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Full Length Research Paper

Growth and bulb yield garlic varieties affected by nitrogen and phosphorus application at Mesqan Woreda, South Central Ethiopia

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In Ethiopia, particularly at Mesqan Woreda appropriate fertilizer management was the major problem accounted for low productivity of garlic. Therefore, a field experiment was conducted with the objective to investigate the effect of nitrogen and phosphorus levels on growth and bulb yield of two garlic varieties at Beressa watershed, Mesqan Woreda, South Central Ethiopia under supplemental irrigation from November to April 2010 to 2011. The treatments consisted of two garlic varieties Local (farmers' variety) and Tsedey92 (G-493), 4 levels of Nitrogen (0, 50, 100 and 150 kg N/ha) and 3 levels of Phosphorus (0, 50 and 100 kg P_2O_5 ha^{-1}) arranged in randomized complete block design. Data on growth and bulb yield were collected. Varieties differed significantly on plant height, leaf area index, shoot dry weight and bulb yield. Nitrogen significantly affected bulb yield along with all the growth parameters. Phosphorus had significant influence on number of leaf per plant and bulb yield. Number of leaf per plant and bulb yield were significantly affected by the interaction of N and P. The highest bulb yield of 3.34 t/ha was achieved at 100 kg N + 100 kg P_2O_5/ha, and was 244% higher than the control and statistically similar to the yield of 3.27 t/ha obtained from 100 kg N and 50 kg/ha P_2O_5 application for variety Tsedey92. Hence, it may be tentatively concluded that the farmers at Beressa watershed should apply 100 kg N and 50 kg P_2O_5 /ha using variety Tsedey92 to improve bulb yield of garlic.

Key words: Garlic, variety, nitrogen, phosphorus ,growth, bulb yield.

INTRODUCTION

Garlic (*Allium sativum* L.) is one of the most important *Allium* plants widely cultivated throughout the world including Ethiopia (Pulseglove, 1972). It is one of the most important bulb vegetables, which is used as spice and flavoring agent for foods and as medicinal plant (Velisek et al., 1997).

Garlic produces unique flavours savored by almost all of the global culture (Havey, 1999). Total area under cultivation in the world is 1,199,929 ha with total production of 17674893 tones (FAO, 2012). In Ethiopia, the total area under garlic production in 2009/2010 reached 15,361.25 ha and the production is estimated to be over 179,657.8 tones (CSA, 2010).

Numerous problems accounted for the low mean yield of garlic in Ethiopia: among which lack of proper planting materials, inappropriate agronomic practices, absence of proper pest and disease management practices and marketing facilities are the prominent ones. Even though, a number of experiments had been conducted on garlic in Ethiopia, there is a large gap between the work done and the demand of the country for the crop. Past efforts have been engaged in identifying production constraints, improving garlic cultivars and its production practices (Getachew and Asfaw, 2010).

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Several production and management related limiting factors have not yet been addressed among which fertilizer management is the major area that should get consideration to improve the production of garlic (Getachew and Asfaw, 2000). In Ethiopia especially in Mesquan Woreda farmers who produce garlic relay on traditional practices with local cultivars and they also do not use fertilizer. Consequently, there is a need to study the effect of nitrogen and phosphorus fertilizer on the growth and bulb yield of garlic. Therefore, a field experiment was conducted with the objective to investigate the effect of nitrogen and phosphorus on growth and bulb yield of two garlic varieties, at Beressa watershed, Mesqan Woreda, South Central Ethiopia.

MATERIALS AND METHODS

Description of the experimental site

A field experiment was conducted on farmers' field in Beresa watershed, Mesqan Woreda, Guraghie Administrative Zone of the South Nations Nationalities and Peoples Region (SNNPR) by using supplementary irrigation during November to April of 2010/2011. The site is located south west of Addis Ababa at 08^o 06′ 422" latitude and 038^o 24′ 909" longitude and with an altitude of 1960 m.a.s.l. The average annual rainfall of the area over a decade was 1206.83 mm with a range of 504.7 mm to 1783.3 mm with average annual temperature of 18.6ºC (NMAHB, 2010).

