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SOIL & CROP SCIENCES | RESEARCH ARTICLE

Response of garlic (*Allium sativum* L.) to nitrogen and phosphorus under irrigation in Lasta district of Amhara Region, Ethiopia

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Abstract: Crop production under irrigation systems is under pronounced challenges resulted in low yield in Lasta district of Amhara region for many reasons among which no or inefficient application of the major nutrients (nitrogen and phosphorus) took considerable share. Hence, a field experiment was conducted to study the effect of nitrogen (N) and phosphorus (P) on the growth and bulb yield of garlic at Lasta district Kechin Abeba irrigation scheme in 2013 and 2015. The treatments were arranged in a factorial combination of three rates of N (0, 46, 92, kg ha⁻¹) and four rates of P (0, 23, 46, 69, kg P₂O₅ ha⁻¹) in a randomized complete block design in three replications. All triple super phosphate (phosphorus source) was applied at transplanting whereas urea (nitrogen source) was applied in two splits (half at transplanting and the other half at 45 days after planting). Irrigation water was applied uniformly to all plots in furrow every 6 days. Agronomic data were collected and analyzed using SAS software and significant treatment means were separated using least significant difference at 5% level of significance. The effect of nitrogen and phosphorus was significant on plant height and bulb yield. Application of 92 and 46 kg P₂O₅ ha⁻¹ increased bulb yield by 48.3% compared to the control and the partial budget analysis shows applying nitrogen and phosphorus at rate of 92N and



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PUBLIC INTEREST STATEMENT

Garlic is one of the most important vegetable crops in Ethiopia and has a tremendous use in the formulation of local medicines. It has a wide area of adaptation and cultivation throughout the world. It uses as food and spice most dishes of various countries in the world including Ethiopia. It is cash crop and economic source of smallholder farmers of the study areas of Lasta district. Despite its importance the productivity of garlic in many parts of the world including Ethiopia is low due to different problems. To ensure sustainable crops production healthy soils are very important. In contrast Poor health or quality soils exhibit various dysfunctional attributes like deficiencies in nutrients, erosion and various other constraints. Adequate application of Nitrogen and phosphorus are very important for production and productivity of Garlic. To enhance the production of garlic such site and soil specific fertilizer recommendation are very crucial.

46 P₂O₅ kg ha⁻¹ was economically dominant over the other treatments. Therefore, application of 92N and 46 P₂O₅ kg ha⁻¹ is an optimum rate for garlic production at Lasta District, Kechin Abeba irrigation scheme and similar agro-ecologies.

Subjects: Soil Sciences; Soil Conservation Technology; Agronomy

Keywords: bulb yield; garlic; nitrogen; phosphorus

1. Introduction

Garlic is one of the vegetable crops known worldwide for its production and economic value (Salomon, 2002). It is widely used around the world for its pungent flavor as a seasoning or condiment. It is a fundamental component of dishes in the world including Ethiopia. It is rich in sugar, protein, fat, calcium, potassium, phosphorus, sulfur, iodine, fiber and silicon in addition to vitamin (Pulseglove, 1972). The total area under garlic production is estimated to be over 17,965 ha in Ethiopia (Central Statistical Authority (CSA, 2014). Many biotic and abiotic factors contribute for the low productivity of garlic in Ethiopia including: declining soil fertility, insufficient and inefficient use of fertilizers, inappropriate agronomic practices and inadequate pest and disease managements. Chemical fertilizers have been the prime means of enhancing soil fertility in small farm agriculture (Thangavel, Shiberu, & Mohammed, 2014). Nitrogen (N) and phosphorus (P) are often referred as the primary macronutrients because of the large quantities they are taken up by plants from the soil relative to other essential nutrients (Marschner, 1995). In order to improve garlic production, proper fertilizer application (type, time and rate) should be considered (Brewster & Butler, 1989). Different investigators have reported that application of Nitrogen and phosphorus had significant effect on growth and yield of garlic. Research conducted by Mulatu, Tesfaye, and Getachew (2014) in southern part of Ethiopia confirms that application of different levels of nitrogen and phosphorus fertilizer had significant effect on the growth and yield of garlic. Similarly research conducted by Diriba Shiferaw et al., (2015) in central Ethiopia indicated that combined application of NPS at rate of 92 kg N ha⁻¹, 40 kg P ha⁻¹ and 30 kg S ha⁻¹ were increased growth, yield and economic potential of garlic. A study conducted by Getu (2015) in north western Ethiopia confirms that application of NPS fertilizer affect the yield and yield components of garlic. He observes that NPS fertilizer applied treatment was superior than control treatment. While, in the study area, garlic is produced as a cash crop and there was no fertilizer recommendation done so far for its production. Therefore, this research was conducted to determine the optimum rate of nitrogen and phosphorus fertilizers for garlic production in Kechin Abeba irrigation scheme.

