RESEARCH ARTICLE

Yield of onion (*Allium cepa* L.) as influenced by nitrogen and phosphorus fertilizer rates at Alage, central rift valley of Ethiopia

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Onions is among the most important vegetable crops produced in Ethiopia by both smallholder farmers and commercial growers for both local and export markets. However, its productivity is low mainly due to absence of location specific fertilizer recommendation. Therefore, the present experiment was conducted on Randomized Complete Block Design (RCBD) in factorial arrangement with three replications at Alage Agriculture Technical Vocational Educational Training College Research field in January 2021 to determine the effects of Nitrogen (N) and Phosphorus (P) fertilizer rate on yield of onion. The results of the experiment revealed that, plant height, leaf length, leaves number, shoot dry matter and bulb length of onion influenced by main effect of N and P and also dry total biomass, bulb weight, bulb diameter, bulb dry matter, marketable bulb yield and Total Suspended Solids (TSS) highly significantly affected by the interaction effect of N-P fertilizer rate. Nevertheless, more researches are needed in different locations and on different seasons to come up with general recommendation.

Key Words: *Growth; Nitrogen; Onion; Phosphorus; Yield*

INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family *Alliaceae* and is a cool season herbaceous bulb vegetable crop and it can be propagated by seed, transplants or sets and used as both green onions and dry onion. Onions can be produced on a wide range of climatic conditions. However, their production is more successful in mild climate in the absence of extremes of heat or cold and too much rainfall.

Ethiopia has diversified agro-climatic conditions that are suitable for the production of a wide range of fruits, vegetables, flowers and onion. Onion is an important cash crop for Ethiopian farmers produced in different parts of the country for house hold, local market consumption and for regional export market. However, the most suitable altitude for onions production in Ethiopian condition ranges between 700 and 1800 m above sea level.

Onion has many medicinal values. Different evidences suggest that onions are effective against the common cold, heart disease, diabetes, osteoporosis and other diseases. Compounds obtained from onion have a wide range of health benefits such as anti-carcinogenic properties, anti-platelet activity, antithrombotic activity, asthmatic and antibiotic effects [1]. In Ethiopia, onion is the main cash crop, which contributes for the commercialization of the rural economy and creation of many off-farm jobs [2].

Onions are more susceptible than most crop plants in extracting nutrients, especially the immobile types, because of their shallow and unbranched root system; thus, often respond well to addition of fertilizers. Nitrogen (N) and Phosphorus (P) are the primary macronutrients that deficient for the plants because of the large quantities taken up from the soil relative to other essential nutrients. Plant demand for N can be achieved from a combination of nitrogen obtained from soil and application of fertilizer N to ensure optimum growth. Phosphorus deficiency is one of the most important constraints to crop production in many tropical soils, due to low native content and high P fixation capacity of the soil. Phosphorus is essential nutrient for root development and plant growth thus when the availability of phosphorus is limited plant growth is usually reduced. In onions, P deficiencies reduce root and leaf growth, bulb size and yield and can also delay maturation.

The utilization of transgenic plants for antibody production not only benefits human health but also contributes to plant protection and agricultural sustainability. By engineering plants to produce antibodies against specific pathogens or pests, farmers can reduce reliance on chemical pesticides and mitigate crop losses due to diseases, thereby promoting sustainable agriculture practices. In Ethiopia, 2020/21 during the rainy season 38,952.58 hectares were planted and approximately 346,048.09 tons of bulbs were obtained at an average yield of 8.88 t ha^{-1}.

Production and productivity in Ethiopia are very low compared with the potential of country. This is due lack of poor agronomic practices, shortage of seeds of improved varieties, diseases, insect pests and poor extension services, high costs of chemical fertilizers [3]. Onion nitrogen demand is higher than most of the nutrients. In the study area, farmers use in appropriate rate of nitrogen and phosphorus fertilizers and don't use improved storage and other agronomic practices. Improved onion production involves use of different agronomic practices such as improved variety, appropriate seed rate, spacing, fertilizer rate and pesticide application at the recommended rate. It is needed to identify the onion yield potential by different rate of nitrogen and phosphorus fertilizer in the study area. Therefore, this study aimed to evaluate the effects of nitrogen and phosphorus rate on the growth, yield and yield components of onion (*Allium cepa* L.).

MATERIALS AND METHODS

Description of the study site

The study was conducted at Alage Agricultural Technical and Vocational Educational and Training College experimental field. Alage is located 217 km south of Addis Ababa and 32 km west of Bulbula town in the vicinity of Abidjata and Shalla lakes. It is situated between 7°65'N latitude and 38°6'E longitudes and at an altitude of 1600 meters above sea level. Its mean annual rainfall is 800 mm with an average maximum and minimum temperature of 29°C and 11°C respectively.

Description of the experimental materials

Experimental material for this study was Bombay red variety of onion.

Treatments and experimental design

The experiment was laid out in factorial arrangement in a Randomized Complete Block Design (RCBD) with three replications. The treatments were factorially the combination of four levels of N (0, 46, 92 and 138 kg ha^{-1}) with four levels of P (0, 35, 70 and 105 kg ha^{-1}). The fertilizer sources were (46% N) and TSP (46% P) respectively. The full dose of P and half dose of N fertilizer were applied at transplanting and the remaining half dose of N is side-dressed forty-five days after transplanting.

