Original Research Article

Influence of Nitrogen and Phosphorus Fertilizers on Bulb Yield and Yield-related Attributes of Onion (*Allium cepa L.*) in Fogera Area, Northwest Ethiopia

ABSTRACT

Aim: Onion is one of the most important vegetable crops grown under irrigation in the Amhara Region of Ethiopia. However, its productivity is affected by sub-optimal fertilization. The present research was conducted to investigate the response and economic returns of onion to N and P fertilizers application under irrigation.
Study Design: Randomized Complete Block Design in Factorial Arrangement with three replications.
Place and Duration of the study: The research was conducted in 2020 and 2021 in the Fogera area of Northwest Ethiopia.
Methodology: Four levels of N (0, 46, 92, and 138 kg N ha^{-1}) and three levels of P (0, 46, and 92 kg P_2O_5 ha^{-1}) were factorially combined and laid in a randomized complete block design with three replications.
Results: The results showed that the yield and yield components of onion were significantly affected by the main effects of N. However, the main effects of P and its interaction with N did not significantly influence the growth and yield of onion. The highest plant height, number of leaves per plant, bulb girth and marketable bulb yield were recorded from the application of N_{138} statistically at par with N_{92}. The maximum net economic return was obtained from the application of N_{138}.
Conclusion: Application of 138 kg N ha^{-1} was the economic optimum rate for maximum bulb yield of onion in the study area. Further investigation on the response of onion to P is recommended.

Key Words: *Fogera, Irrigation, Nitrogen, Onion, Optimum fertilizer rate, Phosphorus.*

1. INTRODUCTION

"Onion *(Allium cepa* L.*)* is a vegetable crop grown for its pungent bulbs and flavorful leaves, and it significantly contributes to the nutritional requirements of human beings"[1]. "It is one of the most important vegetables in Ethiopia. As a bulb crop, it is mainly produced by smallholder farmers as a source of cash income and for flavoring the local stew "wot". However, the productivity of onion in Ethiopia (8.9 t ha^{-1}) is low compared to the average yield in Africa (14.5 t ha^{-1}) and the world average (19.3 t ha^{-1})"[2; 3]. "Different studies have indicated that onion production in

Ethiopia is constrained by poor agronomic practices, including unbalanced fertilization, shortage of seeds of improved varieties, diseases, insect pests, and high costs of agricultural chemicals, including fungicides and insecticides”[4; 5]. According to [6] and[7], “depleted soil fertility and poor agronomic practices are among the major factors contributing to low vegetable productivity in Ethiopia”. “Onion is more susceptible to nutrient deficiencies than most other crop plants because of its shallow and unbranched root systems; hence, they require and often respond well to the addition of fertilizers”[8].

“In the Fogera area, which is located in the South Gondar Zone, Northwest Ethiopia, small-scale onion production in the dry season under irrigation is the most common and is the major source of onion for the local market in the surrounding towns. Accordingly, growers, merchants, consumers, intermediaries, and transporters highly benefit from onion production in the area. However, the production and productivity of the crop in this area areconstrained by different biotic and abiotic stresses, among which low soil fertility and sub-optimal fertilizationare the most important ones”[6; 7].“Adequate management of mineral nutrition is a determining factor for high yield and profitability of the crop”[9].There were no location-specific N and P fertilizer recommendations for onion production in the Fogera area. Therefore, this study was conducted to determine the response of onion to the application of N and P fertilizers and determine the optimum economic rate of N and P fertilizers to maximize the productivity of onion under irrigation in the Fogera area.

2. Materials and Methods

The study area is known for rainfed lowland rice cultivation. Following the rice harvest, onion is cultivated by smallholder farmers under irrigation. Most of the smallholder farmers use rivers as a source of irrigation water. Some smallholder farmers dug wells manually and use groundwater as a source of irrigation.

