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RESEARCH ARTICLE

Effects of bended NPSB fertilizer rates and varieties on growth and yield of garlic (*Allium sativum* L.) in Gummer district, Central Ethiopia

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Abstract

Garlic is grown by farmers using locally available low-yield traditional cultivars with little or no fertilizer input, which results in a low yield in the study area. Therefore, this experiment was conducted to evaluate the responses of garlic varieties to different rates of NPSB. Garlic varieties (Kuriftu, HL (Holeta), Tseday, and 'Tuma') and four levels of NPSB fertilizer rates were arranged in 4X4 factorial and RCBD design was used in three replications. The interaction between fertilizer and variety had a significant effect on plant height, leaf number, and nearly all yield and yield-related parameters. The highest total bulb yield was obtained from variety Kuriftu (8.81 t ha^{-1}) at the N: P_2O_5: S: B rate of 46.1:91.9:16.9:0.2 kg ha^{-1}. The maximum plant height (74.17 cm) was recorded from variety HL at 46.1:91.9:16.9:0.2 kg/ha N: P_2O_5: S: B and the highest number of garlic leaves (10.33) was obtained from variety Kuriftu, which received the highest N: P_2O_5: S: B at a rate of 65:129.7:23.9:0.3 kg/ha. The highest and statistically significant bulb weight was recorded equally from varieties Kuriftu, Tsedey, and HL (43.42, 42.77, and 41.92 g, respectively). Statistically similar and highest marketable bulb yields (8.14 t ha^{-1} and 7.36 t/ha) and total bulb yields (8.81 and 8 t ha^{-1}) was recorded from variety Kuriftu interacted with 46.1:91.9:16.9:0.2 kg ha^{-1} and 65:129.7:23.9:0.3 kg/ha, respectively. Thus, the combined applications of 46.1:91.9:16.9:0.2 kg ha^{-1} NPSB and variety Kuriftu can be provisionally recommended for garlic producers in the Gummer district.

Keywords: Kuriftu, Tsedey, HL, NPSB, Yield.

Introduction

Garlic (*Allium sativum* L., 2n = 16), which is a member of the Alliaceae family is the second most often used *Allium* species (Rubatzky, 1996). Around 10,000 years ago, garlic evolved on the western slope of the Tien Shan Mountains and spread from there to Central Asia, Africa, Europe, and America (Etoh and Simon, 2002; Ipek *et al*., 2008). Since ancient Egypt, garlic has been known, and its cultivation has likely been practiced for 5000–6000 years (Ipek *et al*., 2008). Currently, there are approximately six hundred garlic varieties recognized internationally (Moyer, 2021).

Garlic has a significant economic impact in Ethiopia. It is used to flavor local foods and is farmed as a spice crop. Ethiopian agroecology has ample opportunity and potential for garlic production. However, garlic production declined from 16,411.19 coverage hectares, during 2013/14 to a production coverage hectare of 15,980 in 2020/21 while current garlic productivity in Ethiopia is below potential (CSA, 2021; Shege *et al*., 2021). Internationally, the top garlic producer is China accounting for over 78% of world total production (22.27 million tons) (Desta *et al*., 2021). Following China, other top-ranked countries were India, Bangladesh, Egypt, Spain, the Republic of Korea, Myanmar, Uzbekistan, the USA, and Russia, respectively (FAO 2023). The overall production of Ethiopia was just 113,928.43 tons from 14,576 hectares of land with an average productivity of 7.8 tons/ha (FAO 2023). This shows that Ethiopian garlic productivity is below the global average of 18.4 tons/ha. According to the Gurage Zone Agriculture and Development Office's 2019/2020 survey report, garlic was grown on 148.2 hectares of land, yielding

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1778.4 tons of output. The total area covered by garlic and total output in the Gummer district were 17.5 ha and 210 tons, respectively, during the same production season.

Zaman *et al.* (1970) reported that the growth and yield of garlic were significantly influenced by nitrogen fertilizer. A similar author reported that garlic bulb yield increased with successive increases in the level of sulfur up to 45 kg ha^{-1} and thereafter decreased. Likewise Abraham *et al.* (2017) in report, nitrogen fertilizer significantly affected the bulb yield along with all growth as well as yield components of garlic. According to Adem *et al.* (2014) the highest garlic plant height was recorded by the application of 100 kg N ha^{-1} + 120 kg P_2O_5 ha^{-1} and the highest leaf number and leaf length was obtained from the application of 100 kg N ha^{-1} + 130 P_2O_5 ha^{-1} in Jimma area. On the other hand, Lancaster *et al.* (2001) reported significantly increased yield and yield attributes (bulb diameter and bulb length) of garlic at higher rates of sulfur application.