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Experimental procedure

Before transplanting seedlings, the experimental field ploughed and leveled by tractor; ridges and plots were made manually. Then the total of 48 plots based on experimental design size were prepared in which 16 plots were allocated in each of the three replications. The seedlings were grown in the nursery with careful management and strict follow up until seedlings reach to the required stage as per the treatments. Seedlings were passed hardening before transplanting to the main field. Half dose of N ha^{-1} was applied uniformly to all plots during transplanting. The remaining half dose of N ha^{-1} rates was side-dressed 45 days after transplanting for all plots. Triple Superphosphate (TSP) was applied as a single application as per specific rates at the time of transplanting based on the treatments. Weeding was done manually whenever necessary throughout the experimental period. Mancozeb 80 WP (3 kg ha^{-1}) plus Ridomil (3.5 kg ha^{-1}) were used. All other agronomic practices were applied uniformly for all treatments.

Data collection

Pre-planting soil samples were taken randomly in a *zigzag* fashion from the experimental field at the depth of 0 to 30 cm and analyzed for soil texture, total nitrogen, Cation Exchange Capacity (CEC), exchangeable potassium, organic carbon and available phosphorous at Ziway soil and water analysis laboratory.

Crop data

The following seventeen phonological, growth, yield and yield component data were collected on a plot and plant basis from each experimental unit. These traits were: day to maturity, plant height (cm), leaf number, leaf length (cm), fresh weight (g/plant), shoot dry matter (g/plant), dry total biomass (g), bulb length (cm), neck diameter (cm), bulb diameter (cm), average bulb weight (g), bulb dry matter (g), unmarketable bulb (ton/ha), marketable bulb yield (ton/ha), total bulb yield (ton/ha), harvest index (%) and total soluble solids (%).

Data analysis

Data collected was subjected to Analysis of Variance (ANOVA) using Statistical Analysis System (SAS) Software packages of version 9.3. Significant treatment means were separated using the Least Significance Difference (LSD) test at 5% probability level. Correlation analysis was determined for parameter using the same software.

RESULTS AND DISCUSSION

Soil physio-chemical properties of the experimental site

The result of soil analysis indicated that the texture of the soil was silt loam with a proportion of 31.5, 50.5 and 18% of sand, silt and clay, respectively. The soil was moderately alkaline in reaction with a pH value of 7.82 (Table 1). The pH requirements for different crop is different. However, the preferable pH ranges for most crops and a productive soil range from 4-8. Thus, the pH of the experimental soil was within the range of productive soil for the production of onion crop. According to soil Organic Carbon (OC) content was rated as very low (<2%), low (2-4%), medium (4-10%), high (10-20%) and very high (>20%) and thus the soil at the experimental site has very low OC content 1.39%. The total N is rated as very low (0.25). Hence, total N of the soil of the experimental field was within the low N (0.12%) range which indicates that the application of additional N sources to the soil to achieve optimum crop yields [4]. According to the ratings of top soils having Cation Exchange Capacity (CEC) of >25, 15-25, 5-15 and <5 cmol (+) kg^{-1} is classified as high, medium, low and very low, respectively. Thus, the CEC value (34.74 cmol (+) kg^{-1}) obtained from the analysis indicated the high CEC of the study area site. In general, for soils low in mineral nutrients particularly N, P is needed to be applied to improve the soil fertility and enhance crop productivity.

TABLE 1

Physico-chemical properties of the experimental soil before planting

Analysis result			
Parameters	Methods	Unit	Values
Silt	-	%	31.5
Silt	-	%	50.5
Clay	-	%	18
Textural class	Bouycos hydrometer	-	Silt loam
pH	pH meter	pH (H_2O)	7.82
Organic carbon	Walkley and black	%	1.39
Total nitrogen	Kjeldahl	%	0.12
Electrical conductivity	Electro conductivity meter	ds m^{-1}	0.34
Available phosphorus	Olsen method	mg kg^{-1}	18.36
Available potassium	Ammonium acetate	mg kg^{-1}	570
Cation exchange capacity	Ammonium acetate	cmol kg^{-1}	34.74

Phenology and growth parameters of onion

Days to maturity: The result of the analysis of variance indicated that days to maturity was significantly (P<0.001) affected by the main effects of nitrogen and phosphorus rates. As indicated Table 2 plots that received 138 kg ha^{-1} nitrogen fertilizer took 114.5 days to attain physiological maturity, while non-fertilized onion plants required 99.9 days to mature. Regardless of levels, maximum application of nitrogen fertilizer at 138 kg ha^{-1} extended the day to attain physiological maturity by about 14 days over the unfertilized plot (99 days). This could be due to the fact that nitrogen fertilization extended the vegetative growth period of plants; as a result, it delayed maturity. This result is in agreement with the findings of Aweke et al. [5], Gererufael et al. [6], Kitila et al. [7] and Tadesse et al., [8] who reported that increasing the rate of nitrogen promotes excessive vegetative growth and delayed maturity. Similarly, phosphorus application had shown a highly significant (P<0.001) difference on days to physiological maturity. Application of phosphorus at a rate of 0 kg ha^{-1} (control) delayed days to physiological maturity by about 2 days as compared to 105 kg ha^{-1} rate of phosphorus, whereas 35 kg ha^{-1} and 70 kg ha^{-1} have statically the same results recorded (no significantly difference). Because there is significant hasting effect of phosphorus application above 35 kg ha^{-1} due to enhancing plant biochemical processes. This result is in agreement with that of Limeneh et al. [9], who reported that application of phosphorus at rate of 105 kg P_2O_5 ha^{-1} reduced days to maturity by 4 days as compared to control treatment. Because there is significant hasting effect of phosphorus application above 35 kg ha^{-1} due to enhancing plant biochemical processes.