2.1 Description of the study area

The study was conducted at Fogera National Rice Research and Training Center (FNRRTC) in 2020 and 2021 under irrigation. FNRRTC is located in the Fogera

District of Amhara region, Northwest Ethiopia. It is situated at 11° 54’ 22.84’’N latitude and 37° 41’ 9.97’’E longitude at an altitude of 1806.4 meters above sea level (masl) (Figure 1). Fogera district is located between latitude 11°49’55’’ N and longitude 37° 37′ 40’’ E, with altitudinal ranges of 1774 and 2415 masl. The dominant soil types in the study area are Pellic Vertisols.

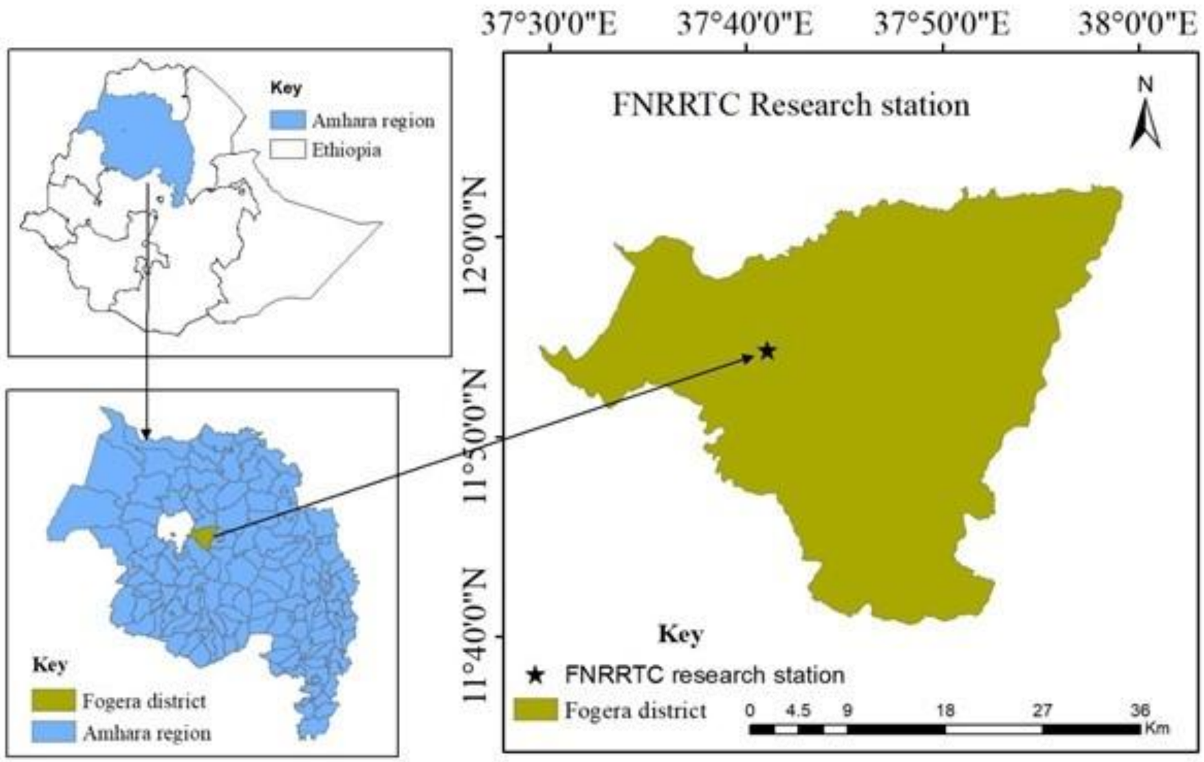

Figure 1. Location map of the study area (Fogera district) and the study site, FNRRTC research station.

