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RESEARCH ARTICLE

Influence of Nitrogen and Phosphorus Application on Bulb Yield and Yield Components of Onion (*Allium Cepa* L.)

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Abstract:

Introduction:

Onion is an important cash crop for smallholder farmers in the Central Rift Valley of Ethiopia. However, the yield of the crop is low owing to a number of constraints out of which soil nutrient depletion and inappropriate soil fertility management practices are the most important ones.

Methods and Materials:

A field experiment was carried out for two consecutive years of 2011 and 2012 using irrigation at Melkassa, Central Rift Valley Region of Ethiopia, to assess the response of onion to different levels of nitrogen and phosphorus fertilizers and to identify economical rates of the fertilizers for optimizing the yield and quality of the crop. The treatments consisted of five levels of nitrogen (0, 34.5, 69, 103.5 and 138 kg ha^{-1}) and four levels of phosphorus (0, 46, 92, and 138 kg P_2O_5 ha^{-1}). The experiment was carried out as a randomized complete block design in a factorial arrangement with three replications.

Results:

The results of the study revealed that the main effect of nitrogen significantly ($P \leq 0.05$) affected most of the growth parameters and bulb characters which all attained maximum values at 138 kg N ha^{-1}. The main effect of P significantly ($P \leq 0.05$) influenced leaf number, leaf length, and bulb diameter. Nitrogen and phosphorus interacted to influence total and marketable bulb yields. Application of N at the rate of 103.5 kg N ha^{-1} combined with 138 kg ha^{-1} P_2O_5 led to the production of the highest total and marketable bulb yield of onion. However, results of the economic analysis revealed that application of N at the rate of 103.5 kg ha^{-1} and P_2O_5 at 92 kg ha^{-1} led to the highest net return.

Keywords: Fertilization, Inorganic, Nitrogen, Onion, Phosphorus, Yield.

1. INTRODUCTION

Onion (*Allium cepa.* L.) is one of the most important vegetables grown in Ethiopia. As a bulb crop, it is mainly produced by smallholder farmers as a source of cash income and for flavouring the local stew ‘***wot’*** [1, 2]. A significant proportion of onion produced in Ethiopia is obtained from the Central Rift Valley region, which is mainly attributed to availability of irrigation potential and proximity to market [3].

The productivity of onion bulbs in Ethiopia, including the Central Rift Valley area, is low with the national average

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yield of 10.75 t ha^{-1} [4] as compared to the world's average yield of 17.30 t ha^{-1} [5]. However, the potential productivity could go far beyond the current national average yield with proper management practices. 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 [6, 2]. Accordingly, research gaps on agronomy of onion crop have been reported in Ethiopia in general and central rift-Valley region in particular [1].

Reference [7] suggested that maintaining soil fertility in Ethiopia is impossible unless appropriate farming system is adopted and inorganic fertilizers are used. Besides, reference [8] indicated that soil physical and chemical characteristics are the most influential factors for growth, yield, and quality of *Alliums*'. In the Central Rift Valley (CRV) region, for maintaining soil fertility and for the sake of higher bulb yields, growers apply higher amount of inorganic nitrogen and phosphorus than the regional blanket recommendations. Most smallholder onion farmers apply rates much higher than the ones commonly recommended by the research system which amounts to 69 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. However, some other farmers under-supply the nutrients to the crop. In both cases, yield and quality of the crop are compromised. Excess application of inorganic nitrogen and phosphorus fertilizers makes luxuriant growth with little effect on yield and causing bulb decays [9, 10].

Deficiencies of nitrogen and phosphorus are widespread in all sub-Saharan Africa including Ethiopia [11, 12]. 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 [13]. 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 [14, 15]. 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 [16 - 18]. In Ethiopia [19, 20], reported increased shallot and onion bulb yields with N application in the range of 75-150 and 69 kg ha^{-1}, respectively. On a sandy loam soil in a semi-arid Rift Valley region of Ethiopia, irrigated onion plants also benefited from application of 90-120 kg ha^{-1} N compared to unfertilized crops [21]

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 [22]. Phosphorus deficiencies in onions reduce root and leaf growth, bulb size, and yield and also delay maturation [13]. Many authors reported that phosphorus application rates of up to 200 kg P ha^{-1} maximized onion yields and bulb weights [23 - 25]. Increased P levels are also known to improve bulb size and the number of marketable bulbs in shallots [26, 27]. Similarly, in Ethiopia [28], 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 [20].