TABLE 2

Main effect of nitrogen and phosphorus fertilizer rate on days of physiological maturity, plant height, leaf length, number of leaves per plant and n shoot dry matter at Alage

Treatments		DM	PH	LL	LN	SDM
Nitrogen rate (kg ha^{-1})	N0	99.91^{d}	54.35^{d}	31.98^{c}	7.91^{c}	2.67^{d}
	N46	104.66^{c}	61.53^{c}	36.14^{b}	10.16^{b}	3.27^{c}
	N92	109.08^{b}	67.01^{b}	37.86^{a}	12.50^{a}	3.70^{b}
	N138	114.500^{a}	78.93^{d}	38.79^{a}	13.00^{a}	4.08^{a}
	LSD (0.05)	1.6	0.73	0.86	0.51	0.28
	CV	1.7	1.35	2.87	5.71	0.45

Phosphorous rate (kg ha^{-1})	P0	108.08^{a}	64.37^{c}	34.81^{c}	9.83^{c}	3.23^{c}
	P35	107.33^{a}	64.90^{bc}	35.68^{c}	10.83^{b}	3.39^{bc}
	P70	107.33^{a}	65.60^{b}	36.64^{c}	11.33^{ab}	3.50^{ab}
	P105	105.41^{b}	66.95^{a}	37.64^{c}	11.58^{a}	3.60^{a}
	LSD (0.05)	1.6	0.73	0.86	0.51	0.35
	CV	1.79	1.35	2.87	5.71	6.1

Note: PDM: Physiological Days of Maturity; PH: Plant Height; LL: Leaf Length; LN: Leaves Number per plant; SDM: Shoot Dry Matter; N0: Nil Nitrogen rate; N46: 46 kg Nitrogen/ha; N92: 92 kg Nitrogen/ha; N138: 138 kg Nitrogen/ha; P0: Nil Phosphorus rate; P35: 35 kg Phosphorus/ha; P70: 70 kg Phosphorus/ha; P105: 105 kg Phosphorus/ha; LSD: Least Significance Difference; CV: Coefficient of Variation.

Plant height (cm): Main factors of nitrogen and phosphorus had shown a highly significant ($p<0.001$) variation on mean plant height at physiological maturity. The longest onion plants (78.93 cm) were observed by the application of nitrogen fertilizer at the rate of 138 kg ha^{-1}, while shortest (54.35 cm) onion plants were observed on non-fertilized treatment (Table 2). Plants without nitrogen fertilizer (control) were generally shorter than those plants supplied with increased level of nitrogen fertilizer. The increase in height at increased application of nitrogen could be attributed to its involvement as building blocks in the synthesis of amino acids, as they link together and form proteins and make up metabolic processes required for plant growth. Similar results have been reported by Aweke et al. [5], Kitila et al. [7], Molla et al. [10], Sharma et al. [11] and Tadesse et al., [8]. Similarly, maximum application of phosphorus at 105 kg ha^{-1} resulted highest (66.95 cm) mean plants height of Bombay red onion plant, while 64.37 cm mean plant height was recorded from control (Table 2). The positive response of onion to phosphorus fertilization was mainly due to the fact that the plants have weak root system to effectively explore and utilize soil phosphorus and it is role as part of the enzyme system having a vital role in the synthesis of other compounds from carbohydrates and is considered as a constituent of nuclear proteins. Similar positive responses of P on onion plant height were reported by Aweke et al., [5].

Leaf length (cm): Onion leaf length was significantly ($P<0.001$) influenced by the main effects of both nitrogen and phosphorus application rates. Leaf length of onion plants increased significantly across the increasing rate of the nitrogen fertilizer. The higher mean value (38.79 cm) was obtained from the plot that received 138 kg of N ha^{-1}, whereas the lowest (31.98 cm) from control (Table 2). The reason for longer leaf length of onion with increasing nitrogen fertilizer level might be due to nitrogen is a constituent of many fundamental cell components and plays a vital role in cell division and elongation in plants. It improves the vegetative growth of the onion which leads to increasing in leaf length through the increased photosynthetic area in response to nitrogen fertilization that enhanced assimilates production and partitioning to the plants. The results of this study are in agreement with finding of Gererufael et al. [6], who reported that application of 103.5 kg ha^{-1} nitrogen gave the highest leaf length. This finding also agrees with that of Tilahun et al. [12], who reported that, application of 200 kg N ha^{-1} significantly enhanced the length of onion leaves. Similarly, Etana et al. [13], indicated that application of nitrogen at 150 kg ha^{-1} gave the highest onion leaf length.

Application of phosphorus had shown a highly significant ($p<0.001$) difference on the leaf length of Bombay red onion plants. As presented in (Table 2), highest leaf length (37.64 cm) was recorded from plots that received 105 kg P ha^{-1}. While the lower (34.81 cm) from the control. This might be because of phosphorus is an essential nutrient and the presence of phosphorus in the soil encourages plant growth. The results are correlated to the findings of Aweke et al. [5], who reported that increasing NPSB fertilizer from 0 to 300 kg increases leaf length of onion.

Leaf number per plant: The analysis of variance revealed that the main effect of nitrogen and phosphorus had shown significant difference ($p<0.001$) on the mean number of leaves per plant at physiological maturity. In the case of nitrogen application rate, the higher mean value (12.50 and 13.00) was obtained from plot that were treated with maximum rate of nitrogen (92 and 138 kg ha^{-1}). On the other hand, the lower mean values (7.91) were recorded in the control treatment. The maximum number of leaves per plant of onion obtained from treatments that received 138 kg N ha^{-1} and 92 kg N ha^{-1} might be due to nitrogen mainly related to production of new shoots and vigor in vegetative growth of plants which is directly responsible for increasing leaf number as described by. This result in agreement with the findings of Aweke et al. [5], who reported that highest leaf number per plant of onion was recorded with the higher application of 300 kg NPSB ha^{-1}. Similarly, Kitila et al. [7], also indicated the highest number of leaves per plant of onion was recorded from treatment that receives 150 Nitrogen, Phosphorus and Sulfur (NPS) kg ha^{-1}. Increased application of phosphorus fertilizer rate increase leaves number per plant in this present study. Higher (11.58) leaves number per plant were recorded from plots treated with 105 kg P ha^{-1}, whereas the lower (9.8) from plots that were not fertilized by phosphorus. This could be probably attributed to better absorption of the nutrients by their complementary function in stimulating of lateral root production.