2. Materials and method

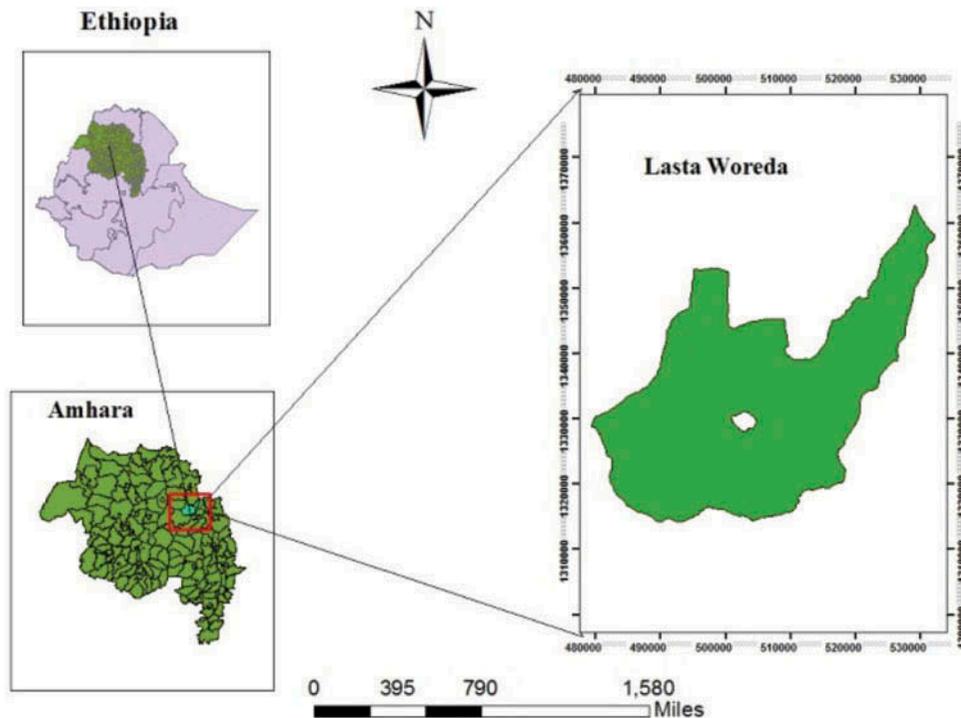
2.1. Description of the study site

A field experiment was carried out during 2013 and 2015 under irrigation in Kechin Abeba Lasta district, North Wollo Administrative Zone of the Amhara Region (Figure 1). Due to irrigation water insufficiency 2014 year of irrigation season was skipped. The site is located 12°35'31.2"N latitude and 39°04'30"E longitude. The altitude of the study area is 1856 m.a.s.l.

2.2. Experimental design and treatments

The experiment was conducted using furrow irrigation system. The treatments consisted of three N levels (0, 46 and 92 kg N ha⁻¹) and four P₂O₅ levels (0, 23, 46 and 69 kg P₂O₅ ha⁻¹). The experiment was laid out in randomized complete block design with three replications in a factorial arrangement. The plot size was 6 m² (2 m × 3 m) and consisted of 10 rows. Distance between plots and blocks, were 0.5 and 1 m, respectively; while the distances between plants and rows were 0.10 and 0.20 m, respectively. Urea and (triple super phosphate were used as source of nitrogen and phosphorus fertilizers, respectively. Nitrogen was applied by splitting; half at transplanting and half after 45 days of transplanting while the whole dose of phosphorus was applied once at transplanting. Agronomic practices such as weeding, cultivation

Figure 1. Location of the study.



and ridging were done uniformly to all treatments. Water was supplied at 6 days interval using furrow irrigation method. A local variety was used. Plant height, bulb yield and biomass of garlic were recorded for each plot.

2.3. Data analysis

Collected data were subjected to statistical analysis using SAS Statistical Software version 9.0 and treatment mean differences were compared using the Fisher's least significant differences test at 5% level of significance.