2.1.2 Climate

The study area lies in a tropical monsoon climate, where the rainfall is dominated by the Intertropical Convergence Zone (ITCZ). The climate of the study area is locally classified as “*woinadega”*(intermediate high-land between 1500-2300 masl)and it lies in tepid moist mid highlands agro-ecological zone based on the classification by [10; 11].Rainfall in the area is uni-modal, usually occurring from June to September

(Figure 2), and its average annual total rainfall is 1363.7 mm (with 90% falling from June to September). The mean minimum and maximum temperature of the study area are 12.7 and 27.4°C, respectively with the lowest occurring in December and January and the highest in Feb to May (Data obtained from Woreta Metrological Station).

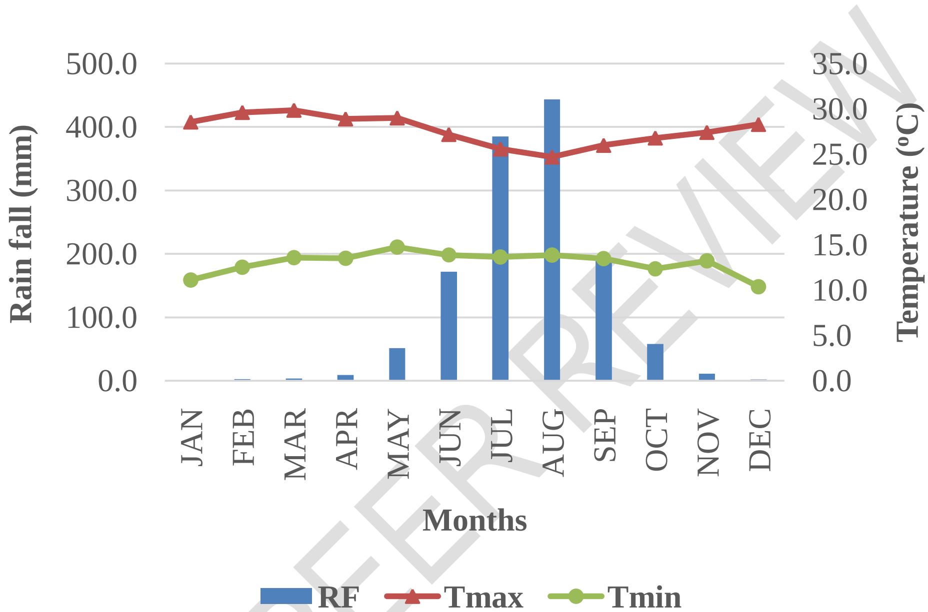

Figure 2. Monthly total rainfall, monthly mean minimum (Tmin) and maximum (Tmax) temperatures of the study area

2.3 Soil sampling and analysis

Five soil samples were collected before transplanting diagonally following 'X' pattern at five spots at a depth of 0-20 cm using auger. Those five soil samples were composited to form one representative soil sample, air-dried, and ground to pass a 2 mm sieve for laboratory analysis. The soil samples were analyzed for pH, organic carbon (OC), total nitrogen (TN), available P, and Cation Exchange Capacity (CEC) using the standard soil testing procedure at the Amahara Design and Supervision Works Enterprise in Bahir Dar, Ethiopia.

2.4 Treatmentsand experimental procedures

Four levels of N (0, 46, 92, and 138 kg N ha^{-1}) and three levels of P (0, 46, and 92 kg P_2O_5 ha^{-1}) were combined in a factorial arrangement and laid in a randomized complete block design with three replicates. The onion variety Bombay Red, which is a widely grown variety in the study area, was used in the study. Onion seedlings were raised in October and November in the two experimental years (2019 and 2020) in a nursery at the FNRRTC research station on well-prepared seed beds. Fifty (50) days old onion seedlings were transplanted to the experimental plots with furrow and ridge spacings of 40 cm and 20 cm, respectively. The seedlings were transplanted on both sides of the ridges with 7 cm spacing between plants. The gross and net size of the experimental plots were 4.2 m * 3.0 m (12.6 m^2) and 3.00 m * 2.94 m (8.82 m^2), respectively. Triple Super Phosphate (TSP) was used as a source of P fertilizer and was band-applied as basal during transplanting. Urea was used as a source of N fertilizer and was applied in split, half was applied in a band at transplanting, and the remaining half was side-dressed 45 days after transplanting. The experimental plots were uniformly furrow- irrigated up to saturation with six days (6) days intervals in the initial and development growth stages, and in 5 days intervals in the mid and late growth stages of the crop.All the other agronomic management practices were implemented uniformly in all plots as per the recommendation.