Shoot dry matter (g/plant): The analysis of variance revealed that the main effects of nitrogen and phosphorus application significantly ($P<0.01$) influenced shoot dry matter yield of onion plants. Shoot dry matter yield per plant of onion significantly increased across the different rates of nitrogen and phosphorus application. Thus, plots that received 138 kg N ha^{-1} results higher (4.08 gm) shoot dry matter over nil application of nitrogen. In the case of phosphorus application, higher (3.60 gm) shoot dry matter was observed from plots that received 105 kg P kg ha^{-1} followed by plots treated with 70 kg P ha^{-1} application rate. While, the lower (3.23 gm) shoot dry matter was recorded from non-fertilized treatment (Table 2). The present finding is in agreement with the results of Aweke et al. [5], who indicated that higher shoot dry weight was obtained when the rate of Nitrogen, Phosphorus, Sulfur and Boron (NPSB) fertilizer was increased from 0 kg N ha^{-1} to 300 kg ha^{-1}. Similarly, Tilahun et al. [12], also reported that combined application of N (200 kg N/ha) and S (45 kg/ha) gives the highest (12.57 g) shoot dry weight whereas the application of Nand S at the rate of 100 and 0 kg ha^{-1} respectively gives the lowest (6.83 g) shoot dry weight.

Fresh weight of above ground biomass (g/plant): Fresh weight of above ground biomass of onion was significantly ($P<0.001$) influenced by the interaction effect of nitrogen and phosphorus fertilizer rates. The higher (48.20 gm) fresh weight of above ground biomass of onion plants were recorded in plots where 138 kg N ha^{-1} and 70 kg P ha^{-1} fertilizer was applied. On the other hand, the lower (34.97 gm) fresh weight was recorded from non-fertilized treatment (Table 3). Fresh weight of above ground biomass per plant of onion significantly increased across the different rates of nitrogen and phosphorus application. This is due to nitrogen increases or enhances assimilate production in onion plants. The results of the present study agree with the results of Sharma et al. [11], who found increased total biomass yields of onion with higher nitrogen application rates.

TABLE 3
Interaction effect of nitrogen and phosphorus on fresh weight

Interactions	Traits		
	FW	DTBY	SC
N0*P0	34.97^{i}	4.70^{k}	85.33^{i}
N0*P35	36.23^{h}	5.70^{j}	87.00^{h}
N0*P70	35.89^{hi}	5.86^{j}	86.00^{i}
N0*P105	36.23^{h}	7.50^{i}	88.66^{g}
N46*P0	39.40^{g}	8.26^{h}	90.33^{f}
N46*P35	38.90^{g}	8.13^{h}	93.00^{e}
N46*P70	39.66^{g}	8.93^{g}	94.00^{d}
N46*P105	40.93^{f}	9.46^{f}	94.33^{cd}
N92*P0	42.50^{e}	10.70^{e}	95.00^{c}
N92*P35	43.90^{d}	10.86^{e}	94.00^{d}
N92*P70	43.9^{d}	11.93^{d}	96.00^{b}
N92*P105	45.15^{c}	12.60^{c}	94.00^{d}
N138*P0	47.06^{b}	12.86^{c}	96.66^{b}
N138*P35	47.45^{ab}	13.43^{b}	96.33^{b}
N138*P70	48.20^{a}	13.73^{ab}	97.66^{a}
N138*P105	47.84^{ab}	13.93^{a}	97.66^{a}
LSD(0.05)	1.01	0.46	0.85
CV	1.45	2.82	0.55

Note: FW: Fresh Weight of above ground biomass; DTBY: Dry Total Biomass Yield; SC: Stand Count; N0: Nil Nitrogen rate; N46: 46 kg Nitrogen/ha; N92: 92 kg Nitrogen/ha; N138: 138 kg Nitrogen/ha; P0: Nil Phosphorus rate; P35: 35 kg Phosphorus/ha; P70: 70 kg Phosphorus/ha; P105: 105 kg Phosphorus/ha; LSD: Least Significance Difference; CV: Coefficient of Variation.

Dry total biomass yield (g): The analysis of variance revealed that the interaction effect of the two factors significantly ($P<0.001$) influenced dry total biomass yield. With the increase in combined application of nitrogen and phosphorus rate, dry total biomass yield of the onion plants increased significantly. Thus, plants treated by 138 kg N ha^{-1} with 70 kg P ha^{-1} and 105 kg P ha^{-1} produced the higher (13.73 and 13.93 gm) dry total biomass yield. However, plants treated with nil kg N and P ha^{-1} produced the lower (4.7 gm) dry total biomass yield (Table 3).

The increase in total dry biomass yield in response to the increasing rate of nitrogen and phosphorus fertilizer may be probably associated with the nitrogen supply, which enhances the vegetative growth of plants like leaf number, leaf diameter, leaf length and plant height which contribute for improved rate of photosynthesis and assimilate production in the vegetative part and partitioning to the bulbs. This finding is in agreement with that of Tilahun et al. [12], who stated that total dry biomass yield increase when the nitrogen rate increases from 100 kg ha^{-1} to 200 kg ha^{-1}.

