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Full length Research Paper

The Influence of Nitrogen and Phosphorus on the growth and bulb yield of Garlic (A*llium sativum L.*) Varieties at Beressa Watershed, MesqanWoreda, South Central Ethiopia

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Garlic is one of the most important bulb vegetables used as spice and flavoring agent of food and medicinal plants throughout the globe. Numerous problems accounted for the low productivity of garlic in Ethiopia, among which appropriate fertilizer management is the major factor. Therefore, this experiment was undertaken 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 2010/11. The treatments for the experiment were two garlic varieties, 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) arranged in Randomized Complete Block Design. Data on growth parameters (days to maturity, plant height, leaf number, leaf area, leaf area index and shoot dry weight) and total bulb yield were collected. The varieties showed significant difference on plant height, leaf area, leaf area index, shoot dry weight and bulb yield. Nitrogen also significantly affected bulb yield along with all the growth parameters. Phosphorus had significantly influenced number of leaf per plant and bulb yield. Leaf number per plant and bulb yield was significantly affected by the interaction of N and P. The highest bulb yield of 3.34 t/ha was recorded at 100 kg N + 100 kg P_2O_5/ha combination, and that was 244 % higher than the control and statistically similar to the yield 3.27 t/ha obtained at 100 kg N and 50 kgP_2O_5/ha combination for Tsedey92. Hence, tentatively 100 kg N and 50 kg P_2O_5 /ha using variety Tsedey92 was recommended for the farmers of the study area.

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 (Pulseglove, 1972) and it 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. Total area under cultivation in the world was 1,199,929ha 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 was estimated to be over 179,657. 8 tones (CSA, 2010).

Numerous production constraints accounted for the low productivity of garlic in Ethiopia: among which lack of proper planting material, inappropriate agronomic practices, absence of proper pest and disease management practices and marketing facilities are the major problems. Past efforts have been engaged in identifying production problem, improving garlic cultivars and its production practices (Getachew and Asfaw, 2000). In Ethiopia, among those constraints, fertilizer management is the major area that should get consideration to improve the productivity of garlic (Getachew and Asfaw, 2000). Most farmers who produce garlic rely on

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traditional practices with local cultivars and they also do not know the appropriate fertilizer rate for garlic production and consequently the researchers were interested to contribute some solution on the existing problem regarding fertilizer management in garlic and therefore, a field experiment was conducted with the objectives to investigate the effect of nitrogen and phosphorus on growth and bulb yield of two garlic varieties.

MATERIALS AND METHODS

Description of the Experimental Site

A field experiment was conducted at farmers' field in Beresa watershed, Mesqanworeda, 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 in the co-ordinates 08^{o} 06′ 422" latitude and 038^{o} 24′ 909" longitude and with an altitude of 1960m.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 18.6^{0}C (NMAHB, 2010).

Collection and Analysis of Pre-sowing Soil Sample of the Experimental Field

Surface soil sample (0-20 cm depth) was 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 2mm 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. 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 $kgNha^{-1}$) and three phosphorus levels (0.50, 100 $kgP_2O_5ha^{-1}$) with two garlic varieties, Local (farmers' variety) and Tsedey92 (G-493). The 2x3x4 treatment combinations were arranged in a Randomized Complete Block Design (RCBD) with three replications. The individual plot sizes were $2.448m^2$ with intra and inter spacing of 17x30cm containing a total of 48plants per plot

Experimental Management

Two varieties of garlic namely Local (farmers' variety) and Tsedey-92(G-493) were got from Debre Ziet Agricultural Research Center (DZARC). Tsedey92 (G-493) characterized by white purple bulb color. Prior to planting, garlic bulbs were split into the individual cloves and planted upright. One third of the nitrogen through urea was applied at the planting time, one third top dressed at 30 days after planting and the remaining one third top dressed 20 days after emergence whereas all the phosphorus was applied at the time of planting through triple super phosphate (TSP). At the time of planting, urea and TSP were applied beneath and to the side of the cloves. 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.