The conventional production methods used by smallholder farmers are to blame for the underwhelming performance of the garlic industry. One of these is a lack of understanding of fertilizer application (i.e. lack of information on how much to apply to attain economically optimum yield). Despite the fact that most farmers use synthetic (chemical) fertilizers, the rate of application is much lower than the countrywide comprehensive recommendation for garlic production, which is roughly 150 kg urea ha^{-1} and 200 kg DAP ha^{-1} (EIAR, 2007). Several agronomic factors impact most garlic output, including the kind and rate of fertilizer inputs. The fact that just urea and di-ammonium phosphate (DAP), which hold barely nitrogen and phosphorous, were used in Ethiopian agriculture may not be enough to meet the nutritional needs of the garlic crop.

Significance of the Study

According to soil analysis map, Ethiopian soils are deficient in both macro and micro components. To address this issue, Ethiopia's Ministry of Agriculture recently introduced a compound fertilizer (NPSB fertilizer) that contains 18.9% nitrogen, 37.7% phosphorous, 6.95% sulfur, and 0.1% boron in a ratio of 18.9% N, 37.7% P_2O_5, 6.95% sulfur, and 0.1% boron. Furthermore, in addition to the use of inappropriate fertilizer application practices the continuing decline of soil fertility and lack of improved varieties are the most important factors that throw into the low productivity of garlic in Ethiopia (ATA, 2012). Despite the fact that several mixed fertilizers are now being introduced into Ethiopia's farming system, there are no recommended application rates for farmers to employ. Farmers in the study area continue to use insufficient amounts of these fertilizers, resulting in low garlic yields. Furthermore, they are cultivating traditional garlic cultivars with low production potential as compared to newly released varieties from the Ethiopian Institute of Agricultural Research (EIAR) and research centers (Debrezait Agriculture Research Center). Consequently, this study was initiated with the general objective of evaluating the response of garlic varieties to diverse rates of the recently introduced blended NPSB fertilizer in the Gummer district, central Ethiopia.

Materials and Methods

Study Area Description

The experiment was conducted under rain-fed conditions in the Gummer district (*'Jenboro Kebele'*), central Ethiopia in 2021. As shown in (Figure 1) the research area's soil has a modest overall nitrogen concentration of 0.25% (Table 1). The available phosphorus of the soil was classed as extremely low (3.34 ppm). If the soil has less than 35 to 40 ppm of P, fertilizing with P will be beneficial for most vegetables (P content using the Bray-Kurtz P1 extraction method). The available potassium content of the soil of the study area was considered high (115.6 ppm). According to the rating of Tadesse *et al.* (1991), the experimental site soil has high organic matter (5%) and high organic carbon (2.9%) (Table 2).

Experimental Materials

Three improved garlic varieties (*Tseday*, *Kuriftu,* and *HL (Holeta)) were* released by the Debre-Zeit Agricultural Research Center (DARC/EIAR), and one local cultivar ("Tuma"), which is produced locally and traditionally around the experimental site. The improved garlic varieties were selected based on their adaptability, yield potential, and relative tolerance to disease and pests as compared to other locally used varieties as indicated in Table 1. The local cultivar which has been in the hands of the farmers under cultivation for several unknown periods of time named as *Tuma* and its yield potential and the name of the releasing center is not clearly known.

Treatments and Experimental Design

Blended NPSB fertilizer at different ratios of 0:0:0:0 (control); (27.2N: 54.3P_2O_5: 10 S: 0.1B); (46.1N: 91.9P_2O_5: 16.9S: 0.2B);

Table 1: Description of garlic varieties used for the experiment

Variety/cultivar	*Year of release*	*Breeder/ Maintainer*	*Altitude(m)*	*Days to maturity*	*Yield on station (t/ha)*	*Yield on farmers field (t/ha)*
Tseday	1999/2000	DZARC/EIAR	1900–2600	138	>8.5	6–7
Kuriftu	2010	DZARC/EIAR	1900–2600	140	8	
Holeta (HL)	2016	DZARC/EIAR	1900–2600	128	7	

Source: Ministry of Agriculture and Natural Resources (2016) *and* (65N: 129.7P_2O_5: 23.9S: 0.3B) *kg* ha^{-1} and four garlic varieties were used in the experiment (namely Tseday, Kuriftu, HL, and "Tuma"). As a result, there were sixteen treatment combinations in the experiment, which were laid out in 4*4 factorial arrangements with three replications using a randomized complete block design (RCBD). Each experimental plot had a gross plot size of 2.1 m x 1.1 m (2.31 m^2). The whole area of the experiment was 10.3 × 27.1 m (279.13 m^2). The space between rows and plants was 30 and 10 cm, respectively, and the space left between blocks and plots was 1 and 0.5 m, respectively.

