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Research Article

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Nitrogen Nutrition Affect the Growth and Bulb Yield of Garlic (*Allium Sativum* L.)

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Abstract

Nitrogen (N) is one of the critical nutrients for productivity and quality of cultivated crop species. However, its overused in crop cultivation caused several environmental concerns. Hence its proper use in agriculture is not only pre-requisite for sustainable crop cultivation but also necessary to control environmental pollution. A field trial was designed at experimental area of Department of Horticulture, Sindh Agriculture university Tando Jam, Pakistanto test the response of garlic varietiesto N nutrition in terms of growth and bulb attributed traits during the winter season, 2020-21. The N effect on growth and yield associated traits of two garlic varieties (local white and purple top) were investigated by applying four Nrates that included 0, 50 kg, 100 kg and 150 kg ha^{-1}. The findings of the trial exhibitedthat N application at various rates had substantial positiveimpact on the growth and bulb development of garlic at ($P<0.05$). The garlic plantation receivedNat maximum rate (150 kg ha^{-1}) resulted tallest plants,better neck thicknesswith more leaves plant^{-1}. The N also positively affected the bulb yield and other yield parameters of garlic.The maximum bulb yield was obtained when plants were nourished with 150 Kg N ha^{-1}that was 381.98 % more than the control. It was noted that increase inN rates was statistically dominant over other doses. The varietal influence on garlic indicated that variety purple top performed better than local white in terms of yield associated traits..These findings provide new insight regarding the significance of N nutrition in improving the growth and bulb yield of garlic genotypes

Keys words: Garlic, Allium sativum L, growth, nitrogen rates, yield,

Introduction

Garlic is economically important bulbous vegetable crop of family Amaryllidaceaeand probably got origin from Central Asian Countries (Amarakoon and Jayasekara, 2017). The cultivation of garlic introduced to other countries through trade(Santhosha*et al*., 2013).Garlic is known as second most important bulbous crop followed by onion (Wen *et al*., 2020). Garlic is grown in a variety of places, the sunny, dry areas, humid and moderately dry environment (Sayadi*et al*., 2020). Because of its diversity, the importance of garlic planting is well known globally (Liu *et al*., 2020). Garlic has a high medicinal value and is used to treat chronic diseases of the stomach, eye and ears (Efiong*et al*., 2020) It is used both as a form of fresh and dry powder (Gonzalez *et al*., 2009; Chen *et al*., 2018). It is useful in the treatment of heart-related diseases (Aviello *et al*., 2009; Colín-González *et al*., 2012).China is the major Producer of Garlic and is estimated that its production is about 77 % of world production (FAO, 2017). Available reports show that garlic production exceeding 22.23 million tons; whereas share of Asian countries is more than 80 % (FAO, 2018). The garlic consumption is increasing day by day from the last decade. Its consumption increased from 1.6 kg to 3 kg per person per year (Gonzalez *et al*., 2009). Pakistan is one of the major importer of garlic since local production cannot meet domestic needs that's why a large amount of garlic comes from abroad to meet the needs of the country.(Baldwin *et al*., 2014).Thus, a large number of foreign exchanges were made on the import of garlic. Globally, considerable increase in economic importance of garlic has been noticed in the recent past. However, yields obtained in Pakistan are critically low. The main reason for low yields is the lack of high yielding varieties, adapted to local conditions and improper and non- judicious used of plant nutrients especially nitrogen (N) (Khan *et al*. 2016). The inadequate supply of organic manures and continuous cropping have caused deficiency of plant nutrients including N in our soil and such conditions led to decreased yield of cultivated crop species (Abbaszadeh *et al*., 2014). Despite N availability abundantly on earth, N deficiency is most common nutritional problem that affects plants (Don Eckert, 2010). Nitrogen availability is very important for plant growth as it is anmajor part of the chemical chlorophyll, which playsasignificant role in the process of photosynthesis (Getu, 2015). The higher N content promotes vegetative growth, enhance high protein content, while reduces anthocyanin synthesis (Luji *et al*. 2016). N stimulates plant growth strongly, expand crop canopy and intercept solar radiation (Milford *et al*., 2000). N is regarded as main nutrient that affects crop production significantly; it is a component of biological molecules including proteins and nucleic acids (Good *et al.,* 2004). N deficiency leads to decline chlorophyll content plant leaves, reduction in leaf area, growth retardation, poor yields and even plant may die (Amtmann and Armengaud, 2009). The application of N in optimum quantity is pre-requisite for getting the higher yield of garlic(Mulatu*et al*., 2014). Sebnie*et al*. (2018) have shown that dose of N of 92 kg ha^{-1}is essential for economic garlic yield. Reddy *et al*. (2000) recommended N dose of 150 kg ha^{-1} to obtain the desired plant height, bulb size and yield; while Talukder*et al*. (2000) recommended N rate(125 kg ha^{-1}) to obtain more cloves of garlic. Zaman *et al*. (2011) tested various N levels on garlic and recommended a rate of 150 kg ha^{-1}for economically acceptable garlic yield; while Ahmad *et al*. (2012) recommended 100 kg N to get more cloves in garlic. However, Shiferaw*et al*. (2013) noted that under extreme nitrogen deficit conditions N dose can be increased up to 400 kg ha^{-1} to obtain a quality garlic product. The above N application recommendations are based on studies in various parts of the world with diverse soils and climatic conditions. In order to optimize the nitrogen demand of garlic under local soil and climatic conditions, current research was conducted to test the response of garlic genotypes to N nutrition under Tandojam conditions.