Collection and analysis of pre-sowing soil sample of the experimental field

Surface soil samples (0-20 cm depth) were collected from 15 spots randomly representing the entire experimental field before planting and composited for soil analysis. The soil sample was air dried and ground to pass through a 2 mm size sieve for analysis except for organic carbon and total N, in which case 0.5 mm sieve was used. Soil texture was determined by using Bouyoucos Hydrometer Method (Day, 1965). The pH of the soil was measured potentiometrically in the supernatant suspension of a 1:2.5 Soil: Water suspension by pH meter and EC by conductivity meter (Chapman, 1965). Cation exchange capacity (CEC) was measured after leaching the ammonium acetate extract soil sample with 10% NaCl solution. Thereafter, it was estimated titrimetrically by distillation of ammonium acetate which was displaced by sodium (Chapman, 1965). Organic matter was computed after determination of percentage organic carbon by following Walkely and Black (1934) wet oxidation method and using the conversion factor 1.724. Total Nitrogen was determined by using micro Kjedahl method as described by Jackson (1958). Available P was extracted with sodium bicarbonate solution at pH 8.5 following Oslen's method (Olsen et al., 1954).

Experimental design and treatments

The treatments consisted of four nitrogen levels (0, 50,100,150 kg N ha^{-1}) and three phosphorus levels (0, 50, 100 kg P_2O_5 ha^{-1}) with two garlic varieties, Local (farmers' variety) and Tsedey92 (G-493). The 2 × 3 × 4 treatment combinations were arranged in a randomized complete block design (RCBD) with three replications. The individual plot sizes were 2.448 m^2 with intra and inter spacing of 17 × 30 cm containing a total of 48 plants per plot

Experimental management

Two varieties of garlic namely Local (farmers' variety) and Tsedey92 (G-493) were collected from DebreZiet Agricultural Research Center (DZARC). Tsedey92 (G-493) was characterized by white purple bulb color. Prior to planting, garlic bulbs were split into individual cloves and planted upright. Nitrogen in the form of urea was applied in spilt at three different times. Initially, at the planting time, secondly, 30 days after planting and finally, 20 days after complete emergence of the cloves. Whereas, all the phosphorus was applied at the time of planting through triple super phosphate (TSP). All management practices were performed as per the general recommendations for garlic (DZARC, 2000).

Data collection

Data on the bulb yield and yield related agronomic traits of garlic were recorded from each plot by taking four random plants. These quantitative traits includes: total bulb yield (t ha^{-1}), days to maturity, plant height (cm), leaf number per plant; leaf area (cm^2), leaf area index (LAI): shoot dry weight (g per plant).

Data analysis

All the data were analyzed using analysis of variance (ANOVA) and the general linear model using SAS (SAS, 2002). Wherever treatment effects were significant at 5% probability level, the means were separated using the Duncan's Multiple range Test (DMRT) procedures. Correlation analysis was carried out using Pearson's simple correlation coefficients for growth, and bulb yield of garlic as affected by nitrogen and phosphorus applications (Gomez and Gomez, 1984).

Table 1. Mean square error for the parameters.

Parameters	Variety (V)	Nitrogen N	Phosphors (P)	V*N	V*P	N*P	V*N*P
DM	767***	606.9***	48.26^{ns}	58.38^{ns}	46.26^{ns}	14.17^{ns}	19.13^{ns}
PH	97.02*	264.07***	16.65^{ns}	18.64^{ns}	11.29^{ns}	43.18^{ns}	16.16^{ns}
LNPP	0.57^{ns}	8.16***	2.84***	0.10^{ns}	0.55^{ns}	1.31***	0.12^{ns}
LA	21966.4**	19370.8**	2007.2^{ns}	5125.8^{ns}	1029.4^{ns}	2750.1^{ns}	1231.8^{ns}
LAI	0.085**	0.077***	0.008^{ns}	0.020^{ns}	0.005^{ns}	0.010^{ns}	0.004^{ns}
SDW	2.03**	5.97***	0.34^{ns}	0.20^{ns}	0.27^{ns}	0.47^{ns}	0.15^{ns}
TBY	0.81**	7.72***	3.77***	0.55***	0.43**	0.42***	0.30**

*, **, *** indicate significance at $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$, respectively, 'ns' = non significant. DM= Days to maturity, PH= plant height, LNPP= Leaf Number per plant, LA= Leaf area, LAI= Leaf area index, SDW= Shoot dry weight and TBY= Total bulb yield.

Table 2. Influence of N and P application on plant height (cm), shoot dry weight (g/plant) and days to maturity of garlic varieties at Beressa.