Reference [29] suggested efficient and economical use of fertilizer because the input constitutes a substantial proportion of the total cost of growing vegetables. Hence, economic feasibility of fertilizer practices is an essential element in improving crop productivity. Therefore, farmers would adopt only improved practices which are more paying. Therefore, owing to the heavy feeding nature of nutrients by the crop as well as due to soil nutrient depletion under the intensive irrigated cropping system in the study area, judicious application of fertilizers is imperative to sustain and enhance onion production and productivity. However, little information is available on the response of the popular Bombay red onion variety to varied rates of the fertilizers in terms of bulb yield, which is important to optimize fertilizer application for enhanced productivity and quality of the crop. This paper presents the results of a study conducted to investigate the response of the onion to varied levels of mineral nitrogen and phosphorus fertilizers in the Central Rift Valley Region of Ethiopia.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted at Melkassa Agricultural Research Centre, during the 2011 and 2012 season using irrigation. The Centre is situated in the Central Rift Valley of Region of Ethiopia with latitude of 8°24' N and longitude of 39°21' E at the elevation of 1550 metres above sea level. The area has an average annual rainfall of 768 mm, which is erratic and uneven in distribution. The site has a mean maximum temperature of 28.5°C and mean minimum temperature of 12.6°C. The soils of the research area are classified as Phallic Andosol with a characteristic feature of deep pumice or volcanic [30]. The total annual rainfall during the growing period of the experiment was 810.1mm and

924.7 mm during 2010/2011 and 2011/2012, respectively. The mean monthly minimum and maximum temperatures were 9.0°C and 28.8°C during the 2011 cropping season and 13.3 and 28.9°C during the 2012 cropping season.

2.2. Treatments and Experimental Design

The treatments consisted of five nitrogen rates (0, 34.5, 69, 103.5 and 138 kg ha^{-1}) and four phosphorus rates (0, 46, 92, and 138 kg P_2O_5 ha^{-1}). The experiment was laid out as a randomized complete block design in a factorial arrangement and replicated three times per treatment. Urea (46% N) and Triple Superphosphate (46% P_2O_5) were used as a source of nitrogen and phosphorus, respectively. Urea was applied in two splits, with one half at planting and the remaining half side-dressed 45 days after transplanting. The full dose of phosphorus was applied at the time of planting.

2.3. Planting and Agronomic Practices

An onion variety named Bombay Red, which is the most widely cultivated variety in the region, was used for the study. Seeds were sown in a nursery bed on a well-prepared seed bed. Seedlings were transplanted to the experimental field 50 days after sowing when they attained a 3 to 4 leaf stage. Planting was done on ridges of about 25 cm high, adopting the recommended spacing of 40 cm between furrows, 20 cm between rows on the ridge, and 5 cm between plants. The plot size was 3.6 m x 2.0 m and a total of 80 plants were planted per double row. Each experimental plot had six rows and a distance of 1.0 m was maintained between plots and 1.5 m between blocks. Transplanting was done at start of January 2011 and 2012 and harvesting was carried out at mid April 2011 and 2012 during both years. All cultural practices were employed as per the recommendations by [1].

2.4. Soil Sampling and Analysis

Before planting, composite soil samples were collected from rooting depth of the crop. The collected soil samples were analysed for different soil physico-chemical properties. Determination of soil particle size distribution was carried out using the hydrometer method according to [31]. Soil pH was measured potentiometrically using a digital a pH meter in 1:2.5 soil to solution ratio with H_2O. Organic carbon was determined following the wet digestion method as described by [32]. Total N was determined by the Kjeldahl procedure as described by [33]. Available P in the soil samples was determined using the Olsen method [34]. Exchangeable cations were extracted with 1.0 M-ammonium acetate at pH 7 and were measured by the atomic adsorption spectrophotometer.

2.5. Data Collection and Measurement

Data were collected and measurements were carried out on the following growth parameters and bulb characters at physiological maturity and harvesting. Plant height was measured from the soil surface to the top of the longest mature leaf. Leaf number per plant was measured by counting the total number of leaves of ten randomly taken plants from each plot and averaging it. The length of the longest leaf was measured with a metre scale from the base to the apex. Leaf diameter was determined by measuring the central width of each leaf of ten randomly sampled plants from each plot and taking the average. Neck thickness was measured at the narrowest point using a vernier caliper. Leaf area index was recorded by dividing the average leaf area per plant to ground area, where leaf area was measured using portable leaf area meter Model CI-202.

Bulb length and diameter were measured centrally from ten randomly taken bulbs from each plot using a vernier caliper, and averaged. Bulb weight was determined by weighing ten bulbs and calculating the average. Total dry biomass yield was recorded as the weight of ten randomly taken dried bulbs, above ground parts and roots at the time of maturity. Drying was performed at the temperature of 70°C in an oven until a constant weight was attained. Dry weights of bulb were determined by taking ten bulbs and chopping them into small 1-2 cm cubes, and then mixing them thoroughly. Two sub-samples each weighing 200 g was weighed. The exact weight of each sub-sample was determined and recorded as fresh weight. Each sub-sample was placed in a paper bag and put in an oven until a constant dry weight was attained. Each sub-sample was immediately weighed and recorded as dry weight. Harvest index was calculated as the ratio of dry bulb weight to the total dry biomass yield per plant.