2.5 Data collection

Data on growth, bulb yield, and yield-related parameters of onion were measured and recorded at physiological maturity from the net plot area of 8.82 m^2 using their respective standard procedures described below.

2.5.1 Plant height (cm): was obtained by measuringfive randomly selected plants from the ground to the tip of the longest mature leaf using a ruler at physiological maturity.

2.5.2 Number of leaves per plant: number of leavesper plant was measured by counting the total number of leaves of five randomly selected plants from the net plot area, and the mean value was used for the analysis.

2.5.3 Bulb dimeter (cm): was measured from five randomly selected matured bulbs at harvest using a vernier caliper.

2.5.4 Marketable bulb yield (kg ha^{-1}):"Bulbs that were free of mechanical, disease, and insect pest damage, uniform in color, and medium to large in size (20-160 g) were considered marketable"[6].The weight of the bulbs obtained from the net plot area was measured in kilograms using a scaled balance and expressed as kilograms per hectare.

2.5.5 Unmarketable bulb yield (kg ha^{-1}):"Bulbs under (<20 g) and oversized (>160 g), decayed, discolored, diseased, and physiologically disordered bulbs are considered unmarketable" according to[6]. The weight of the bulbs obtained from the net plot area was measured in kilograms using a scaled balance and expressed as kilograms per hectare.

2.5.6 Total bulb yield (kg ha^{-1}):total bulb yield of onion was obtained by adding marketable and unmarketable bulb yields.

2.6 Data analysis

"The agronomic data collected were subjected to a two-way analysis of variance using the SAS Statistical Software package version 9.2"[12]. Means were separated using the Least Significant Difference (LSD) test method at a 5% level of significance. A combined analysis of the variance of the agronomic data over the two years was performed after testing and confirming the homogeneity of error variances in the two years. In the combined analysis, year was considered a random variable, while treatment was considered a fixed variable.

2.7 Economic analysis

Partial budget analysis was performed following the procedure described by [13]. Based on the data obtained from the Fogera District Trade and Industry Bureau, the farm gate price of onion bulb yield was 12.33 birr kg^{-1} and the cost of urea fertilizer was 14.38 birr kg^{-1}. The mean marketable bulb yield used for the partial budget analysis was adjusted to 90% of the measured yield. The most profitable treatment was selected based on the highest net economic return, with a marginal rate of return above 100%.

3. RESULTS AND DISCUSSION

3.1 Initial soil fertility status of the study site

The soil analysis results of the surface soil samples collected from the study site before establishing the experiment showed that the surface soil was clay in texture with a very high [14]cation exchange capacity and high exchangeable K content [15]. The surface soil was slightly acidic (pH-H_2O 6.2) in soil reaction with low [16]organic carbon, low[16] total N, and medium [17]available P contents (Table 1).

Table 1. Some soil physico-chemical properties of surface soil (0-20 cm) of the study site

Parameter	Values	Rating
pH (H_2O)	6.2	Slightly acidic
Organic carbon (%)	1.39	Low
Total N (%)	0.12	Low
$P_{(Olsen)}$ (mg kg^{-1})	17.2	Medium
Exchangeable K ($Cmol_c$/kg)	0.61	High
Cation Exchange Capacity ($Cmol_c$ kg^{-1})	46.1	Very high
Soil texture(%) (Sand, Silt and Clay)	18, 28, and 54	Clay