Materials and Methods

Experimental site: Present study was done during 2020-2021 at Department of Horticulture Garden, Sindh Agriculture University.The experimental site lies at 28°35'N to 81°37'E. It is divided by four different seasons: rainy monsoon (June-October), cold winter (November-February), and warm spring (March-May).The soil was silty loam, non- saline (0.7 dSm^{-1} electrical conductivity) alkaline in nature having pH (8.5) with poor organic matter (0.64 %) and N content (0.032 %), respectively. The phosphorous and potassium contents in the soil were (3.4 and 285 ppm)analyzed using spectrophotometer and flame photometer, respectively.

Experimental design and treatment details: The trial was based on randomized complete block design (RCBD) design factorial with a 4x3 (12m^2) plot/experimental unit size. The growth and yield performance of two garlic varieties local white and purple top were determinedby applying four nitrogen (N) treatments with three replications. The N treatments included 0 kg, 50 kg, 100 kg and 150 Kg N ha^{-1}.

Preparation of the land: The soil was prepared by providing two dry ploughings and clod crushing followed by land levelling for a uniform distributionof irrigation water.

Sowing of Cloves: The cloves of two most famous varieties of the garlic (Local white and purple top) were sown on both sides of ridges at the distance of 5 cm between plants. The sowing was done in the 15th of October, 2020. All the standard cultural practices were followed during the entire course of trial

Fertilizer application: For N nutrition, Urea (46 % N) was used in three split applications.Therecommendedrates of P (60 Kg ha^{-1}) and K (50 kg ha^{-1}) were used as single super phosphate (SSP) contains 18% P_2O_5 and Sulphate of potash (SOP) contains 50 % K_2O. The first split of urea was applied along with full doses of SSP and SOP at the time of sowing of crop. The other splits of urea were applied at the interval of 40 and 60 days respectively.

Parameters Measured: When the crop reached maturity, ten plants plot^{-1} were marked and tested by the growth and bulb associated parameters

Data Recorded

Plant height (cm): Measuring tape was used to calculate the plant height from bottom to the top of the plant.

Neck thickness (mm): The Neck thickness was measured by using vernier caliper.Three readings were noted top bottom and end of plant. After thatmean of three values were considered.

Leaves plant^{-1}: Leaves number plant^{-1} was counted separately from sample plants

Cloves bulb^{-1}: Cloves were recorded by counting cloves from individual bulb of the marked plants

Single clove weight: The cloves from the bulbs were separated and weighed in grams (g) by using electronic balance.

Single Bulb Weight: The single bulb weight was done using electronic weight balance

Blub Yield plot^{-1}(kg): From each sub-plot, the total number of bulbs were collected and carefully counted in all treatments and replications.

Bulb yield ha^{-1}: The average yield is determined by counting and measuring the bulbs found in each plot and then converted into yield ha^{-1} applying formula given below:

$$\text{Yield per hectare} = \frac{\text{Bulb yield per plot}}{\text{Plot size}} \times 10000$$

Statistical analysis: ANOVA (Analysis of Variance) was done through computer software Statistix 8.1 (Statistix, 2006). The treatment means were separated by using least significant difference (LSD) test at 0.05 probability.

