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BULB YIELD, PRE-MATURE SPROUTING AND NITROGEN USE EFFICIENCY OF GARLIC VARIETIES AS INFLUENCED BY NITROGEN

S. BRAHMA[1], M. N. YOUSUF[2*], A. J. M. SIRAJUL KARIM[3]
M. I. HAQUE[1] AND M. M. KAMAL[2]

Abstract

The field experiment was carried out at the research farm of Regional Spices Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur ($23^0 59^/$North Latitude and $90^0 24^/$East Longitude) during two successive winter seasons of 2020-21 and 2021-22, to find out the optimum dose of nitrogen and suitable garlic variety for up scaling bulb production. The experiment was laid out in a two-factor randomized complete block design with three replications having four garlic varieties (BARI Rashun-1, BARI Rashun-2, BARI Rashun-3 and BARI Rashun-4) with four different levels of nitrogen (0, 50, 100 and 150 kg ha^{-1}). A blanket dose of 60-160-20-2-1 kg ha^{-1} of P-K-S-Zn-B along with cowdung @ 5 t ha^{-1} was applied in each experimental plot. Both factors such as garlic variety and nitrogen level showed significant effects on the yield, yield components, pre-mature sprouting and nitrogen use efficiency of garlic. The highest bulb yield of (8.58 and 8.91 t ha^{-1} in 2020-21 and 2021-22, respectively) was obtained from BARI Rashun-3 regardless of N dose. On the other hand, application of 100 kg N ha^{-1} produced the highest bulb yield (8.1 and 9.55 t ha^{-1} in 2020-21 and 2021-22, respectively). The response of garlic varieties to N was appeared to be quadratic in nature (R^2 = 0.9914). From the quadratic response function, the optimum dose was estimated to be 92.75 kg ha^{-1}. The minimum number of pre-mature sprouted bulb (2.5%) was noted in BARI Rashun-4 when N was not applied. The maximum nitrogen use efficiency (138.44 and 144.72% in 2020-21 and 2021-22, respectively) was recorded from BARI Rashun-4 with 50 kg N ha^{-1}. Among the BARI released garlic varieties, BARI Rashun-3 performed better in this region. Thus, it may be concluded that BAR Rashun-3 could be cultivated by applying 92.75 kg N ha^{-1} along with blanket dose of 60-160-20-2-1 kg ha^{-1} of P-K-S-Zn-B and cowdung @5 t ha^{-1} in the Grey Terrace Soil of Madhupur Tract (AEZ-28).

Keywords: Nitrogen fertilizer, nitrogen use efficiency, pre-mature sprouting, bulb yield, garlic

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[1]Principal Scientific Officer and [2]Senior Scientific Officer, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, [3]Professor, College of Agricultural Sciences, International University of Business Agriculture and Technology (IUBAT), [4]Embankment Drive Road, Sector-10, Uttara Model Town, Dhaka-1230.