3.2 Effect of N and P on the growth, bulb yield and yield components of onion

3.2.1 Plant height

The plant height of onionwas significantly ($p<0.01$) affected by the main effect of N in the first and second experimental years (Table 2). Pooled analysis over the two experimental years showed that the tallest plants were recorded from the highest rates of N (N_{92} and N_{138}). Increasing the rate of N from 0 to 92 increased the plant height by 14.6%. The positive effect of N on plant height might be attributed to the role of N in improving the leaf area index and chlorophyll content, thus resulting in a higher photosynthetic rate and vegetative growth [18; 19].The results of the present study are supported by those of [20]and [21], who reported that increasing N levels up to 103.5 kg ha^{-1} increased plant height, but the application of N beyond 103.5 kg ha^{-1} decreased plant height. [22] also revealed that nitrogen fertilizer rates (0, 46, 69, 92, 115, and 138 kg ha^{-1}) significantly affected plant height of onion. However, in the present study, the main effect of P and its interaction with N did not significantly ($p \geq 0.05$) influence the plant height. This result is in agreement with those of [21]and [23], who reported the absence of significant differences in plant height owing to the application of P fertilizer.

3.2.2 Leaf number per plant

The number of leaves per plant was significantly ($p<0.01$) affected by the main effect of N in the first experimental year (Table 2). Although not statistically significant ($p \geq 0.05$), the pooled analysis over the two experimental years indicated that the application of N_{138} resulted in the highest leaf number par plant (10.2), exceeding the leaf number per plant recorded from the N_0 treatment by 14.6%. In accordance with the present research findings, [23]reported an increased number of leaves due to the application of higher rates of N. [22]reported a significant effect of N fertilization up to a rate of 138 kg ha^{-1} on the leaf number and plant maturity of onion. This could be attributed to increased vegetative growth associated with the role of N in the production of proteins and amino acids required for leaf growth and development [19]. [24] also found a significant improvement in the number of leaves as the rate of N application increased to 120 kg ha^{-1}, which declined as the level of N increased to 160 kg ha^{-1}. However, the main effect of P and its interaction with N did not significantly ($p>0.05$) affect the leaf number in either experimental year. This result is supported by [23], who reported a non-significant difference in the number of onion leaves due to the application of P. However, in contrast, [21]reported significant differences in the number of onion leaves in response to P application.

3.2.3 Bulb diameter

The influence of N on bulb diameterwas highly significant ($p<0.01$) in the two experimental years (Table 2). The highest bulb diameter(5.4 cm) was recorded from N_{138}, at par with N_{92}. The lowest bulb diameterwas recorded in N_0. The pooled analysis over the two years indicated that the application of N_{138} increased the bulb diameterby 5.9% compared to the N_0 treatment. In line with the present result, an increase in bulb diameterby about 12 and 16% due to application of 138 and 150 kg N ha^{-1} over the control was reported by [23]. Similarly, [21]reported a significant difference in bulb diameter due to application of N and P. However, the main effect of P and its interaction with N had no significant ($p\geq0.05$) effect on bulb diameter. In agreement with our results, [23] also reported a non-significant difference in bulb girth of onion due to the application of P fertilizer. In accordance with the present results, highest (6.6 cm) bulb diameter of onion was recorded from application of N fertilizer at the rate of 103.5 kg ha^{-1} with 30 t ha^{-1} farm yard manure [25].