Results

Plant height (cm): The maximum supply of N (150 kg ha^{-1}) significantly produced taller plants with plant height 45.72 cm(Table-1). The decreasing trend in plant height was observed with the decrease of N supply. Plants nourished with N @100 and 50 kg ha^{-1} showed height of plants (39.23 and 29.25 cm), respectively. Whereas the minimum plant height (23.25 cm) was noted where plants were not nourished with N.On the basis of mean of varieties, the maximum plant height (35.19 cm) was observed in Local white variety (Table-1). The Purple top produced smaller plants with plant height (33.53 cm).

Table 1: Influence of Nitrogen rates and varieties on the Plant height (cm) of garlic varieties

Nitrogen levels	**Garlic varieties**		**Mean**
	Local white	**Purple top**	
N_1 = Control	24.17	22.33	23.25 D
N_2 = 50 kg ha^{-1}	30.19	28.31	29.25 C
N_3 = 100 kg ha^{-1}	40.20	38.27	39.23 B
N_4 = 150 kg ha^{-1}	46.22	45.21	45.72 A
Mean	**35.19 A**	**33.53 B**	-

	N rates (N)	**Varieties (V)**	**N x V**
S.E.±	0.9384	0.6636	1.3271
LSD 0.05	2.0127	1.4232	2.8464
Probability value	0.0000	0.0250	0.9533
CV%	4.73		

Neck thickness (mm): The adequate N (150 kg N ha^{-1}) showed maximum neck thickness of 9.600 mm (Table-2). The inadequate N supply induced reduction in neck thickness. The average neck thickness from 100 kg N ha^{-1} and 50 kg N ha^{-1} was observed 9.483 mm and 7.230 mm respectively. Whereas, the minimum neck thickness (5.230) was observed where plants did not receive N nutrition (control). On the basis of mean of varieties, the maximum neck thickness (10.00) was observed in Purple top variety (Table-2). The Local white variety showed minimum neck thickness (5.96 mm)

Table 2: Influence of Nitrogen rates and varieties on the Neck thickness (cm) of garlic

Nitrogen levels	**Garlic varieties**		**Mean**
	Local white	**Purple top**	
N_1 = Control	3.57	6.88	5.2300 D
N_2 = 50 kg ha^{-1}	5.70	9.54	7.6233 C
N_3 = 100 kg ha^{-1}	7.26	11.70	9.48333 B
N_4 = 150 kg ha^{-1}	7.32	11.88	9.6000 A
Mean	5.96 B	10.001 A	

	N rates (N)	**Varieties (V)**	**N x V**
S.E.±	0.0141	9.945E-03	0.0199
LSD 0.05	0.0302	0.0213	0.0427
Probability value	0.0000	0.0000	0.0000
CV%	0.31		

Table 3: Influence of Nitrogen rates and varieties on the Number of leaves plant^{-1} of garlic

Nitrogen levels	Garlic varieties		Mean
	Local white	**Purple top**	
N_1 = Control	4.70	5.12	4.912 D
N_2 = 50 kg ha^{-1}	6.62	6.62	7.373 C
N_3 = 100 kg ha^{-1}	9.15	9.15	9.15 B
N_4 = 150 kg ha^{-1}	11.75	13.53	12.64 A
Mean	8.05 B	8.98 A	

	N rates (N)	**Varieties (V)**	**N × V**
S.E.±	0.1412	0.0999	0.1997
LSD 0.05	0.3029	0.2142	0.2142
Probability value	0.0000	0.0000	0.0000
CV%	2.87		

Number of leaves plant $^{-1}$: The more leaves (12.64) in single plant was noted at adequate N fertilization (150 kg N ha^{-1}), while leaves number decreased to 9.15 and 7.37 in crop receiving N 100 kg ha^{-1} and 50 kg ha^{-1}, respectively (Table-3). However, minimum leaves (4.912) was noted in crop kept unfertilized (control). Among varieties, "Purple top" possessed more leaves plant^{-1} (8.98) than "Local white" variety with 8.05 leaves number in individual plant (Table-3).

Number of cloves bulb^{-1}: The Data showed that N rates and varieties both showed significant variation for number of cloves bulb^{-1}. However, interaction between N rates x garlic varieties did not affect this trait significantly. The crop supplied N at adequate rate (150 kg ha^{-1}) showed maximum cloves (40); followed by N application rates of 100 kg ha^{-1} and 50 kg ha^{-1} producing cloves number 35.83 and 30.66, respectively (Table-4). The minimum cloves bulb^{-1}(8.00) was noted in control. In case of varieties, "local white" produced more cloves bulb^{-1} (37.58) than variety "purple top" (24.66) (Table-4).