Yield and yield components

Average bulb weight (g): The interaction effect of nitrogen and phosphorus application levels showed significant ($P<0.001$) variation on mean bulb weight. The higher (49.70 gm) mean bulb weight was recorded from maximum combined application of 138 kg N ha^{-1} and 105 kg P ha^{-1} and the lowest (39.60 gm) from control treatment (Table 4). The mean bulb weight improvement in response to increased application of nitrogen and phosphorus may be attributed to the increase in plant height, number of leaves produced, leaf diameter, leaf length and extended physiological maturity in response to the fertilization all might have increased assimilate production and allocation to the bulbs. This finding is in agreement with the finding of Tadesse et al. [8], who stated that average bulb weight of onion significantly raised when the rate of nitrogen rate increase from 0 to 50, 50 to 100 and from 100 to 150 kg ha^{-1}. Similarly, to this finding again Sharma et al. [11], reported that the average bulb weight shows significant increment (41.32%) compared to the control when the rate of nitrogen increases to 150 kg ha^{-1}.

TABLE 4

Interaction effect of nitrogen and phosphorus on fresh weight

Interactions	Traits							
	ABW	BD	BDMY	MY ha^{-1} (ton)	UMYha^{-1} (ton)	TBYha^{-1} (ton)	HI	TSS
N0*P0	39.60^{i}	2.43^{j}	2.26^{j}	7.30^{g}	1.56^{a}	8.86^{f}	48.12^{i}	7.73^{h}
N0*P35	40.70^{h}	2.60^{i}	3.10^{i}	8.83^{f}	1.36^{b}	10.20^{e}	54.42^{h}	8.36^{g}
N0*P70	42.30^{g}	2.66^{hi}	3.20^{i}	9.03^{f}	1.23^{c}	10.26^{e}	54.54^{h}	8.10^{gh}
N0*P105	42.56^{g}	3.00^{gh}	4.50^{h}	9.10^{f}	1.10^{cd}	10.20^{e}	60.32^{fg}	8.50^{g}
N46*P0	44.20^{f}	3.16^{fg}	5.10^{g}	11.20^{e}	1.16^{ed}	12.36^{d}	61.69^{fg}	9.10^{f}
N46*P35	45.06^{ef}	3.33^{efg}	4.83g	11.76^{d}	1.00^{ef}	12.76^{d}	59.42^{g}	9.23^{f}
N46*P70	45.46^{e}	3.33^{fg}	5.60^{f}	11.76^{e}	0.90^{fg}	13.00^{d}	62.69^{ef}	9.26^{ef}
N46*P105	45.46^{e}	3.30^{fg}	6.16^{e}	12.10^{e}	0.80^{gh}	14.13^{c}	65.14^{de}	9.70^{de}
N92*P0	46.90^{d}	3.50^{def}	7.20^{d}	13.33^{d}	0.7^{h}	14.30^{c}	67.30^{bcd}	10.10^{d}
N92*P35	46.70^{d}	3.66^{cde}	7.20^{d}	13.60^{d}	0.60^{ij}	14.90^{bc}	66.27^{cd}	11.31^{b}
N92*P70	48.10^{c}	3.83^{bcd}	8.10^{c}	14.36^{cd}	0.50^{jk}	14.86^{bc}	67.88^{bc}	10.83^{c}
N92*P105	48.20^{c}	3.80^{cd}	8.80^{c}	15.33^{bc}	0.40^{kl}	15.7^{a}	68.89^{bc}	11.10^{bc}
N138*P0	48.36^{bc}	3.8333^{bcd}	9.03^{b}	16.30^{a}	0.36^{l}	16.66^{a}	70.20^{a}	12.80^{a}
N138*P35	49.36^{ab}	4.00^{abc}	9.43^{a}	16.43^{ab}	0.23^{kl}	16.66^{a}	70.22^{a}	12.40^{a}
N138*P70	48.73^{abc}	4.16^{ab}	9.56^{a}	16.70^{a}	0.10^{m}	16.80^{a}	69.67^{ab}	12.66^{a}
N138*P105	49.70^{a}	4.33^{a}	9.60^{a}	16.70^{a}	0.10^{m}	16.80^{a}	68.89^{bc}	12.70^{a}
LSD(0.05)	1.05	0.1581	0.26	1.1	0.13	1.12	2.79	0.46
CV	1.38	1.9	2.46	4.34	6.06	4.17	2.64	2.73

Note: ABW: Average Bulb Weight; BD: Bulb Diameter; BDMY: Bulb Dry Matter Yield; MY: Marketable Yield; UMY: Unmarketable Yield; TBY: Total Bulb Yield; HI: Harvesting Index; TSS: Total Soluble Solid; N0: Nil Nitrogen rate; N46: 46 kg Nitrogen/ ha; N92: 92 kg Nitrogen/ha; N138: 138 kg Nitrogen/ha; P0: Nil Phosphorus rate; P35: 35 kg Phosphorus /ha; P70: 70 kg Phosphorus/ha; P105: 105 kg Phosphorus/ha; LSD: Least Significance Difference; CV: Coefficient of Variation.

Bulb diameter (cm): The diameter of onion bulbs was significantly (P<0.001) influenced by the combined application of nitrogen and phosphorus fertilizer. Regardless of levels, maximum combined application of nitrogen and phosphorus at 138:105, 138:70 and 138:35 kg ha^{-1} gave larger bulb diameter 4.33:4.16 and 4.00 cm, whereas the smaller 2.43 cm bulb diameter was recorded from control treatment (Table 4). Larger bulb diameter onion due to nitrogen application is likely as because nitrogen encourages cell elongation, above ground vegetative growth and to impart dark green color of leaves which may be linked to the increase in dry matter production and allocation to the bulb. On the other hand, phosphorus plays a role in cell division, so that combined application of nitrogen and phosphorus fertilizer leads larger bulbs of onion plants. This result is in agreement with Aweke et al. [5], who reported that the bulb diameter significantly increased when the rate of NPSB rate increased from 0 to 75 kg ,75 to 150 kg 150 to 300 kg ha^{-1}. Similarly, Tadesse et al. [8], also reported that bulb diameter significantly increased when the rate of nitrogen increases.

