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Optimal Rate of Nitrogen and Phosphorus Fertilizers for Economical Production of Onion (*Allium cepa* L.) Under Irrigation Condition In Southern, Ethiopia

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Abstract

Onion is one of the most important vegetable crops grown under irrigation in Southern, Ethiopia. Nitrogen and phosphorus are most essential nutrients/ important inputs/, to increase yields of vegetables including onion typically depends on the fertility status of the particular soil. An experiment was carried out to find suitable levels of nitrogen and phosphorus fertilizers under balanced fertilizer and to assess economic feasibility of N and P fertilizer at Meskan, Gurage districts of Ethiopia. This experiment was designed in a Randomized Complete Block Design with factorial arrangement in three replicates. Treatments were four nitrogen level (0, 46, 92, and 138 kg ha^{-1}) and four phosphorous level (0, 20, 40, and 60 kg ha^{-1}). The results of this study revealed that there significant ($P < 0.05$) interaction effects of nitrogen and phosphorus fertilizer application during all growing seasons on total and marketable bulb yields of onion. However, unmarketable bulb yield did not show significant effect. The maximum un unmarketable bulb yield was obtained from unfertilized or control plot. The maximum marketable bulb yields (34.0, 30.8 and 32.2 tone ha^{-1}) were obtained in response to the application of 92 kg ha^{-1} of N combined with 40 kg ha^{-1} of P during three consecutive growing seasons respectively. Likewise, the maximum total bulb yields (34.4, 31.1 and 32.7 tone ha^{-1}) were obtained in response to the application of 92 kg ha^{-1} of N combined with 40 kg ha^{-1} of P during three consecutive growing seasons respectively. Economic analysis revealed the highest net benefit of 555,4430.00 Eth-Birr with MRR% of 362.1% was obtained by application of 92 kg ha-1 of N and 40 kg ha-1. However, the lowest net benefit, 381,100.00 Eth-Birr was obtained from the control or unfertilized plot. Therefore, application 92 kg ha^{-1} of N combined with 40 kg ha^{-1} P fertilizers pointed out that the fertilizer level of seems to allow a good balance production and productivity and economically advisable for farmers in the study area for better onion production, with similar soil types and agro-ecologies.

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Keywords

Nitrogen, Phosphorous, Onion and Bulb yield.

Introduction

Onion (*Allium cepa* L.) is the most widely cultivated species of the genus *Allium*. The crop belongs to the family *Alliaceae* (Hanelt, 1990) and is one of the most important vegetables produced throughout the world. Ethiopia has diversified agro-climatic conditions suitable for the production of a broad range of fruits and vegetables including onion. As a bulb crop, it is mainly produced by smallholder farmers as a source of cash income and for flavoring the local stew ‘wot’ (Lemma and Shimelis, 2003). According to Central Statistical

Agency (CSA) (2014), the average annual onion production in Ethiopia is about 230,745.2 tons with the productivity of about 9.5 t ha^{-1}. However, the potential productivity could go far beyond the current national average yield. Many reports indicated that vegetable production in Ethiopia is constrained mainly by, among others, depleting soil fertility and poor agronomic practices such as unbalanced/improper fertilization (Melkamu *et al.,* 2015).

The production and productivity of the crop in Ethiopia is influenced by different factors among declining soil fertility, insufficient and inefficient use of fertilizers, inappropriate agronomic practices and inadequate pest and disease managements are the major ones (Lemma and Shimelis, 2003). Chemical fertilizers have been the prime means of enhancing soil fertility in small farm agriculture (Thangavel and Mohammed, 2014). Many investigators reported that the vegetative growth of onion plants and minerals uptake was increased with increasing the level of NP and other essential nutrients. Deficiencies of nitrogen and phosphorus are widespread in all sub-Saharan Africa including Ethiopia (CIAT, 2006). Onions are more susceptible to nutrient deficiencies than most other crop plants because of their shallow and unbranched root system; hence they require and often respond well to addition of fertilizers (Brewster, 2008).

Nitrogen and phosphorus are often referred to as the primary macronutrients because of the probability of plants being deficient in these nutrients and because of the large quantities taken up from the soil relative to other essential nutrients (Marschner, 1995). Nitrogen is required in much greater quantities than most of the nutrients. Nitrogen is an important component of proteins, enzymes, and vitamins in plants, and is a central part of the essential photosynthetic molecule, chlorophyll (Marschner, 1995). Plant demand for N can be satisfied from a combination of soil and fertilizer N to ensure optimum growth. Phosphorus deficiency is one of the largest constraints to crop production in many tropical soils, owing to low native content and high P fixation capacity of the soil (Fairhurst *et al.*, 1999).