Soil Analysis

Before planting, soil samples were gathered in zigzag style from the whole experimental field at random depths of 20 cm.

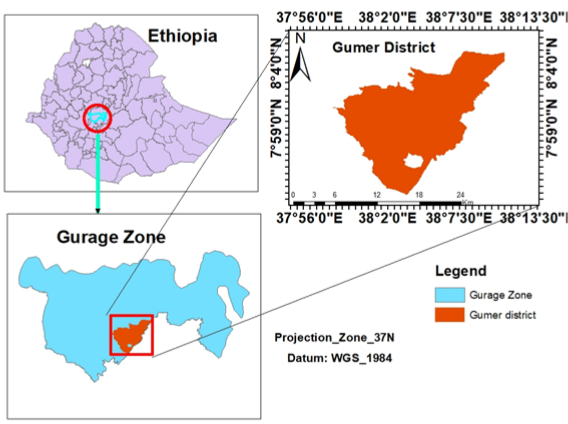

Figure 1: Map of the study area

The soil samples were organized into a one-kilogram composite sample size in order to evaluate the soil's physicochemical properties. The composite soil sample was air-dried and mashed with a wooden pestle and mortar to pass through a 2 mm sieve size in order to examine the physical and chemical properties. The soil analysis was done at Welkite soil laboratory, and the procedure and result of soil analysis is indicated under section 2.1.

Experimental Procedure and Field Management

The experimental site was effectively prepared using the accepted procedures. The area was plowed and leveled appropriately before planting. Each treatment was randomly allocated to the experimental plots within each replication separately after designing and setting up the field layout.

Medium-sized, healthy garlic cloves were planted at a depth of 5 cm in well-prepared raised beds with 10 cm plant spacing and 30 cm row spacing. The planting materials (cloves) were placed with the tip of the clove facing up and the base of the clove facing down (Figure 2). The complete amount (full dose) of NPSB fertilizer was administered at the time of planting based on the treatment setup. Following the comprehensive recommendation (150 kg ha^{-1}), urea was treated in two split applications: Urea was applied in two splits; the first half amount was applied four weeks after planting, and the second half was applied eight weeks later. Other than the experimental treatments all other variables were held constant and administered as directed by the Ethiopian Institute of Agricultural Research (EIAR, 2007).

Table 2: Physical and chemical characteristics of the soil at the study site

1. Physical properties	*Value*	*Rating*	*References*
Sand (%)	30	-	
Silt (%)	51	-	
Clay (%)	19	-	
Textural Class	Silt loam	-	(USDA, 1987)
2. Chemical properties			
pH (1: 2.5 H_2O)	6.02	Slightly acidic	(Hazelton and Murphy, 2007)
CEC (meq/100 g soil)	31.22	High	(Hazelton and Murphy, 2007)
Total Nitrogen (%)	0.25	Medium	
Available phosphorus (ppm)	3.34	Very low	
Available potassium (ppm)	115.6	High	
Organic matter /OM/ (%)	5	High	Tadesse *et al.* (1991)
Organic carbon /OC/ (%)	2.9	High	Tadesse *et al.* (1991)
Available sulfur (ppm)	7.57	Low	
Available boron (ppm)	0.083	Low	
Exchangeable cations (meq/100g soil)			
- EA-exchangeable acids	0.72	-	
- EAl-exchangeable Al	0.33	-	
- ECa-exchangeable Ca	6.7	-	
- EMg- exchangeable Mg	2.25	-	
- EK- exchangeable K	3.85	-	

Data Collection

Phenological variables

- *Days to 50% emergence*

The number of days from planting to when 50% of the planted cloves in each plot germinated was recorded as days to 50% emergence (Ayalew *et al.*, 2015).

- *Days to physiological maturity*

The plants in each plot reached physiological maturity when 75% of their leaves turned yellow, dried out, or displayed senescence (Ayalew *et al.*, 2015).

Growth parameters

- *Plant height (cm)*

At physiological maturity, 20 randomly selected plants from each net plot area were measured to determine the average height of the plant using measuring tape from the soil's surface to the tips of the plant (Ayalew *et al.*, 2015).

- *Leaf length*

As indicated in Figure 3 (cm) lengths of leaves from 20 randomly taken plants from a net plot were measured at physiological maturity using a ruler from the attachment of the pseudo-stem to the tip of the leaves and averaged.