Introduction

Garlic or 'Rashun' (*Allium sativum* L.) is a major spice crop in Bangladesh belonging to the family Alliaceae. It is an aromatic herbaceous crop originated in Mediterranean region (Brewster, 2008). It is the second most important *Allium* crops after onions widely cultivated throughout the world (Ali *et al*., 2023; Usman *et al*., 2016). Its leaves, bulbils (flowers) and bulbs are used as spice and vegetables for its medicinal and seasonal properties (Kumari *et al*., 2023; Yitayih *et al*., 2017). Bangladesh is the world's third largest garlic producing country having production of 4.66 lakh metric tons bulb in 0.72 lakh hectares of land (FAO, 2023). The diversified uses of garlic with its increasing demand for domestic consumption as well as used as raw-material for pharmaceutical and cosmetic industries. The garlic productivity is lower due to genetic and environmental factors which affect its quality traits (Sahu *et al*., 2023). Spices Research Centre, Bangladesh Agricultural Research Institute, Bogura developed four high yielding garlic varieties, namely s BARI Rashun-1, BARI Rashun-2, BARI Rashun-3 and BARI Rashun-4 which are less susceptible to disease and insect pests with distinct genotypic and phenotypic variation having yield potentiality of 6-11 t ha^{-1} (Rahman *et al*., 2020). There are many factors for lower productivity of garlic such as lack of high yielding varieties, low soil fertility, imbalanced use of fertilizers, lack of irrigation facilities, inappropriate pest and agronomic management, and improper marketing facilities (Kenea and Gedamu, 2020; Haque *et al*., 2013, Nasreen *et al*., 2009). Among the yield limiting factors, nitrogen management is one of the key factors for garlic productivity as well as maintaining its quality. Nitrogen is a major element of amino acids which is the building block of proteins, nucleic acid and chlorophyll molecules (Kumari *et al*., 2023; Yitayih *et al*., 2017). The demand of N can be met up from judicious use of nitrogenous fertilizer to ensure optimum growth and development of garlic (Yousuf *et al*., 2013). The dose of N is determined generally based on soil organic matter content, crop uptake, yield levels, cropping season and also crop variety (Zaman *et al*., 2011). Nitrogen deficiency may cause stunted growth with small bulb size and reduced yields of garlic (Kevlani *et al*., 2023). Excessive N leads to pre-mature sprouting, excess vegetative growth, delayed maturity, increased susceptibility to diseases, increased premature sprouting, reduced dry matter content, storability and thus, reduced yield and quality of marketable bulbs (Anas *et al*., 2020; Pruthi, 2001). Excessive N application has become a concern because washed out, leached out and denitrified N in ecosystem leads to significant direct and indirect negative effects on environmental quality, biodiversity, human health and sustainable agricultural production (Anas *et al*., 2020; Kevlani *et al*., 2023). Nitrogen uptake level of garlic crops may vary from less than 50 kg to more than 200 kg depending on cultivar, climate, plant density, and fertilization and yield levels (Usman *et al*., 2016; Kenea and Gedamu, 2020).

Optimum N fertilization and N efficient germplasm with better nitrogen use efficiency (NUE) are the possible ways to overcome N application problem (Noor, 2017). Excessive application of N has now accumulated in the soil due to this high level of N application resulting in low NUE (Savci, 2012). Therefore, the experiment was conducted to study the effect of nitrogen on yield and NUE of garlic and evaluate the response of garlic varieties to nitrogen rates.

Materials and Methods

The field experiment was conducted in the research field of Regional Spices Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur, during two consecutive growing seasons (winter) of 2020-21 and 2021-22. The experimental site was situated at $23^{0}59^{/}$ North Latitude and $90^{0}24^{/}$ East Longitude, at an altitude of 8.4 m above the mean sea level. The soil of the experimental site belongs to Chhiata Soil series classified as Grey Terrace Soil of Inceptisol Order (USDA Soil Taxonomy) under AEZ-28 (Madhupur Tract) (Brammer, 1971). The initial composite soil samples (0-15 cm depth) of the experimental field were collected and analyzed in the Soil Science Laboratory, BARI, Gazipur following standard and recommended methods (Table 1). The experiment was laid out in a two-factor randomized complete block design with three replications having four garlic varieties (BARI Rashun-1, BARI Rashun-2, BARI Rashun-3 and BARI Rashun-4) with four different levels of nitrogen (0.0, 50, 100 and 150 kg ha^{-1}). The blanket dose of other fertilizers was 60-160-20-2-1kg ha^{-1} of P-K-S-Zn-B along with cowdung @ 5 t ha^{-1}. The total amount of cowdung, Triple super phosphate (TSP) for P, ½ of Muriate of potash (MoP) for K, gypsum for S, $ZnSO_4$ for Zn and boric acid for B were applied during final land preparation. Urea as a source of N was applied in 3 equal splits at 30, 45 and 60 days after planting (DAP) and the rest half of MoP was applied at 45 DAP. The unit plot size was 3 m x 3 m. The cloves of garlic bulb were used as planting materials. The similar sized cloves (2.0 to 2.5 g) were planted on 09 November 2020 and 10 November 2021, for the first and second year, respectively, with a spacing of 15 cm x 10 cm. The cloves were placed into the soil 3-4 cm deep with the growing point upward and covered lightly with soil for consolidation. Before planting, the cloves were treated with Autostin (Carbendazim) @ 2 g kg^{-1} to reduce the primary seed borne diseases. Weeding was done three times at 25, 50 and 75 DAP manually by handpicking. The experimental plots were irrigated four times at 30, 60, 80 and 110 DAP by surface flooding method and stopped three weeks before harvest to allow for uniform maturity. Spraying of Rovral (Iprodione) @ 2 g L^{-1} + Ridomil Gold (Mancozeb + Metalaxyl) @ 2 g L^{-1} was done at every 10 days interval for controlling purple blotch disease and Imitaf (Imidacloprid) @ 2 ml L^{-1} for management of *Thrips* were done throughout the cropping season.

