Journal of Agriculture and Crops
ISSN(e): 2412-6381, ISSN(p): 2413-886X
Vol. 6, Issue. 8, pp: 113-118, 2020
URL: https://arpgweb.com/journal/journal/14
DOI: https://doi.org/10.32861/jac.68.113.118

Academic Research Publishing Group

Original Research **Open Access**

Effects of Nitrogen and NPS Fertilizer Rates on Fresh Yield of Garlic (*Allium sativum L.*) at Debre Berhan, Ethiopia

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Article History
Received: June 15, 2020
Revised: July 21, 2020
Accepted: August 19, 2020
Published: August 25, 2020

Abstract

Keeping in view of lack of recommended rates of N and NPS fertilizers, a field experiment was conducted to evaluate the effect of the newly introduced NPS fertilizer and nitrogen on growth, physiology and above ground biomass of garlic. Four NPS (0-0-0, 78.75-69-12.75, 105-92-17 and 131.25-115-21.25 kg N-P-S ha^{-1}) and three nitrogen fertilizer rates (114.13, 228.26 and 278.33 kg N ha^{-1}) were laid out in Randomized Complete Block Design with three replications. Significantly highest plant height (28.02 cm), leaf diameter (1.27 cm), dry and fresh weight (4.71 g and 6.11 g) and leaf length were recorded on garlic plants supplied with 105-92-17 kg N-P-S ha^{-1} and also the highest plant height (27.75 cm), leaf length (24.02 cm), fresh and dry weight (6.23 g and 5.04 g) were recorded on garlic plants supplied with 278.33 kg N ha^{-1}. The interaction effect also show a significant effect in almost all the growth parameters; the early day to 50% emergence was recorded from a plot which received 228.26 kg N ha^{-1} and 105-92-17 kg NPS ha^{-1} and the highest plant height, leaf length, fresh and dry above ground biomass and leaf diameter were 29.62 cm, 25.60 cm, 6.93 g, 5.59 g and 1.4 cm, respectively were observed by the interaction of 278.33 kg N ha^{-1} and 105-92-17 kg N-P-S ha^{-1} with no significant difference with 228.26 N and 78.75-69-12.75 kg N-P-S ha^{-1}. From this one season experiment, fertilizer rates 307.01-69-12.75 kg N-P-S ha^{-1} could be recommended for garlic production.

Keywords: NPS fertilizer; Growth; Above ground biomass; Fresh garlic; Garlic physiology.

1. Introduction

Garlic (*Allium sativum* L.) belongs to the family *Alliaceae (Amaryllidaceae)* and the second most important bulb crop next to onion [1]. The origin of garlic is thought to be in central Asia (India, Afghanistan, west China, Russia) and spread to other part of the World through trade and colonization [2]. With respect to its production and economic value, garlic is one of the main *Allium* vegetable crops in the world and used as a seasoning in many foods throughout the globe. Garlic is volatile and has sulphur combining compounds which is responsible for strong odour, its unique flavour and pungency as well as for healthful benefits [3]. Garlic has also medicinal value which is well recognized in the disease, diabetes, cancer, ulcer rheumatism [4].

Total area under garlic cultivation in the world is 1,546,741 ha with total production of 28,494,130 tonnes [5]. In Ethiopia, the total area under garlic production reached 15,381 ha and the production is estimated to 138,664.3 tons with an average yield of 9.02 t ha^{-1} [6]. This is far below the world average 18.4 t ha^{-1}.

One of the major problems affecting crop production in Africa including Ethiopia is the rapid depletion of nutrients in smallholder farms [7]. In many garlic producing areas, low availability of nutrients is the major factor limiting garlic production next to soil moisture stress, which constrains liberation of nitrogen, phosphorus and sulfur from soil organic matter and their uptake by plant root [8].

The type of fertilizer mainly applied in Ethiopian agriculture system are only Urea and DAP which contain only N and P with the National blanket recommendation of 105 kg N ha^{-1} and 92 kg P ha^{-1} for garlic production [9].

However, application of N and P fertilizers may not probably satisfy the nutritional requirement of garlic and other crops. As a result, to overcome this problem the new combined fertilizer which contain N, P and S with the ratio of 19%-38%-7% respectively has been formulated recently.