Leaf number per plant

Just before physiological maturity, the number of healthy leaves from 20 randomly selected plants from the middle five center rows were counted and averaged.

Yield parameters

- *Average bulb weight (g)*

Was determined after weighing mature bulb weight from 20 plants generated in the net plot (1.2 m x 0.9 m= 1.08 m^2) and divided by the number of plants (Ayalew *et al.*, 2015).

- *Average bulb diameter (cm)*

Using a graduated caliper, the diameter of 20 randomly chosen bulbs was measured at its widest point in the middle, and the result was divided by 20 (Ayalew *et al.*, 2015).

- *Marketable bulb yield per hectare (t ha^{-1})*

All bulbs from net plot area (1.08 m^2) that were deemed marketable, bulbs that were free of mechanical damage, disease free, marketable bulbs with a weight of (20–160 g) were harvested and recorded in kilos and then represented as tons per hectare.

- *Unmarketable yield per hectare (t ha^{-1})*

Damaged, undersized (< 20 g), misshaped, and rotten harvested bulbs were sorted and deemed unmarketable (Teshale and Negasi, 2020). Using a weighing scale, the weight of these bulbs collected from each net plot was measured in kilos and represented as tons per hectare.

- *Total yield per hectare (t ha^{-1})*

All the marketable and unmarketable yields were combined to get the total yield.

Data Analysis

The significance of the effects of varieties and NPSB fertilizer on the response variables was determined using Analysis of Variance (ANOVA) computed by the GLM procedure of SAS software (version 9.3). For each response variable, the validity of normal distribution and constant variance assumptions on the error terms was verified by examining the residuals. The independence assumption was met due to the randomization of the varieties within each block. Means comparison was conducted using the DMRT method at 5% level of significance.

Results and Discussion

Phenological Parameters

Days to 50% emergence

The analysis of variance revealed that the main effects of variety and NPSB showed significant differences (Table 3). However, the interaction of variety and NPSB showed statistically non-significant differences.

The variety *Tsedey* showed the shortest days to emergence (11.91 days). However, all the other varieties are in statistical parity. Therefore, varieties *Tsedey* emerged earlier by 12.87, 9.5, and 12% than varieties *Kuriftu*, *HL,* and local, respectively (Table 3). The difference in the response of varieties to emergence among the different varieties may be due to differences in their genetic makeup.

The application of *N:* P_2O_5*: S: B* at the highest rate of 65:129.7:23.9: 0.3 kg ha^{-1} resulted in the significantly shortest

Table 3: The main effects of variety and NPSB for days to 50% emergence, leaf length and bulb weight

Varieties	*Days to 50% emergence*	*Leaf length (cm)*	*Bulb weight (g)*
HL	13.16^a	32.596^{ab}	41.92^{ab}
Kuriftu	13.67^a	34.154^a	43.42^a
Local	13.58^a	30.729^b	40.48^b
Tsedey	11.91^b	34.875^a	42.78^a
S.E. (±)	0.3	1	0.653
LSD (0.05)	0.85***	2.9*	1.9*
CV (%)	7.8	10.47	5.36
$N:P_2O_5:S:B$ (kg/ha)			
0:0:0:0	13.33^a	30.633^b	39.94^b
*27.*2: 54.3:10:0.1	13.41^a	32.638^b	41.96^a
46.1:91.9:16.9:0.2	13.25^a	36.125^a	43.75^a
65:129.7:23.9:0.3	12.33^b	32.958^b	42.94^a
S.E. (±)	0.3	1	0.653
LSD (0.05)	0.85*	2.9**	1.9**
CV (%)	7.8	10.47	5.36

Means followed with same letter(s) are not significantly different with each other at 0.05 significant level, S.E. (±) = standard error, CV (%) = coefficient of variation and LSD (5%) = least significant difference at $p < 0.05$

days to emergence (12.33 days). However, all the other fertilizer treatments are in statistical parity. The earliest emergence at the highest NPSB fertilizer application may be due to the increased amount of phosphorus added to the soil, which has an increased role in the emergence of garlic. This result agrees with the report (Sebnie *et al.*, 2018), which observed the earliest days of emergence at an optimum phosphorus level.