Phosphorus is essential for root development. When the availability is limited, plant growth is usually reduced. In soils that are moderately low in P, onion growth and yield can be enhanced by applied P. Uptake levels of nutrients by onion crops may vary from less than 50 kg to more than 300 kg N ha^{-1}, depending on cultivar, climate, plant density, fertilization and yield levels (Pire *et al.,* 2001). Supplying an optimum nitrogen level was proved to be very essential for plant growth and production of high yield as well as improving the quality of onion bulbs (Balemi *et al.*, 2007). Abdissa *et al.*, (2011) reported increased shallot and onion bulb yields with N application in the range of 75-150 and 69 kg ha^{-1}, respectively. Comparative studies of nutrient requirement of vegetables have shown that onion requires higher level of available P content to achieve maximum yield than most other temperate vegetables (Shimeles, 1999). Phosphorus deficiencies in onions reduce root and leaf growth, bulb size, and yield and also delay maturation (Brewster, 2008). Many authors reported that phosphorus application rates of up to 200 kg P ha maximized onion yields and bulb weights (Singh, 2000). Increased P levels are also known to improve bulb size and the number of marketable bulbs in shallots (Zaharah, 1994). Similarly, Kebede, (2003) indicated that phosphorus fertilization at the rates of 25 or 50 kg ha^{-1} increased yield and bulb weight of shallots even when soil analysis did not show deficiency of the nutrient. However, differing results were reported that P application did not significantly influence yield of onions (Abdissa *et al.*, 2011).

Sustainable agriculture production requires balanced and judicious, efficient, eco-friendly, and environmentally sound management practices. To achieve the national goal of agricultural sustainability and food security, vertical diversification of agriculture in terms of more crops output from unit quantity of land through judicious use of fertilizer inputs especially nitrogen has special significance in modern agriculture (Kumar *et al.,* 2016). However, little information is available on the response of the onion rates of the fertilizers in terms of bulb yield, which is important to optimize fertilizer application for enhanced productivity and quality of the crop. Keeping in view these aspects, the present study was initiated to the response of onion to different rates of nitrogen and phosphorus fertilizers under balanced fertilizer and to assess economic feasibility of N and P fertilizer rate at Meskan, Gurage districts of Ethiopia.

Materials and Methods

The study was conducted on farmers' field in Mesqan Woreda, Gurage Zone of the South Nations Nationalities and Peoples Region under irrigation condition during 2019-2021. The site is situated at latitude of 8°06′N and longitude of 38°24′E with an altitude of 1960 *m.a.s.l*. The mean average annual rainfall of the area was 1206.8 mm with a range of 504.7mm to 1783.3 mm with average annual temperature of18.6ºC.

The improved onion variety Red Bombay was used for the experiment. The experiment was consisted of four levels of Nitrogen (0, 46, 92, and 138 kg ha^{-1}) and Phosphorous (0, 20, 40, and 60 kg ha^{-1}) with 16 treatments combination was laid out in RCBD Design with factorial arrangement in three replications.

The source of Nitrogen and phosphorus was Urea and TSP respectively. The full dose of P and half dose of N fertilizer were applied at transplanting time and the remaining half dose of N was side-dressed two weeks after transplanting. Other agronomic practices were carried out uniformly for all treatments as recommendation. Before the establishment of the experiment composite soil samples (0 to 20cm) was collected for the analysis of texture, soil pH, total N, available P, CEC, micronutrient (B, Zn, Fe, Cu, Mn) based on their recommended and standard laboratory procedure.

Data collection

All Agronomic data on yield and yield components were measured and taken from 10 randomly selected plants per plot. The marketable bulbs which were free of mechanical, disease and insect pest damages, uniform in color and medium to large in size (20 - 160 g) were considered as marketable and under (<20g) as well as oversized (>160g), misshaped, decayed, discolored, diseased and physiologically disordered bulbs are considered as unmarketable. (Lemma Dessalen and Shimeles Hailu, 2003).

Economic analysis

Besides, an economic analysis was carried out for every treatment using partial budget analysis involving marginal rate of return was calculated for the marketable bulb yield to obtain the economically optimum rate of applied NP fertilizer.