RESULTS AND DISCUSSION

Analysis of Variance

There was a significant ($P \leq 0.01$) interaction effect between variety, nitrogen and phosphorus on total bulb yield (tha^{-1}) and also a highly significant ($P \leq 0.001$) interaction effect between nitrogen and phosphorus in total bulb yield and leaf number per plant. Nitrogen imparted significant differences with regard to the days to maturity, plant height (cm), leaf number per plant, leaf area (cm^2), leaf area index, shoot dry weight ($g\ plant^{-1}$)

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**

*NB: *, **, *** indicate significance at p≤0.05, p≤0.01, p≤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 yiled.*

and total bulb yield (t ha^{-1}). The varietal difference was also observed to be significant for all the traits considered in the experiment (Table 1).

Days to Maturity

Varieties significantly (P≤0.001) varied on days to maturity (Table 1). The variety Tsedey92took 126 days to mature and the local variety delayed 7 days to 50% maturity (Table 2). This could be due to genetic difference between the two varieties. This agrees with the worksof (Kotinska et al., 1990; Kassahun, 2006).

Nitrogen fertilizer had a significant (P≤0.001) effect on days to maturity (Table 1). Days to maturity were delayed by 13 days at 150 kg N ha^{-1}compared with that of control treatment, but statistically similar with the days at 100 kg N ha^{-1} (Table 2). Delay in days to 50% maturity with high levels of N could be attributed to delayed senescence and extended physiological activity to continue in photosynthesis and this result is in agreement with the findings of earlier workers (Tesfaye et al., 2007; Showel, 2010).

Plant Height

The difference in plant height was observed to be significant (P≤0.05) between the two varieties through the growth period (Table 1). Tsedey92 had significantly higher plant height than farmers' variety (Table 2). Plants of Tsedey92 variety were 2.23, 1.62 and 2.32 cm taller than local variety at 50, 70 and 90 days after emergence respectively. The difference between the varieties could be attributed to the genotypic variability and this result is in line with the findings of (Brewster 1994; Etoh and Simon 2002 and Kassahun, 2006).

Nitrogen significantly (P≤0.001) affected plant height of garlic (Table 1) and mean plant height of garlic at 100 and 150 kg N ha^{-1} was significantly higher than the lower rate, but was similar to 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 in response to nitrogen 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 earlier findings (Aregawi 2006; Farooqui et al., 2009).

Shoot Dry Weight

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

Application of N had a highly significant (P≤0.001) effect on shoot dry weight of garlic (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 control plots at 50, 70 and 90 DAE, respectively (Table 2); showing that towards the maturity assimilates translocated from shoot to bulbs (Bertoni et al., 1992) and this result is in close conformity with the earlier reports by (Lujiu et al., 2004); Aregawi, 2006).

Leaf Number per Plant

The interaction between N and P had a highly significant (P≤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_5ha^{-1} combination and the lowest leaf number (6.23) was observed in control plots (Figure 1). Comparing the mean values of fertilized plots with that of

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

Treatments	Days After Emergence (DAE)						
	50	70	90	50	70	90	
	Plant height (cm)			Shoot dry weight (g/plant)		Days to maturity	
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

