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Response of Nano Fertilizers and Varieties on Growth and Yield of Brinjal (*Solanum melongena*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was conducted at Bundelkhand University's organic research farm in Jhansi (U.P.) during the Rabi season of 2023-24. The site had favorable climatic conditions with an average

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annual temperature of 30.03°C and an annual precipitation of 871 mm. The experiment followed a Randomized Block Design (RBD) with three replications, involving three brinjal varieties (Hybrid Snow Ball, VNR-58, VNR-212) and nine treatments, including Urea, DAP, and Urea + DAP. Each plot measured 2.4×1.8 m with a gross experimental area of 370 m². Growth and yield parameters, including plant height, branches, leaves, fruit characteristics, and yield, were recorded. The results showed that Urea + DAP treatment consistently outperformed others across all growth and yield parameters. At 90 DAT, the Purple variety had the highest plant height (50.33 cm), number of leaves (73.91), and branches (17.02). The Urea + DAP treatment resulted in the largest fruit size and highest yield. The Purple variety showed the best fruit characteristics, including the largest fruit diameter (58.74 mm) and highest single fruit weight (105.76 g). Yields per plant were highest for the Purple variety (422.77 g) and Urea + DAP treatment (417.77 g).

Keywords: Brinjal; growth; nanofertilizers; variety and yield.

1. INTRODUCTION

The eggplant, also known as brinjal or *Solanum melongena* L., is a widely cultivated vegetable crop in India and other parts of the world (Bhosale et al., 2020). It is particularly important in warm regions of the Far East, including India, Bangladesh, Pakistan, and the Philippines, and major producers of brinjal also include China, Turkey, Japan, Egypt, Indonesia, Iraq, Italy, Syria, and Spain (Ahanger et al., 2021). Brinjal is believed to have originated in the Indo-Burma region of India, with its cultivation dating back centuries. It belongs to the Solanaceae family and is highly productive, making it a staple vegetable, particularly for low-income populations (Baruah & Dutta, 2009). The fruit is rich in nutrients such as calcium, phosphorus, iron, and B vitamins and is recognized for its medicinal properties. It has been found to lower cholesterol due to the presence of polyunsaturated fatty acids like linoleic and lenolenic acids, as well as magnesium and potassium salts (BBS, 2020).

In addition to its nutritional benefits, brinjal is traditionally used in treating a variety of health conditions, including liver disease, allergies, rheumatism, and intestinal worms (Sahu et al., 2022, Al-Fahdawi & Allawi, 2019). Like other vegetables, it also provides dietary fiber, minerals, vitamins, carbohydrates, and protein, making it an important part of a balanced diet (Chauhan & Rai, 2019, Kadhim et al., 2021, Kazem et al., 2021). The cultivation of brinjal can be further enhanced by the use of micro-nutrients and fertilizers at recommended levels. Proper fertilizer management is essential for improving crop yields and achieving better production, as well as more efficient utilization of fertilizers (FAOSTAT, 2009). Ensuring an adequate supply of customized fertilizers that provide secondary and micronutrients is crucial for the successful integrated management of nutrient requirements in brinjal production (Khan et al., 2018).

The use of nano-technology in agriculture offers a promising solution to mitigate the harmful effects of overusing fertilizers and soil nutrient toxicity (Hossain et al., 2002). Nano-fertilizers, which are composed of tiny particles, improve nutrient release patterns, allowing for better nutrient efficiency and targeted delivery to the rhizosphere (Janmohammadi et al., 2016). These fertilizers require less frequent application compared to traditional fertilizers, thus reducing labor and cultivation costs. Nano-fertilizers have enhanced properties, such as increased surface area, which improves their nutrient adsorption capacity, ion exchange, and the prevention of nutrient fixation in the soil (Janmohammadi et al., 2016). This makes the nutrients more available for plant uptake, enhancing crop growth and yield. Nano-fertilizers also have a slow release, providing nutrients over an extended period of time (Jian et al., 2008). Incorporating nano-technology in agriculture could contribute to more sustainable farming practices and help address food security challenges, particularly in developing nations like India. A study titled "Response of nano-fertilizers and varieties on growth and yield of brinjal (*Solanum melongena* L.) under Bundelkhand region" has been conducted to explore the benefits of nano-fertilizers for improving brinjal production.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the organic research farm of the Department of Horticulture, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.), during the *Rabi* season of 2023-24. The site was chosen for its conducive environment for crop growth and availability of necessary facilities for the research.