Diriba, *et al.* [10], reported that garlic bulbs supplied with N, P and S improve bulb quality. But, nutritional content did not significantly respond to highest level of phosphorus. On the other hand, N and S application showed a direct and positive effect on pungency and total soluble sugar (TSS) content.

Nitrogen is necessary and important element for increasing the yield and quality of vegetables such as garlic. As increased the level of N, increased the growth trend of the number of leaves, leaf length and plant body that garlic has a high nitrogen requirement, particularly in the early stages of growth [11].

Garlic (*Allium sativum* L.) is one of the most important vegetable (bulbs) crops cultivated both under rain and irrigated condition in Ethiopia. But the productivity, both at the country and regional level, is very low due to poor agronomic practice mainly poor application of fertilizer both in terms of rate and type.

The application of fertilizer by many small holder farmers considered as extra cost especially for vegetable, although some farmers are use DAP and Urea only with the rate of application far below or above the national blanket recommendation which is about 105 kg N ha^{-1} and 92 kg P ha^{-1} for garlic production [9].

Furthermore, the type of fertilizers mainly applied in Ethiopian by agriculture system until recently are only N and P containing fertilizers without considering the impact of sulfur on onion production. Even if recently the ministry of agriculture introduced NPS fertilizer the farmer in north shewa particularly in the research area still doesn't understand the role and the agronomic optimum rate of this newly introduced fertilizer. On the other hand, garlic plant is harvested and used without reaching its bulb production stage as a spice for different purposes. Now a days, due to diseases problems in the later stage of the plant, it is harvested fresh and sold on the market. But, the effect of NPS fertilizer on fresh yield of garlic was not quantified. Therefore, this study was designed with an objective of:

1.1. Objectives of the Study

- To investigate the effect of nitrogen and NPS fertilizer rates on growth, physiology and above ground biomass of garlic

2. Material and Method

2.1. Description of the Study Area

The experiment was conduct at Debre Berhan University agricultural demonstration site. The area is suited with an elevation ranging between 2800 and 2845 m above sea level (masl). It is found in north Shewa zone of Amhara regional state, central highland of Ethiopia about 130 km from Addis Ababa on the way to Dessie. The area receives a mean annual rainfall of 927.1 mm and characterized by a bimodal rainfall pattern with maximum (293.02 mm) and minimum (4.72 mm) peaks in August and December respectively. In general, the areas fall under highland (dega) agro-ecological zone with a frost incidence from October to December. The soil type of the area is vertisols.

2.2. Experimental Material

The experimental materials used for this research were nitrogen (urea) and NPS (19%-38%-7% N-P-S) fertilizer and local variety of garlic.

2.3. Experimental Design and Treatment

The treatment combination was 10, within two factors namely NPS fertilizer rate and nitrogen fertilizer rate. The experiment was conducted using randomized complete block design (RCBD) in a factorial arrangement with three replications. The treatments were three NPS fertilizer rates, below the recommended level by 25% (78.75-69-12.75 kg N-P-S ha^{-1}), national blanket recommendation for N, P, and S independently (105-92-17 kg N-P-S ha^{-1}), above the recommended level by 25% (131.25-115-21.25 kg N-P-S ha^{-1}) and three nitrogen fertilizer rate those are below recommend level by 50% (114.13 kg N ha^{-1}), recommended rate (228.26 kg N ha^{-1}), above recommend level by 25% (278.33 kg N ha^{-1}) and control (0-0-0 kg N-P-S ha^{-1}). The nitrogen fertilizer is added by urea fertilizer and N-P-S as blended fertilizer rate which is available at market. All the treatments were randomly allocated to different plots in each replication. The spacing between plots was 0.5 m and a distance of 1 m was maintained between blocks. The plots size was 2.00 m × 2.40 m. The plots were partitioned eight rows which far apart by 30 cm. In each rows in all plots contain 20 plant with 10 cm difference between each plant. Data were collected from the middle two rows and the other serve as a border.