Table 1. Physical and chemical properties of initial soil at the experimental field

Soil characteristics	Analytical value		Analytical method
	2020-21	2021-22	
Soil Textual class	clay loam	clay loam	Hydrometer method
Bulk density (g cm^{-3})	1.38	1.39	Core sampling method
Particle density (g cm^{-3})	2.59	2.61	Pycnometer method
Soil pH	6.3	6.3	Soil: water=1:2.5
Total N (%)	0.09	0.09	Modified Kjeldhal Method
Organic C (%)	0.88	0.89	Wet oxidation method
Available P (ppm)	6.82	6.81	Bray and Kurtz method
Exchangeable K (meq100g^{-1}soil)	0.06	0.06	N NH_4OAc extraction method
CEC (meq 100g^{-1} soil)	9.35	9.05	Schollenberger method
Available S (ppm)	6.8	6.9	Calcium dihydrogen phosphate extraction method
Available B (ppm)	0.11	0.12	Calcium chloride extraction method
Available Zn (ppm)	0.42	0.43	DTPA Extraction method
Available Cu (ppm)	0.17	0.18	DTPA Extraction method
Available Mn (ppm)	0.65	0.66	DTPA Extraction method

Harvesting of garlic was done on 02 April both the years, when around 75% of the leaves of the plants in each plot become straw colour, dry and/or shown senescence with neck fall then the bulbs were harvested by pulling up single plants by hand. The harvested bulbs were cured in the field and sun-dried for 7 days, folding of leaves over the bulbs was done for protecting them from sunburn. After a week of drying, necks and roots were cut. Yields obtained from the net plot were weighed and recorded after curing. After harvesting, 15 (fifteen) selected garlic plants from each plot were uprooted, air-dried in the laboratory and finally oven-dried for 72 hours at 70^0C to estimate the dry matter production. The dry matter was calculated using the following formula:

$$DM = [\{(DY /15) \times NP\} \times 10000)]/1000$$

Where,

DM = Dry matter (kg ha^{-1})

DY = Total dry matter yield of 15 plants per plot (g)

NP = Total number of plants per plot

For computing nitrogen uptake at the younger and entirely expanded leaf of garlic at 45 DAP (when leaf nutrient concentration was high) was taken after beginning of clove differentiation by sampling of 15 (fifteen) leaves at four distinct points of every plot were cut at the bottom, chopped with a sharp knife, air dried for 3 days then oven dried for 72 hours at 70^0C followed by grinding the oven-dry samples by an electric grinding machine.

Nitrogen uptake from the soil was calculated by using the formula:

Nitrogen uptake = % A x Y / 100 kg ha^{-1}

Where,

% A = Nitrogen content of plant in percent; Y = Total dry matter production of plant (kg ha^{-1})

Nitrogen use efficiency was calculated by using following formula:

NUE= (NU/NA) X 100

Where,

NUE = Nitrogen use efficiency (%)

NU = Total amount of nitrogen uptake (kg ha^{-1})

NA = Total amount of applied nitrogen (kg ha^{-1})

Nitrogen recovery efficiency was calculated by using following formula:

$$NRE = \{(NU_{\text{fertilized}} - NU_{\text{un-fertilized}}) / N_{\text{fertilizer dose}}\} \times 100$$

Where,

NRE = Nitrogen recovery efficiency (%)

$NU_{\text{fertilized}}$ = Total amount of nitrogen uptake under fertilized plot (kg ha^{-1})

$NU_{\text{un-fertilized}}$ = Total amount of nitrogen uptake under un-fertilized plot (kg ha^{-1})

$N_{\text{fertilizer dose}}$ = Total amount of nitrogen fertilizer applied under fertilized plot (kg ha^{-1})

The recorded data on different parameters were subjected to statistical analysis using *R* version 3.5.0 to find out the significant of variation among the treatments. The difference between treatments means were judged by the Least Significant Difference (LSD) test at 5% level of significance.