The prices of Urea, TSP and onion bulb yield were valued based on the prices of the local market during the time of planting and harvesting which were considered to be 19.50, 22.20 and 18.50 ETB kg^{-1}, respectively. Gross field benefit (GFB), total variable cost (TVC) and net benefit (NB) were some of the concepts used in the partial budget analysis. The dominance analysis was also carried out to select potentially profitable treatments and a percentage marginal rate of return (% MRR) was calculated for the non-dominated treatments (CIMMYT, 1988)

Data analysis

All collected data were subjected to a two-way analysis of variance to test for least significant differences (LSD) at 5% level. All analyses were performed using Statistics Analysis System (SAS version 9.4) software package (SAS, 2014)

Results and Discussion

Physicochemical properties of Soil

The experimental site was analysis results indicated that soil particle size distribution of the experimental sites was in proportions of 22% of sand, 30 of silt and 48 of clay with textural class of clay loam (Table 1). When the proportion of clay is > 45% on surface area, more active both chemically and biologically, high water holding capacity (WHC), relatively high nutrient holding capacity, slow movement of water and air, hardier for workability of implements and slow release of water to plants with poor drainage are its important features (Chandrasekaran *et al.*, 2010).

Similarly, high clay proportion of the soil may be important as it describes the stability in soil aggregates and less liability of the surface soil layers to wind and water erosion. Therefore, this characteristic of the soil of the study area indicates its potential to increase crop productivity provided that other limitations are minimized.

The soil pH (H_2O) analysis is show the pH value 7.10 which is neutral (Table 1). Tekalign (1991) reported that when the soil pH ranges from 6.7-7.3 rates as neutral. Soil pH has a vital role in determining several chemical reactions and in influencing plant growth by affecting the activity of soil microorganisms and altering the solubility and availability of most of the essential plant nutrients and particularly the micronutrients such as Fe, Zn, B, Cu and Mn (Sumner, 2000). The analysis result show that available P content was 18 mg kg^{-1} (Table 1) which is rated as medium according to Cottenie (1980). The total nitrogen content was 0.32% which is ranged at high level according to Tekalign (1991) classification. Similarly, organic carbon content was 4.25% which is ranged at high level according to Tekalign (1991) classification.

The cation exchange capacity (CEC) of the soils was 60 cmol (+) kg^{-1} which is very high (Table 1). Hazelton, and Murphy (2007) classified that the CEC values moderate 12-25, and very high >40 cmol (+) kg^{-1}.

Table.1 Some physic-chemical properties of the experiment field soil

Properties	Level
Sand	22
Silt	30
Clay	48
Textural Class	Clay loam
pH H_2O (1:2.5)	7.10
Available P (mg kg^{-1})	18.0
% Total Nitrogen	0.32
Organic Carbon %	4.25
CEC (cmol $(^{+})$ kg^{-1})	60.0
Ca (cmol $(^{+})$ kg^{-1})	38.3
Mg (cmol $(^{+})$ kg^{-1})	7.28
K (cmol $(^{+})$ kg^{-1})	1.13
Na (cmol $(^{+})$ kg^{-1})	2.03
Fe (mg kg^{-1})	0.62
Mn (mg kg^{-1})	3.75
Cu (mg kg^{-1})	1.44
Zn (mg kg^{-1})	0.75

Table.2 Interaction effects NP fertilizers on onion yield during 2019 cropping season

N level (Kg ha^{-1})	Marketable bulb yield (t ha^{-1})				Unmarketable bulb yield (t ha^{-1})				Total bulb yield (t ha^{-1})			
	P level (Kg ha^{-1})				P level (Kg ha^{-1})				P level (Kg ha^{-1})			
	0	20	40	60	0	20	40	60	0	20	40	60
0	19.4^{f}	21.6^{ef}	22.8^{def}	22.0^{ef}	1.0^{a}	0.9^{ab}	0.9^{ab}	0.8^{ab}	20.4^{e}	21.8^{de}	23.7^{bcd}	22.7^{cd}
46	24.0^{cdef}	26.3^{bcde}	28.3^{bc}	28.0^{bc}	0.7^{abc}	0.5^{bc}	0.5^{bc}	0.5^{bc}	24.7^{bcd}	26.8^{bc}	28.8^{abc}	28.5^{abc}
92	27.4^{bcd}	29.5^{ab}	34.0^{a}	29.5^{ab}	0.9^{ab}	0.5^{bc}	0.4^{c}	0.6^{bc}	28.2^{ab}	30.0^{ab}	34.4^{a}	30.1^{ab}
138	27.3^{bcd}	30.5^{ab}	29.2^{ab}	29.5^{ab}	0.8^{ab}	0.5^{bc}	0.5^{bc}	0.6^{bc}	28.1^{ab}	31.0^{ab}	29.7^{abc}	30.1^{ab}
CV	11.3				13.9				16.1			
Lsd≤0.05%	5.1*				0.2*				7.5*			