Treatments	Days After Emergence (DAE)						
	Plant height (cm)			Shoot dry weight (g/plant)			Days to maturity
	50	70	90	50	70	90	
Variety							
Local	33.66b	38.06^{b}	50.45^{b}	1.41^{a}	2.64^{b}	3.98^{b}	133.2^{b}
Tsedey92	35.89^{a}	39.68^{a}	52.77^{a}	1.49^{a}	2.94^{a}	4.32^{a}	126.4^{a}
N (kg/ha)							
0	30.51^{c}	35.21^{d}	47.06^{b}	0.99^{d}	2.31^{c}	3.48^{c}	122.2^{c}
50	33.15b	37.89c	49.81^{b}	1.28^{c}	2.71^{b}	3.89^{b}	128.0^{b}
100	37.15a	40.08b	54.69^{a}	1.62^{b}	2.89^{b}	4.45^{a}	133.4^{a}
150	38.25a	42.31a	54.86^{a}	1.89^{a}	3.23^{a}	4.77^{a}	135.0^{a}
P_2O_5(kg/ha)							
0	34.09^{a}	38.50^{a}	50.99^{a}	1.40^{a}	2.64^{a}	4.02^{a}	128.54
50	34.53^{a}	38.76^{a}	51.27^{a}	1.41^{a}	2.84^{a}	4.17^{a}	129.17
100	35.69^{a}	39.35^{a}	52.55^{a}	1.52^{a}	2.88^{a}	4.26^{a}	131.25
CV(%)	10.78	6.99	9.16	22.68	15.01	11.94	3.67

Means followed by the same letter(s) are not significantly different at DMRT=0.001, 0.01 and 0.05.

RESULTS AND DISCUSSION

Total bulb yield was significantly ($P<0.05$) increased by the interaction of variety, nitrogen and phosphorus. Similarly, nitrogen and phosphorus alone or in interaction across the varieties significantly ($P<0.01$) increased total bulb yield and leaf number per plant. Nitrogen imparted significant differences with regard to the days to maturity, plant height, leaf number per plant, leaf area, leaf area index, shoot dry weight and total bulb yield. Significant differences were also observed in days to maturity, plant height, leaf area, leaf area index, shoot dry weight and total bulb yield due to varieties (Table 1).

Days to maturity

Varieties significantly ($P \leq 0.001$) varied in days to maturity (Table 1). Tsedey92 variety took 126 days to mature whereas Local variety took 7 days more to maturity (Table 2). This may be due to the fact that there is a genetic difference between the two varieties. This result agree with the work of Kassahun (2006) and Kotinska et al. (1990) who reported the existence of variability in days to maturity for different accessions of garlic.

Nitrogen fertilizer had a significant ($P \leq 0.001$) effect on days to maturity (Table 1). Days to maturity was delayed by 13 days when 150 kg N ha^{-1} was applied compared with the control, but statistically at par with the application from 100 kg N ha^{-1} (Table 2). Delay in days to maturity with high levels of N could be attributed to delayed senescence of the canopy of the crop (garlic) and extended physiological activity and continuing in photosynthesis. This result is in agreement with the findings of Showel (2010) and Tesfaye et al. (2007) who reported the effect of N on days to maturity for onion.

Plant height

The difference in plant height was observed to be significant ($P \leq 0.05$) between the varieties Tsedey92 and Local (farmers' variety) throughout the growth period (Table 1). Tsedey92 had significantly higher plant height than farmers' (local) variety (Table 2). Tsedey92 variety was 2.23, 1.62 and 2.32 cm taller than the local variety at 50, 70 and 90 DAE, respectively. The difference between the varieties could be attributed to the genotypic variability. The result is in agreement with the findings of Kassahun (2006), who observed a wide range of variation in plant height among different garlic varieties. Etoh and Simon (2002) also reported wide variation among garlic varieties in plant height.