Results and Discussion

Effect of varieties on yield and yield contributing characters of garlic

The garlic varieties differed significantly for yield and most of the yield contributing characters viz. plant height, number of leaves per plant, bulb size, number of cloves, bulb size, bulb and biomass yield regardless of N dose (Table 2a and 2b). The pre-mature sprouting of garlic also differed significantly among the tested varieties (Figure 1). The tallest garlic plant (61.86 and 60.97 cm), maximum number of leaves

(9.21 and 10.0), maximum bulb size (3.44 cm x 3.15 cm and 3.82 cm x 3.49 cm), maximum number of cloves per plant (20.85 and 51.78), heaviest bulb (24.0 g and 29.8 g), bulb yield (8.58 t $ha^{-1}$and 8.91 t ha^{-1}) and biomass yield (3.35 and 3.49 t ha^{-1}) were recorded from BARI Rashun-3 in 2020-2021 and 2021-2022, respectively, which was followed by BARI Rashun-4 and these were significantly higher over other two varieties (Yousuf *et al*., 2016). However, the smallest garlic plant (54.51 and 60.97 cm), minimum number of leaves (7.88 and 8.0), minimum bulb size (3.28 cm x 3.15 cm and 3.66 cm x 3.28 cm), minimum number of cloves per plant (19.01 and 17.55), lightest bulb (21.57 g and 27.53g), minimum bulb yield (7.08 t $ha^{-1}$and 8.91 t ha^{-1}) and minimum biomass yield (3.07 and 3.27 t ha^{-1}) were noted from BARI Rashun-1. The maximum average pre-mature sprouted bulb of garlic (12.83%) was noted in BARI Rashun-1 and the minimum pre-mature sprouted bulb (4.75%) was recorded in BARI Rashun-4. It might be due to greater genetic variation among the tested garlic varieties in respect of bulb size & weight, clove numbers and pre-mature sprouting. The results are in agreement with Gashaw (2021) and Usman *et al.* (2016).

Table 2a. Effect garlic varieties on yield and yield components of garlic

Variety	Plant height (cm)		No. of leaves/plant		Bulb length (cm)		Bulb diameter (cm)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
V_1	54.51c	51.78b	7.88c	8.0b	3.28	3.66	2.91	3.28
V_2	56.09bc	52.33b	8.03bc	8.25b	3.34	3.73	2.92	3.33
V_3	61.86a	60.97a	9.21a	10.0a	3.44	3.82	3.15	3.49
V_4	58.57ab	58.83a	8.99ab	9.83a	3.35	3.74	3.06	3.25
CV (%)	7.39	7.55	2.04	7.23	NS	NS	NS	10.49

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD.

V_1 = BARI Rashun-1; V_2 = BARI Rashun-2; V_3 = BARI Rashun-3 and V_4 = BARI Rashun-4, Y_1 = 2020-21, Y_2 = 2021-22.

Table 2b. Effect of garlic varieties on yield and yield components of garlic

Variety	No. of cloves/ bulb		Single bulb weight (g)		Yield (t ha^{-1})		Biomass (t ha^{-1})	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
V_1	19.01b	17.55b	21.57c	27.53a	7.08c	8.05b	3.07b	3.27
V_2	19.58ab	18.41ab	23.38ab	29.63b	7.13bc	8.28b	3.21ab	3.35
V_3	20.85a	19.77a	24.08a	29.80b	8.58a	8.91a	3.35a	3.44
V_4	20.62a	18.85ab	23.07b	27.95b	7.63b	8.44b	3.29a	3.34
CV (%)	7.63	13.12	6.94	14.90	11.02	8.24	6.78	NS

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD.

V_1 = BARI Rashun-1; V_2 = BARI Rashun-2; V_3 = BARI Rashun-3 and V_4 = BARI Rashun-4, Y_1 = 2020-21, Y_2 = 2021-22.