2.4. Experimental Procedure

First the selected land was properly ploughed, cleaned and labelled. Then the plots were prepared based on the number and size of experimental unit. Individual clove of garlic was planted in a spacing of 30 cm x 10 cm between rows and plants, respectively and covered lightly by soil. Water was added on the planted seed bed. The total quantity of phosphorus in the form of NPS fertilizers was applied before the time of planting, whereas, urea as a main source of nitrogen was applied in three splits at planting, 4 and 8 weeks after planting as indicated by Kumschick, *et al.* [12]. Other cultural practices like weeding, irrigation, cultivation and plant protection measures were done uniformly for all plots as required.

2.5. Filed Layout of the Experiment

Table-1. Rate of NPS Fertilizer, nitrogen fertilizer and treatment combination used in the study

kg N ha^{-1}	kg N-P-S ha^{-1}	Treatments
114.13	78.75-69-12.75	T1
	105-92-17	T2
	131.25-115-21.25	T3
228.26	78.75-69-12.75	T4
	105-92-17	T5
	131.25-115-21.25	T6
278.33	78.75-69-12.75	T7
	105-92-17	T8
	131.25-115-21.25	T9
Control	0-0-0	T10

2.6. Data Collection

The growth parameters of garlic were collected from the middle two central rows (effective sample row) by selecting representative plant sample randomly on the basis as described below.

A. **Plant height (cm)**: Plant height was recorded by selecting four plants randomly from the middle two rows. And the height was measured from the attachment of the ground level up to the tip of the growing point.
B. **Number of leaves per plant**: Total number of leaves per plant was counted from four representative sample plants which were selected randomly from the middle two rows.
C. **Above ground biomass (g)**:

✓ **Fresh weight (g):** Fresh weight was measured from four randomly selected garlic plants from the middle two rows of each plot by using balance.
✓ **Dry weight (g)**: Dry weight of above ground biomass was recorded in gram after drying under oven at a temperature of 70 ^{0}C for 48 hours from four randomly taken plants. The averages were calculated and above ground dry biological yield per plant was recorded.

D. **Leaf length (cm)**: Leaf length was measured from four randomly selected garlic plants from the middle two rows from the stalk of the leaf to the tip of the leaf part.
E. **Days to 50% emergence:** Days to emergence was recorded when 50% of the planted cloves sprouted and emerged out of the soil in each plot.
F. **Leaf diameter (cm)**: The average width of leaves was recorded from four randomly taken plants in the two central rows. One leaf from each sample plant was measured at the widest part at the time of physiological maturity.

2.7. Data Analysis

The data was subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) version 9.1. Mean separation was carried out using Duncan's Multiple Range Test (DMRT) at 5% probability level.

3. Results and Discussion

3.1. Days to 50% Emergence

The interaction effects of NPS and nitrogen fertilizer significantly affected days to emergence ($p < 0.05$) but there was no significant effect due to the main factor (Table 2). The earliest days to emergence (9 and 9.33 days after planting) was recorded by the interaction of 105-92-17 kg N-P-S ha^{-1} and 228.26 kg N ha^{-1} followed by interaction of 131.25-115-21.25 kg N-P-S ha^{-1} and 278.33 kg N ha^{-1}. The late days to emergence was recorded by the interaction of higher fertilizer rates 228.26 kg N ha^{-1} and 131.25-115-21.25 kg N-P-S ha^{-1}.

In agreement with this study, Abadi [13] reported that an increase in the level of nitrogen fertilizer decreases days to emergence in which the highest days to emergence was recorded from highest rate of nitrogen fertilization. This could be attributed to the impact of nitrogen on enhancing leaf and root formation during the earliest time of the plant. Furthermore, the earliest days to emergence at optimum fertilizer levels is due to the role of phosphorous in root initiation [14].

3.2. Fresh Weight

The fresh weight of garlic was affected significantly ($p < 0.05$) both by main and interaction effects of NPS and nitrogen fertilizers (Table 2 and 3). The highest fresh weight was recorded from 278.33 kg N ha^{-1} and 78.75-69-12.75 kg N-P-S ha^{-1} and the lowest was recorded from the control plot. On the other hand, the interaction of 228.26 kg N ha^{-1} and 78.75-69-12.75 kg N-P-S ha^{-1} resulted the highest fresh weight than the other treatments.