2.2 Climate and Weather Conditions

Jhansi experiences a Mediterranean hot summer climate (Csa) characterized by hot summers and mild winters. The city is located at an elevation of 0 meters above sea level, and its average annual temperature is 30.03°C (86.05°F), which is 4.06% higher than the national average. The mean annual temperature in Jhansi is recorded at 25.8°C (78.4°F), and the total annual precipitation is approximately 871 mm (34.3 inches), which supports the farming activities in the region.

3. METHODOLOGY

The present experiment was design and optimized under Randomized block design with three replication *Rabi* Season (2022-2023) brinjal variety Hybridsnowball (white), VNR-58(Green) VNR-212(Purple) with plot size- (2.4×1.8) m and number of rows per plant-5 rows per plant accommodating spacing (60×45) cm under F.R.B.D design. Gross experimental area - 370 m^2. The Net experimental area - 214 m^2 with number of treatments 9 including the check/control plot. The total number of plots were 24 with plot size - 2.7 x 3.0 m. The data collected during the experimentation period were categorized into growth and yield parameters, including plant height, number of branches, leaves, flowers, clusters, and fruits per plant, as well as fruit length, girth, weight, and yield at both plant and plot levels, with measurements taken at various stages post-transplanting and harvest.

4. RESULTS AND DISCUSSION

The effect of nano-fertilizers on the plant height of different Brinjal varieties was assessed at three stages: 30 DAT, 60 DAT, and 90 DAT, involving two factors: Brinjal varieties (Green, Purple, White) and treatments (Urea, DAP, Urea + DAP). At 30 DAT, the Green variety had an average height of 12.16 cm, White had 13.11 cm, and Purple had 14.86 cm, with the Urea + DAP treatment yielding the tallest plants (14.38 cm), while Urea and DAP treatments had 12.02 cm and 13.72 cm, respectively, with a critical difference (CD) of 0.49 cm. At 60 DAT, the Green variety averaged 26.17 cm, White 28.01 cm, and Purple 30.67 cm, with the Urea + DAP treatment showing the highest average height of 29.97 cm, followed by DAP at 28.79 cm and Urea at 26.08 cm, but no significant differences were found between varieties and treatments at this stage. At 90 DAT, the Purple variety had an average height of 45.53 cm, White reached 48.55 cm, and Green had 46.67 cm, with the Urea + DAP treatment again showing the tallest plants (50.33 cm), followed by DAP (48.51 cm) and Urea (45.91 cm), with a critical difference of 0.75 cm. Similar results were observed by (Janmohammadi et al., 2016, Lombin et al., 1988).

Table 1. Effect of different Varieties and treatment on plant height of Brinjal

Treatment		**Plant height (cm)**		
		30DAT	**60DAT**	**90DAT**
Factor A Varieties(V)				
V1	Green	12.16	26.17	46.67
V2	White	13.11	28.01	48.55
V3	Purple	14.86	30.67	45.53
Factor B Treatments(T)				
T1	Urea	12.02	26.08	45.91
T2	DAP	13.72	28.79	48.51
T3	Urea +DAP	14.38	29.97	50.33
SEm±(Variety and Treatment)		0.09	0.23	0.14
CD at 5% level (Variety and Treatment)		0.28	0.71	0.43
Interaction(V×T)				
SEm±		0.16	0.41	0.25
CDat5%level		0.49	N/A	0.75