2.4. Soil analysis

A disturbed composite soil sample was collected from 0 to 20 cm depth, air-dried and sieved through 2 mm sieve to determine most nutrients in this case (soil pH, texture) while through 0.5 mm to determine Total Nitrogen and Organic Carbon. Soil pH was determined in H₂O using 1:2.5 soils to solution ratio using a combined glass electrode pH meter (Chopra and Kanwar, 1976). Organic carbon of the soils was determined following the wet digestion method as described by Walkley and Black (1934) while percentage organic matter of the soils was determined by multiplying the percent organic carbon value by 1.724. Total N was analyzed by the Kjeldahl digestion and distillation procedure (Bremner and Mulvaney, 1982), and Particle size distribution was analyzed by hydrometer method.

2.5. Partial budget analysis

The partial budget analysis was done to evaluate the economic feasibility of nitrogen and phosphorus application based on the manual developed by CIMMYT (International Maize and Wheat Improvement Center) (1988). The cost fertilizer, mean price of garlic was collected from the district. For the purpose of partial budget analysis (sensitivity analysis), yields were adjusted to 90 of the actual yield collected from the field (reduced by 10%).

3. Results and discussion

The major soil properties including soil pH, soil organic matter, total nitrogen and soil texture of the study site are discussed below. The pH of the surface soil of study site was 6.8 according to Tadesse (1991) it rates as neutral. Soil organic matter content of surface soil was 1.01% and total nitrogen content was 0.062% both organic matter and total nitrogen were rated as very low (Tadesse, 1991). The textural class of the study soil was clay loam with 30% sand, 30% silt and 40% clay. The response of the test crop to nitrogen and phosphorus under irrigation was reflected to these major soil chemical and physical properties of the study sites.

3.1. Plant height

The result in Table 1 shows that plant height of garlic was not significantly influenced by nitrogen and phosphorus rates. However, relatively higher plant height (54.85 cm) was recorded from 92N and 69 P₂O₅ ha⁻¹ followed by 46N and 23 kg P₂O₅ ha⁻¹ (54.41 cm) while the minimum (45.36 cm) was found from the control plot. Hence, application of nitrogen and phosphorus increases plant height of garlic by 9.43 cm but not statically significant different. This might be due to a problem of irrigation water application in amount and time. In the second year (2015) of experimentation there was a problem of irrigation water insufficiency this may affect the availability of nutrient to the plant. The result is in agreement with the findings of Mulatu et al. (2014) who reported that application of Nitrogen at 46 and 69 kg N and P₂O₅ ha⁻¹ increased the plant height significantly. Adem and Tadesse, (2014) and Khan, Zubai, Bari, and Maula (2007) also reported that nitrogen at 46 kg N ha⁻¹ increased the plant height of garlic significantly. The increment in vegetative parameters for garlic with the addition of N had a profound influence on the development of the crop. Application of adequate quantity of nitrogen ensures healthy plant growth that manifests through increasing vigor, size and deeper green color of foliage (Miko, 1999).

3.2. Bulb yield

The interaction of nitrogen and phosphorus fertilizers significantly affected the total bulb yield. The maximum bulb yield (7.11 t ha⁻¹) was obtained from plots fertilized with nitrogen and phosphorus at the rate of 92 N 46 P₂O₅ kg ha⁻¹ followed by 46 N and 46 P₂O₅ (6.7 t ha⁻¹) (Table 1). However, further increase of nitrogen and phosphorus rates showed a decreasing trend of the bulb yield (Table 2). The minimum average yield (4.8 t ha⁻¹) was obtained from the control plot. This shows that application of nitrogen and phosphorus increases the bulb yield by 2.31 t ha⁻¹ as compares with the control treatment. This yield increment might be due to the fact that nitrogen supply increase the rate of metabolism that in turn results in a synthesis of more carbohydrate and high bulb yield (Miko, 1999) and the fact that phosphorus is essential nutrient for root development and when the availability is limited, the growth of plant can be reduced and it is involved in several physiological and biochemical processes (Miller & Donanue, 1995; Tisdale, Nelson, Beaton, & Halvin, 1993). The result is also in line with the findings of Farooqui, Naruka, and Rathore (2009) and Hore and Chanchan (2014) who reported that application of nitrogen at rate of 92 N kg h⁻¹ increased the total bulb yield of garlic.

3.3. Partial budget analysis

The partial budget analysis of the research showed that applying 92 kg N/ha and 46 kg P₂O₅ ha⁻¹ had highest net benefit of 188,326.5 ETB ha⁻¹ with MRR of 4,173.73% and followed by 46 kg N ha⁻¹ and 46 kg P₂O₅ ha⁻¹ with a net benefit of 177,361.4 ETB ha⁻¹ and MRR of 2,506.82% (Table 2).