Table.3 Interaction effects NP fertilizers on onion yield during 2020 cropping season

N level (Kg ha^{-1})	Marketable bulb yield (t ha^{-1})				Unmarketable bulb yield (t ha^{-1})				Total bulb yield (t ha^{-1})			
	P level (Kg ha^{-1})				P level (Kg ha^{-1})				P level (Kg ha^{-1})			
	0	20	40	60	0	20	40	60	0	20	40	60
0	14.1^{f}	17.1^{de}	16.6^{de}	15.2^{ef}	0.9^{a}	0.8^{a}	0.9^{a}	0.7^{ab}	16.4^{efg}	17.9^{ef}	17.5^{ef}	14.8^{g}
46	17.1^{de}	20.4^{cde}	22.1^{bcd}	22.4^{bcd}	0.7^{ab}	0.5^{bc}	0.4^{cd}	0.4^{cd}	17.8^{ef}	20.9^{de}	22.5^{cde}	22.9^{cde}
92	21.2^{cde}	26.3^{ab}	30.8^{a}	25.7^{ab}	0.8^{a}	0.4^{cd}	0.4^{cd}	0.5^{bc}	22.0^{cde}	26.7^{ab}	31.1^{a}	26.2^{ab}
138	21.1^{cde}	24.3^{abc}	23.0^{abc}	23.7^{abc}	0.7^{ab}	0.5^{bc}	0.4^{bc}	0.5^{bc}	21.8	24.7^{bc}	23.5^{bcd}	24.2^{bc}
CV	20.1				24.1				19.1			
Lsd≤0.05%	7.7*				0.24				7.1*			

Table.4 Interaction effects NP fertilizers on onion yield during 2021 cropping season

N level (Kg ha^{-1})	Marketable bulb yield (t ha^{-1})				Unmarketable bulb yield (t ha^{-1})				Total bulb yield (t ha^{-1})			
	P level (Kg ha^{-1})				P level (Kg ha^{-1})				P level (Kg ha^{-1})			
	0	20	40	60	0	20	40	60	0	20	40	60
0	19.1^{f}	21.0^{ef}	25.8^{def}	26.7^{cde}	0.9^{a}	0.8^{b}	0.7^{bc}	0.7^{bc}	20.0^{f}	21.8^{ef}	26.5^{cde}	27.4^{cd}
46	21.7^{ef}	28.5^{bcd}	29.1^{b}	28.8^{bcd}	0.7^{bc}	0.5^{cde}	0.5^{cde}	0.6^{c}	22.4^{def}	29.0^{bc}	29.5^{bc}	29.4^{bc}
92	26.2^{cde}	29.9^{b}	32.2^{a}	29.1^{b}	0.7^{bc}	0.5^{cde}	0.4^{e}	0.4^{e}	26.9^{cde}	32.6^{b}	32.7^{a}	29.5^{bc}
138	25.9	28.9^{bcd}	25.4	29.4^{b}	0.8^{bc}	0.5^{cde}	0.4^{e}	0.5^{cde}	26.7^{cde}	29.4^{bc}	25.8	30.0^{b}
CV	10.5				26.1				14.3			
Lsd≤0.05%	5.4*				0.3				7.7*			

Table.5 Pooled mean interaction effects NP fertilizers on onion yield during 2019-2021 cropping season

N level (Kg ha^{-1})	Marketable bulb yield (t ha^{-1})				Unmarketable bulb yield (t ha^{-1})				Total bulb yield (t ha^{-1})			
	P level (Kg ha^{-1})				P level (Kg ha^{-1})				P level (Kg ha^{-1})			
	0	20	40	60	0	20	40	60	0	20	40	60
0	20.6^{de}	21.1^{de}	22.4^{cde}	20.0^{e}	0.80^{a}	0.78^{ab}	0.73^{ab}	0.71^{ab}	21.5^{ef}	21.7^{ef}	23.2^{de}	20.7^{f}
46	22.4^{cde}	24.4^{bcd}	25.9^{bc}	25.1^{bc}	0.62	0.55^{cd}	0.51^{cd}	0.50^{cd}	23.0^{de}	24.9^{cde}	26.4^{bc}	25.6^{bcd}
92	24.6	26.8^{ab}	30.3^{a}	27.9^{ab}	0.80^{a}	0.45^{d}	0.52^{cd}	0.53^{cd}	25.4^{bcd}	26.5^{bc}	31.9^{a}	28.4^{ab}
138	25.0^{bc}	26.0^{ab}	26.0^{ab}	26.2^{ab}	0.73^{ab}	0.62^{bc}	0.51^{cd}	0.64^{bc}	25.8^{bcd}	25.5^{bcd}	26.5^{bc}	27.7^{abc}
CV	15.7				24.3				18.2			
Lsd≤0.05%	3.6^{*}				0.14				4.3^{*}			