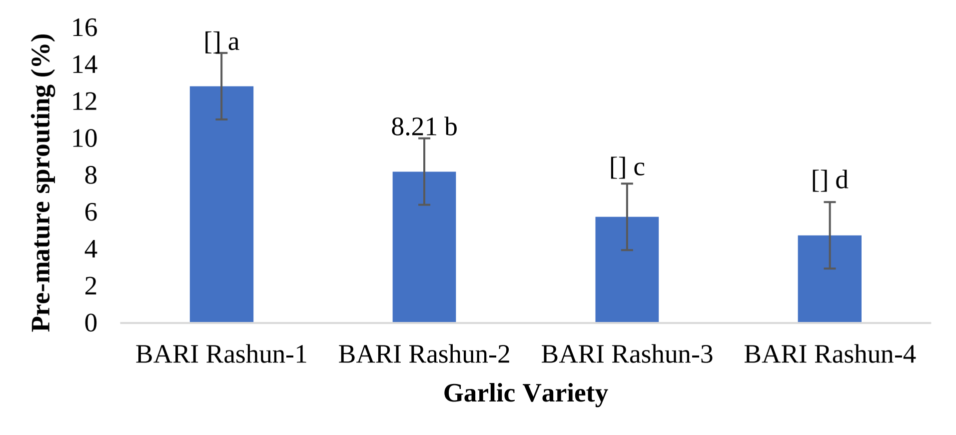

Fig. 1. Pre-mature sprouting of garlic varieties (average of two years).

Effect of nitrogen on yield and yield contributing characters of garlic

Application of N significantly influenced the yield contributing characters and yield of garlic (Table 3a and 3b) and also pre-mature sprouting of garlic (Figure 2). The tallest garlic plant (60.21 and 57.91 cm), maximum number of leaves (9.73 and 10.75), maximum bulb size (3.92 cm x 3.37 cm and 4.54 cm x 3.87 cm), maximum number of cloves per plant (21.16 and 19.97), heaviest bulb (24.11 g and 36.52 g), bulb yield (8.1 t ha^{-1} and 9.55 t ha^{-1}) and biomass yield (3.37 and 3.92 t ha^{-1}) were observed from application of nitrogen @100 kg ha^{-1} in 2020-21 and 2021-22, respectively, which was followed by nitrogen @ 150 kg ha^{-1}. However, the smallest garlic plant (51.47 and 51.16 cm), minimum number of leaves (7.21 and 7.0), minimum bulb size (2.75 cm x 2.52 cm and 2.98 cm x 3.20 cm), minimum number of cloves/plant (17.69 and 15.66), lightest bulb (21.63 g and 25 g), minimum bulb yield (6.64 t ha^{-1}and 6.85 t ha^{-1}) and minimum biomass yield (2.52 and 2.76 t ha^{-1}) were documented in control treatment (N_0) in 2020-21 and 2021-22, respectively. This might be due to optimum level of nitrogen which is a major constitute of chlorophyll that enhances to produce maximum photosynthates, a simulative effect on cell division and cell enlargement leading to vigour's growth and increased uptake of nutrients at higher levels to produced assimilates to fill the sink which result in increased bulb size and weight (Fathi, 2022). The bulb size and weight of garlic decreased beyond optimum levels might be due to imbalance of nutrients for excess application of nitrogen (Diriba-Shiferaw *et al*., 2015). It is well established that nitrogen is the major responsible element for photosynthesis and maintaining photosynthate from source to sink (Anas *et al*., 2020). This investigation is similar with the findings of Gashaw (2021), Kenea and Gedamu (2020) and Yousuf *et al*. (2013). The maximum average pre-mature sprouted bulb (10.75%) was recorded from the application of N @ 150 kg ha^{-1} and the minimum pre-mature sprouted bulb (5.33%) was noted in control treatment, which indicate that higher dose of N might have caused pre-mature sprouting of garlic, which is not desirable and so N dose should be optimized considering yield as well as quality of garlic (Pruthi, 2001).

Table 3a. Effect nitrogen on yield and yield attributing characters of garlic

Nitrogen (kg ha^{-1})	Plant height (cm)		Number of leaves/ plant		Bulb length (cm)		Bulb diameter (cm)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
0	51.47b	51.16b	7.21c	7.0d	2.75d	2.98d	2.52c	2.75d
50	59.39a	57.14a	8.20b	8.66c	3.16c	3.41c	2.98b	3.20c
100	60.21a	57.91a	9.73a	10.75a	3.92a	4.54a	3.37a	3.87a
150	59.97a	57.69a	8.97ab	9.66b	4.57b	4.03c	3.17ab	3.52b
CV (%)	7.39	7.55	2.04	7.23	12.13	7.29	13.06	10.49

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD.

Y_1 = 2020-21, Y_2 = 2021-22.