Nitrogen significantly ($P \leq 0.001$) affected plant height of garlic at all sampling dates (Table 1). Mean plant height of garlic at 100 and 150 kg N ha^{-1} was significantly higher than the lower rate, but were at par with each other at 70 DAE that responded linearly. Height of garlic was longer by 7.63 and 4.78 cm at 100 kg N ha^{-1} compared with the control and 50 kg N ha^{-1} at 90 DAE, respectively (Table 2).The increment in plant height due to N application could be attributed to the effect of nitrogen on cell division and elongation which lead to growth and increased height of the stems and leaves (Rabinowitch and Kamenetsky, 2002). The result of this study is in close conformity with the findings of Farooqui et al., (2009) and Aregawi (2006) also reported that amount of nitrogen fertilizer applied increased plant height significantly. Similarly, Kakara et al. (2002) and Gebrehawaria (2007) had also reported significant effect of N on plant height. However, the effect of N on plant height was more pronounced at early growth phase, which was 21.76, 20.16 and 16.21% at 50, 70 and 90 DAE, respectively.

Shoot dry weight

A significant ($P \leq 0.01$) difference was observed between varieties for shoot dry weight at the day 70 and 90 after emergence (Table 1). The variety Tsedey92 had shown 11.36 and 8.5% higher shoot dry weight than the local (farmers') variety (Table 2). The difference in shoot dry weight between the cultivars could be attributed to the genotypic variability that regulated plant height and leaf number per plant.

Application of N had a highly significant ($P \leq 0.001$) effect on shoot dry weight of garlic at the three sampling dates (Table 1). The growth rate of shoot dry weight increased linearly with applied N in the early growth stage but showed a decreasing trend to the maturity. The highest N rate (150 kg ha^{-1}) enhanced the shoot dry weight by 0.90, 0.92 and 1.29 g/plant as compared to the unfertilized plot at 50, 70 and 90 DAE, respectively (Table 2); showing that towards the maturity assimilates translocated from shoot to bulbs (Bertoni et al., 1992). In harmony to this, Lujiu et al. (2004) and Aregawi (2006) reported a significant increase in shoot dry weight of garlic due to N application at higher rate.

Leaf number per plant

The interaction of N and P had a highly significant ($P \leq 0.001$) effect on the mean leaf number of garlic (Table 1). The highest leaf number of (8.98) was recorded at NP combination of 150 kg N +100 kg P_2O_5. However, this was similar to the value (8.90) obtained from the 150 kg N and 50 kg P_2O_5 ha^{-1} combination and the lowest leaf number (6.23) was observed in unfertilized plots (Figure 1). Comparing the mean values of fertilized plots with that of no fertilizer (control), 8 to 44% more number of leaves were achieved due to N x P interactions. The positive effect of N and P on leaf number could be attributed to the favorable effects of the two nutrients on plant growth and development (Minard, 1978). This result is consistent with that of Gebrehawaria (2007) who reported a significant effect of nitrogen and phosphorus interactions on leaf number of garlic and observed highest leaf number (8.71) from N P combination of 120 kg N and 60 kg P/ha.

Leaf area

A significant ($P \leq 0.05$) difference was observed between the varieties in leaf area per plant at 70 and 90 DAE (Table 1). More leaf area $plant^{-1}$ (6.3 and 7.8%) was recorded in Tsedey92 at the two sampling dates of 70 and 90 after emergence, respectively (Table 3).

Nitrogen fertilization significantly ($P<0.01$) affected the mean leaf area per plant of garlic (Table 1). On all sampling days after emergence, the highest mean leaf area per plant was achieved at 150 kg N ha^{-1}. Which was statistically at par with 100kg N ha^{-1} and the lowest was obtained from the unfertilized plots (Table 3). Therefore; increasing N up to 100 kg N ha^{-1} resulted in increased leaf area of garlic. Similarly, Mudziwa (2010) also reported a linear and significant increase in leaf area due to N application to garlic.

Leaf area index

There were significant ($P \leq 0.01$) differences in LAI between the varieties at 70 and 90 DAE (Table 1). In both periods the variety Tsedey92 has got higher (0.71 and 0.94) LAI values at 70 and 90 DAE respectively (Table 3). This is in agreement with Shawol (2010) who observed a significant variation of LAI between two onion varieties. On the contrary to this, Seifu (2008) reported a non

