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Research Article

Evaluation of Different Rates of NPS on Growth and Yield Performances of Garlic (*Allium sativum* L.) in Cheha District, Gurage Zone, Ethiopia

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A field experiment was conducted on 2019 growing season to evaluate effects of different rates of nitrogen, phosphorus, and sulfur on growth and yield of garlic under supplemental irrigation. A local variety, Tuma, was used and treated with six rates of NPS (T1 (0 : 0 : 0 kg/ha NPS) (control), T2 (19 : 38 : 7 kg/ha NPS), T3 (28.5 : 57 : 10.5 kg/ha NPS), T4 (47.5 : 76 : 14 kg/ha NPS), T5 (47.5 : 95 : 17.5 kg/ha NPS), and T6 (57 : 114 : 21 kg/ha NPS)). The experiment was laid out in randomized complete block design and replicated three times. Data were collected for days to 50% emergence, plant height, leaf number, leaf length, bulb weight, and total bulb yield. SAS version 9.2 was used to analyze the data. Means were separated using Fisher's test at 5% level of significance. All parameters were significantly ($P < 0.05$) affected by the rates of NPS. The early days to 50% emergence (16) was recorded from T6 (57 : 114 : 21 kg/ha NPS), whereas the late days to 50% emergence was recorded from the control treatment (T1). Significantly highest leaf length (41.51 cm), leaf number (13.63), plant height (61.19 cm), bulb weight (39.44 g), and total bulb yield (14.91 ton ha^{-1}) were recorded from T6 (57 : 114 : 21 kg/ha NPS). Therefore, from the result of this study, it can be concluded that the maximum total bulb yield of garlic was obtained with the application of 57 : 114 : 21 kg/ha NPS rate.

1. Introduction

Garlic (*Allium sativum* L.) belongs to the Alliaceae family, and it is considered as the most important *Allium* crop and ranks second after onion in the world [1]. Garlic is used as a seasoning agent in many foods worldwide; without garlic, many popular dishes may lack its flavor.

Garlic needs higher temperature throughout bulbing, whereas cooler conditions were required in the early stages for favoring vegetative growth. An average temperature in range of 12–24°C is generally accepted as best-growing temperature for garlic productions [2]. Because, garlic is a shallow-rooted vegetable with a unbranched root system, it has low nutrient extraction capacity [3]. Therefore, it requires a relatively high amount of nutrients for best growth and development. In the highlands of Ethiopia, garlic can be grown in diverse soil types from black heavy soils to red soils. Growing soils rich in organic matter, well-drained, capable of holding adequate moisture, and pH ranging from 6.5–7.5 are ideal for garlic production [4].

Lack of available nutrients and soil water were the limiting factors for growth and yield in many garlic-producing areas. Diammonium phosphate (DAP) and urea fertilizer have been used for a long period as a source for nitrogen and phosphorus leading to use other fertilizers such as sulfur to get maximum yield. As a result, the Ethiopian Ministry of Agriculture has recently introduced a new compound fertilizer (NPS) instead of DAP, containing nitrogen (N), phosphorous (P_2O_5), and sulfur (S) with a ratio of 19%, 38%, and 7%, respectively. However, there is limited information about effects of NPS on growth and yield of garlic for growers and researchers in Gurage zone, Ethiopia. Therefore, this investigation is initiated to evaluate different NPS rates on growth and yield of garlic.

2. Materials and Methods

2.1. Description of the Study Area. The experiment was conducted in Wolkite University research site, Cheha district, Gurage zone, in the 2019 production season. The area is located at 7.8°–8.5° N latitude and 37.5°–38.7° E longitude at an altitude of 2000 meters above sea level. The average annual temperature ranges from 14 to 24°C, and the annual rainfall is 1294 mm. The soil type of the experimental area is heavy vertisol with a pH of 5.6. The total N content and organic carbon content of the surface soils ranged from 0.06 to 0.28% and 0.63% to 2.77%, respectively. The available phosphorus of the area ranged from 0.49 to 6.05 $mg{\cdot}kg^{-1}$. The overall cation exchange capacity of the soils ranged between 32 and 51 cmolc kg^{-1} [5].

2.2. Description of the Plant Material. A local garlic cultivar called "Tuma" which is a soft neck in type was used for the experiment. The newly introduced blended fertilizer NPS (19% N : 38% P_2O_5 : 7% S) was used as a source for nitrogen, phosphorus, and sulfur.