Table 3b. Effect nitrogen on yield and yield attributing characters of garlic

Nitrogen (kgha^{-1})	Number of cloves/ bulb		Single bulb weight (g)		Yield (t ha^{-1})		Biomass (tha^{-1})	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
0	17.69b	15.66b	21.63c	25.0d	6.64b	6.85d	2.78d	2.76d
50	20.68a	19.69a	23.05b	29.93c	7.75a	8.35c	3.07c	3.15c
100	21.16a	19.97a	24.21a	36.52a	8.10a	9.55a	3.66a	3.92a
150	20.54a	19.27a	23.21b	33.36b	7.91a	8.97b	3.39b	3.58b
CV (%)	7.63	13.12	6.94	14.90	11.02	8.24	6.78	12.11

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD.

Y_1 = 2020-21, Y_2 = 2021-22.

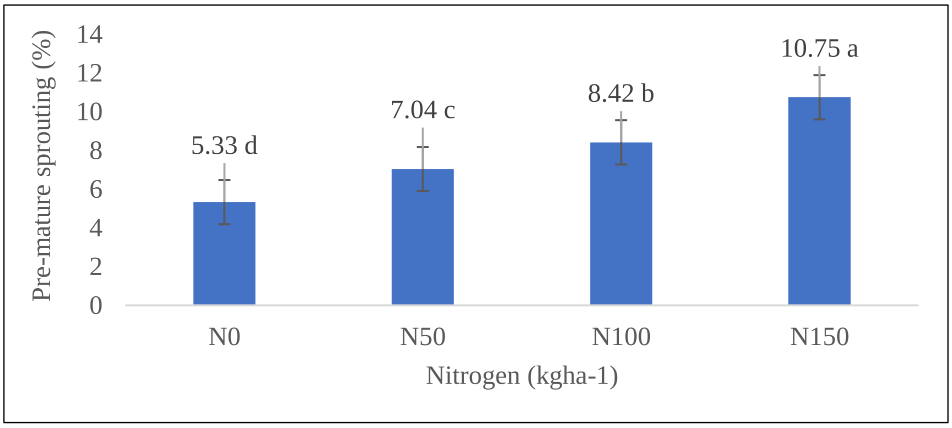

Fig. 2. Application of nitrogen on pre-mature sprouting of garlic (average of two years).

Response of garlic to nitrogen

Garlic responded to added nitrogen significantly. However, from regression analysis, a quadratic response (R^2 = 0.9914) was noted (Table 5). The bulb yield increased up to 100 kg N ha^{-1} and thereafter declined due to application of higher dose. From this quadratic response function, the optimum dose of N for garlic cultivation is estimated to be (92.75 kg ha^{-1}) and the maximum bulb yield is expected to be 11.88 t ha^{-1}. The nitrogen use efficiency showed that each 1 kg of N could produce 18.55 kg ha^{-1} garlic bulb up to optimum level after which bulb yield could reduce to 0.2 kg ha^{-1} for each 1 kg of applied N. Response of different levels of nitrogen from 0.0 to 150 kg N ha^{-1} on garlic in positive increment of yield and thereafter the yield declined. It might be due to excessive nitrogen creates imbalance of nutrients (*Zaman et al.*, 2011).

Table 5. Response function of garlic to nitrogen for bulb yield (using pooled data)

Response function	Pooled in both the years
Regression equation	$Y = -0.0002N^2 + 0.0371N + 6.7175$
R^2	0.9914
Optimum rate of N (kg ha^{-1})	92.75
Maximum bulb yield (t ha^{-1}) for optimum N level	11.88
Production of bulb (kg) for 1 kg N (use efficiency)	18.55
Beyond optimum level the reduction of bulb (kg) for each 1 kg N	0.2
Optimum economic rate of N (kg ha^{-1})	92.7

Effect of garlic varieties and nitrogen on nitrogen content, uptake and use efficiency of garlic

Nitrogen content

Nitrogen content in garlic plant was significantly influenced by variety and nitrogen levels (Tables 6-7). Considering the main effect of variety, the maximum N content per plant (2.2 and 2.33%) was recorded from BARI Rashun-3 which was significantly higher overall other varieties in both the years. The lowest N content (2.11 and 2.21%) was observed in BARIN Rashun-1 in both the years (Table 6). Application of nitrogen fertilizer significantly increased then nitrogen content in garlic plant. The maximum N content per plant (2.22 and 2.44%) was noted with the application of 150 kg N ha^{-1}. And the minimum N content (2.07 and 2.08%) was recorded in control (Table 7). Maintaining optimum level of nitrogen in soil had improved nutritional status in garlic plants. Similar results were reported by Cunha *et al*. (2015) and Yitayih *et al.* (2017).