Table 2. Main effects of N and P fertilizers on growth and yield-related attributes of onion as affected by the main effects of N and P fertilizers in the 2020 and 2021 experimental years

N level*	**2020**			**2021**			**Pooled**		
(kg N ha^{-1})	**PH**	**LN**	**BD**	**PH**	**LN**	**BD**	**PH**	**LN**	**BD**
N_0	40.9^b	9.3^b	5.6^c	39.0^c	8.4	4.6^c	39.7^c	8.9	5.1^c
N_{46}	41.0^b	10.7^a	5.7^b	41.8^b	9.1	4.8^b	41.4^b	10.1	5.3^b
N_{92}	45.3^a	10.7^a	5.9^a	45.6^a	8.6	5.0^a	45.5^a	10.1	5.4^a
N_{138}	42.1^b	11.0^a	5.8^{ab}	47.4^a	8.8	5.1^a	45.1^a	10.2	5.4^a
LSD (5%)	1.5	1.0	0.14	2.2	NS	0.11	1.4	NS	0.08
P level* **(kg P_2O_5 ha^{-1})**									
P_0	41.4^a	10.9	5.7	44.2	8.7	4.8^b	42.9^{ab}	10.1	5.3
P_{46}	44.5^a	10.5	5.7	43.8	9.4	5.0^a	44.1^a	10.1	5.3
P_{92}	40.8^b	10.1	5.8	42.4	8.3	4.4^b	41.7^b	9.3	5.3
Mean	42.3	10.5	5.7	43.5	8.7	4.9	43	9.8	5.3
CV (%)	3.1	9.8	2.2	5.2	11	2.3	4.6	10.1	2.2

LSD (5%)	1.3	NS	NS	NS	NS	0.1	1.2	NS	0.1
N level * P level	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: PH: Plant height (cm); LN: Leaf number per plant; BD: Bulb diameter (cm); CV: Coefficient of variation; LSD: Least significant difference. *Treatments within a column followed by the same letter are not significantly different at 5% probability level. NS: Non-significant at the 5% significance level.

3.2.4 Bulb yield

The marketable bulb yield of onionwas significantly ($p<0.01$) affected by the main effect of N in the two experimental years (Table 3). However, the main effect of P and its interaction with N did not significantly influence ($p\geq0.05$) the bulb yield of onion. Pooled analysis over the two experimental years indicated that the highest marketable bulb yield (21.1 t ha^{-1}) was obtained from N_{138}. The lowest marketable bulb yield (13.0 t ha^{-1}) was obtained in the N_0 treatment. The marketable bulb yield increased by 62.2% owing to the application of N_{138} compared to the marketable bulb yield obtained from the N_0 treatment.

Table 3. The marketable bulb yield of onion as affected by the main effects of application of N and P fertilizers

N level* **(kg N ha^{-1})**	**Marketable bulb yield (kg ha^{-1})**		
	2020	**2021**	**Pooled**
N_0	14519.6^{c}	11713^{d}	13033.6^{d}
N_{46}	15779.9^{bc}	16071^{c}	15934.0^{c}
N_{92}	17346.9^{ab}	20698^{b}	19232.1^{b}
N_{138}	18185.1^{a}	23763^{a}	21137.9^{a}
LSD (5%)	1795.8	2509.5	1521.4
P level* **(kg P_2O_5 ha^{-1})**			
P_0	17002.4	17649	17339.5
P_{46}	15721.4	18900	17379.9
P_{92}	16593.8	17635	17188.7
Mean	16429.2	18061.2	17306.1
CV (%)	10.2	14.2	12.5

LSD (5%)	NS	NS	NS
N level * P level	NS	NS	NS

Note: CV: Coefficient of variation; LSD: Least Significant Difference. *Treatments within a column followed by the same letter are not significantly different at 5% probability level. NS: Non-significant at the 5% significance level.

In agreement with the present research results, [26]revealed that application of 138 kg N ha^{-1} was the best treatment in terms of yield and yield components of onion.The present research finding was also supported by [27] who reported a significant marketable bulb yield increase fromthe application of 138 kg N $ha^{-1}$with the highest level of irrigation.A study conducted around the Rib area in Fogera district by [28] revealed application of 150 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} as an economically optimum rate for onion production. A research report on integrated nutrient management for onion by [29] showed an increased bulb yield of onion as a result of applications of higher levels of inorganic and organic fertilizers.The significant yield improvement in response to higher rates of N could be due to the enhancement of growth and production of assimilates and their partitioning into the bulbs[30].Overall, the results from the present study and research findings from various studies revealed that good growth performance of onion was obtained from N fertilization with 138 kg N ha^{-1}.However, there was no significant ($p \geq 0.05$) yield difference from the zero P (P_0) due to the application of P_{46} and P_{92}, which might be because of the medium level available P content of the surface soil of the study site.