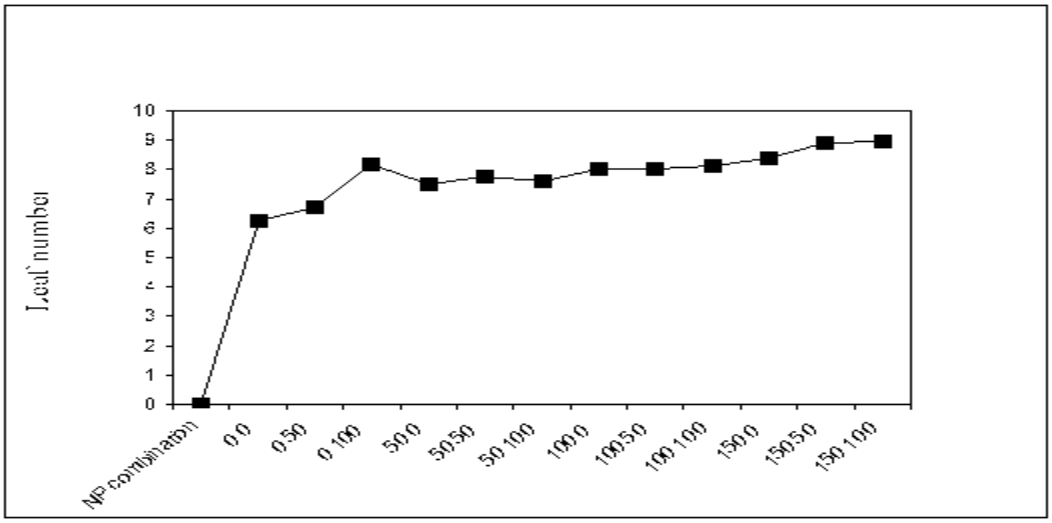

Figure 1. Interaction effect of nitrogen and phosphorus on leaf number of garlic varieties at Beressa

non fertilized, 8 to 44% more number of leaves were observed due to NxP 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 the finding of (Gebrehawaria, 2007).

Table 3. Effects of N and P on leaf area (cm^2) and leaf area index of garlic varieties, at Beressa during 2010-11.

Treatments	Days After Emergence (DAE)					
	50	70	90	50	70	90
	Leaf area (cm^2)			Leaf area index		
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

Leaf Area

A significant (P≤0.05) difference was observed between the varieties in leaf area per plant (Table 1). More leaf area plant^{-1} (6.3 and 7.8%) was recorded in Tsedey92 at 70 and 90 days after emergence, respectively (Table 3). Nitrogen fertilization significantly (P<0.01) affected the mean leaf area per plant of garlic (Table 1). The highest mean leaf area per plant was recorded at 150 kg N ha^{-1}. Which was statistically similar with 100kg N ha^{-1} and the lowest was obtained from the control (with no fertilizer) plots (Table 3).From the data, increasing N up to 100 kg N ha^{-1} resulted in increased leaf area of garlic. Similarly result was reported earlier (Mudziwa, 2010).

Leaf Area Index

There was a significant (P≤0.01) differences in LAI between the two garlic varieties (Table 1). Higher values (0.71 and 0.94) were recorded for variety Tsedey92 at 70 and 90 DAE respectively (Table 3).

Leaf area index was significantly (P≤0.001) affected by 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 value was from the control. However, leaf area index at 100 and 150 kg N ha^{-1} were statistically similar each other through 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 100kg 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. Similarly, earlier works had shown positive response of garlic to N fertilizer for lea area index (Aregawi, 2006; Ahmed and Fraihat, 2009).

Total Bulb Yield per Hectare

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

Table 4. Interaction effect of variety, nitrogen and phosphorus on bulb yield of garlic at Beressa during 2010-11.

Variety	P_2O_5 (Kg ha^{-1})	Bulb Yield of Garlic (t/ha) 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		

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 plots with no fertilizer. Moreover, the highest bulb yield of 3.34 tha^{-1} was obtained with this variety at 100 kg N + 100 kg $P_2O_5ha^{-1}$combination but it was statistically similar with the yield obtained from 100 kg N + 50 kg P_2Oha^{-1} (Table 4). On the other hand, the local (farmers') variety resulted in highest bulb yield of 2.76 t ha^{-1} from a combined application of 100 kg N and 100 kg P_2O_5 and became 311 % more than the control treatment. This yield was statistically similar to the yield obtained with some other combinations of N and P. Without P_2O_5 application, bulb yield of Tsedey92 increased 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 0.97 to 1.6 t ha^{-1}without N at 50 kgP_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 - 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 application. 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 kgP_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 the difference between the two varieties in response to the applied fertilizer could be attributed to the genotypic variability (Kassahun 2006).Phosphorus uptake is enhanced by N (Mengel and Kirkby, 1996), and its application promotes vegetative growth as the result more leaves were produced and assimilatory surface would increase so as to enhance the physiological activity, which leads to the production of more assimilates and consequently resulting in higher bulb yield.

CONCLUSION

Selection of best variety with appropriate nutrient management are very important factors to improve the quality and productivity of garlic and the present study indicated that varieties significantly differed almost for all the parameters considered for 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 and the interaction effects of N x P were significant for leaf number per plant and also the 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). Hence, considering the overall results, the combination of variety Tsedey92 and application of 100 kg N and 50 kg P_2O_5 $ha^{-1}$was recommended for the study area to improve garlic productivity.

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