2.3. Treatments and Experimental Design. The treatment consisted of one local variety (Tuma) and six levels of NPS (T1 (0 : 0 : 0 kg/ha NPS) (control), T2 (19 : 38 : 7 kg/ha NPS), T3 (28.5 : 57 : 10.5 kg/ha NPS), T4 (47.5 : 76 : 14 kg/ha NPS), T5 (47.5 : 95 : 17.5 kg/ha NPS), and T6 (57 : 114 : 21 kg/ha NPS)). The experiment was laid out in randomized complete block design with three replications. Thus, there were a total of six treatments which account for eighteen experimental plots. The spacing between rows was 30 cm, and the spacing between plants was 10 cm. Raised plot size was prepared as 1.5 m and 1.8 m in width and length, respectively. Each plot consisted of 5 planting rows, and each planting row consisted of 18 plants. Spaces of 0.75 m between plots and 1 m between blocks were maintained for cultural operations.

2.4. Experimental Procedures. At planting time, cloves were separated from the bulbs and selected according to size categories such as large (2.0–2.5 g), medium (1.5–1.9 g), and small (1.0–1.49 g) [6]. Based on these categories, large to medium size (2.5 to 1.5 g) cloves were used for planting. The cloves were planted to a depth of 3-4 cm by sticking them into raised beds by hand in May 2019.

The experimental fields were plowed three times and well harrowed. Soil clods were broken by human labor, and experimental plots were laid out on fine seedbed. NPS fertilizer was applied during sowing based on the assigned rate of fertilizer for each experimental plot. Weed control was done by hoeing and shallow earthing up. Harvesting was done by hand in August when 70% of the leaves had fallen [7]. The harvested bulbs were cured in the field and sundried for 10 days, folding the leaves over the bulbs to protect them from sunburn [7]. After a week of drying, necks and roots were trimmed. Yields obtained from the net plot (0.84 m^2) were weighed and recorded after curing.

2.5. Measurements. Days to 50% emergence: it was determined by counting when about 50% of the plants had emerged.

Plant height (cm): it was determined by measuring the height of 10 randomly selected plants using a ruler from the net plot (0.84 m^2) and taking the average value.

Leaf number per plant: it was determined by counting the leaves of 10 randomly taken plants from the net plot (0.84 m^2) before bulbing at an active leaf growth stage and calculated the average.

Leaf length: the average length of the longest leaf, at active leaf growth stage, was measured in cm from the 10 randomly taken plants from the net plot (0.84 m^2).

Average bulb weight: it was measured by taking ten bulbs from the net plot area, and their weight was recorded by using sensitive balance. The average weight was expressed as bulb weight.

Total bulb yield: The yield was calculated by weighting all bulbs (g/plot) harvested from the net plot (0.84 m^2) and then converted it into ton/ha.

2.6. Data Analysis. Data were subjected to one-way analysis of variance (ANOVA) using SAS 9.3. Treatments were found to be significant, and means were separated using the Fisher test at a 5% level of significance.

3. Result and Discussion

3.1. Days of 50% Emergence. Analysis of the variance showed that T6 which was fertilized with the rate of 57 : 114 : 21 kg/ha NPS emerged 16 days after planting whereas T1 showed delayed emergence (Table 1). The result is in agreement with Getachew and Temesgen [8] who observed early emergence (9 days) by the application of 105 : 92 : 17 kg/ha NPS. This result generally indicated that the highest rate of NPS boosted the garlic bulbs to emerge faster. The hastened duration of emergence might be attributed to the influence of available N, P, and S on root initiation and development which might have led to early shoot emergence. Besides, as reported by Argüello et al. [9], the availability of these nutrients might increase the soluble carbohydrates and a subsequent modification in the nonstructural carbohydrate distribution patterns. These conditions produced an earlier shoot emergence.

3.2. Leaf Length. The experiment showed leaf length was highly influenced by the application of NPS fertilizer ($P < 0.05$). The highest leaf length (41.50 cm) was recorded from T6 (57 : 114 : 21 kg/ha NPS), followed by T4 (38 : 76 : 14 kg/ha NPS) and T5 (47.5 : 95 : 17.5 kg/ha NPS) whereas, the lowest (21.46 cm) was recorded from T1 (Table 2). This increasing of garlic leaf length might be attributed to more availability of nutrients especially N, which enhances the leaf length by a simulative effect on cell division and cell enlargement leading to increased plant growth [10]. Phosphorus plays an important role in metabolic processes, and it is the main constituent of energy compounds, nucleic acids, phospholipids, and coenzymes. Also, it may be attributed to

Table 1: Effect of different rates of NPS on days to 50% emergence.