3.3 Yield response to N

Marketable bulb yield increased with increasing levels of N fertilizer and it was best expressed by a quadratic response curve (r^2=0.993 and 0.998 in 2020 and 2021, respectively), as shown in Figure 3 below. Excessive N application decreases economic returns and increases the risk of groundwater nitrate contamination. Furthermore, a high fertilization rate leads to saline soil problems, and onion is sensitive to soil salinity. Salt damage to young onion plants ultimately has an impact on yield[31; 32]. Different studies have revealed that excessive N fertilization reduces bulb dry matter content and storability by enhancing sprouting and rotting percentages[33].

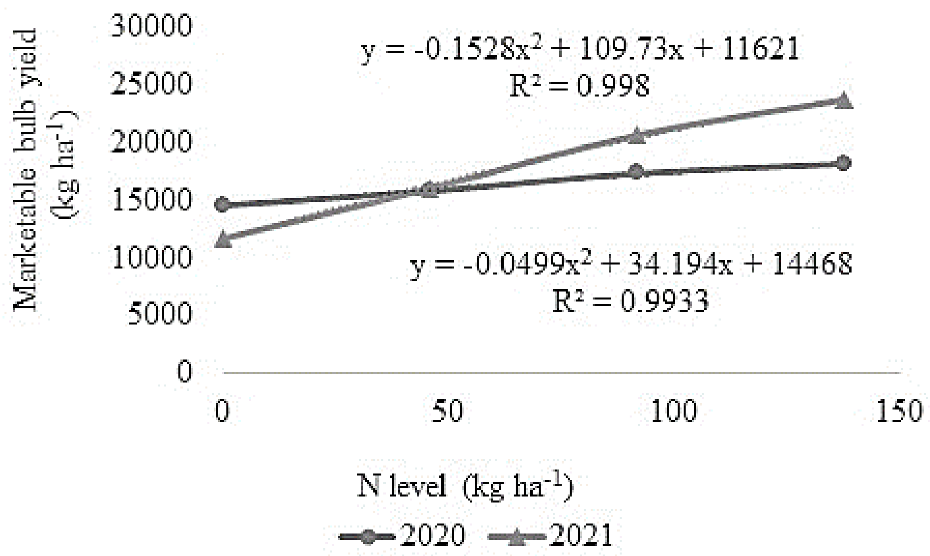

Figure 3.Bulb yield response of onion to N fertilizer in the 2020 and 2021, where Y is marketable bulb yield and x is the level of N applied in kg N ha^{-1}.

3.4 Yield response to P

The bulb yield response to P in the two experimental years was not significant, regardless of the rate of Papplication (0, 46, and 92 kg P_2O_5 ha^{-1}) (Figure 4). This might be attributed to the medium level of available soil P in the surface soil of the study site. Moreover, the non-significant yield response to P might be due to the fact that,with regard to P, onion crop is inefficient in the extraction of P from the soil because the root hairs are mostly shorter than the length of phosphate diffusion. This result is similar with findings of [28], where the effect of P and its interaction with N was found statistically non-significant on the yield of onion. According to [34], special care from growers is required with respect to the levels of this nutrient in the soil, as well as the sources and forms of application of phosphate-based fertilizers. Furthermore, the response of onion to P fertilization depends on the genotype used, P level in the soil, P source, soil, and weather conditions[35]. Therefore, further studies with higher rates of P need to be conducted for the onion in the study area.