Table 2. Effect of different Varieties and treatment on number of leaves/plant of Brinjal

Treatment		Number of leaves per plant		
		30 DAT	60 DAT	90 DAT
Factor A Varieties(V)				
V1	Green	10.82	46.93	69.44
V2	White	11.37	47.57	69.66
V3	Purple	12.51	49.42	72.33
Factor B Treatments(T)				
T1	Urea	9.13	45.42	67.31
T2	DAP	12.35	48.48	70.22
T3	Urea +DAP	13.22	50.02	73.91
SEm±(Variety and Treatment)		0.90	0.22	0.17
CDat5% level (Variety and Treatment)		0.29	0.66	0.51
Interaction(V×T)				
SEm±		0.16	0.38	0.29
CDat5%level		0.51	N/A	N/A

Table 3. Effect of nano-fertilizers on number of branches plant^{-1} of brinjal

Treatment		Number of branches	
		60DAT	90DAT
Factor A Varieties(V)			
V1	Green	7.84	14.71
V2	White	8.13	15.02
V3	Purple	9.26	15.91
Factor B Treatments(T)			
T1	Urea	7.31	13.11
T2	DAP	8.55	15.51
T3	Urea +DAP	9.37	17.02
SEm±(Variety and Treatment)		0.06	0.08
CDat5% level (Variety and Treatment)		0.19	0.24
Interaction(V×T)			
SEm±		0.11	1.14
CDat5%level		0.34	N/A

Table 4. Effect of different Varieties and treatment on stem diameter of Brinjal

Treatment		Stem Diameter (mm)		
		30DAT	60DAT	90 DAT
Factor A Varieties(V)				
V1	Green	5.06	9.43	12.09
V2	White	5.48	9.31	13.68
V3	Purple	5.86	9.84	14.59
Factor B Treatments(T)				
T1	Urea	4.43	8.20	12.98
T2	DAP	5.58	9.58	13.44
T3	Urea +DAP	6.38	10.80	13.94
SEm±(Variety and Treatment)		0.06	0.08	0.12
CDat5% level (Variety and Treatment)		0.18	0.25	0.38
Interaction(V×T)				
SEm±		0.10	1.14	0.22
CDat5%level		N/A	N/A	0.66

Table 5. Effect of nano-fertilizers on canopy of brinjal

Treatment		Canopy East to west		Canopy north to south	
		60 DAT	90 DAT	60 DAT	90 DAT
Factor A Varieties(V)					
V1	Green	34.20	52.89	33.89	53.68
V2	White	34.92	53.02	34.58	54.53
V3	Purple	36.00	54.68	36.15	55.25
Factor B Treatments(T)					
T1	Urea	32.84	50.58	32.01	51.34
T2	DAP	34.37	53.58	35.30	54.71
T3	Urea +DAP	37.91	56.43	37.31	57.41
SEm±(Variety and Treatment)		0.16	0.15	0.18	0.22
CDat5% level (Variety and Treatment)		0.50	0.45	0.55	0.69
Interaction(V×T)					
SEm±		0.28	0.25	0.31	0.39
CDat5%level		0.87	N/A	N/A	N/A

Table 6. Effect of nano-fertilizers on Number of cluster of brinjal

Treatment		Cluster	
		60DAT	90DAT
Factor A Varieties(V)			
V1	Green	2.88	12.42
V2	White	2.95	12.64
V3	Purple	3.15	14.06
Factor B Treatments(T)			
T1	Urea	2.53	10.95
T2	DAP	2.75	12.84
T3	Urea +DAP	3.71	15.33
SEm±(Variety and Treatment)		0.05	0.15
CDat5% level (Variety and Treatment)		0.15	0.46
Interaction(V×T)			
SEm±		0.08	0.26
CDat5%level		0.26	0.80