The following parameters were recorded at the appropriate growth stages and computed as the mean of individual plots. Bolter plants per plot were determined by counting as the number of plants producing flower stalks and expressed in percentage in relation to the total number of plants. Days to physiological maturity were determined as the actual number of days from transplanting to the date on which the leaves of more than 80% of the plants in each plot senesced. Total bulb yield was computed based on the weight of matured fresh bulb yield per plot and calculated on a hectare basis in tonnes. Marketable bulb yield was determined after discarding bulbs smaller than 20 g in weight as well split, thick necked, rotten, and dis-coloured bulbs [1]. Split bulb percentage was determined by counting the number of split bulbs per plot and expressing in percentage in reference to the total number of normal bulbs per plot.

2.6. Economic Evaluation

The economic evaluation comprising partial budget with dominance, and marginal rate of return was carried out. To estimate economic parameters, the marketable bulb yield was valued based on average market price collected from the local markets during two consecutive years of production where dry onion bulb was 8 Birr per kg. The average cost of urea and DAP were 7.50 and 9.5 Birr per kg respectively. A wage rate of 25.0 Birr per man-day was considered.

Some of the concepts used in the partial budget analysis are gross field benefit (GFB), total variable cost (TVC) and the net benefit (NB). The GFB ha^{-1} was obtained as the products of real price and the mean onion bulb yield for each treatment. TVC refers to the sum of all costs of variable inputs (fertilizers) and management practices whereas the NB ha^{-1} is the difference between the GFB and the TVC [35].

The dominance analysis procedure, which was used to select potentially profitable treatments, comprised ranking of treatments in an ascending order of TVC from the lowest to the highest cost to eliminate treatments costing more but producing a lower NB than the next lowest costing treatment. The selected and rejected treatments by using this technique were referred to as undominated and dominated treatments, respectively. For each pair of ranked undominated treatments, a percentage marginal rate of return (% MRR) was calculated. The percent MRR between any pair of undominated treatments denoted the return per unit of investment in crop management practices expressed as percentage. The MRR (%) was calculated as follows [35].

For a treatment to be considered a worthwhile option to farmers, the marginal rate of return (MRR) needed to be at least between 50 and 100% [35]. Thus, the minimum acceptable rate of return was considered to be 50%.

2.7. Statistical Analysis

Data were subjected to analysis of variance using SAS (Statistical Analysis System, version 9.1, Copyright 2003, SAS institute Inc.USA). The analysis was conducted on combined data of the two years. Mean separation was done using Fisher's LSD. Economic analysis was carried out according to the economic manual of [35].

3. RESULTS AND DISCUSSION

3.1. Soil Analysis

The results of the soil analysis before fertilizer application indicated that soils of the study site is dominantly sandy loam with organic carbon content of 1.5%, total nitrogen content of 0.12% which are low according [36, 37]. The available phosphorus content of the soil is 5.10 ppm Table (**1**), which is low according to [38]. The low organic carbon as well as total nitrogen contents could possibly be due to continuous cultivation through removal of crop residues for other competing ends such as feed and fuel wood and lack of incorporation of organic materials into the soils as suggested by [39 - 41]. The pH of the soil is neutral in reaction having a value of 6.68, which is optimal for the growth of onion crop [13]. The exchangeable bases are optimal for crop production; with high and medium ranges [42].

Table 1. Physico-chemical properties of the soil before the experiment.

Soil Properties	Composition
Sand (%)	50
Silt(%)	21
Clay (%)	29
Texture	Sandy loam
P^H(1:2.5)	6.68
OC (%)	1.50
TN (%)	0.12
Avail P (ppm)	5.10
Exchangeable cations (C mol(+)/kg soil	
Na	0.75
Ca	20.6

(Table 1) contd.....

Soil Properties	Composition
K	1.93
Mg	4.70

3.2. Growth Parameters, Bolting and Physiological Maturity

The main effect of nitrogen significantly *(P≤0.05)* increased plant height while P and its interaction with N did not Table (**2**). Increasing the rate of nitrogen from nil to 34.5 and 69 kg N ha^{-1} increased plant height by 26 and 30%, respectively. The heights of plants grown at these two rates of the nutrient were in statistical parity. However, when the rate of nitrogen was increased from 69 to 103.5 and 138 kg N ha^{-1}, plant height increased further significantly. Increasing the rate of nitrogen from 103.5 to 138 kg N ha^{-1} tended to decrease plant height. Thus, the tallest plants grew in the treatment that received 103.5 kg N ha^{-1} whereas the shortest plants were obtained from nil application of the nutrient Table (**2**). The average height of plants grown at the rate of 103.5 kg N ha^{-1} exceeded the average height of plants grown at nil application by an additional 39%.