Table 4: Influence of Nitrogen rates and varieties on the Number of cloves blub^{-1} of garlic

Nitrogen levels	Garlic varieties		Mean
	Local white	**Purple top**	
N_1 = Control	22.00	14.00	18.00 D
N_2 = 50 kg ha^{-1}	35.33	26.00	30.66 C
N_3 = 100 kg ha^{-1}	45.00	26.66	35.83 B
N_4 = 150 kg ha^{-1}	48.00	32.00	40.00 A
Mean	37.58 A	24.66 B	

	N rates (N)	**Varieties**	**N× V**
S.E. ±	1.7967	1.2705	2.5409
LSD 0.05	3.8536	2.7249	5.4498
Probability value	0.0000	0.0000	0.0319
CV %	10.000		

Table 5: Influence Nitrogen rate and varieties on the Single clove weight of garlic

Nitrogen levels	Garlic varieties		Mean
	Local white	**Purple top**	
N_1 = Control	0.38	0.98	0.68 C
N_2 = 50 kg ha^{-1}	0.49	1.18	0.83 C
N_3 = 100 kg ha^{-1}	0.69	1.39	1.04 B
N_4 = 150 kg ha^{-1}	0.88	2.09	1.48 A
Mean	0.61 B	1.41 A	

	N rates (N)	**Varieties**	**N×V**
S.E. ±	0.0736	0.0521	0.1041
LSD 0.05	0.1579	0.1116	0.2233
Probability Value	0.0000	0.0000	0.0038
CV %	12.58		

Table 6: Influence of Nitrogen rates and varieties on the Single blub weight of garlic

Nitrogen levels	Garlic varieties		Mean
	Local white	Purple top	
N_1 = Control	10.94	11.52	11.23 D
N_2 = 50 kg ha^{-1}	17.62	33.74	25.68 C
N_3 = 100 kg ha^{-1}	31.04	37.88	34.46B
N_4 = 150 kg ha^{-1}	42.38	55.53	48.95 A
Mean	25.49 B	34.66 A	

	N rates (N)	Varieties	N×V
S.E	0.4366	0.3087	0.6174
LSD	0.9363	0.6621	1.3242
Probability Value	0.0000	0.0000	0.0000
CV%	2.51		

Table 7: Influence of Nitrogen rates and varieties on the Blub yield plot^{-1} of garlic varieties

Nitrogen levels	Garlic varieties		Mean
	Local white	Purple top	
N_1 = Control	2.53	3.00	2.76 D
N_2 = 50 kg ha^{-1}	5.46	6.39	5.92 C
N_3 = 100 kg ha^{-1}	9.43	10.50	9.96 B
N_4 = 150 kg ha^{-1}	10.10	11.03	10.56 A
Mean	6.88 B	7.73 A	

	N Rates	Varieties	N×V
S.E	0.0749	0.0530	0.1060
LSD	0.1607	0.1137	0.2273
Probability value	0.0000	0.0000	0.0070
CV%	1.78		

Table 8: Influence of Nitrogen rates and varieties on the Bulb yield ha^{-1} of garlic varieties

Nitrogen levels	Garlic varieties		Mean
	Local white	Purple top	
N_1 = Control	2110.7	2499.7	2305.2D
N_2 = 50 kg ha^{-1}	4555.0	5324.8	4939.9 C
N_3 = 100 kg ha^{-1}	7861.1	8750.0	8305.6 B
N_4 = 150 kg ha^{-1}	8416.7	9194.4	8805.6 A
Mean	5735.9 B	6442.2 A	

	N Rates	Varieties	N×V
S.E	62.395	44.120	88.240
LSD	133.82	94.628	189.26
Probability value	0.0000	0.0000	0.0070
CV%	1.77		

Single clove weight (g): The results demonstrated that nitrogen application rates had significant affect on bulb weight plant^{-1}; and varietal effect on this trait was also significant ($P<0.05$). However, interactive effect of garlic varieties × N levels on this trait was not significant ($P>0.05$). It is obvious from the data that highest N application rate of 150 kg ha^{-1} caused maximum single clove weight (1.48 g); followed by N rates of 100 kg and50 kg ha^{-1} producing bulbs with single clove weight (1.04 and 0.83 g), respectively (Table-5). Whereas the minimum single clove weight (0.68 g) was recorded in control. In varieties, “Purple top” resulted in maximum single clove weight(1.41 g) as compared to variety “Local white” (0.61 g) (Table-5).