The data on Table 2 and 3 showed that the highest fresh weight was recorded in high rates of N and NPS fertilization. Whereas, further increase from 105-92-17 kg N-P-S ha^{-1} to 131.25-115-21.25 kg N-P-S ha^{-1} shows reduced amount of fresh weight. This could indicate that further increase in the level of NPS is non-usable by the plant and may induce toxicity effect on the plant. Accordingly, results in also clearly indicated that the interaction of highest nitrogen and medium rate of NPS fertilizer enhanced the fresh weight of garlic. This could imply that the

level of N in the NPS fertilizer is very low to support the yield of the plant and there is a need of application of high rate of N. The reason for an increase in fresh weight with an increase of N and NPS fertilization could be due to the availability of the nutrients in the root zone of the plant. This result is in agreement with the findings reported by other scholars [15-17]. In line with this experiment, [14] observed an increase in biomass when the level of N and P increased from 0 to 46 kg ha^{-1}.

3.3. Dry Weight

The main and interaction effect of nitrogen and NPS fertilization highly significantly ($p < 0.01$) affected the dry weight of garlic (Table 2 and 3). The highest dry weight (5.59 g) was recorded by the interaction of 278.33 kg N ha^{-1} and 105-92-17 kg N-P-S ha^{-1}, but there were no significant differences with 278.33 kg N ha^{-1} and 78.75-69-12.75 kg N-P-S ha^{-1}. Whereas, the highest dry weight due to the main effect of nitrogen and NPS was recorded by the application of 278.33 kg N ha^{-1} and 105-92-17 kg N-P-S ha^{-1}.

This research result shows that the highest dry weight was recorded on the highest fertilizer rates. As the level of fertilizer increased from control, the amount of dry weight increases significantly. It could be due to the role of nitrogen, phosphorous and sulfur fertilization on dry matter production of garlic plant. In line with this research, Assefa, *et al.* [15] reported that an increase in NPSZn levels increases the dry weight content of garlic in which the highest was recorded by addition of 130-20-21-15 kg N-P-S-Zn ha^{-1}. Zaman, *et al.* [18], also reported that sulfur have significant influence on the dry weight of garlic in which the highest was recorded in the rate of 45 kg S ha^{-1}. In contrast with this result, Bloem, *et al.* [19] reported that the interaction of N and S doesn't show significant effect on the quality of garlic.

3.4. Plant Height

Plant height was highly significantly ($p < 0.01$) affected by main as well as interaction effects of NPS and nitrogen fertilizer rates (Table 2 and 3). The highest mean plant height by the main effect of NPS and N (27.75 cm and 28.02 cm) was recorded by the application of 105-92-17 kg N-P-S ha^{-1} and 278.33 kg N ha^{-1} fertilizer, respectively. Whereas, there was no significant difference with 78-69-12.75 kg N-P-S ha^{-1} with the mean value of 68.5 cm and 114.13 kg N ha^{-1} with the main value of 27.08 cm. The lowest mean plant height of 23.75 cm was recorded from the control plot where no fertilizer was applied. In this result, the plant height indicated that there are long plants in medium rates of fertilizers (228.26 kg N ha^{-1} and 105-92-17 kg N-P-S ha^{-1}). On the other hand, the shortest plants were from very high, low and without fertilizer application treatments.

Similarly, the highest plant height was recorded by interaction of 278.33 kg N ha^{-1} and 10592-17 kg N-P-S ha^{-1} with no significant difference with 278.33 kg N ha^{-1} 78.75-69-12.75 kg N-P-S ha^{-1}. Increasing fertilizer from the lower to higher rates showed an increase in plant height. This progress may indicate that the role of nitrogen in enhancing vegetative growth mainly plant height. Furthermore, increase in level of nitrogen enhances an increase in number of leafs which is the ultimate source for carbohydrate. The produced carbohydrate may increase the amount of assimilate for the increase in height of the plant. But further increase showed reduction in plant height. This could be that further increase in the level of Nitrogen creates toxicity on the plant.