Treatments	Rates of NPS N (kg/ha)	P (kg/ha)	S (kg/ha)	Days to emergence
T1 (control)	0	0	0	29.333[a]
T2	19	38	7	26.000[b]
T3	28.5	57	10.5	21.667[c]
T4	38	76	14	19.667[c]
T5	47.5	95	17.5	19.667[c]
T6	57	114	21	16.000[d]
LSD (5%)	—	—	—	2.85
CV (%)	—	—	—	7.1

*NPS: nitrogen, phosphorus, and sulphur. Means followed by the same letter are not significantly different at 5% level of significance.

Table 2: Effect of different rates of NPS on leaf length.

Treatments	Rates of NPS			Leaf length (cm)
	N (kg/ha)	P (kg/ha)	S (kg/ha)	
T1 (control)	0	0	0	21.46[c]
T2	19	38	7	33.09[b]
T3	28.5	57	10.5	33.13[b]
T4	38	76	14	41.48[a]
T5	47.5	95	17.5	39.99[a]
T6	57	114	21	41.51[a]
LSD (5%)	—	—	—	5.55
CV (%)	—	—	—	8.7

*NPS: nitrogen, phosphorus, and sulphur. Means followed by the same letter are not significantly different at 5% level of significance.

the favorable effects of phosphorus on root development and formation of carbohydrates. The application of sulfur helps in the availability of other nutrients resulting in better growth and increased uptake of all the nutrients at higher levels of sulfur [11].

3.3. Leaf Number per Plant. Analysis of variance indicated that rates of NPS fertilizer significantly ($P < 0.05$) affected the leaf number. The highest and the lowest leaf number was recorded as 13.63 and 7.63 from T6 and T1, respectively (Table 3). In agreement with the result, Yayeh et al. [4] reported the highest leaf number (12.1) by the application of 140 : 122.6 : 22.6 kg·ha^{-1} NPS fertilizer. The result of this study is also in line with the findings of Assefa et al. [12] who reported that the application of the blended NPS fertilizer increased the growth and development of garlic including the number and size of garlic leaves. The increased leaf number as a result of higher rates of NPS might be because N, P, and S are among the nutrients required largely for the metabolic process. Nitrogen is a major constituent of chlorophyll which contributes to the production of photosynthates, leading to better vigor. Similarly, phosphorus being an essential constituent of cellular protein and nucleic acid might have encouraged the meristematic activity of plants resulting in increased plant height and number of leaves per plant. Sulphur helps in the availability of other nutrients resulting in better growth and increased uptake of all the nutrients at higher levels of sulfur [11].

Table 3: Effect of different rates of NPS fertilizer on leaf number per plant.

Treatments	Rates of NPS			Leaf number
	N (kg/ha)	P (kg/ha)	S (kg/ha)	
T1 (control)	0	0	0	7.63 d[a]
T2	19	38	7	8.210[a]
T3	28.5	57	10.5	9.523[ab]
T4	38	76	14	10.413[bc]
T5	47.5	95	17.5	11.657[c]
T6	57	114	21	13.633[d]
LSD (5%)	—	—	—	1.94
CV (%)	—	—	—	10.51

*NPS: nitrogen, phosphorus, and sulphur. Means followed by the same letter are not significantly different at 5% level of significance.

3.4. Plant Height. NPS fertilizer was found effective on the plant height of garlic. The highest plant height (61.19 cm) was found in T6 (57 : 114 : 21 kg/ha NPS fertilizer), while the lowest value was recorded from T1 (Table 4). The present study is in line with a report by Yayeh et al. (2017), who observed that highest height of garlic plant (69.2 cm) by the application of 105 : 122.6 : 22.6 kg/ha NPS fertilizer rate. The highest rate of NPS fertilizer enhanced the growth of the garlic plant. This might be caused by N, P, and S contributing to the metabolic processes, such as the formation of nucleic acids, phospholipids, and coenzymes. Besides, Farooqui et al. [13] reported that combined application of 200 kg/ha nitrogen and 60 kg/ha sulfur increased the plant heights. Similarly, Babaleshwar et al. [14] reported that the highest plant height of garlic was noted in the application of 60 kg/ha sulfur. However, the authors also showed that applying with S above 60 kg/ha decreased the garlic height.

