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Impact of nitrogen management and nano-urea on yield, quality and storage attributes of garlic (*Allium sativum*)

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ABSTRACT

The present study was carried out during winter (*rabi*) seasons of 2020–21 and 2021–22 at Sri Karan Narendra College of Agriculture, Jobner, Jaipur, Rajasthan to evaluate the impact of nitrogen management (organic and inorganic sources), biofertilizer and foliar spraying of nano-urea on yield, quality and storage attributes of garlic (*Allium sativum* L.). The experiment consisted of 3 levels of organic and inorganic fertilization, 2 levels of bio-fertilizers in main plot, and 4 levels of nano-urea arranged in split plot design (SPD) in sub plot. The results showed that yield, quality and storage attributes of garlic, viz. number of cloves/bulb (16.46%), clove length and girth, average weight of clove (1.56 gm), nitrogen, phosphorus and potassium content in bulb (1.10, 0.31 and 0.51%), physiological loss in weight, shelf-life of bulbs and rooting percentage of bulbs were significantly enhanced by 100% recommended dose of nitrogen through inorganic fertilizers and bio-fertilizer in main plot. In sub plot, the foliar spray of nano-urea @75 ml/ha recorded highest number of cloves per bulb (16.26%), clove length and girth (2.86 and 1.07 cm), average weight of clove (1.55 gm), nitrogen, phosphorus and potassium content in bulb (1.09, 0.31 and 0.51%), shelf-life of bulbs and rooting percentage of bulbs. Therefore, this study concluded that the nitrogen management and nano-urea in garlic crop gives better yield, quality and storage attributes, and can be opted in semi-arid climatic conditions.

Keywords: *Azotobacter*, Nano-urea, Quality, Storage attributes, Vermicompost, Yield

Garlic (*Allium sativum* L.) belongs to the family Alliaceae is a vital bulb crop commonly used as a spice. India produce a staggering amount of vegetables with 12.31 Mha of land and 212.91 Mt of production (Anonymous 2022–23). It is grown on approximately 68.0 thousand ha, where it produces 416.0 thousand Mt in total in Rajasthan (Anonymous 2020–21). The garlic production is expanding globally as a result of its high profit per unit area and simplicity of production (FAO 2020). The low crop yield in Rajasthan and India may be the result of growers' disregard for proper nutritional management and lack of scientific farming practices. Use of chemical fertilizers has pushed up the agricultural production. However, among major nutrients nitrogen is lost in soil through leaching or to the atmosphere because of denitrification (Jha *et al.* 2006). High productivity is linked to rapid vegetative development and the most effective utilization of available inputs.

Vermicompost is an organic amendment, rich in nutrients that is created when organic materials decompose (Fu *et al.* 2015). This process yields a material that resembles peat and has a low carbon to nitrogen ratio. It is also enhanced with microbiologically active agents that increase porosity and water-holding capacity, as well as essential nutrients (Edwards *et al.* 2004, Lim *et al.* 2015, Dubey *et al.* 2020). Azotobacter has move to beneficial macro elements from unusable to usable states and boost crop productivity by improving soil fertility (Kurrey *et al.* 2018).

Agriculture is making significant progress in the area of sustainable crop enhancement, with nano-nitrogen playing a key role (Zuliger *et al.* 2019). With the use of nano-fertilizer technology, nutrients may be delivered in a controlled manner in accordance with crop needs, improving nutrient-use efficiency without having negative side effects (Liu and Lal 2015). Several researchers also looked at the effects of nano-fertilizer on crop development and yield

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like Davarpanah *et al.* (2016) in pomegranates and Abdel-Aziz *et al.* (2021) in chilies. The purpose of the current study was to determine the effects of spraying nano-urea in combination with organic, inorganic, and biofertilizer on garlic yield, quality and storage properties.

MATERIALS AND METHODS

The present study was carried out during winter (*rabi)* seasons of 2020–21 and 2021–22 at Sri Karan Narendra College of Agriculture, Jobner, Jaipur, Rajasthan. The experimental soil was loamy sand with *p*H 7.95, having low levels of organic carbon (0.21%), medium levels of readily available P (15.84 kg/ha) and K (148.98 kg/ha). The experiment was laid out in split plot design (SPD) with 3 replications.