Table 7. Effect of nano-fertilizers on yield per plant of brinjal

Treatment		Yield per plant in (g)	
		1st harvesting	2nd harvesting
Factor A Varieties(V)			
V1	Green	317.77	386.66
V2	White	320.55	396.66
V3	Purple	335.06	415.55
Factor B Treatments(T)			
T1	Urea	311.66	386.66
T2	DAP	315.55	393.33
T3	Urea +DAP	346.11	418.88
SEm±(Variety and Treatment)		1.76	1.87
CDat5% level (Variety and Treatment)		5.34	5.65
Interaction(V×T)			
SEm±		3.06	3.23
CDat5%level		N/A	N/A

Number of leaves per plant of Brinjal was assessed across three stages: 30 DAT, 60 DAT, and 90 DAT, involving two factors: Brinjal varieties (Green, Purple, White) and treatments (Urea, DAP, Urea + DAP). At 30 DAT, the Purple variety (V3) had the highest mean number of leaves per plant at 12.51, followed by White (V2) with 11.37 and Green (V1) with 10.82, with the Urea + DAP treatment (T3) yielding the highest number of leaves (13.22), compared to DAP (12.35) and Urea (9.13), with a critical difference (CD) of 0.51 cm. At 60 DAT, the Purple variety again showed the most vigorous leaf growth with 49.42 leaves per plant, followed by White (47.57) and Green (46.93), with the Urea + DAP treatment (T3) resulting in the highest mean of 50.02 leaves, followed by DAP (48.48) and Urea (45.42), though no significant differences were found between varieties and treatments at this stage. At 90 DAT, the Purple variety had the highest number of leaves (72.33), followed by White (69.66) and Green (69.44), with Urea + DAP (T3) again showing the highest number of leaves (73.91), followed by DAP (70.22) and Urea (67.31), with no significant differences observed at this stage either. The present results were in accordance with (Hossain et al., 2002, Lombin et al., 1988, Sharma & Dhakar, 2003).

Number of branches per plant of brinjal were assessed at 60 DAT and 90 DAT, involving Brinjal varieties (Green, Purple, White) and treatments (Urea, DAP, Urea + DAP). At 60 DAT, the Green variety had an average of 7.84 branches, White had 8.13, and Purple had 9.26 branches, with the Urea + DAP treatment (T3) showing the highest average of 9.37 branches, followed by DAP (8.55) and Urea (7.31), with a critical difference (CD) of 0.34. At 90 DAT, the Green variety averaged 14.71 branches, White had 15.02, and Purple had 15.91, with the Urea + DAP treatment (T3) again showing the highest number of branches at 17.02, followed by DAP (15.51) and Urea (13.11), though no significant differences were found at this stage. The present results were in accordance with (Hossain et al., 2002, Lombin et al., 1988, Sharma & Dhakar, 2003).

Stem diameter of Brinjal was evaluated at 30, 60, and 90 DAT, considering Brinjal varieties (Green, Purple, White) and treatments (Urea, DAP, Urea + DAP). At 30 DAT, the Green variety had an average stem diameter of 5.06 mm, White had 5.48 mm, and Purple had 5.86 mm, with Urea + DAP (T3) treatment resulting in the widest stems (6.38 mm), followed by DAP (5.58 mm) and Urea (4.43 mm), with no significant differences found (NS). At 60 DAT, White had an average stem diameter of 9.31 mm, Purple had 9.84 mm, and Green had 9.43 mm, with Urea + DAP (T3) showing the largest stem diameter (10.80 mm), followed by DAP (9.58 mm) and Urea (8.20 mm), with no significant differences observed. At 90 DAT, Green had an average diameter of 12.09 mm, White had 13.68 mm, and Purple had 14.59 mm, with Urea + DAP (T3) showing the widest stems (13.94 mm), followed by DAP (13.44 mm) and Urea (12.98 mm), with a critical difference of 0.66 cm. Similar findings were quoted by (Jian et al., 2008, Lombin et al., 1988, Zenia & Halina, 2008).