This result agreed with the study of Abreham, *et al.* [20], who reported that the highest plant height was recorded by the addition of highest fertilizer rate of 130-20-21 kg N-P-S ha^{-1}. In regard with the impact of S on plant height, Zaman, *et al.* [18], reported that the increase in the level of sulfur from 0 to 45 kg S ha^{-1} plant height increases dramatically. This could be due to the impact of sulfur in dry matter production. Svanem, *et al.* [21], reported that low level in sulphur increases glucosinolate catabolism which enhance protein synthesis. Therefore, the lower the sulfur level the lower could be the plant height. In line with this research, Sebnie, *et al.* [14] reported that an increase in the level of phosphorous increase the height of garlic plant.

Table-2. Main effect of NPS and N on growth and fresh weight of garlic

	Days to 50% emergence	Plant height (cm)	Leaf length (cm)	Leaf diameter (cm)	Leaf number	Fresh weight (g)	Dry weight (g)
N (kg ha^{-1})							
114.13	9.78a	25.70^{b}	23.54^{a}	1.17^{b}	6.50^{b}	5.12b	3.67c
228.26	9.56 a	27.08^{a}	23.68^{a}	1.56^{a}	6.99^{a}	5.87a	4.20b
278.33	9.76 a	27.75^{a}	24.02^{a}	1.28^{ab}	6.84^{a}	6.23a	5.04a
Level of sign.	NS	*	NS	**	*	*	**
NPS (kg ha^{-1})							
78.75-69-12.75	9.67a	27.55^{a}	24.21^{a}	1.22^{a}	7.03^{a}	5.92a	4.26ab
105-92-17	9.56a	28.02^{a}	24.51^{a}	1.27^{a}	6.79a	6.11a	4.71a
131.25-115-21.25	9.78a	25.25^{b}	22.52^{b}	1.11^{a}	6.52b	5.21b	3.93b
Control (0-0-0)	8.56a	23.75^{e}	21.53^{c}	1.0^{a}	6.0^{b}	4.0dc	3.21cd
Level of sign.	NS	*	*	**	*	*	**
CV	4	4.9	6.14	10	3.7	7.7	11

*NPS = Nitrogen, phosphors and sulfur, NS = Non-significant; CV = Coefficient of variation; * Significant at P≤0.05, ** highly significant at P≤0.01. Means sharing the same letter in column do not differ significantly.*

3.5. Leaf Length and Leaf Diameter

The interaction of NPS and N significantly ($p<0.05$) affected leaf length of garlic (Table 3). The main effect of NPS fertilizer had significant influence on leaf length at ($p<0.05$) (Table 2). The highest leaf length (25.6 cm) was recorded by the interaction of 278.33 kg N ha^{-1} and 105-92-17 kg N-P-S ha^{-1} with no significant difference with 228.26 kg N ha^{-1} and 78.75-69-12.75 kg N-P-S ha^{-1}. The main effect of 105-92-17 kg N-P-S ha^{-1} also resulted the highest leaf length of (24.51 cm) followed by leaf length of 22.52 cm in a plot which treated by 131.25-115-21.25 kg N-P-S ha^{-1}. Among all the treatments, the lowest leaf length was observed from the control plot where no fertilizer was applied. This result is in line with the result of Lujiu, *et al.* [22] as verified that an increase in the level of NPK fertilizer levels increase the shoot length of garlic. Similarly Fikru and Fikreyohannes [23] reported that leaf length was significantly influenced by nitrogen fertilization. However, the main effect of nitrogen did not significantly influence this parameter.

The analysis of variance revealed that the leaf diameter was highly significantly ($P< 0.01$) influenced by N and interaction effect of N and NPS fertilizer rates (Table 2 and 3). Application of nitrogen at the rate of 278.33 kg N ha^{-1} also gave the largest diameter of leaf (1.56 cm). Similarly, the interaction of 278.33 kg N ha^{-1} and 105-92-17 kg N-P-S ha^{-1} resulted the largest diameter of leaf. However, the lowest leaf diameter was recorded from control treatment which is without fertilizer. Similar with this result, Fikru and Fikreyohannes [23] reported that the highest leaf diameter was recorded by highest level of nitrogen fertilization 130 kg N ha^{-1}. The main effect of NPS fertilizer was found non-significant.