Treatment	Symbol
Main plot	
Nitrogen application through organic and inorganic sources	
100% Recommend dose of N through inorganic fertilizers	O_1
75% Recommend dose of N through inorganic fertilizers + 25% through organic manure	O_2
50% Recommend dose of N through inorganic fertilizers + 50% through organic manure	O_3
Nitrogen application through bio-fertilizers	
Without *Azotobacter* inoculation	B_0
With *Azotobacter* inoculation	B_1
Sub plot	
Nitrogen application through nano urea	
Control	N_0
25 ml/ha	N_1
50 ml/ha	N_2
75 ml/ha	N_3

The National Horticultural Research and Development Foundation, Karnal, Haryana provided the bulbs of cultivar G-282. To prevent seed-borne disease, garlic cloves were first treated with carbendazim @2 g/kg seed. For garlic crops, optimum dose of nitrogen, phosphorus and potassium was @120: 60: 60 kg/ha. The vermicompost was applied before the planting and urea was applied in 3 equal split doses and single super phosphate (SSP) (80 kg/ha) and potassium sulphate (80 kg/ha) as basal dose. To calculate the mean number of cloves per bulb, the total number of cloves from the bulbs of five tagged plants was counted. In order to calculate the average length and girth, the length and girth of 10 randomly chosen cloves from each bulb of the tagged plants were also measured using a veneer caliper. Using a balance to weigh five cloves that had already been used to measure their length and girth, the average fresh weight of the cloves was determined.

To estimate the amount of nitrogen the colorimetric approach as proposed by Snell and Snell (1949) through the spectronic-20 (Model SL-177) was used. The amount of phosphorus in the bulb was ascertained using the "vanadomoloybdo" phosphoric acid yellow colour technique (Richards 1954). Potassium content in the samples was determined by digesting in tri-acid mixture of HNO_3: H_2SO_4: $HClO_4$ and intensity of emission determined in flame photometer using K filter (Bhargava and Raghupathi 1993).

Using an electronic balance, physiological weight loss (PLW) of bulb was measured 30, 60, 90, and 120 days after storage as:

$$\text{PLW (\%)} = \frac{P_0\text{-}P_1 \text{ or } P_2 \text{ or } P_3 \text{ or } P_4}{P_0} \times 100$$

where P_0, Initial weight; P_1, Weight after 30 days; P_2, Weight after 60 days, P_3, Weight after 90 days, P_4 Weight after 120 days.

Shelf-life of garlic is the period started from the harvest and extends to the time the sample stayed in storage systems before drying of cloves. For determining the rotting percentage of bulbs on stipulated days after storage, the bulbs showing a rot were separated from the lot and counted. The following formula was used to determine the rotting percentage:

$$\text{Rotting (\%)} = \frac{\text{Number of rotten bulbs}}{\text{Total number of the bulbs}} \times 100$$

Analysis of variance (ANOVA) was performed on the gathered data, and the results showed that integrated nitrogen management had a significant (*P*=0.05) impact. Prism-8.0.1 was used to perform a statistical analysis of the data. We used Microsoft Excel 2016 and Prism 8.0.1 for tables and visualization, respectively.

RESULTS AND DISCUSSION

Yield attributes: Nitrogen management, implemented through integrated nitrogen management (INM) and foliar application of nano-urea, significantly influenced the yield attributes of garlic (Table 1). Notably, the application of 100% recommended dose of nitrogen (RDN) in combination with inorganic fertilizer and bio fertilizer (O_1B_1) resulted in the highest number of cloves/bulb (17.46). This performance was comparable to treatments O_1B_0 and O_2B_0. Similarly, O_1B_1 treatment produced the longest cloves, although statistically similar to O_1B_0, O_2B_0 and O_2B_1 treatments. The application of 100% RDN through inorganic fertilizers and biofertilizer led to a significant increase in clove length by 13.65% and 9.27% compared to O_3B_0 and O_3B_1, respectively. Additionally, O_1B_1 treatment recorded the highest clove girth and average clove weight, indicating the positive impact of nitrogen management approach on garlic productivity. These improvements are attributed to the optimal moisture content and balanced organic and inorganic nutrient levels, fostering enhanced plant growth and yield, aligning with the findings of Doodhawal *et al.* (2021) and Esringii *et al.* (2022). Moreover, the positive influence of vermicompost on plant growth, as noted by Ansari and Kumar (2010), Gebretsadik and Dechassa (2018), Musa *et al.* (2018), Karagoz *et al.* (2019) and Aechra *et al.* (2022), supports