Single bulb weight (g): The adequate N nutrition(150 kg ha^{-1}) produced plants with relatively more weightbulb^{-1} (48.95); followed by 100 kg and 150 kg ha^{-1} N with the production of 34.46 and 25.68 g single bulb weight, respectively; while lowest bulb weight

(11.23 g) was obtained in control plots where plants were not nourished with N (Table-6). On the basis of mean results of varieties, the maximum bulb weight (34.66 g) was observed in Purple top variety (Table-6). The Local white variety showed less single bulb weight (25.49 g).

Bulb yield plot^{-1}: The garlic crop given N at the highest rate (150 kg ha^{-1}) produced maximum garlic bulb yield plot^{-1} (10.56 kg); followed by N application rates of 100 kg and 50 kg ha^{-1} with average bulb yield of 9.96kg and 5.92kg plot^{-1}, respectively. However, the lowest bulb yield plot^{-1} (2.76 kg) was noted in control plots, kept without N fertilization (Table-7). In varieties, "Purple top" produced higher bulb yield (4.34 kg plot^{-1}) than the yield plot^{-1} (3.71 kg) obtained in variety "Local white" (Table-7).

Bulb yield kg ha^{-1}: The garlic yield data (Table-8) revealed a significant impact of N levels and varieties on bulb yield ha^{-1} ($P<0.05$). The crop supplied adequate N nutrition (150 kg ha^{-1}) showed maximum garlic bulb yield (8805.6 kg ha^{-1}); followed by N rates of 100 kg and 50 kg producing average bulb yield of 8305.6 and 4939.9 kg ha^{-1}, respectively (Table-8). However, the minimum bulb yield ha^{-1} (2305.2 kg) was noticed in control where plants were not nourished with N. In varieties, "Purple top" produced higher bulb yield (6442.2 kg ha^{-1}) than the yield (5735.9 kg ha^{-1}) noted in "Local white" variety (Table-8).

Discussion

Nitrogen (N) significantly contributes in obtaining the acceptable crop yield and its deficiency in Pakistani soils is well documented (Khan *et al*. 2016). N consumption has a significant impact on the growth and development of garlic (Kakar *et al*. 2002). The results show that the N rates and varieties have significant effects on growth and total bulb yield. The growth characteristics and productivity of the control plants were very low. For plant height, data showed that the response of 150 kg N ha^{-1} was significantly high where taller plants were produced as against the deficient nitrogen conditions. Under different N conditions plant lengths of varieties were different, which may be due to different genetic responses of varieties to the availability, uptake and utilization of nitrogen (Hossein, *et al*., 2014). Other researchers Zaki *et al*., 2014 and Zaman et al. 2011 also described good performance of garlic under ideal N conditions and reported that the height of the garlic plant increased from 42.4 to 64.7cm as nitrogen levels increased from 0 to 200 kg N ha^{-1}. In the current study, purple top performance was better as compared to local white. This result is consistent with the study of Abraham *et al*. (2014) who also found different response of varieties to different N conditions. Etoh and Simon (2002) also report significant differences in crop yields between varieties of garlic. Similarly, Yudhvir and Ramesh, 2003; Youssef, and Tony, 2014; explained that in different clones, data for different features showed significant differences (Hazem, 2013). Abou El-Magd, *et al*., (2012) also found significant differences under different nitrogen regimes. There was a significant difference in neck thickness between varieties and levels of nitrogen. Panse, *et al*., 2013 reported different varietal response for neck diameter under different N environments. This might be due to different genetic response of the varieties rather than application of N This is also consistent with previous studies performed by Hazem, (2013); Farooqui *et al*. (2009), which have shown significant response of garlic genotypes for most of the traits. There were significant differences in the number of leaves plant^{-1} between varieties. Moreover, different nitrogen rates also showed significant differences for leaves number. This reflects the essential role of N in the leaf growth and development. Moreover, it is well documented that N plays a major role in the formation of chlorophyll for photosynthesis, thereby promoting cell division and growth (Hazem, 2013). Adequate nitrogen is an important component of chlorophyll, which is essential for the growth and development of plants ((Nori *et al*., 2012). The soil deficient in nitrogen, chlorophyll cannot be properly synthesized, leading to small size and shape of the leaves, and necrosis also occurs (Tibebu *et al*., 2014). In the present study, the increased N rate (150 kg ha^{-1}) showed more value in all aspects of garlic (growth and yield characteristics). The decrease in nitrogen rate up to 100, 50 and 0 kg ha^{-1} showed reduction in growth and bulb development and lower values for most of the traits were recorded. It was further noted that with each increase in nitrogen supplementation, the performance of garlic crop increased significantly. This revealed that experimental soil showed signs of severe N deficiency. This was further advocated by analysis of soil. Due to continuous cropping, the soil has become severely deficient in N, such a situation has resulted in a significant decline in crop yields (Abbas *et al*., 2014). Moreover, this also reflected that by getting the acceptable garlic yield, the application of N at appropriate amount is required. The strong and positive effect of N nutrition has also been documented on other bulbous crop including onion (Bezabihand Girmay,2020;Piriand Naserin,2020). Other researchers including Bekele*etal*., 2018 andTekeste*etal*., 2018 described that bulb size increased notably at optimal N supply to onion crop.