Table 2. Effect of N and P on bolting, days to physiological maturity and growth parameter of on.

N (kg ha^{-1})	Bolting (%)	DPM	Plant height (cm)	Leaf number per plant	Leaf length (cm)	Leaf Diameter (cm)	LAI
0	2.50a	99.92d	49.03d	8.00d	45.75d	0.97c	2.77c
34.5	2.41a	100.46c	61.82c	9.33c	49.07c	1.06c	3.23c
69	2.39ab	101.67c	64.03bc	9.92c	50.52abc	1.23b	3.93b
103.5	2.36b	102.92b	68.01a	10.62b	52.13ab	1.27ab	3.99ab
138	2.30b	104.29a	66.37ab	12.33a	53.81a	1.35a	4.39a
LSD	0.123	1.233	3.021	0.605	2.453	0.107	0.456
F-test	*	***	***	***	***	***	***
P_2O_5(kg ha^{-1})							
0	2.37	101.73	60.23	9.30c	48.61b	1.16	3.48
46	2.39	101.17	62.59	9.93b	50.57ab	1.15	3.59
92	2.40	102.03	61.87	10.27ab	50.08ab	1.18	3.71
138	2.40	102.21	62.71	10.67a	51.77a	1.23	3.86
LSD	0.110	1.103	2.702	0.541	2.194	0.096	0.408
F-test	NS	NS	NS	***	*	NS	NS
CV (%)	9.0	2.1	8.50	10.5	8.4	16.0	21.0

Means with the same letter within a column are statistically non-significant at P ≤ 0.05 according to Fishers' LSD, NS=non-significant, DPM=Days to physiological maturity, LAI=Leaf area index

The increase in plant height in response to the increased application of nitrogen may be attributed to the increment in vegetative growth parameters which could probably be due to the important role of nitrogen in plant photosynthesis by improving leaf area index and chlorophyll contents thus resulting in higher photosynthetic rate and higher vegetative growth [43]. In line with the present study, it has been reported that maximum plant height of onion at maximum N rates of 120 kg ha^{-1} N [44]. Phosphorus application did not affect plant height. In line with the findings of this study, reference [20] reported the absence of significant differences in plant height of onion plants due to application of different rates of phosphorus on vertisoles of central Ethiopian highlands.

The main effects of both nitrogen and phosphorus fertilizer significantly *(P≤0.001)* enhanced the number of leaves produced per plant (Table 2). Increasing the rate of nitrogen from nil to 34.5, 69, 103.5, and 138 kg N ha^{-1} enhanced leaf number per plant by additional values of 17, 24, 33, and 54%, in the order mentioned here.

The increased number of leaves due to the increase in N application could be attributed to the role nitrogen plays in enhancing biochemical processes, which in turn enhance vegetative growth. Reference [45] stated that N is a constituent of many fundamental cell components and it plays a vital role in all living tissues of the plant and no other element has such an effect on promoting vigorous plant growth. Accordingly [46], indicated that nitrogen is an essential element for onion growth through build-up of protoplasm and proteins, which induce cell division and meristematic activities. Consistent to the findings of this study, Reference [47] revealed increased number of leaves with increasing rates of N, with the maximum values up to 150 kg ha^{-1} and 200 kg ha^{-1} in onion and garlic, respectively.

Increasing the rates of phosphate from 0 to 46, 92 and 138 kg P_2O_5 ha^{-1} increased leaf number significantly by 7.0, 10, and 15%, respectively. However, the leaf numbers per plant obtained from plants grown at 46 and 92 kg P_2O_5 ha^{-1} and that obtained from 92 and 138 kg P_2O_5 ha^{-1} were in statistical parity Table (**2**). The maximum leaf number was obtained from plants grown at 138 kg P_2O_5 ha^{-1} whilst the minimum was obtained from those grown at nil application of phosphate. The increase in leaf number in response to the increased application of phosphate may be attributed to the role phosphorus plays in root growth and development and formation of phosphoproteins and phospho-lipids that encourage meristematic activity of plants, resulting in increased number of leaves per plant [48]. In line with the findings of the study, References [49, 20] reported significant increases in the number of leaves of onions due to increased application of P.