Days to 75% maturity

Days to 75% physiological maturity was strongly influenced by the interaction between variety and NPSB fertilizer (Table 4). A very highly significant difference was also seen in the major effect of variety. However, NPSB fertilizer treatment did not influence this parameter significantly. Variety *Tsedey* exhibited the shortest days to physiological maturity (127.67 and 127.33 days) at NPSB fertilizer rates of 46.1 N: 91.9 P_2O_5: 16.9S: 0.2 B kg ha^{-1} and 65:129.7:23.9:0.3 kg ha^{-1}, respectively, which were not statistically different from the NPSB rate of 27.2: 54.3:10:0.1 kg ha^{-1} (Table 4). This showed that variety *Tsedey* took the shortest days to physiological maturity of the other varieties in the interaction with NPSB fertilizer. This is due to the genetic difference among the varieties when interacting with high and small amounts of fertilizer, which makes them mature early or late. The current result is in compliance with the report (Abreham *et al.*, 2017) which stated that the *Tsedey* variety matured earlier (126 days) than the local cultivar.

Growth Parameters

Plant height

The interaction between the garlic cultivars and NPSB fertilizer rates significantly affected plant height, according to the analysis of variance. Similarly, the main effects of variety and NPSB fertilizer were highly significantly ($p < 0.001$) influenced this parameter.

The highest plant height (74.17 cm) was recorded from the *HL* variety at a 46.1:91.9:16.9:0.2 kg ha^{-1} *N: P_2O_5: S: B* rate, which was not significantly different from the values (71.62cm and 69.08cm) recorded from the same variety at 65:129.7:23.9:0.3 kg ha^{-1} and 27.2: 54.3:10:0.1 kg/ha NPSB, and from the *Kuriftu* variety at 46.1:91.9:16.9:0.2 kg ha^{-1} NPSB, respectively (Table 5). The minimum plant height (60.8 cm) was recorded from the variety *Kuriftu* at the unfertilized treatment (0:0:0:0 kg ha^{-1} NPSB), which was not significantly different from the local cultivar and *Tsedey* variety at all rates of NPSB, and the *HL* variety at zero level of NPSB.

Table 4: Interaction effect of varieties and NPSB on days to 75% maturity

N:P_2O_5:S:B kg ha^{-1}	*Varieties*			
	HL	*Kuriftu*	*Local*	*Tsedey*
0:0:0:0	134.67^{abc}	134.33^{abc}	135.00^{ab}	132.33^{abcd}
27.2: 54.3:10:0.1	132.33^{abcd}	134.33^{abc}	135.33^{ab}	129.67^{cd}
46.1:91.9:16.9:0.2	134.00^{abc}	134.00^{abc}	136.00^{ab}	127.67^{d}
65:129.7:23.9:0.3	134.67^{abc}	131.67^{bcd}	137.00^{a}	127.33^{d}
S.E. (±)	0.2341			
LSD (0.05)	1.35*			
CV (%)	1.22			

Means followed with same letter(s) are not significantly different with each other. S.E. (±) = standard error, CV (%) = coefficient of variation and LSD (5%) = least significant difference at $p < 0.05$

The findings of this study unmistakably demonstrated that NPSB fertilizers increase the plant height of several garlic species. As a result, fertilizer treatments below and beyond the reduction ratio had no discernible impact on the plant height of different garlic kinds. A considerably different outcome in terms of plant height was also observed by (Bewuket, 2022).

Number of leaves per plant

The interaction between the garlic varieties and NPSB fertilizer rates had a significant ($p < 0.05$) effect on leaf number, according to the analysis of variance (Table 5). Similarly, a highly significant difference was seen in the major influence of variety and NPSB fertilizer. The significantly highest number of garlic leaves per plant (10.33) was obtained from a variety *kuriftu* that received the highest NPSB rate of 65 N: 129.7P_2O_5: 23.9S: 0.3B kg/ha, which was not significantly different from the leaf number (9.15), recorded from the same variety at 46.1:91.9:16.9:0.2 kg ha^{-1} NPSB (Table 5). There was a significant difference between the other treatments.

The presence of sufficient plant nutrients through the use of NPSB fertilizer that favorably affected the vegetative growth of the plants is one explanation for the largest number of leaves per plant that was found. These nutrients allow for the production of the many protein subunits needed for photosynthesis, the metabolic activities necessary for plant growth, and leaf development. The increased photosynthetic area has been linked to the formation of additional leaves by phosphorus and nitrogen.

These results are in line with the findings of Adem *et al.* (2014), who showed that the availability of nitrogen increased the number of leaves per plant. It has been reported that applying low quantities of phosphorus fertilizer causes a decrease in the number of leaves, leaf surface area, and leaf growth in garlic (Tekeste *et al.*, 2018). Additionally, it might be due to phosphorus' beneficial effects on root growth and the production of carbohydrates. Sulfur application facilitates the availability of other nutrients, leading to improved growth and greater nutrient absorption at higher sulfur levels (Tucker, 1999). Adem *et al.* (2014) Reported that the highest garlic leaf number was obtained by the application of 100 kg N ha^{-1} + 130 kg P_2O_5 ha^{-1}. According to a researcher, the number of leaves per plant in garlic steadily grew with rising sulfur levels up to 45 kg ha^{-1}, after which it declined.