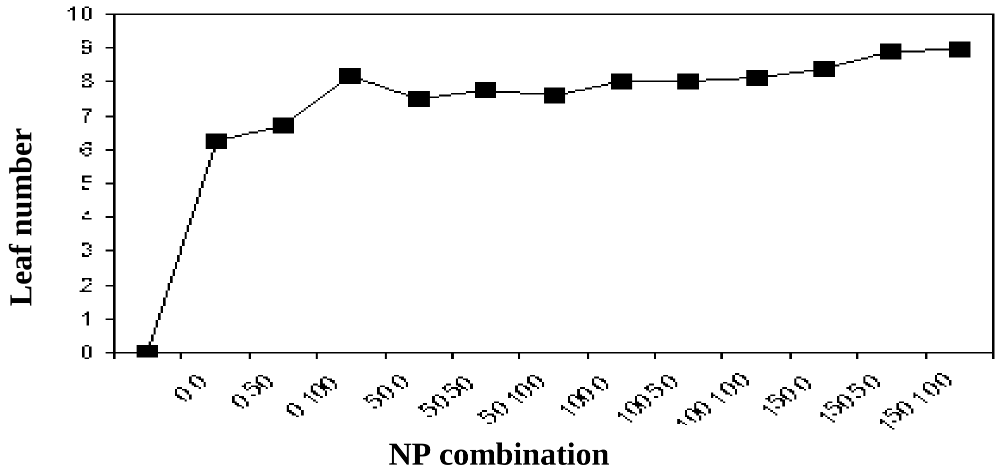

Figure 1. Interaction effect of nitrogen and phosphorus on leaf number of garlic varieties at Beressa water shade.

Table 3. Effects of N and P application on leaf area (cm^2) and leaf area index of garlic varieties, at Beressa water shade.

Treatments	**Days after emergence**					
	Leaf area (cm^2)			**Leaf area index**		
	50 Days	**70 Days**	**90 Days**	**50 Days**	**70 Days**	**90 Days**
Variety						
Local	125.53[a]	340.57[b]	444.10[b]	0.24[a]	0.67[b]	0.87[b]
Tsedey 92	128.40[a]	362.10[a]	478.99[a]	0.25[a]	0.71[a]	0.94[a]
N (Kg/ha)						
0	112.10[c]	323.54[b]	422.32[b]	0.22[c]	0.63[b]	0.83[b]
50	123.34[b]	354.82[a]	446.56[b]	0.24[b]	0.69[a]	0.87[b]
100	135.51[a]	363.12[a]	488.10[a]	0.26[a]	0.71[a]	0.95[a]
150	136.91[a]	363.80[a]	489.15[a]	0.27[a]	0.72[a]	0.96[a]
P (Kg/ha)						
0	125.39[a]	348.54[a]	451.97[a]	0.24[a]	0.67[a]	0.88[a]
50	126.95[a]	348.93[a]	464.97[a]	0.25[a]	0.68[a]	0.91[a]
100	128.55[a]	356.50[a]	468.45[a]	0.25[a]	0.70[a]	0.92[a]
CV%	11.3	9.6	11.11	11.12	9.59	11.11

Means followed by the same letter(s) are not significantly different at DMRT=0.001, 0.01 and 0.05.

significant difference in LAI between three onion varieties.

Leaf area index was significantly ($P \leq 0.001$) affected by applied N rates (Table 1). In all the sampling periods, the highest values of LAI were recorded at 150 kg N ha^{-1} and the lowest from the control. However, leaf area index at 100 and 150 kg N ha^{-1} were at par with each other throughout the growth period of the crop and LAI was higher by 18.2, 12.7 and 14.5% at 50, 70 and 90 DAE at 100 kg N ha^{-1} compared with the control, respectively (Table 3). The increase in leaf area index with N application might be due to the fact that nitrogen fertilizer during the early stage of development greatly increases leaf area by delaying leaf senescence, sustained leaf photosynthesis and extended leaf area duration, which ultimately resulted in maximum leaf area index. Ahmed and Fraihat (2009) also noticed that N fertilization enhanced cell division and enlargement that in turn may increase number of leaves and leaf dimensions. Similarly, Aregawi (2006) conducted a field experiment on garlic

Table 4. Interaction effect of variety, nitrogen and phosphorus on bulb yield of garlic at Beressa water shade.

Variety	Bulb yield of garlic (t/ha)				
	P_2O_5 (Kg ha^{-1})	N rate (kg ha^{-1})			
		0	50	100	150
Local	0	0.67^{j}	1.42^{g-i}	1.88^{fg}	2.31^{d-f}
	50	1.17^{hi}	1.62^{gh}	2.15^{ef}	2.44^{de}
	100	1.85^{fg}	2.37^{de}	2.76^{cd}	2.55^{c-e}
Tsedey92	0	0.97^{ij}	1.39^{g-i}	1.47^{gh}	2.80^{b-d}
	50	1.60^{gh}	1.56^{gh}	3.27^{ab}	3.03^{a-c}
	100	1.60^{gh}	1.66^{gh}	3.34^{a}	3.04^{a-c}
CV(%)			13.18		

and reported a significant effect of N on leaf area index.