Table 1 Effect of integrated nitrogen management on number of cloves/bulb, clove length, clove girth and average weight of clove at harvest of garlic (2 years pooled data)

Treatment	Number of cloves/ bulb	Clove length (cm)	Clove girth (cm)	Average weight of clove (g)
N application through organic, inorganic and biofertilizer sources				
O_1B_0	17.09	2.76	1.03	1.50
O_1B_1	17.46	2.83	1.05	1.56
O_2B_0	16.22	2.73	1.01	1.42
O_2B_1	16.95	2.74	1.02	1.48
O_3B_0	15.17	2.49	0.90	1.34
O_3B_1	15.97	2.59	0.95	1.40
CD (*P*=0.05%)	0.75	0.13	0.05	0.08
N application through nano-urea				
N_0	15.24	2.46	0.89	1.34
N_1	16.31	2.64	0.97	1.43
N_2	17.08	2.81	1.05	1.52
N_3	17.28	2.86	1.07	1.55
CD (*P*= 0.05)	0.53	0.11	0.04	0.06

Treatment details are given under Materials and Methods.

Table 2 Effect of integrated nitrogen management on N, P and K content in clove of garlic (2 years pooled data)

Treatment	N content (%)	P content (%)	K content (%)
N application through organic, inorganic and biofertilizer sources			
O_1B_0	1.08	0.30	0.49
O_1B_1	1.10	0.31	0.51
O_2B_0	0.96	0.29	0.48
O_2B_1	1.07	0.30	0.49
O_3B_0	0.85	0.28	0.47
O_3B_1	0.94	0.29	0.47
CD (*P* = 0.05)	0.04	0.01	0.01
N application through nano-urea			
N_0	0.86	0.27	0.44
N_1	0.97	0.29	0.49
N_2	1.07	0.31	0.51
N_3	1.09	0.31	0.51
CD (*P* = 0.05)	0.03	0.01	0.01

Treatment details are given under Materials and Methods.

the observed yield attributes. The Plant development is promoted by the presence of more mycorrhizal fungi and N-fixing bacteria in vermicompost. The study aligns with the findings of Kadam *et al.* (2022) regarding the positive impact of azotobacter on crop yield, emphasizing its role in nitrogen fixation and growth promotion. In the sub-plot analysis, treatment N_3 exhibited enhanced yield attributes, with the highest number of cloves/bulb (17.25), a maximum clove girth, and the longest cloves. Nano-urea application at 75 ml/ha further amplified these effects, demonstrating its efficacy in improving yield attributes by providing sufficient nitrogen for enhanced nutrient uptake, metabolism, and vegetative growth. These findings align with previous studies on garlic (Ajit-Kumar *et al.* 2021).

Nutrient content: The main plot analysis revealed that 100% RDN via inorganic fertilizer with biofertilizer (O_1B_1) resulted in the maximum nitrogen content in garlic cloves (1.10%). This was statistically comparable to O_1B_0 and O_2B_1, while O_2B_0 exhibited the minimum nitrogen content. The application of 100% RDN through O_1B_1 significantly increased phosphorus content in cloves compared to O_2B_0, O_3B_0 and O_3B_1. Similarly, the highest potassium content in cloves was observed with O_1B_1 treatment (Table 2). Nitrogen uptake in garlic cloves significantly increased with the application of 100% RDN of nitrogen through inorganic fertilizers and biofertilizer (O_1B_1) compared to other treatments over both the years, supporting the idea that increased nutrient availability positively impacts nutritional status. The improved nutrient uptake and metabolism resulting in higher nutrient concentration at harvest could be attributed to nitrogen fertilization (Pathma and Sakthivel 2012). Biofertilizers contribute to this process by producing vitamin B complex and phytohormones, preventing root infections, promoting root growth, and enhancing nutrient content. These findings align with previous studies of Prakash *et al.* (2000), Nasreen *et al.* (2007) and Mahala *et al.* (2018). In sub-plot, foliar application of nano urea at 75 ml/ha significantly increased nitrogen, phosphorus and potassium content in garlic bulb compared to other treatments. The study suggests that nano urea, by gradually releasing nutrients, enhances nutrient use efficiency without adverse effects, aligning with the environmental safety goals of nano fertilizers (Ghormade *et al.* 2011). Manjunath *et al.* (2018) observed that application of fertilizers in the form of nano particles, enable slow and controlled release of nutrients for the plants' which ultimately led to increase in the crop production with less adverse effect on environment (Scott and Chen 2013).