Average leaf length

According to the analysis of variance, leaf length was considerably ($p < 0.05$) and extremely significantly ($p < 0.01$)

Table 5: Interaction effect of varieties and NPSB on plant height and leaf number per plant of garlic crop

$N:P_2O_5:S:B$ (kg ha^{-1})	*Plant height (cm)*				*Number of leaves*			
	Variety				*Variety*			
	HL	*Kuriftu*	*Local*	*Tsedey*	*HL*	*Kuriftu*	*Local*	*Tsedey*
0:0:0:0	65.167^{bcd}	60.08^{d}	60.10^{d}	64.416^{bcd}	7.600^{c}	7.70^{bc}	7.15^{c}	7.167^{c}
27.2: 54.3:10:0.1	69.080^{abc}	65.48^{bcd}	62.25^{cd}	62.917^{cd}	7.920^{bc}	8.32^{bc}	7.98^{bc}	7.783^{bc}
46.1:91.9:16.9:0.2	74.170^{a}	69.83^{abc}	61.67^{cd}	64.330^{bcd}	7.990^{bc}	9.15^{ab}	7.95^{bc}	8.100^{bc}
65:129.7:23.9:0.3	71.620^{ab}	62.67^{cd}	63.00^{cd}	61.416^{cd}	8.367^{bc}	10.33^{a}	7.95^{bc}	8.330^{bc}
S.E. (±)	0.38				0.068			
LSD (0.05)	2.2*				0.4*			
CV (%)	4.04				5.79			

Means followed with same letter(s) are not significantly different with each other. S.E. (±) = standard error, CV (%) = coefficient of variation and LSD (5%) = least significant difference at $p < 0.05$

influenced by the main effects of cultivars and NPSB, respectively (Table 3). However, varieties and NPSB did not interact to significantly influence leaf length.

The longest leaf length was recorded from variety *Tsedey* (34.875 cm), which was not statistically different from the leaf length recorded from varieties *Kuriftu* (34.154 cm) and *HL* (32.596 cm). However, the shortest leaf length was recorded from the local cultivar (30.729 cm) (Table 3).

Regarding NPSB blended fertilizer treatment, the highest leaf length was recorded at 46.1N: 91.9 P_2O_5: 16.9 S: 0.2B kg ha^{-1} fertilizer application rate, which was significantly different compared with the other fertilizer rates. Even though the shortest leaf length was recorded from the unfertilized treatment, it was in statistical parity with the other fertilizer treatments. This showed that the addition of NPSB fertilizer of more or less than 46.1:91.9:16.9:0.2 kg/ha will not have a significant positive effect on the leaf length of garlic (Table 3).

The increased leaf length at the 46.1N: 91.9 P_2O_5: 16.9 S: 0.2B kg/ha of nutrient application is due to the fact that the addition of the optimum amount of NPSB may be linked to increased nutritional availability, which lengthens garlic leaves by simulating cell division and cell expansion, which in turn may lengthen leaves. Additionally, this improves protein synthesis, which raises the accumulation of carbohydrates and improves the properties of plant development. Phosphorus, the primary component of energy molecules, nucleic acids, phospholipids, and co-enzymes, is crucial to metabolic activities. Additionally, it might be due to phosphorus' beneficial effects on root growth and the production of carbohydrates. Sulfur application increases the availability of other nutrients, which promotes better development and greater nutrient absorption at higher sulfur concentrations (Tucker, 1999).

Yield and Yield Components

Average bulb weight

The results of the analysis of variance revealed that the primary influences of varieties and NPSB on bulb weight are, respectively, significant ($p < 0.05$) and extremely significant differences ($p < 0.01$). Variety and NPSB's combined influence on bulb weight, however, had no appreciable differences. The highest bulb weight was recorded from varieties *Kuriftu, Tsedey,* and *HL* (43.42, 42.78, and 41.92 g, respectively), which were not statistically different (Table 3). The local variety generated the lowest bulb weight (40.48 g), it was noted that there was substantial variance in bulb weight amongst different garlic kinds (Woldeyes, 2017).