Conclusions and Suggestions

Adequate N supply enhanced the yield of garlic because performance gap between adequate N nutrition and control was markedly high. Both the varieties were sensitive to Low N supply and showed positive response to higher N nutrition. This indicates that experimental soil was severely deficient in N. The response of Purple top was better under all N conditions. Hence, for achieving higher garlic yield, variety "Purple top" may preferably be cultivated and fertilized with N at the rate of 150 kg ha^{-1} under Tando Jam conditions. However, the growth and yield performance of other cultivars of garlic may also be investigated by applying other nitrogen doses and sources under different agro-climatic conditions to validate the nitrogen requirements of the garlic.

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References

Abbas, Z., Muhammad, A., Khan K.S., & Hassan, F. (2014). Effect of Buctril Super (Bromoxynil) Herbicide on Soil Microbial Biomass and Bacterial Population. *Journal of Plant Science*. **57**(1): 9-14.

Abou El-Magd, M., El-Shourbagy, T., &Shehata. (2012). A comparative study on the productivity of four Egyptian garlic cultivars grown under various organic materials in comparison to conventional chemical fertilizer. *Australian Journal of Basic and Applied Sciences*, **6**(3): 415-421.

Abreham, Mulatu, BizuayehuTesfeye & Essubalew G. (2014). Growth and bulb yield garlic varieties affected by nitrogen and phosphorus application at MesqanWoreda, South Central Ethiopia. *Sky Journal of Agricultural Research*, **3**(11): 249-255.

Ahmed, H.G., Magaji, M.D., Yakutu, A.I.,& Singh. A. (2012). Response of garlic (*Allium sativum* L.) to irrigation interval and clove size in semi-Arid, Nigeria. *Journal of Plant Science*,**22**(2): 202-208.

Amarakoon, S., &Jayasekara., D. (2017). A review on garlic (*Allium sativum* L.) as a functional food.*Journal of Pharmacognosy & Phytochemistry***6**(6): 1777-1780.

Aviello, G., Abenavoli, L., Borrelli, F., Capasso, R., Izzo, A.A., Lembo, F., Romano, B.,& Capasso, F. (2009). Garlic: empiricism or science. *Natural Product Communications*, **4**(12): 1-12.

Bezabih,T.T.,&Girmay, S. (2020). Nutrient use efficiency and agro-economic performance of onion (*Allium cepa*L.) under combined applications of N, K and S nutrients, 33, 117-127

Baldwin, S., Revanna, R., Pither-Joyce, M.M., Shaw, K. Wright, S. Thomson, L. Moya, R. Lee, Macknight, R.,& McCallum. J.(2014). Genetic analyses of bolting in bulb onion (*Allium cepa* L.).*Theoretical and Applied Genetics*. **127**(54): 535–547.

Bekele,M.,Mohammed,A.,& Nebiyu, A. (2018). Quality and storage life of onion (*Allium cepa* L.) as influenced by applications of nitrogen, phosphorus and potassium fertilizer, at Jimma, South Western Ethiopia. *Journal of Natural Science and Research*.**8**(22): 31-44

Chen, X., Liu, X.,. Zhu, S., Tang, S., Mei, S., Chen, J., Li, S., Liu, M., Gu, Y., Dai, Q.,&Liu, T.(2018). Transcriptome-referenced association study of clove shape traits in garlic. DNA Research.**25**(6): 587-596.