Storage attributes: Nitrogen management significantly influenced the storage attributes of garlic bulb (Table 3). In the main plot, O_1B_1 treatment resulted in the minimum physiological loss in weight (PLW) of garlic bulb at 60, 90, and 120 days after harvesting compared to O_2B_0, O_3B_0, and O_3B_1 treatments. Notably, O_3B_0 treatment exhibited the maximum PLW throughout the experimentation period. The better shelf-life of garlic was associated with O_1B_1 treatment, while O_3B_0 treatment showed the minimum shelf-life. Additionally, O_3B_0 treatment recorded the minimum rotting percentage of garlic bulb at 90 days after harvesting compared to O_2B_0, O_3B_0, and O_3B_1 treatments. However, O_1B_1 treatment exhibited the maximum rotting percentage. The study suggests that higher air temperature in the storage room could contribute to bulb weight loss, potentially through increased evaporation and respiration

Table 3 Effect of integrated nitrogen management on physiological weight loss, shelf-life and rotting of garlic (2 years pooled data)

Treatment	30 Days after harvesting	60 Days after harvesting	90 Days after harvesting	120 Days after harvesting	Shelf-life (days)	Rotting (%)
N application through organic, inorganic and biofertilizer sources						
O_1B_0	4.08	9.15	12.34	19.62	114.64	1.94
O_1B_1	4.02	8.89	12.69	18.89	111.61	1.99
O_2B_0	4.12	9.45	13.67	21.11	107.57	2.19
O_2B_1	4.06	9.15	12.45	19.43	118.68	1.31
O_3B_0	4.22	9.64	13.87	21.47	115.65	1.44
O_3B_1	4.14	9.49	13.72	21.18	110.60	1.48
CD (P=0.05)	NS	0.41	0.47	0.92	4.81	0.07
N application through nano-urea						
N_0	4.18	9.62	13.48	12.09	107.00	2.04
N_1	4.16	9.50	13.37	11.99	112.00	1.91
N_2	4.11	9.16	13.24	11.71	116.00	1.72
N_3	3.98	8.90	12.41	10.98	116.00	1.25
CD (P = 0.05)	NS	0.29	0.38	0.60	1.38	0.05

Treatment details are given under Materials and Methods.

of dry matter. In the sub-plot analysis, foliar application of nano urea at 75 ml/ha resulted in the minimum physiological weight loss over different durations (60, 90, and 120 days after harvesting). This treatment significantly outperformed other nano urea doses in terms of PLW. Moreover, nano urea at 75 ml/ha recorded the maximum shelf-life and rotting percentage in garlic bulb compared to other treatments, demonstrating its efficacy in improving storage attributes.

However, it is important to note that the observed storage attributes may be associated with an increased incidence of sprouting and rotting, potentially due to higher respiration rates. This aligns with the findings of Bekele (2023) and emphasizes the need for careful consideration of storage conditions. Overall, the study provides valuable insights into the impact of nitrogen management strategies and nano urea application on yield attributes, nutrient content, and storage attributes of garlic. The results support the importance of balanced nutrient management practices for optimizing garlic production and quality.

The study concludes that effective nitrogen management, especially through the application of 100% RDN via inorganic fertilizer with biofertilizer and foliar application of nano-urea at 75 ml/ha, positively influences garlic yield attributes, nutrient content, and storage attributes. These findings contribute valuable insights for optimizing garlic production practices with a focus on nitrogen management strategies.

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