4. Conclusion and recommendation

In Ethiopia, low soil fertility is one of the factors limiting the productivity of crops, including garlic. Hence, sustaining soil fertility in intensive cropping systems for higher yields of better quality can be achieved through optimum levels of fertilizer applications. Nitrogen and

Table 1. Effects of nitrogen and phosphorus fertilizer application on growth and yield of garlic

N	P ₂ O ₅	Plant height (cm)			Bulb yield (t ha ⁻¹)			Biomass yield (t ha ⁻¹)		
		Year-1	Year-2	Mean	Year-1	Year-2	Mean	Year-1	Year-2	Mean
0	0	47.66	43.40	45.53	5.79	4.18	4.79	6.75	5.14	5.95
46	0	54.40	45.60	50.00	5.76	5.07	5.42	6.32	6.08	6.20
92	0	51.96	47.86	49.91	6.16	5.74	5.95	6.72	6.97	6.84
0	23	48.93	45.13	47.03	5.25	4.79	5.02	650	6.04	6.27
46	23	56.56	52.46	54.51	6.15	5.82	5.99	7.31	7.00	7.15
92	23	55.93	51.93	53.93	5.17	6.84	6.01	5.76	8.35	7.05
0	46	47.33	44.06	45.86	5.43	4.84	5.14	6.30	6.32	6.31
46	46	50.10	46.00	48.05	7.39	5.92	6.66	8.47	7.38	7.93
92	46	54.00	53.26	51.96	6.72	7.48	7.11	7.90	8.61	8.26
0	69	47.66	43.60	45.63	5.45	4.25	4.85	6.28	5.35	5.81
46	69	52.43	48.33	50.38	5.25	5.71	5.48	6.08	6.75	6.42
92	69	56.90	52.80	54.85	7.34	5.86	6.61	7.72	7.29	7.51
LSD (5 %)		10.47	11.66	11.09	1.82	1.49	1.22	2.29	1.73	1.40
CV (%)		9.17	8.60	6.37	18.05	16.94	18.28	19.93	15.12	17.91

Table 2. Partial budget analysis result of the research

Fertilizer (kg ha ⁻¹)		P ₂ O ₅	Yield*	Gross benefit*	Cost*	Net benefit*	MRR%
Nitrogen							
0		0	4.31	134,827.2	0	134,827.2	
0		23	4.52	135,650.7	694.87	134,955.8	18.51
46		0	4.87	146,291.4	1114.75	145,176.7	2434.22
0		46	4.62	138,763.8	1389.75	137,374.1	D
46		23	5.39	161,751.6	1809.62	159,942	2124.91
0		69	4.36	130,977	2084.65	128,892.4	D
92		0	5.35	160,706.7	2229.5	158,477.2	D
46		46	5.99	179,865.9	2504.5	177,361.4	2506.82
92		23	5.40	162,248.4	2924.37	159,324	D
46		69	4.93	148,151.7	3199.4	144,952.3	D
92		46	6.39	191,945.7	3619.25	188,326.5	4173.73
92		69	5.94	178,372.8	4314.15	174,058.7	D

* indicates yield is the yield in t ha⁻¹, gross benefit is the benefit in Ethiopian Birr ha⁻¹, Cost is the variable cost in Ethiopian Birr ha⁻¹ and net benefit is the net benefit in Ethiopian Birr ha⁻¹ while D stands for dominated treatments MRR stands for marginal rate of return.

phosphorus fertilizers are very vital nutrients for growth, development and productivity of crops as well as to improve the productivity of land resource. The result of this study showed a significant response in yield to the applied rates of nitrogen and phosphorus. Growth and yield of garlic increased significantly with increasing rate of nitrogen and phosphorus fertilizer. Thus, application of nitrogen and phosphorus at the rate of 92 kg N and 46 kg P₂O₅ ha⁻¹ had 2.31 t ha⁻¹ yield advantages over the control (no fertilizer). Application of 92 kg N ha⁻¹ and 46 kg P₂O₅ ha⁻¹ gave the highest economic return followed by 46 kg N ha⁻¹ and 46 kg P₂O₅ ha⁻¹. Therefore, the combination of 92 kg N ha⁻¹ and 46 kg P₂O₅ ha⁻¹ is recommended for Kechin Abeba irrigation scheme and similar agro-ecologies to produce maximum yield of garlic. The areas of Wag-Lasta are characterized by mountainous agriculture with slope gradients ranging from 5 to 45%. Since soil degradation is the most serious problem in these areas. To alleviate this soil fertility problem further should conduct research in integrated nutrient management, should avoid complete removal of crop residue and application of organic fertilizer are very crucial to increase production and productivity of the areas.

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Competing interests

The authors declare no competing interests.

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