Colín-González, A.L., Santana, R.A., Silva-Islas, C.A., Chánez-Cárdenas, M.E., Santamaría, A., &Maldonado, P.D.(2012). The antioxidant mechanisms underlying the aged garlic extract- and Sallylcysteine-induced protection. Oxidative medicine and cellular longevity.

Don Eckert. 2010. Efficient Fertilizer Use of Nitrogen. Book of Nitrogen Fertilizers, Pp. 1-19.

Efiong, E. E., Akumba, L.P., Chukwu, E.C., Olusesan, A.I. & Obochi. G. (2020). Comparative qualitative phytochemical analysis of oil, juice and dry forms of garlic (*Allium sativum*) and different varieties of onions (*Allium cepa*) consumed in Makurdi metropolis. International *Journal of Plant Physiology & Biochemistry*.**12**(1): 9-16.

Etoh, T.,& Simon P. (2002). Diversity, fertility and seed production in garlic. Pp. 101-118. In: Rabinowitch, H. & Currah L. (Eds) *Allium* Crop Science: Recent Advances. CABI Publishing, Wallingford, UK.

Farooqui, M.A., Naruka, I.S., Rathore, S.S., Singh, P.P.,&Shaktawat, R.P.S. (2009). Effect of nitrogen and sulfur levels on growth and yield of garlic (*Allium sativum* L.)".*Asian Journal of Food & Agro-Industry***2**(1): 223-229.

Gebretsadik, K. &Dechassa, N.(2018). Response of Onion (*Allium cepa* L.) to nitrogen fertilizer rates and spacing under rain fed condition at TahtayKoraro, *Ethiopia. Scientific reports*.**8**(1):1-8.

Getu, S. (2015). Assessment of garlic production practices and effects of different rates of NPS fertilizer on yield and yield components of Garlic (*Allium Sativum* L.) under irrigated farming system in YilmanaDensa District, Amhara Region, Ethiopia MSc Thesis. Bahir Dar University,India.

Gonzalez, R.E., Soto, V.C., Sance, M.M., Camargo, A.B.,&Galmarini, C.R. (2009). Variability of solids, organosulfur compounds, pungency and health enhancing traits in garlic (*Allium sativum* L.) cultivars belonging to different eco-physiological groups. *Journal of Agricultural & Food Chemistry*, 57(21): 10282-10288.

Good, M., Moral, R., &Escrich,E. (2004). Unsuitability of using ribosomal RNA as loading control for Northern blot analyses related to the imbalance between messenger and ribosomal RNA content in rat mammary tumors. *Analytical Biochemistry*. 288: 99-102.

Hazem, A. (2013). Screening of Thirteen Garlic (*Allium sativum* L.) Genotypes for Characteristics of Yield and Quality under Sohag Conditions. *American-Eurasian Journal of Agricultural Environmental Science*. **13**(12): 1626-1631.

Hossein, M., Sharafzadeh, S.,& Bazrafshan F. (2014). The influence of nitrogen levels on growth and bulb yield of two garlic cultivars. *European Journal of Experimental Biology*, **4**(1): 270-272.

Kakar, A.A., Abdullahzai, M.K., Saleem, M., & Qaim Shah, S.A. (2002). Effect of nitrogenous fertilizer on growth and yield of garlic. *Asian Journal of Plant Science*. **1**(5): 544-545.

Khan, N.H., M.U. Khan, M. Junaid, J. Rehman and I. Hussain. 2016. Combine application of nitrogen, phosphorus and potassium for improving garlic productivity. *International Journal of Agriculture & Environmental Research*. 2(2): 146-150.

Liu, H.J., Huang, C.P., Tong, P.J., Xue, Y., Cui, M.M., & Cheng. Z.H. (2020). Response of axillary bud development in garlic (*Allium sativum* L.) to seed cloves soaked in gibberellic acid (GA3) solution. Journal of Integrative Agriculture.**19**(4): 1044-1054.

Luji, X., Xu, W., Du, E., Pan, Y.,&Goulding, K.(2016). Reduced nitrogen dominated nitrogen deposition in the United States, but its contribution to nitrogen deposition in China decreased. *Proceeding of Natural Academy of Science*. USA, 113:3590–3591.

Mulatu, A., Tesfaye, B.,&Getachew, E.(2014). Growth and bulb yield garlic varieties affected by nitrogen and phosphorus application at MesqanWoreda, South Central Ethiopia. *Sky Journal of Agricultural Research*. 3: 249–255.