Table.6 Partial budget analysis Partial budget analysis of different levels of NP fertilizer for Onion production in the area

Treatments (kg ha^{-1})	MBY (tone ha^{-1})	GB (ETB ha^{-1})	TVC (ETB ha^{-1})	NBC (ETB ha^{-1})	MRR%	D
1	20.6	381100	0	381100.00		
5	22.4	414400	1950	412450.00	16.1	
2	21.1	390350	2220	388130.00		d
9	24.6	455100	3900	451200.00	37.5	
8	25.1	464350	4170	460180.00	33.3	
3	22.4	414400	4440	409960.00		d
13	25	462500	5850	456650.00	33.1	
11	30.3	560550	6120	554430.00	362.1	
6	24.4	451400	6390	445010.00		d
4	20	370000	6660	363340.00		d
14	26	481000	8070	472930.00	77.7	
12	27.9	516150	8340	507810.00	129.2	
7	25.9	479150	8610	470540.00		d
15	26	481000	10290	470710.00	0.1	
10	26.8	495800	10560	485240.00	53.8	
16	26.2	484700	12510	472190.00		d

Where: ETB = Ethiopian Birr (currency); TCV = Total cost that vary; NBC = Net benefit cost; MRR = MBY=marketable bulb yield, GB=Growth benefit, Marginal rate of return; d=Dominance.

Effect of Nitrogen and Phosphorous fertilizer on Onion bulb yield

There were significant ($P < 0.05$) interaction effects of nitrogen and phosphorus fertilizer application during all growing seasons on total and marketable bulb yields of onion Table (2-5). However, unmarketable bulb yield did not show significant effect. But, maximum unmarketable bulb yield was obtained from unfertilized or control plot.

The maximum marketable bulb yields (34.0, 30.8 and 32.2 tone ha^{-1}) were obtained in response to the application of 92 kg ha^{-1} of N combined with 40 kg ha^{-1} of P during three consecutive growing seasons respectively (Table 2-5).Likewise, the maximum total bulb yields (34.4, 31.1 and 32.7 tone ha^{-1}) were obtained in response to the application of 92 kg ha^{-1} of N combined with 40 kg ha^{-1} of P during three consecutive growing seasons respectively (Table 2-5). However, both total and marketable bulb yields were obtained from unfertilized or control plot (Table 2-5). In conformity with the results of this study (Ghaffoor *et al., 2003)* were reported a significant interaction effect of nitrogen and phosphorus on bulb yield of onion (Singh and Mohanty, 1998) similarly reported a significant increase in marketable bulb yield of onion with the combined application of 100:50:50 NPK kg ha^{-1} and 160 N kg ha^{-1}, 60 P_2O_5 and 80 K_2O kg ha^{-1}, respectively. The trend of these results is similar to those of total yield and marketable yield and significant N and P interaction (Sign *et al.*, 2000, Rashid and Salim, 1991 and Zhang *et al.*, (2010).

Economic Analysis

The cost benefit analysis revealed that, the highest net benefit of 555,4430.0Eth-Birr with MRR% of 362.1% was obtained by application of 92 kg ha^{-1} of N and 40 kg ha^{-1} P (Table 6). The lowest net benefit, 381,100.00 Eth-Birr was obtained from the control or unfertilized plot. Moreover, the dominance analysis showed that 2,3, 4,6, 7 and 16 treatments were dominated (Table 6). Scheming of net benefit accounts for costs that vary but also it is important to compare the extra or marginal costs with the extra or marginal net benefits.

Therefore, applications of 92 kg ha^{-1} N and 40 kg ha^{-1} P is economically advisable for farmers in the study area for better onion production; beneficial as compared to the other treatments in the study area because the highest net benefit and the marginal rate of return were above the minimum level (100%). Thus, 362.1% MRR indicates that by investing 1 Birr a farmer can get 36.21 Eth-birr.

Nitrogen and Phosphorous plays important role in vegetative and fruit development in crops. The results of this research pointed out that the fertilizer level of 92 kg ha^{-1} of N combined with 40 kg ha^{-1} P seems to allow a good balance among production and productivity in the area. Were provides 30.3 t ha^{-1} marketable fruit yield and economically advisable for farmers in the study area for better onion production.

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Conflicts of Interest

The authors declare no conflict of interest.

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