Nitrogen and phosphorus significantly affected leaf length of onion plants. However, there was no significant interaction effect of N and P on leaf length (Table 2). The highest leaf length was recorded at the highest N rate of 138 kg ha^{-1}, which, however, did not differ statistically from that at 103.5 kg N ha^{-1}. The positive effect of N on leaf length may be due to its role on chlorophyll, enzymes, and proteins syntheses. Reference [45] indicated that N is the major constituent of proteins and the presence of abundant protein tends to increase the size of the leaves and ultimately increase carbohydrate synthesis. In conformity to the present study, reference [44] reported significant increases in leaf length and diameter of onion with increases in N up to 150 kg ha^{-1} and 200 kg ha^{-1}, respectively.

With respect to phosphorus application, the longest leaves were obtained in response to the application of 138 kg P_2O_5 ha^{-1}. However, the leaf length value obtained at this rate of was in statistical parity with that obtained in response to the applying 46 and 92 kg P_2O_5 ha^{-1}. The shortest leaf was recorded for the control treatment (Table 2). The increase in leaf number in response to the increased application of phosphate may be attributed to the growth-promoting effect of the nutrient. In line with the findings of this study [50], reported an increased leaf length of onion plants with increasing rates of phosphorus.

Nitrogen fertilization significantly (*$P \leq 0.001$*) affected leaf diameter of onion plants. However, phosphorus application and its interaction with nitrogen did not (Table 3.2). The highest leaf diameter was observed at 138 kg N ha^{-1}, while the lowest leaf diameter was recorded for plants grown at the control treatment. There was about 39% increment in leaf diameter at 138 kg N ha^{-1} compared to the control treatment (Table 2).

The present findings are also in accord with those of [44, 51], who reported highest values of vegetative growth parameters of onion at the highest rates of nitrogen application. P application did not significantly affect leaf diameter, which is in line with the findings of [20] on vertisoles of central highlands of Ethiopia.

The leaf area index (LAI) of onion was significantly ($P \leq 0.001$) affected by application of different doses of nitrogen. However, phosphorus fertilization and its interaction with N did not affect this parameter Table (**2**). Although there was no significant difference with N at 103.5 kg ha^{-1}, N at 138 kg ha^{-1} resulted in a maximum leaf area index of 4.39. The minimum (2.77) was obtained at the control which was in statistical parity with N at 34.5 kg ha^{-1} Table (**2**). This might be due to the fact that nitrogen is an integral component of many essential plant compounds like chlorophyll, proteins and amino acids promotes carbohydrate synthesis through photosynthesis and ultimately increase vegetative growth of plants [52]. Similarly, reported that increasing the nitrogen application rate remarkably enhanced LAI expansion rate in Persian shallot, and maximum LAI was obtained at the highest dose of 300kg ha^{-1}.

Increasing the rate of nitrogen from nil to 34.5 and 69 kg N ha^{-1} did not affect bolting percentage. However, increasing the rate of nitrogen from 0 to 103.5 and 138 kg N ha^{-1} significantly decreased bolting percentage by 5.6 to 8%, respectively.

The results of this study also indicated that nitrogen application prolonged the days required to reach physiological maturity by the crop Table (**2**). When the rate of nitrogen was increased from 0 to 34.5, 69, 103.5, and 138 kg N ha^{-1}, the duration in days required to reach physiological maturity increased by 0.5, 1.7, 3, and 4.4% in the order listed here (Table **2**).

3.3. Bulb Characters

Nitrogen and phosphorus fertilization and their interaction did not significantly ($P \leq 0.05$) affect the formation of thick-necked bulbs Table (**3**). This could be due to the minimal direct effect of fertilization in the formation of thick-necked bulbs. In agreement with this suggestion, Brewster (2008) reported that neck-thickness is a physiological disorder that is influenced by seasons, sites and cultivars, not by fertility.

Table 3. Effect of N and P on neck thickness, split bulb, bulb length, bulb diameter, and mean bulb weight of onion.

Nitrogen (kg ha^{-1})	Neck thickness (cm)	Split bulbs (%)	Bulb diameter (cm)	Bulb length (cm)	Average bulb weight(g)
0	1.02	1.88(1.37)	4.52c	6.09b	105.84c
34.5	1.09	2.02(1.42)	4.93b	6.24b	109.10bc
69	1.16	2.07(1.44)	5.45a	6.58a	114.93a
103.5	1.16	2.25(1.50)	5.45a	6.84a	120.00ab
138	1.12	2.46(1.57)	5.67a	6.82a	119.78a
LSD	0.143	0.018	0.237	0.256	8.323
F-test	NS	NS	***	***	***
P_2O_5(kg ha^{-1})					
0	1.12	1.93 (1.39)	4.75c	6.58	113.38
46	1.09	2.04 (1.43)	5.11b	6.51	114.86
92	1.11	2.16 (1.47)	5.32b	6.41	111.87
138	1.10	2.37 (1.54)	5.64a	6.56	115.60
F-test	NS	NS	***	NS	NS
LSD	0.128	0.016	0.212	0.229	7.444
CV(%)	22.7	22	8.01	6.7	12.8

Means with the same letter within a column are statistically non-significant at $P \leq 0.05$ according to Fisher's LSD; NS=non-significant, the numbers in parenthesis are square root-transformed.