Bulb dry matter yield (g): The analysis of variance revealed that bulb dry matter yield per plant of onion was significantly (P<0.001) affected by the interaction effect of nitrogen and phosphorus fertilizer rates. Increasing the combined rate of nitrogen and phosphorus application steadily increased the bulb dry matter yield of the onion plants. Accordingly, the higher bulb dry matter 9.60:9.56 and 9.43 gm/plant was found in response to the application of 138 kg N ha^{-1} and 105 kg P ha^{-1} which is statically similar with the results obtained in application of 138 kg N ha^{-1} combined with 70 and 35 kg P ha^{-1}. On the other hand, lower (2.26 gm/plant) bulb dry matter yield was achieved at the nil nitrogen and phosphorus rates (Table 4). The lower bulb dry matter yield of onion observed at nil and lower combined application rate of nitrogen and phosphorus fertilizer might be due stiffer to competition among plants for the limited growth resources, which may have resulted in reduced vegetative growth like leaf number, leaf diameter, leaf length and plant height. Thus, finally the weight of bulb and diameter becomes small, leading to lower value of bulb dry matter of onion. This finding is in agreement with bulb dry matter visibly increased when the application rate of phosphorous increases. Again in line with this finding Tilahun et al. [12], reported that the bulb dry mater significantly increases when the rate of nitrogen increases. Similarly, Aweke et al. [5], reported that the bulb dry weight increases around 50% when the rate of NPSB fertilizer rate increases as compared to the control treatment.

Marketable and unmarketable bulb yield (ton/ha): The interaction effect of nitrogen and phosphorus had shown a highly significant (p<0.001) difference on marketable, unmarketable and total bulb yield. As the result presented in (Table 4), the highest (16.7-ton ha^{-1}) marketable yield was obtained from combined application of N-P at 138:105 and 92:105 kg ha^{-1} levels which is statically similar to the results obtained in application of nitrogen at 138 kg ha^{-1} with each level of phosphorus rate. The lower (7.30-ton ha^{-1}) marketable yield was obtained from control treatments. In the case of unmarketable yield, the highest value (1.56-ton ha^{-1}) was recorded from control treatment. However, the lowest (0.10-ton ha^{-1}) unmarketable bulb yield was obtained from combination of 138:105 and 92:105 kg ha^{-1} of N-P fertilizers. This finding is in agreement with the finding of Fikre et al. [2], Aweke et al. [5], Kitila et al. [7], who reported that the highest amount of marketable yield obtained when the rate of blended fertilizers increases and the increase in the amount of the fertilizers causes a significant difference in the amount of marketable bulb yield. The authors also described that the amount of unmarketable bulb yield increases when the rate of the fertilizers reduced. In addition, in onion, low as well as lack of nitrogen fertilizer may have been associated with early bulb formation, stunted growth, with bulb size and marketable yields reduced.

Total bulb yield (g): There was statistically highly significant (p<0.001) difference in total bulb due to interaction effect of nitrogen and phosphorus fertilizer application at different levels. Total bulb was increased in response of combined increased rate of nitrogen and phosphorus fertilizer in this study. The higher total bulb yields of onion were obtained at the level of 92:105, 138:0, 138:35, 138:70 and 138:105 kg ha^{-1} N-P fertilizer, whereas the lower from control (Table 4). The general increase in the yield of onion is obviously associated with the combined effects of plant nutrients (nitrogen and phosphorus). The application of nitrogen and phosphorus containing fertilizer like NPS modifies soil pH, improves soil-water relation and increases the availability of plant nutrients like P, Fe, Mn and Zn, which may increase the bulb yield of onion. Furthermore, nitrogen stimulates the enzymatic actions as well as chlorophyll formation, which promote the growth and development of plants and improve the yielding performance of onion plants. Thus, an adequate supply of nutrients to plants is associated with vigorous vegetative growth, resulting in higher productivity of crops including onion. The result of this finding is in consistent with the finding of Aweke et al. [5], Kitila et al. [7], Sharma et al. [11], who reported that total bulb yield shows significant increase in yield when the rate of nitrogen increases.

Harvest index: The results from (Table 4) revealed that main application of N and P had shown a highly significant ($P<0.001$) difference on the harvest index of onion plants. The observed harvest index improvement could be attributed to an increased photosynthetic area in response to N fertilization that enhanced assimilate production and partitioning to the bulbs. The investigation of Gererufael et al. [7], Tadesse et al. [8], who reported that when the rate of nitrogen fertilizer increases the harvest index also increases on onion supports this result. Similarly, to this finding and those authors investigated that maximum application of N at 150 kg ha^{-1} increased the harvest index by about 17.6% over the respective checks. There is a finding indicated in soils that are moderately low in P, onion growth and yield can be enhanced in response to P fertilization [14].

Total soluble solids: Total soluble solid of onion plants was significantly ($P<0.001$) affected by the interaction effect of nitrogen and phosphorus application rates. The higher total soluble solids were recorded for plants grown at the rates of 138:0, 138:35, 138:70 and 138:105 kg N and P ha^{-1}. On the other hand, the smaller total soluble solids were recorded for onion plants grown at the nil rate of nitrogen and phosphorus application. The results are in conformity with the findings that increasing the rate of nitrogen fertilizer levels increased total soluble solid values.