The bulb weight of garlic was also significantly influenced by the application of NPSB fertilizer. As compared to the unfertilized treatments, all treatments with NPSB fertilizer showed a significantly ($p < 0.05$) higher weight of garlic bulbs, but there was no significant difference among them. The lowest bulb weight (39.94 g) was obtained from the unfertilized treatment. The highest bulb weight of garlic was recorded at a rate of 46.1 N: 91.9 P_2O_5: 16.9 S: 0.2 B kg ha^{-1}. The bulb weight of different types of garlic is decreased or not significantly improved by fertilizer applications above this ratio.

The present study's findings are largely consistent with those of other researchers who found that applying single nutrients like phosphorus and sulfur or mixed fertilizers like NPKS boosted bulb weight (Tucker, 1999). Numerous authors have documented the considerable variations in bulb weight across garlic cultivars as a result of fertilizer use.

Average bulb diameter

Bulb diameter was significantly ($p < 0.01$) influenced by the interaction effects of the garlic variety and NPSB fertilizer. Similarly, the main effects of variety and NPSB fertilizer highly significantly influenced the same parameter. The largest bulb diameter (5.87 cm) was measured in variety *kuriftu* at a fertilizer rate of 46.1:91.9:16.9:0.2 kg ha^{-1} NPSB, followed by a value (5.53 cm) measured in the same variety at a rate of 65:129.7:23.9:0.3 kg/ha NPSB. However, bulb diameters obtained from these treatment interactions were statistically similar. Applications of fertilizer below and above 46.1:91.9:16.9:0.2 kg ha^{-1} reduce or have no significant positive effect on the bulb diameter of garlic varieties. On the other hand, the smallest bulb diameter (3.87 cm) was recorded from a local variety that interacted with the unfertilized treatment (Table 6).

The increase in bulb diameter is unquestionably linked to an increase in the production of dry matter and the allocation of assimilates to the bulb through an increase in the number of leaves, plant height, and leaf length. This results in a higher concentration of photo-assimilates in the bulbs, which ensures a large bulb diameter. The findings of the current study showed that the varying rates of NPSB fertilizer had an impact on the width of the garlic bulb, which may be related to the impact of various nutrients on the crop's metabolic activity. The largest bulb diameter was 5.53 cm, according to (Yudhvir and Ramesh, 2003), whereas 4.84 cm was recorded by (Singh *et al.*, 2018).

Marketable bulb yield

Garlic's marketable bulb production was impacted by the interaction effect of variety and NPSB fertilizer, which was highly significant ($p < 0.01$) according to an analysis of variance. Variety and NPSB fertilizer had major impacts that were highly significant and had an impact on this parameter (Table 7). The variety *kuriftu* produced the highest marketable bulb yield (8.14 t ha^{-1}) at a fertilizer rate of 46.1:91.9:16.9:0.2 kg ha^{-1} NPSB, which was statistically similar to the value (7.36 t ha^{-1}), produced by the same variety at a fertilizer rate of 344 kg ha^{-1} NPSB. The local cultivar's lowest marketable bulb production (4.76 t ha^{-1}) was seen in an unfertilized regimen. Therefore, increasing rates of fertilizer from 0 kg to 46.1:91.9:16.9:0.2 kg/ha was found to increase the marketable yield of garlic. However, garlic varieties exhibited a reduced yield of marketable bulbs at 0 kg ha^{-1} and 27.2: 54.3:10:0.1 kg ha^{-1} rates.

Zaman (1970), reported that garlic marketable bulb production rose with rising sulfur levels up to 45 kg ha^{-1} before declining after that. In the current experiment, the highest marketable bulb yield was obtained from the variety *Kuriftu* at NPSB fertilizer treatments of 46.1:91.9:16.9:0.2 kg ha^{-1} and 65:129.7:23.9:0.3 kg ha^{-1}, which do have sulfur content of 16.96 and 23.91, respectively, by excluding the residual sulfur content of the soil.

Table 6: Bulb diameter of garlic as influenced by the interaction of varieties and NPSB fertilizer

Bulb diameter (cm)				
N:P_2O_5:S:B kg/ha	*Varieties*			
	HL	*Kuriftu*	*Local*	*Tsedey*
0:0:0:0	4.75^{cd}	4.85^{cd}	3.87^{f}	4.61^{de}
27.2:54.3:10:0.1	5.03^{cd}	5.14^{bc}	4.15^{ef}	4.99^{cd}
46.1:91.9:16.9:0.2	5.15^{bc}	5.87^{a}	4.18^{ef}	5.22^{bc}
65:129.7:23.9:0.3	5.09^{bcd}	5.53^{ab}	4.18^{ef}	4.95^{cd}
S.E. (±)	0.0214			
LSD (0.05)	0.1224**			
CV (%)	3.027			