The formation of split bulbs was not significantly (*P ≤ 0.05*) influenced by N, P fertilization and their interaction Table (**3**). Consistent with the results of this study, [53, 13] indicated that bulb splitting is under genetic control, where growth in high temperatures and short days increases lateral shoot production.

It has been shown in Table (**3**) that nitrogen fertilization highly significantly (*P ≤0.001*) affected bulb length and diameter, while P fertilization only significantly affected bulb diameter. The interaction of N and P did not significantly affect both bulb length and diameter Table (**3**). The highest bulb diameter and length were observed at N rates of 138 and 103.5 kg ha^{-1}, respectively whilst the lowest bulb length and diameter were recorded at the control treatment, which were in statistical parity with bulb length recorded at the rate of 34.5 kg N ha^{-1} (Table **3**).

N fertilization at the rate of 138 kg ha^{-1} increased bulb diameter by almost 25% in comparison to the bulb diameter obtained in the control treatment. This may be linked to the increase in dry matter production and its allocation to the bulb. The maximum bulb length recorded at 103.5 kg N ha^{-1} was 12% higher than the bulb length obtained in the control treatment Table (**3**). In agreement with this finding [54 - 56], reported a significant increase in bulb diameter of onion with increase in nitrogen fertilization. Consistent with the results of this study [55 - 58], also reported increased onion bulb lengths in response to nitrogen application.

Bulb diameter was significantly (*P ≤0.001*) affected by phosphorus fertilization. The maximum bulb diameter was recorded in response to the application of 138 kg P_2O_5 ha^{-1}, showing about 19% increment over the control treatment Table (**3**). In accord with this result, phosphorus fertilization at 60 kg ha^{-1} significantly increased onion bulb diameter [59, 49]. The positive effect of P on bulb diameter could be attributed to its influence on partitioning assimilates to bulb development as suggested by [59].

Average bulb weight was significantly (*P ≤ 0.001*) affected by nitrogen but not by phosphorus fertilization and its interaction with N Table (**3**). The highest bulb weight was recorded in response to the application of 103.5 kg N ha^{-1}, which was in statistical parity with the bulb weight obtained at 69 and 138 kg N ha^{-1} whilst the lowest was obtained in the control treatment. There was a 13% increment in bulb weight at 103.5 kg N ha^{-1} in comparison with the control treatment Table (**3**). In conformity with these findings [59, 60], reported increased bulb weights of onions and shallots with increase in nitrogen application in Ethiopia, respectively. Moreover [56], reported similar findings. The increased bulb weight with N fertilization in the current study could be attributed to the increase in plant height, number of leaves produced, leaf length, and extended physiological maturity, which may have increased assimilate production and allocation to the bulbs.

3.4. Total and marketable bulb yields

There were significant (*P ≤ 0.001*) interaction effects of nitrogen and phosphorus fertilization on total and marketable bulb yields of onion Table (**4**). The highest total bulb yield was obtained in response to the application of 103.5 kg N ha^{-1} combined with 138 kg P_2O_5 ha^{-1}. However, the bulb yields obtained at these rates of the two combined fertilizers were in statistical parity with the total bulb yields obtained at 138 kg P_2O_5 ha^{-1}combined with 138 kg N ha^{-1} and 92 kg P_2O_5, and combined with 103.5 and 138 kg N ha^{-1}. The lowest total and marketable bulb yields were recorded at 0 kg N and P_2O_5 ha^{-1} Table (**4**). Thus, the maximum total bulb yield obtained in response to the combined application of 103.5 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1} exceeded the minimum total bulb yield obtained at nil application of the two fertilizers by about 53%. This increase was 57.4% for marketable bulb yield at the same combined rates of the two fertilizers. Increasing the rate of N up to 103.5 kg ha^{-1} combined with all doses of P_2O_5 led to increased production of total and marketable bulb yield.

Table 4. Effect of N and P fertilization on total and marketable bulb yield of onion.