3.5. Average Bulb Weight. Statistical evaluations showed that average bulb weight was significantly affected by NPS fertilizer ($P < 0.05$). The highest average bulb weight was recorded in the T6 (57 : 114 : 21 kg/ha NPS fertilizer) as 39.44 g which was 29% higher than T1 (Table 5). The results also showed that increasing the rate of NPS fertilizer increased the average bulb weight. This might be because the highest nitrogen, phosphorus, and sulfur contribute to the metabolic process such as the formation of nucleic acids, phospholipids, coenzymes, and chlorophyll which in turn enhances the bulb weight of garlic plants as described by Shafie and Gamaily [11]. This study is in agreement with the report of Getachew and Temesgen [8] who reported that higher bulb weight was achieved by the application of 78.75-69-12.7 kg·ha^{-1} NPS.

3.6. Total Bulb Yield. Bulb yield of garlic was significantly affected by the different rates of NPS fertilizer ($P < 0.05$). The highest yield (14.91 ton ha^{-1}) was recorded from T6 (57 : 114 : 21 kg/ha NPS) which was 65% higher than T1 (Table 6). T2 (19 : 38 : 7 kg/ha NPS) and T3 (28.5 : 57 : 10.5 kg/ha NPS) were not statistically different when they are compared to each other. Similarly, T4 (38 : 76 : 14 kg/ha NPS) and T5 (47.5 : 95 : 17.5 kg/ha NPS) were statistically similar when

Table 4: Effect of different rates of NPS fertilizer on the plant height of garlic.

Treatments	Rates of NPS			Plant height (cm)
	N (kg/ha)	P (kg/ha)	S (kg/ha)	
T1 (control)	0	0	0	35.783^{a}
T2	19	38	7	42.907^{b}
T3	28.5	57	10.5	46.027^{b}
T4	38	76	14	52.710^{c}
T5	47.5	95	17.5	55.520^{c}
T6	57	114	21	61.190^{d}
LSD (5%)	—	—	—	4.92
CV (%)	—	—	—	5.51

*NPS: nitrogen, phosphorus, and sulphur. Means followed by the same letter are not significantly different at 5% level of significance.

Table 5: Effect of different rates of NPS fertilizer on average bulb weight.

Treatments	Rates of NPS			Bulb weight (g)
	N (kg/ha)	P (kg/ha)	S (kg/ha)	
T1	0	0	0	28.00^{a}
T2	19	38	7	32.95^{b}
T3	28.5	57	10.5	33.00^{b}
T4	38	76	14	33.85^{b}
T5	47.5	95	17.5	35.50^{b}
T6	57	114	21	39.44^{c}
LSD (5%)	—	—	—	4.51
CV (%)	—	—	—	7.11

*Means followed by the same letter are not significantly different at 5% level of significance.

Table 6: Effect of different rates of NPS fertilizer on total bulb yield of garlic.

Treatments	Rates of NPS			Total bulb yield (ton/ha)
	N (kg/ha)	P (kg/ha)	S (kg/ha)	
T1 (control)	0	0	0	5.12^{a}
T2	19	38	7	8.95^{b}
T3	28.5	57	10.5	9.62^{b}
T4	38	76	14	12.33^{c}
T5	47.5	95	17.5	13.10^{c}
T6	57	114	21	14.91^{d}
LSD (5%)	—	—	—	1.05
CV (%)	—	—	—	8.94

*Means followed by the same letter are not significantly different at 5% level of significance.

compared to each other. This result is in line with the findings of Yeyeh et al. (2017), Getachew and Temesgen [8], who reported that increased rate of blende NPS gave the higher bulb yield of garlic.

4. Conclusion

This research was carried out with the objective of evaluating effects of different rates of nitrogen, phosphorus, and sulfur on growth and yield of garlic under supplemental irrigation. The results showed that all of the garlic and growth parameters showed significant difference ($P < 0.05$) in response to different NPS rates. The early days to 50% emergence (16) was obtained from T6 (57 : 114 : 21 kg/ha NPS) followed by T5 (47.5 : 95 : 17.5 kg/ha NPS) and T6 (38 : 76 : 14 kg/ha NPS). The highest leaf length (41.51 cm), leaf number per plant (13.63), plant height (61.19 cm), average bulb weight (39.44 g), and total bulb yield were obtained from T6 (57 : 114 : 21 kg/ha NPS). Based on the results obtained, it can be concluded that application of NPS at the rate of 57 : 114 : 21 kg/ha NPS can give the maximum total bulb yield of garlic.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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