Means followed with same letter(s) are not significantly different with each other. S.E. (±) = standard error, CV (%) = coefficient of variation and LSD (5%) = least significant difference at P<0.05

Unmarketable bulb yield

The interaction effect of varieties and NPSB fertilizer was significantly different ($p < 0.05$) on the yield of unmarketable garlic bulbs, according to an analysis of variance. Variety and NPSB fertilizer had major impacts that were extremely significant and had an impact on this parameter (Table 7). The highest unmarketable bulb yield was obtained from the *HL* variety (0.92 t ha^{-1}) at unfertilized treatment, which was statistically similar to values (0.85 and 0.84 t ha^{-1}) recorded from the *HL* variety at fertilizer rates of 27.2: 54.3:10:0.1 kg ha^{-1} NPSB and variety *kuriftu* at unfertilized treatment, respectively. A statistically lower unmarketable bulb yield was obtained from all varieties that interacted with a fertilizer rate of 344 kg ha^{-1} NPSB (Table 7).

Increased soil nitrogen levels caused less-than-ideal growth, which led to larger or heavier bulbs, split bulbs, physiologically disordered bulbs, doubles, rotting, off-color and discolored bulbs, and a higher output of unsalable bulbs (Sharma, 2016).

(a)At time of clove planting (b) after application of treatments

Figure 2: Field status before and after treatment application

Figure 3: The researcher during growth data recording

Table 7: Garlic variety and NPSB fertilizer interactions' effect on the production of marketable, non-marketable, and total bulbs yield

$N:P_2O_5:S:B$ (kg/ha)	*Marketable bulb yield (t ha-1)*				*Unmarketable bulb yield (t ha-1)*				*Total bulb yield (t ha -1)*			
	Variety											
	HL	*Kuriftu*	*Local*	*Tsedey*	*HL*	*Kuriftu*	*Local*	*Tsedey*	*HL*	*Kuriftu*	*Local*	*Tsedey*
0:0:0:0	5.83cde	5.88cde	4.76f	5.65def	0.92a	0.84abc	0.76bcd	0.64cdef	6.75cdef	6.72cdef	5.52g	6.29efg
27.2: 54.3:10:0.1	6.34bcde	6.44bcde	5.44ef	6.1cde	0.85ab	0.69cdef	0.71bcde	0.57ef	7.19cdef	7.13cdef	6.15fg	6.67cdef
46.1:91.9:16.9:0.2	6.68bcd	8.14a	6.2cde	6.4bcde	0.76bcd	0.67cdef	0.7bcdef	0.57ef	7.44bcd	8.81a	6.9cdef	6.97cdef
65:129.7:23.9:0.3	6.71bc	7.36ab	6.47bcde	6.5bcde	0.67cdef	0.64def	0.69cdef	0.55f	7.38bcde	8ab	7.16cdef	7.05cdef
S.E. (±)	0.011				0.002				0.01			
LSD (0.05)	0.062**				0.0093*				0.061**			
CV (%)	5.122				7.13				4.5			

Means followed with same letter(s) are not significantly different with each other. S.E. (±) = standard error, CV (%) = coefficient of variation and LSD (5%) = least significant difference at $p < 0.05$

Total bulb yield

Variety and NPSB interacted to significantly influence the total bulb yield of garlic. The main effects of variety and NPSB were found to influence this parameter highly significantly (Table 7). The highest total bulb yield was recorded from variety *kuriftu* (8.81 t ha^{-1}) at 46.1:91.9:16.9:0.2 kg ha^{-1} NPSB, which was statistically similar to the value (8 t ha^{-1}) recorded from the same variety at a rate of 65:129.7:23.9:0.3 kg ha^{-1} NPSB. However, the lowest total bulb yield of garlic (5.52 t ha^{-1}) was recorded from a local cultivar at 0 kg ha^{-1} and which was not significantly different from the value (6.15 t ha^{-1}) recorded from the same variety at 27.2: 54.3:10:0.1 kg ha^{-1} NPSB (Table 7). This is because the enzymatic processes and chlorophyll production that promote growth and development, as well as high-yielding performance in plants, are both stimulated by sulfur and nitrogen.

Additionally, it is consistent with the results of Zaman *et al.* (1970), which showed that the yield of garlic bulbs increased as sulfur levels rose up to 45 kg ha^{-1} before declining. According to reports, there were disparities in total bulb production amongst garlic types that ranged from 10.24 to 7.76 t ha^{-1} (Hersi and Abdalla, 2022; Woldeyes *et al.*, 2017).

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