Fertilizer levels	**Total Yield (t ha^{-1})**			
	P_2O_5 (kg ha^{-1})			
N (kg ha^{-1})	**0**	**46**	**92**	**138**
0	24.80k	25.95ijk	27.96ghi	25.30jk
34.5	26.73hijk	29.10fgh	29.46fg	28.64gh
69	27.84ghij	31.38def	29.71efg	34.35bc
103.5	29.51fg	32.73cd	35.61ab	37.94a
138	31.50def	32.19cde	35.86ab	37.82a
F-test	***			
LSD	2.632			
CV (%)	7.4			
	Marketable yield(t ha^{-1})			
	P_2O_5 (kg ha^{-1})			
N (kg ha^{-1})	0	46	92	138
0	21.98k	23.83jk	26.84fghi	22.83K
34.5	24.43ijk	26.65ghi	26.12ghij	25.61hij
69	24.48ijk	28.22efgh	28.08efgh	31.15bcd
103.5	24.97cdef	29.65cde	32.24abc	34.60a
138	28.69defg	27.65efgh	32.09abc	33.06ab
F-test	***			
LSD	2.772			
CV (%)	8.6			

Means with the same letter within a column are statistically non-significant at $P \leq 0.05$ according to Fisher's LSD.

In conformity with the results of this study [61], reported a significant interaction effect of nitrogen and phosphorus on bulb yield of onion [62]. 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, 60 P_2O_5 and 80 K_2O kg ha^{-1}, respectively. However, absence of significant interaction effect of nitrogen and phosphorus on bulb yield of onion was reported in central Rift Valley Region of Ethiopia [63]. This significant N and P interaction observed in the current study might be attributed to the effect of phosphate fertilizers in increasing use efficiency of nitrogen fertilizer as suggested by [64].

3.5. Dry Bulb Yield, Total Dry Biomass, and Harvest Index

Nitrogen fertilization significantly *($P \leq 0.001$)* affected both bulb dry weight and total dry biomass yield of onion while it did not significantly affect harvest index. Moreover, P and its interaction with N did not significantly affect all parameters considered Table (**5**). Bulb dry weight and total dry biomass yield increased by about 15% and 14% at 103.5 kg N ha^{-1} over the checks, respectively. These characters showed a tendency to increase with the increase in N up to 138 kg ha^{-1}. However, further increases in N supply beyond 103.5 kg ha^{-1} did not affect the characters Table (**5**). In line with this finding, nitrogen at the concentration up to 5,000 $mg \cdot L^{-1}$ increased bulb fresh and dry weights [65]. The observed improvement in bulb dry weight as well as total dry biomass yield could be attributed to increased photosynthetic area in response to N fertilization that may have enhanced assimilate production and partitioning to the bulbs [66]. also reported a positive and significant correlation of leaf area index with total dry biomass and dry bulb yield of onion.

Table 5. Effect of nitrogen and phosphorus fertilization on mean dry bulb yield, total dry biomass and harvest index of onion.

Fertilizer levels (Kg ha^{-1})	Dry bulb yield per plant (g)	Total dry biomass per plant (g)	Harvest index
N			
0	9.95b	13.96c	0.70
34.5	8.25c	12.19d	0.69
69	10.66ab	15.38b	0.69
103.5	11.48a	15.91ab	0.73
138	11.40a	16.53a	0.72
F-test	***	***	NS
LSD	0.938	0.953	0.047
P_2O_5			
0	10.50	14.71	0.72
46	10.37	14.61	0.72
92	10.15	14.76	0.69
138	10.38	15.10	0.69
F-test	NS	NS	NS
LSD	0.839	0.852	0.042
CV (%)	15.9	11.3	11.8

Means with the same letter within a column are statistically non-significant at $P \leq 0.05$ according to Fisher's LSD, NS=non-significant

3.6. Economic Analysis

Partial budget with dominance for the fertilizer N and P is shown in Table (**6**). Dominance analysis revealed that treatments N0$P_2O_5$0, N34.5 $P_2O_5$0, N34.5 $P_2O_5$46, N0 $P_2O_5$92, N69 P_2O_5 46, N138$P_2O_5$0, N103.5$P_2O_5$46, N103.5P_2O_5 92 and N103.5$P_2O_5$138 were undominated. This indicated that increase in the total cost of the dominated treatments did not increase the net benefit proportionally; that means benefits were lower than the lowest total costs. Treatments without fertilizer N and P had lower total variable cost (TVC) when ranking treatments in order of increasing total cost. However, the highest net benefit was obtained with N103.5P138 resulting in the earning of 244491.75 Birr ha^{-1}.

Table 6. Partial budget with dominance.