Nori, M., Bayat, F.,&Esmaeili, A.(2012). Changes of vegetative growth indices and yield of garlic (*Allium sativum* L.) in different sources and levels of nitrogen fertilizer.*International Journal of Agricultural Crop Sciences*.**4**(18): 134-140.

Piri, H., &Naserin, A. (2020). Effect of different levels of water, applied nitrogen and irrigation methods on yield, yield components and IWUE of onion.*Scientia Horticulturae*,268: 109361.

Panse, R., Jain P., Gupta A. & Singh D. (2013). Morphological Variability and Character Association in Diverse Collection of Garlic Germplasm. *African Journal of Agricultural Research*, **8**(23): 2861-2869.

Reddy, K.R., Delaune, R.D., Debusk, W.F., &Koch, M.S. (2000). Long-term nutrient accumulation rates in the Everglades. *Soil Science Society of America Journal*. 57: 1147–1155.

Statistix., 2006. Statistics 8 user guide, version 1.0. Analytical software, P.O. Box 12185, Tallahassee fl 32317 USA. Copyright @ 2006 by Analytical software.

Santhosha, S., Jamuna, P.,& Prabhavathi, S. (2013). Bioactive components of garlic and their physiological role in health maintenance: A review. *Food Bioscience*. 3, 59-74.

Sayadi, V., Karimzadeh, G., Monfared, S.R., &Naghavi, M.R. (2020). Identification and expression analysis of S-alk (en) yl-L-cysteine sulfoxide lyase isoform genes and determination of allicin contents in Allium species. Plos One, **15**(2): 7-13.

Sebnie, W., Mengesha, M., Girmay, G.,& Feyisa, T.(2018). Response of garlic (*Allium sativum* L.) to nitrogen and phosphorus under irrigation in Lasta district of Amhara region, Ethiopia. Soil and Crop Sciences, **2**(1): 102-109.

Shiferaw, D.G.,Nigussie-Dechassa, R., Woldetsadik, K., Tabor, G.,& Sharma, J. J. (2013). Bulb quality of garlic (*Allium sativum* L.) as influenced by the application of inorganic fertilizers. *African Journal of Agricultural Research*.**8**(43): 5387-5398.

Tekeste, N.,Nigussie, D., Woldetsadik, K.,Dessalegne, L.,Takele, A. (2018). Influence of nitrogen and phosphorus application on bulb yield and yield components of onion (*Allium cepa* L.)*Open Agricultural Journal*. **12**(2018): 194-206,

Talukder, A.F., Rahim, M.H., &Anwar, H.R.M. (2000). Effects of planting time and different levels of nitrogen on the growth and yield of garlic. *Training and Development Journal*. **13**(2): 159-166.

Tibebu S., Melese T., Abrham S. & Samuel U. (2014). The Effect of Variety, Nitrogen and Phosphorous Fertilization on Growth and Bulb Yield of Onion (*Allium Cepa* L.) at Wolaita, Southern Ethiopia. *Journal of Biology, Agriculture and Healthcare*, **4**(11): 89-98.

Wen, Y.B., Liu, X.X., Liu, H.J., Wu, C.N., Meng, H.W., &Cheng, Z.H. (2020). High-frequency direct shoot organogenesis from garlic (*Allium sativum* L.) inflorescence and clonal fidelity assessment in regenerants. *Plant Cell, Tissue & Organ Culture*. 141, 275-287.

Youssef, N.,& Tony, H. (2014). Influence of Different Planting Date on the Performance of New Garlic

Genotypes Grown Under El-Minia Governorate Conditions. *Nature and Science*, **12** (2):112-119.

Yudhvir, S., & Ramesh C. (2003). Performance studies of some garlic (*Allium sativum* L.) clones. *Himachal Journal of Agricultural Research*, **29**(1&2): 35-42.

Zaman, M.S., Hasheem, M.A, Jahiruddin, M., &Rahim, M.A. (2011). Effect of nitrogen for yield maximization of garlic in old brahmaputra flood plain soil. *Bangladesh Journal of Agricultural Research*. **36**(2): 357-367.

Zaki, H., Toney, H. & AbdElraouf, R. (2014). Response of two garlic cultivars (*Allium sativum* L.) to inorganic and organic fertilization. *Journal of Nature & Science*, **12**(10):52- 60.