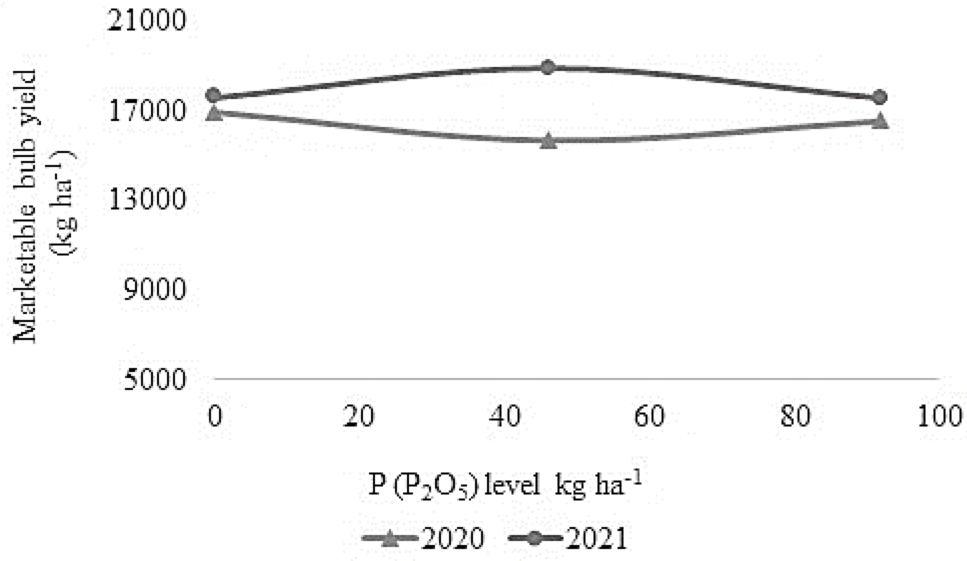

Figure 4. Yield (Marketable bulb yield) response of onion to application of P fertilizer in 2020 and 2021

3.5 Partial budget analysis

The partial budget analysis indicated that the highest net economic return of Ethiopian currency (Birr) 230,252.4 was obtained from the application of N_{138} followed by the net economic return of Birr 210,542.1, which was obtained from the application of N_{92} (Table 4). There was a rate of return of 137.0 and 244.5 birr for every birr invested on onion production by application of 138 and 92 kg N ha^{-1}, respectively. The result is supported by the findings of [28]who found out application of 150 kg N ha^{-1} as an economic optimum rate of N fertilizer for onion production.

Table 4. Partial budget analysis for the mean effect of N fertilizer on the marketable bulb yield of onion in Fogera area of Northwest Ethiopia

N (kg ha^{-1})	**MBY (kg ha^{-1})**	**Adj. MBY (kg ha^{-1})**	**Gross return**	**Production cost**	**Net return**	**MRR (%)**
N_0	13033.6	11730.2	144633.9	0	144633.9	-
N_{46}	15934.0	14340.6	176819.6	1438	175381.3	2137.8
N_{92}	19232.1	17308.9	213418.6	2877	210542.1	2444.6

N_{138}	21137.9	19024.1	234567.3	4315	230252.4	1370.4

Note: MBY: Marketable bulb yield, Adj. MBY: Adjusted Marketable bulb yield, MRR: Marginal Rate of Return (%). All costs are in Ethiopian currency (Birr).

4. CONCLUSION

The results of the study revealed that the growth, yield, and yield components of onion were significantly influenced by the main effects of N. However, the application of P fertilizer and its interaction with N did not significantly affect the growth and yield of onion. Application of N_{138} was found superior in the plant height, number of leaves per plant, bulb diameter, and marketable bulb yield recorded. Based on the partial budget analysis, the highest net economic return was obtained from N_{138} followed by N_{92}. Therefore, the application of 138 kg N ha^{-1} can be recommended for maximum bulb yield and maximum net economic return of onion production in the study area and similar agro-ecologies. However, further investigation on the response of onion to P should be done.

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