Total bulb yield

Interaction effect of variety, nitrogen and phosphorus significantly (P≤0.01) increased the bulb yield of garlic (Table 1). The variety Tsedey92 resulted in significantly higher mean bulb yield of 3.27 t ha^{-1} from the application of 100 kg N and 50 kg P_2O_5 ha^{-1}, which was 237% higher than that of unfertilized plots. Moreover, the highest garlic production of 3.34 t/ha was obtained with this variety by application of 100 kg N + 100 kg P_2O_5 /ha but it was statistically at par yield produced with 100 kg N + 50 kg P_2O_5/ha (Table 4). On the other hand, the local (farmers') variety resulted in highest bulb yield of 2.76 t ha^{-1} from combined application of 100 kg N and 100 kg P_2O_5 resulting in 311% more over the unfertilized plots. This yield was statistically at par to yield obtained with some other combinations of N and P inputs. Without P_2O_5 application, bulb yield of Tsedey92 increased from 0.97 to 2.8 t ha^{-1} when the level of applied N increased from 0 to 150 kg ha^{-1} while it was increased from 0.97 to 1.6 t ha^{-1} without N at 50 kg P_2O_5 application and further increase in P had no effect. Similarly, without P_2O_5 application, the bulb yield of the local (farmers') variety increased from 0.67 to 2.31 t ha^{-1} as the level of N application increased zero to 150 kg ha^{-1} while it was increased 0.67 to 1.85 t ha^{-1} under no N applied. In general, higher mean bulb yield of garlic was obtained from the application of 100 kg N and 50 kg P_2O_5 ha^{-1} for Tsedey92 and 100 kg N and 100 kg P_2O_5 for local variety (Table 4). The increment in bulb yield due to nitrogen and phosphorus combination might be associated to the synergistic effect of the two nutrients on photosynthetic activity, translocation of assimilates and more absorption of nutrients by the plants (Marschner, 1995) and could also be attributed to deficiency of these nutrients in the experimental soil as soil was medium in organic carbon which is used as index of N availability and low in available P having 1.2% organic carbon and 6.9 mg kg^{-1} of Olsen's and the difference between the two varieties in response to the applied fertilizer could be attributed to the genotypic variability (Kassahun, 2006).

Conclusion

Garlic is one of the most important bulb vegetables, which is used as spice and flavoring agent for foods and as medicinal plant. Selections of the best variety with their proper rate of fertilizer rate are very important factors to increase the productivity and marketability of garlic. The present experiment was conducted to assess the effect of variety, nitrogen and phosphorus on growth and yield of garlic at Beressa watershed, SNNPR

The results showed that varieties significantly differed almost for all the parameters considered in this experiment and application of N fertilizer significantly influenced days to 50% maturity, plant height, leaf area index, number of leaves per plant and shoot dry weight of garlic while these parameters did not give a response for the applied phosphorus levels except leaf number per plant.

The interaction effects of N and P were significant for leaf number per plant. The three way interaction between variety, nitrogen and phosphorus were significant for bulb yield of garlic. The maximum bulb yield of 3.34 t ha^{-1} was obtained from Tsedey92 in combination with nitrogen and phosphorus (P_2O_5) at 100 kg ha^{-1} of each and was statistically similar to the value from treatment combination, Tsedey92 (100 kg N+50 kg P_2O_5).

Therefore, the result of this study has shown that application of different levels nitrogen and phosphorus fertilizers along with varieties had a significant positive influence on the yield and growth of garlic. From this study it can be conclude that garlic Tsedey92 variety in combination with nitrogen and phosphorus (P_2O_5) at the rate of 100 kg ha^{-1} had a potential to increase the yield and growth of garlic under Mesqan Woreda condition. Hence, farmers and any new commercial growers and/or investors at Mesqan Woreda and similar agro–ecology areas would use these packages for growing garlic with better yield. This study based on only one location, single season with only two varieties. Therefore, such types of investigations need to be repeated under at different locations and seasons with additional varieties.

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