Bulb length (cm): The application of nitrogen at different levels had shown a highly significant ($P<0.001$) difference on mean bulb length of onion plants. Similarly, phosphorus application had shown a highly significant ($P<0.001$) difference on bulb length. As the result presented in Table 5, the higher bulb length (5.1 cm) was recorded in the plot that received maximum nitrogen at 138 kg ha^{-1} followed by the results obtained in application 92 kg ha^{-1} and the lower mean bulb length was recorded in the control treatments (4.05 cm). Similarly, maximum fertilization of phosphorus at 105 kg ha^{-1} increased the bulb length by about 11.95% in reference to the control treatments (4.35 cm). This could be due to the activities of nitrogen in different physiological and metabolic processes through increase in dry matter production and the role of phosphorus in cell division and assimilate production. This was in agreement with Tadesse et al. [8], who reported that the length of onion bulb shows a significant difference in length when the rate of nitrogen increases from 0 kg to 150 kg ha^{-1}. Another authors Gererufael et al. [6], Tilahun et al. [12], also reported that bulb length shows a significant increment when the rate of nitrogen and other nutrients increases.

Nick diameter (cm): As the result indicates that, phosphorus fertilization showed significant effect on neck diameter of onion. However, nitrogen and interaction of both fertilizers did not significantly ($p>0.05$) affect the formation of thick-necked bulbs in onion (Table 6). This might be due to the minimal direct effect of fertilization in the formation of thick-necked bulbs. In favor of our finding Brewster et al. [15], reported that neck-thickness is a physiological disorder that is influenced by seasons, sites and cultivars. In contrast to this finding Sharma et al. [11], reported that highest increase in neck thickness of bulbs was recorded from the treatment treated with 150 kg ha^{-1} (32.94%), 100 kg N ha^{-1} (21.18%) and 50 N kg (11.76%) greater than a nick thickness obtained from control and also those authors stated that there was an increment in nick thickness when the rate of Sulphur increases from 30-90 kg ha^{-1}.

Economic analysis: A partial budget is a way of calculating the total costs that vary and the net benefits of each treatment. From the result of this study, the average yield of 16 treatments was obtained. According to International Maize and Wheat Improvement Center (CIMMYT), the average yield was adjusted down wards by 10%. This is for the reason that, researchers have assumed that using the same treatments the yields from the experimental plots and farmers' fields are different, thus average yields should be adjusted downward. Based on this, the recommended level of 10% was adjusted from all 16 treatments to get the net yield. In addition to this, to obtain the gross field benefits, it is essential to know the field price value of one kg of onion bulb during harvesting time. Then finally, adjusted yield was multiplied by field price to obtain gross field benefit of onion. For the different treatment combinations, the total costs and net benefits were calculated. The different costs of this experiment which includes cost for nitrogen (urea) and phosphorus are varied among the different treatments. The purchasing price of urea and TSP were 14.50 Birr kg^{-1} and 18.50 Birr kg^{-1}. The field price of onion during the harvesting season was 15-birr kg^{-1}. To obtain net benefit all the variable costs were subtracted from gross benefit. The partial budget analysis revealed, the highest net benefit of 218284.79 Birr with higher cost was recorded from the combination of 138 and 70 kg N-P ha^{-1} which was followed by net benefit of Birr 217627.19 from the treatment combination of 138 and 105 kg N-P ha^{-1} (Table 7).

To calculate the Marginal Rate of Return (MRR), the dominance analysis was carried out by listing the treatments in order of increasing the total variable cost. According to CIMMYT any treatments that have net benefit less or equal to the previous treatment was dominated and eliminated from further analysis. Thus, treatment combination of 0:70 N-P kg ha^{-1}, 0:105N-P kg ha^{-1}, 46:105 N-P kg ha^{-1}, 92:105 N-P kg ha^{-1} and 138:105 N-P kg ha^{-1} were dominated and eliminated for further analysis (Table 8).

The minimum acceptable Marginal Rate of Return (MAR%) should be between 50% and 100%. Thus, the current study indicated that marginal rate of return is higher than 100% (Table 9). This showed that all the treatment combinations are economically important as per the MRR is greater than 100%. Hence, the most economically attractive combinations for small scale farmers with low cost of production and higher benefits were in response to the application of 92:35 N-P kg ha^{-1} fertilizer combination with acceptable marginal rate of return.

TABLE 5

Main effect of nitrogen and phosphorus on bulb length

Treatments		BL
Nitrogen rate (kg ha^{-1})	N0	4.05^{d}
	N46	4.45^{c}
	N92	4.63^{b}
	N138	5.1^{a}
	LSD (0.05)	0.02
	CV	3.14
Phosphorous rate (kg ha^{-1})	P0	4.35^{c}
	P35	4.46^{bc}
	P70	4.59^{b}
	P105	4.87^{a}
	LSD (0.05)	0.27
	CV	3.57

Note: BL: Bulb Length; N0: Nil Nitrogen rate; N46: 46 kg Nitrogen/ ha; N92: 92 kg Nitrogen/ha; N138: 138 kg Nitrogen/ha; P0: Nil Phosphorus rate; P35: 35 kg Phosphorus/ha; P70: 70 kg Phosphorus/ha; P105: 105 kg Phosphorus/ha; LSD: Least Significance Difference; CV: Coefficient of Variation.

TABLE 6

Main effect of phosphorus on neck diameter

Treatments	ND	
	Phosphorus rate	
Phosphorous rate (kg ha^{-1})	P0	11.75^{d}
	P35	12.82^{c}
	P70	13.67^{b}
	P105	14.40^{a}
	LSD (0.05)	0.62
	CV	5.73

Note: ND: Nick Diameter; N0: Nil Nitrogen rate; N46: 46 kg Nitrogen/ha; N92: 92 kg Nitrogen/ha; N138: 138 kg Nitrogen/ha; P0: Nil Phosphorus rate; P35: 35 kg Phosphorus/ha; P70: 70 kg Phosphorus/ha; P105: 105 kg Phosphorus/ha; LSD: Least Significance Difference; CV: Coefficient of Variation.