Nitrogen uptake

Nitrogen uptake by garlic plant varied due to single as well as interaction application of variety and nitrogen (Tables 6-7). Irrespective of N dose, the maximum nitrogen uptake (79.42 and 91.73 kg ha^{-1}) was observed with BARI Rashun-3 (V_3) where the minimum N uptake (64.78 and 72.27 kg ha^{-1}) was recorded in BARI Rashun-1 (Table 6). The maximum nitrogen uptake (79.42 and 91.73 kg ha^{-1}) were observed from 100 kg N ha^{-1} (N_3) and the minimum (57.55 and 57.01 kg ha^{-1}) were observed from native fertility (Table 7), regardless of variety. A steady supply of nitrogen stimulates root & shoot growth and development which governed uptake of macro and micro nutrients. These results of present study are at par with the findings of Kumari *et al*., (2023) and Thangasamy and Chavan (2017).

Nitrogen use efficiency

Nitrogen use efficiency (NUE) of garlic varied due to irrigation regimes and nitrogen levels (Tables 6-8). Considering the main effect of variety, the maximum of nitrogen use efficiency (99.16 and 106.05%) was recorded with BARI Rashun-3 and the minimum (86.37 and 96.36%) at BARI Rashun-1 in both the years (Table 6). On the other hand, considering the nitrogen dose, the maximum nitrogen use efficiency (130.78 and 137.98%) was observed by the application of 50 kg N ha^{-1} but gradually decreased with higher dose N applied in garlic (Table 7). The interaction effect of varieties and N levels on nitrogen use efficiency (NUE) of garlic was considerable. Similar result was documented by Sahu *et al.* (2023). NUE is an indicator for a crop to use the nitrogen fertilizer that has been supplied. NUE depends on the physiological and metabolic changes, such as N uptake by plant, assimilation from root to other parts, source sink relationship for transportation, signaling and regulatory path-ways which are responsible for N status within plan (Anas *et al.,* 2020).

Table 6. Effect of variety on nitrogen content, uptake and use efficiency of garlic

Garlic Variety	N content per plant (%)		N uptake (kgha^{-1})		N use efficiency (%)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
BARI Rashun-1	2.11c	2.21b	64.78	72.27	86.37	96.36
BARI Rashun-2	2.13bc	2.24ab	68.37	75.04	91.16	100.05
BARI Rashun-3	2.20a	2.33a	74.37	80.15	99.16	106.87
BARI Rashun-4	2.16b	2.26ab	71.06	75.48	94.75	100.64
CV (%)	3.78	9.00	-	-	-	-

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD

Y_1 = 2020-21, Y_2 = 2021-22

Table 7. Effect of nitrogen levels on nitrogen content, uptake and use efficiency of garlic

Nitrogen (kgha^{-1})	N content per plant (%)		N uptake (kg ha^{-1})		N use efficiency (%)		N recovery efficiency (%)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
0	2.07d	2.08d	57.55	57.01	-	-	-	-
50	2.13c	2.19c	65.39	68.99	130.78	137.98	15.68	23.96
100	2.22a	2.44a	79.42	91.73	79.42	91.73	21.87	34.72
150	2.17b	2.34b	75.24	87.35	50.28	58.23	11.79	20.23
CV (%)	3.78	9.00	-	-	-	-		

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD.

Y_1 = 2020-21, Y_2 = 2021-22.

Conclusion

The garlic variety cv. BARI Rashun-3 appeared as the potential variety in respect of bulb yield followed by BARI Rashun-4. Regardless of variety, the garlic plant performed the best with 100 kg N ha^{-1}. Nitrogen response to garlic yield was quadratic in nature (R^2 = 0.9914). From the quadratic response function ($Y = 6.7175 + 0.0371N - 0.0002N^2$), the optimum dose and optimum economic dose were estimated to be 92.75 and 92.70 kg ha^{-1}, respectively. Therefore, BARI Rashun-3 may be cultivated by applying 92.75 kg N ha^{-1} along with blanket dose of 60-160-20-2-1 kg ha^{-1} of P-K-S-Zn-B plus cowdung @ 5 t ha^{-1} in Grey Terrace Soil and similar other soils under AEZ-28. Similar trials may be conducted in different AEZs of the country for finding out suitable variety (s) and the optimum dose of N for maximizing the yield of garlic.

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