Treat	Yld(t ha^{-1})	Ajy(t ha^{-1})	Urea(birr)	TSP(kg ha^{-1})	Labour(birr)	TVC	GFB(AjY)	NB	Dominance
N0P0	21.98	19.97	0	0	0	0	158281.5	158281.50	ND
N34.5P0	24.44	21.99	562.5	0	18.75	581	175934.25	175353.00	ND
N0P46	23.83	21.45	0	950	25	975	171607.50	170632.50	D
N69P0	24.48	22.04	1125	0	37.5	1163	176281.50	175119.00	D
N34.5P46	26.65	23.99	562.5	950	43.75	1556	191884.50	190328.25	ND
N103.5P0	24.97	22.47	1687.5	0	56.25	1744	179784.00	178040.25	D
N0P92	26.85	24.16	0	1900	50	1950	193309.50	191359.50	ND
N69P46	28.22	25.40	1125	950	62.5	2138	203211.00	201073.50	ND
N138P0	28.70	25.83	2250	0	75	2325	206638.50	204313.50	ND
N34.5P92	26.13	23.51	562.5	1900	68.75	2531	188106.00	185574.75	D
N103.5P46	29.66	26.69	1687.5	950	81.25	2719	213540.38	210821.63	ND
N0P138	22.83	20.55	0	2850	75	2925	164408.25	161483.25	D
N69P92	28.08	25.27	1125	1900	87.5	3113	202185.00	199072.50	D
N138P46	27.65	24.89	2250	950	100	3300	199110.00	195810.00	D
N34.5P138	25.62	23.05	562.5	2850	94.02	3507	184434.00	180927.48	D
N103.5P92	32.25	29.02	1687.5	1900	106.25	3694	232197.00	228503.25	ND
N69P138	31.15	28.04	1125	2850	112.5	4088	224283.75	220196.25	D
N138P92	32.10	28.89	2250	1900	125	4275	231111.00	226836.00	D
N103.5P138	34.61	31.15	1687.5	2850	131.25	4669	249160.50	244491.75	ND
N138P138	33.06	29.75	2250	2850	150	5250	238034.25	232784.25	D

The analysis of marginal rate of return, on the other hand, revealed that the return per unit cost of production was highest with N69 $P_2O_5$46 followed by N34.5 $P_2O_5$0 and N103.5 $P_2O_5$92 having 5180.8, 2937.0 and 1813.5 Birr, respectively Table (**7**). This indicates that there was a rate of return of 518, 293.7 and 181.3 Birr for every Birr invested. All the undominated treatments resulted in a rate of return above the minimum acceptable rate of return (50-100%) [35]. In this experiment, the highest marginal rate of return (1813.5%) was obtained at the shift of treatment from N103.5 $P_2O_5$46 to N103.5 $P_2O_5$92 which resulted in a rate of return above 50%. Therefore, treatment N103.5 P_2O_5 92 had the highest marginal rate of return (1813.5%) which is above the minimum required acceptable rate of return (Table **7**).

Table 7. Marginal rate of return (MRR) and Sensitivity analysis to establish the profitability of onion to nitrogen and phosphorus.

Treatment	Ajy (t/ha)	Urea (birr)	TSP (birr)	Labor (birr)	TVC	NB	C.TC	C.NB	MRR(%)
N0P0	19.97	0	0	0	0	158281.50			
N34.5P0	21.99	562.5	0	18.75	581	175353.00	581	17071.50	2937.0
N34.5P46	23.99	562.5	950	43.75	1556	190328.25	975	14975.25	1535.9
N0P92	24.16	0	1900	50	1950	191359.50	394	1031.25	261.9
N69P46	25.40	1125	950	62.5	2138	201073.50	188	9714.00	5180.8
N138P0	25.83	2250	0	75	2325	204313.50	188	3240.00	1728.0
N103.5P46	26.69	1687.5	950	81.25	2719	210821.63	394	6508.12	1652.9
N103.5P92	29.02	1687.5	1900	106.25	3694	228503.25	975	17681.63	1813.5
N103.5P138	31.15	1687.5	2850	131.25	4669	244491.75	975	15988.50	1639.8

CONCLUSION

The findings of this study revealed that onion responded well to the application of nitrogen and phosphorus fertilizers. The two fertilizers interacted to influence the yield of the crop. Application of nitrogen at the rate of 103.5kg N ha^{-1} and phosphorus at the rate of 138 P_2O_5 ha^{-1} resulted in higher total and marketable bulb yields. However, these bulb yields were in statistical parity with the bulb yields obtained at 103.5 and 138 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. This result shows that the optimum biological bulb yield of the crop was obtained at the combined application of 103.5 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. Moreover, based on economic analysis, the highest net benefit and economic returns were recorded at 103.5 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. Therefore, nitrogen at the rate of 103.5 kg N ha^{-1} and phosphorus at the rate of 92 kg P_2O_5 ha^{-1} should be applied to enhance the productivity and economic benefit of Bombay Red onion variety in the in the study area. Further studies should be done over locations and growing seasons to find area-specific recommendation of the two fertilizers for onion production in the Central Rift Valley region of the country.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this review.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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