TABLE 7

Partial budget and Marginal Rate of Return (MRR) % analysis for combined nitrogen and phosphorus fertilizer

Treatments	Unadjusted marketable yield (t ha^{-1})	Adjusted marketable yield (t ha^{-1})	Gross benefit (Birr ha^{-1})	Variable cost (Birr)	Net benefit (Birr ha^{-1})	Rank
T1	7.3	6.57	98550	0	98550	16
T2	8.83	7.947	119100	1407.59	117692.41	15
T3	9.03	8.127	121800	2815.21	118984.79	14
T4	9.16	8.244	123600	4222.81	119377.19	13
T5	11.2	10.08	151200	1450	149750	12
T6	11.76	10.584	158700	2857.59	155842.41	11
T7	12.16	10.94	164100	4265.21	159834.79	10
T8	13.33	11.99	179850	5672.81	174177.19	9
T9	13.63	12.26	183900	2900	181000	8
T10	14.36	12.92	193800	4307.59	189492.41	6
T11	14.36	12.92	193800	5715.21	188084.79	7
T12	15.36	13.82	207300	7122.81	200177.19	5
T13	16.36	14.72	220800	4350	216450	3
T14	16.43	14.78	221700	5757.59	215942.41	4
T15	16.7	15.03	2,25,450	7165.21	218284.79	1
T16	16.76	15.08	226200	8572.81	217627.19	2

TABLE 8

Dominance analysis for onion marketable bulb yield as influenced by nitrogen and phosphorus combined application at Alage during 2021

Treatments	Total variable cost (Ethiopian Birr ha^{-1})	Net benefit (Ethiopian Birr ha^{-1})	Dominance
T1	0	98550	-
T2	1407.59	117692.41	-
T3	1450	149750	-
T4	2815.21	118984.79	Dominated
T5	2857.59	155842.41	-
T6	2900	181000	-
T7	4222.81	119377.19	Dominated
T8	4265.21	159834.79	-
T9	4307.59	189492.41	-
T10	4350	216450	-
T11	5672.81	174177.19	Dominated
T12	5715.21	188084.79	-
T13	5757.59	215942.41	-
T14	7122.81	200177.19	Dominated
T15	7165.21	218284.79	-
T16	8572.81	217627.19	Dominated

TABLE 9

Marginal Rate of Return (MRR %) for onion marketable bulb yield as influenced by nitrogen and phosphorus combined application at Alage

Treatments	Total variable cost (Ethiopian Birr ha^{-1})	Net benefit (Ethiopian Birr ha^{-1})	MRR (%)	Rank
T1	0	98550	0	-
T2	1407.59	117692.41	1359.94	8
T5	1450	149750	7589.7	5
T6	2857.59	155842.41	432.82	9
T9	2900	181000	59319.95	4
T7	4265.21	159834.79	1550.33	7
T10	4307.59	189492.41	69,980.23	1
T13	4350	216450	63564.23	3
T11	5715.21	188084.79	2077.72	6
T14	5757.59	215942.41	65732.94	2
T15	7165.21	218284.79	166.4	10

CONCLUSION

The enhancement of onion production and productivity can be related with different growth factors. Thus, the use of appropriate agronomic management has an undoubted contribution to increased crop yields. The uses of different combination levels of nitrogen and phosphorus fertilizer are among the key agronomic practices which affect yield of onion. A field experiment was carried out at Alage Agricultural Technical Vocational Educational Training College Research site under irrigation condition in 2021 with the objectives of to assess the effect different combination levels of nitrogen and phosphorus fertilizer and to identify the optimum rate that improves yield of onion. A factorial randomized complete block design with 4 × 4 combinations in which four levels of nitrogen fertilizer (0, 46, 92 and 138 kg ha^{-1}) and four levels of phosphorus (0, 35, 70 and 105 kg ha^{-1}) was used with three replications. The results of the study showed that main effects of nitrogen and phosphorus as well as their interacted dose had considerable influence on different parameters. The analysis of variance showed that day of physiological maturity, plant height, leaf length, leaves number per plant, shoot dry matter, bulb length was significantly influenced by the main effect of both nitrogen and phosphorus fertilizer levels. However, neck diameter was affected by the main application of phosphorus only. Dry total biomass, stand count percentage, fresh weight bulb weight and diameter, bulb dry mass, marketable bulb yield, unmarketable bulb yield, total bulb yield and total soluble solid were significantly influenced by the interaction effect of nitrogen and phosphorus fertilizer levels. Regardless of the levels, maximum combined application of N-Pat 138:105 kg ha^{-1} gave high fresh weight, dry total biomass, stand count percentage, bulb weight, bulb dry mass, marketable and total bulb yield. From this study, taller plant height, higher leaves number, longer leaf and bulb length, highest shoot dry matter was observed at plots treated with 138 kg N ha^{-1} and 105 kg P ha^{-1} as affected by main effect of both fertilizers. The partial budget analysis revealed, the highest net benefit of 218284.79 Birr with higher cost was recorded from the combination of 138 and 70 kg N-P ha^{-1} which was followed by net benefit of Birr 217627.19 from the treatment combination of 138 and 105 kg N-P ha^{-1}. Therefore, the most economically attractive combinations for small scale farmers with low cost of production and higher benefits were in response to the application of 138:105 N-P kg ha^{-1} fertilizer combination with acceptable marginal rate of return. Therefore, application of N and P fertilizer at the rate of 138:105 kg ha^{-1} can be recommended for the production of onion in the study area as well as in other areas with similar agro-ecologies under irrigated production system. However, as the experiment was done for only one season and single location, it has to be repeated over seasons and locations to make a conclusive recommendation.

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