3.6. Leaf Number

Garlic leaf number was significantly ($p \leq 0.05$) influenced by different rates of N, NPS and by the interaction of N and NPS (Table 2 and 3). The highest number of garlic leaves (6.99 and 7.0) was observed on plants that received the nitrogen rate of 228.26 kg N ha^{-1} and by the interaction of 278.33 kg N ha^{-1} and 78.75-69-12.75 kg N-P-S ha^{-1}. Similarly, the main effect of NPS also affected leaf number significantly in which the highest leaf number was observed by the application of 78.75-69-12.75 kg N-P-S ha^{-1}. Whereas, the lowest leaf numbered was observed from the control plot where no fertilizer was applied. The results obtained in this experiment is in agreement with the findings of various researchers who described that the application of nitrogen, phosphorous and sulfur alone or in combination increased the growth and development of garlic including the number and size of garlic leaves Shege, *et al.* [24]. Gateri, *et al.* [25], reported that the highest leaf number was recorded by the application of highest rate of nitrogen 104 kg N ha^{-1} and the lowest was recorded by the control.

Table-3. Interaction effect of nitrogen and NPS fertilizer on the growth parameter of garlic during the year of 2018 at Debre Berhan University in dry season

N (kg ha^{-1})	NPS (kg ha^{-1})	DE	PH (cm)	LL (cm)	LD (cm)	LN	FW (g)	DW (g)
114.13	78.75-69-12.75	9.67ab	25.0d	23.96abc	1.10a	6.43c	3.90d	2.85e
	105-92-17	9.67ab	26.90bcd	23.63bc	1.20a	6.66bc	5.80b	4.30cd
	131.25-115-21.25	10.0a	25.16d	23.03bc	1.20a	6.43c	5.66bc	3.83cd
228.26	78.75-69-12.75	9.7ab	27.87abc	24.63ab	1.3a	7.30a	6.93a	4.60bc
	105-92-17	9.0b	27.54cd	24.30abc	1.16a	6.93ab	5.60bc	4.24cd
	131.25-115-21.25	10.0a	25.83cd	22.10c	1.0a	6.70bc	5.06bc	3.76d
278.33	78.75-69-12.75	9.70ab	28.87ab	24.03abc	1.2a	7.33a	6.93a	5.33ab
	105-92-17	10.0a	29.62a	25.60a	1.4a	6.76bc	6.93a	5.59a
	131.25-115-21.25	9.33ab	24.75d	22.43bc	1.1a	6.43c	4.90c	4.19cd
Sign. level		*	*	*	NS	*	*	**
CV		4	4.9	6.14	10	3.7	7.7	11

NPS = Nitrogen, phosphors and sulfur DE= Days to emergency: FW = Fresh weight, LN= Leaf length; LD = Leaf diameter; PH = Plant height, DW = Dry weight, LN = Leaf number; CV = Coefficient of variation; Means sharing the same letter in column do not differ significantly

4. Conclusion

This study illustrated that application of mineral fertilizers is necessary to improve the production and productivity of fresh garlic in the study area since almost all growth fresh yield parameters of garlic were significantly influenced by N and NPS fertilizer rates. Accordingly, most growth parameters were significantly highest at 105-92-17 kg N-P-S ha^{-1}. Due to the application of 228.26 kg N ha^{-1} almost all the growth parameter was significantly affected. The interaction of 278.33 N and 105-92-17 N-P-S ha^{-1} was better in all parameters except leaf number of the plat than other parameters. But it doesn't show any significant difference with the application of 228.26 N and 78.75-69-12.75 N-P-S ha^{-1}. Therefore, based on this study, it could be recommended that the application of 307.01 N and 78.75-69-12.75 N-P-S ha^{-1} could be recommended for fresh garlic production as it shows significantly higher fresh yield and quality when interreacted. However, this growth parameter is only for fresh garlic production and is not enough to recommend the optimum nitrogen, NPS and its interaction fertilizer rate as optimum rate for bulb production. As result for bulb production and to give conclusive recommendation it needs further investigation up to yield with various location and multiple seasons.

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