Canopy height of Brinjal plants was assessed at 60 and 90 DAT, across both east-to-west and north-to-south axes. At 60 DAT, on the east-to-west axis, the Green variety had a canopy size of 34.20 cm, White had 34.92 cm, and Purple had 36.00 cm, with the Urea + DAP treatment (T3) showing the largest canopy size at 37.91 cm, followed by DAP (34.37 cm) and Urea (32.84 cm), with a critical difference (CD) of 0.87 cm. At 90 DAT, on the same axis, the Green variety had a canopy size of 52.89 cm, White had 53.02 cm, and Purple had 54.68 cm, with Urea + DAP (T3) again showing the largest canopy size at 56.43 cm, followed by DAP (53.58 cm) and Urea (50.58 cm), but no significant differences were found (NS). On the north-to-south axis, at 60 DAT, the Green variety displayed a canopy size of 33.89 cm, White had 34.58 cm, and Purple had 36.15 cm, with Urea + DAP (T3) having the largest canopy at 37.31 cm, followed by DAP (35.30 cm) and Urea (32.01 cm), with no significant differences (NS). At 90 DAT, on the north-to-south axis, Green had a canopy size of 53.68 cm, White had 54.53 cm, and Purple had 55.25 cm, with Urea + DAP (T3) again showing the largest canopy size at 57.41 cm, followed by DAP (54.71 cm) and Urea (51.34 cm), with no significant interactions between varieties and treatments. The present results were in conformity with (Khan et al., 2018, Lombin et al., 1988).

4.1 Phenological Parameter

Number of clusters of Brinjal plants was evaluated at 60 and 90 DAT, considering three varieties (Green, Purple, White) and three treatments (Urea, DAP, Urea + DAP). At 60 DAT, the Purple variety produced the highest number of clusters with an average of 3.15, followed by the White variety (2.95) and Green variety (2.88).

At 90 DAT, the Purple variety again showed the highest number of clusters with 14.06, followed by the White variety (12.64) and Green variety (12.42). Among the treatments, Urea + DAP (T3) resulted in the highest number of clusters, averaging 3.71 at 60 DAT and 15.33 at 90 DAT, followed by DAP (2.75 at 60 DAT and 12.84 at 90 DAT), and Urea (2.53 at 60 DAT and 10.95 at 90 DAT). The critical difference (CD) at a 5% significance level was 0.26 at 60 DAT and 0.80 at 90 DAT. Previous studies have reported are similar to the present findings with that of (Lombin et al., 1988, Sharma & Dhakar, 2003, Zenia & Halina, 2008).

Number of flowers of brinjal plants was evaluated at 60 and 90 DAT across three varieties (Green, White, and Purple) and three treatments (Urea, DAP, Urea + DAP). At 60 DAT, the mean number of flowers was highest in the Purple variety (13.88), followed by the White (12.75) and Green varieties (12.57). At 90 DAT, the mean number of flowers increased, with the Purple variety again having the highest number (68.06), followed by White (66.82) and Green (66.62). In terms of treatments, the Urea + DAP combination produced the highest number of flowers, with 15.35 at 60 DAT and 72.51 at 90 DAT, followed by DAP treatment (12.51 at 60 DAT and 67.40 at 90 DAT) and Urea treatment (11.28 at 60 DAT and 61.60 at 90 DAT). The critical difference (CD) at 60 DAT was 0.51, while the CD value for the interaction at 90 DAT was not significant (NS) at the 5% level. These results were in consistent with the observation with that of (FAOSTAT, 2009, Lombin et al., 1988, Khan et al., 2018).

