	58630.75	D
200	20	24.46	22.01	57676.68	4172.832304	53503.85	1535.7
200	40	26.04	23.44	61402.32	4799.695043	56602.62	543.7642
200	60	26.18	23.56	61732.44	5426.557783	56305.88	D
250	20	25.89	23.30	61048.62	5059.324696	55989.3	R
250	40	24.93	22.44	58784.94	5686.187435	53098.75	D
250	60	25.39	22.85	59869.62	6313.050174	53556.57	R

D Stands for dominated treatment. R stands for rejected treatment

than 10 tons per hectare as compared to without fertilizer application. It is observed that maximum bulb yields were recorded at maximum phosphorus applications. This could be an indication that the applied phosphorus might have been fixed due to the strongly acidic soils of the study area. Thus, such studies at Koga irrigation scheme needs to be conducted with the application of lime to understand the readily available phosphorus applied.

The results of the partial budget analysis (Table 8) showed that applying 100 kg N ha^{-1} and 60 kg P ha^{-1} had the highest net benefit (65247 ETB ha^{-1}) and MRR (1996

%) followed by 150 kg N ha^{-1} and 40 kg P ha^{-1} with net benefit of 61498 ETB ha^{-1} and MRR of 1711% (Table 8). Therefore, 100/60 and 150/40 kg N/P ha^{-1} are recommended as first and second options, respectively for onion production at Koga irrigation scheme. The studies at both sites indicate that for onion production under irrigation fertilizer application will increase marketable and total bulb yield; hence farmers and other onion growers should apply N and P fertilizers so that to increase their income and the woredas as well as country GDP.

CONCLUSION AND RECOMMENDATIONS

At Ribb, application of 150 kg N ha^{-1} with 20 kg P ha^{-1} as the first and 250 kg N ha^{-1} with 20 kg P ha^{-1} as second options are recommended for onion production. Onion did not respond to P application at Ribb due to the high phosphorus content of the soil. Therefore, for future phosphorus fertilizer recommendation for Ribb command area needs to be developed based on soil test based study.

At Koga irrigation scheme application of 100 kg N ha^{-1} and 60 kg P ha^{-1} is recommended as the first option. As a second option application of 50 kg N ha^{-1} and 60 kg P ha^{-1} is recommended. The highest yield in response to the tested P fertilizer rates was not attained in the current study, therefore P rates above 60 kg P ha^{-1} needs to be studied for Koga irrigation scheme so as to attain the point of diminishing response. At Koga irrigation scheme fertilizer rate study needs to be done along with soil liming as the soil in the command area is acidic.

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