4.2 Yield Parameter

Yield parameters, including fruit length, stalk length, fruit diameter, and single fruit weight in brinjal plants. For the three varieties (Green, White, and Purple), the mean fruit length was highest in the Purple variety (82.55 mm), followed by the White (78.37 mm) and Green (77.84 mm) varieties. The mean stalk length was also highest in the Purple variety (57.55 mm), followed by White (55.60 mm) and Green (55.45 mm). Similarly, the Purple variety had the largest fruit diameter (58.74 mm), followed by White (56.27 mm) and Green (56.25 mm), and the highest single fruit weight was observed in the Purple variety (105.76 g), followed by White (102.20 g) and Green (101.98 g). Regarding treatments, Urea + DAP resulted in the highest mean values across all parameters: fruit length (81.05 mm), stalk length (57.01 mm), fruit diameter (57.87 mm), and single fruit weight (104.90 g). The DAP treatment followed with slightly smaller values, while the Urea treatment showed the lowest results. The critical difference (CD) for fruit diameter was 0.66, while the CD for the interaction was not significant (NS) at the 5% level for fruit length, stalk length, and single fruit weight.

For Factor A, three different brinjal varieties were tested: Green (V1), White (V2), and Purple (V3). The yields per plant for these varieties at the first harvesting were 317.77 g, 320.55 g, and 335.06 g, respectively, with the Purple variety (V3) exhibiting the highest yield, followed by the White variety (V2) and the Green variety (V1) having the lowest. At the second harvesting, the yields for the varieties were 386.66 g, 396.66 g, and 415.55 g, respectively, again showing the Purple variety leading, followed by White, and Green with the lowest yield. At the third harvesting, the yields were 392.22 g, 397.77 g, and 422.77 g, respectively, with the Purple variety continuing to show the highest yield per plant. For Factor B, three different treatments were applied: Urea (T1), DAP (T2), and Urea + DAP (T3). At the first harvesting, the yields per plant were 311.66 g, 315.55 g, and 346.11 g, with the Urea + DAP treatment (T3) resulting in the highest yield, followed by DAP (T2), while Urea (T1) resulted in the lowest yield. At the second harvesting, the yields were 386.66 g, 393.33 g, and 418.88 g, respectively, with Urea + DAP still yielding the most, followed by DAP and Urea. At the third harvesting, the yields were 393.33 g, 401.06 g, and 417.77 g, with the Urea + DAP treatment again resulting in the highest yield. The interaction between the brinjal varieties and treatments (V×T) was also examined, but the critical difference (CD) at a 5% significance level was determined to be not significant (NS). This indicates that there was no statistically significant interaction between the brinjal varieties and treatments in terms of yield per plant. These results are in agreement with those (Hossain et al., 2002, Jian et al., 2008, Khan et al., 2018, Lombin et al., 1988).

5. FUTURE SCOPE

The future scope of this research could explore the long-term effects of nano-fertilizers on the overall growth and yield of Brinjal plants under varying environmental conditions. Further studies could focus on optimizing the dosage and application methods of nano-fertilizers to enhance plant productivity while minimizing environmental impact. Additionally, the mechanisms behind the differential responses of Brinjal varieties to nano-fertilizer treatments should be investigated at the molecular level, exploring changes in gene expression, nutrient uptake, and metabolic pathways. Research could also examine the potential synergistic effects of combining nano-fertilizers with other sustainable agricultural practices, such as integrated pest management and water-efficient irrigation, to ensure the environmental sustainability and economic feasibility of these practices in commercial Brinjal cultivation.

6. CONCLUSION

In conclusion, the application of nano-fertilizers, particularly the Urea + DAP combination, significantly enhanced the growth and yield of Brinjal plants across various varieties. The Purple variety consistently showed superior growth in terms of plant height, leaf number, branches, and yield compared to Green and White varieties. These findings suggest that nano-fertilizers can be an effective tool for improving Brinjal productivity, and further research into optimizing their application and understanding the underlying molecular mechanisms could lead to more sustainable agricultural practices for increased yield and environmental sustainability.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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