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STUDY THE FOLIAR APPLICATION OF NANO UREA AND NAA ON YIELD OF BROCCOLI

Kajal Singh, Pushpendra Kumar*, Shipra Singh Parmar, Divya Panday, Saikat Jana and Hiya Dashora

Department of Horticulture, School of Agriculture, ITM University, Gwalior (M.P.), India.

*Corresponding author E-mail : pkgoyal4699@gmail.com

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ABSTRACT

The experiment of the foliar application of nano urea and NAA on yield of broccoli (*Brassica oleracea* var. *italica*) involved the variety of Pusa Broccoli KTS-1 for seventeen characters *viz*., plant height (cm), number of leaves per plant, leaf length (cm), leaf breadth (cm), days to 1st curd initiation, days to first curd harvest, stem length (cm), stem diameter (cm), root length (cm), number of roots per plant, primary curd diameter (cm), primary curd weight (g), number of secondary curds per plant, secondary curds weight (g), curd yield plant per plant (g), curd yield per plot (kg) and curd yield per hectare (ton) was evaluated during the beginning of September until the middle of March (2024-2025). The experiment was late by Randomize Block Design (RBD) with twelve treatments and three replications, each including the recommended dose of fertilizers (RDF) combined with nano urea and NAA at the Crop Research Centre (CRC-3), School of Agriculture, Department of Horticulture, ITM University, Gwalior, (M.P.). Growth and yield parameters were monitored throughout the study. The highest values for plant height were recorded in treatment T_5: 100 % RDF + 100 ppm NAA, diameter of curd was recorded in treatment T_8: 25% RDF + 75% through nano urea + 100 ppm NAA and yield recorded in treatment T_8: 25% RDF + 75% through nano urea + 100 ppm NAA.

Key words : Nano, Urea, NAA and Yield.

Introduction

Cruciferous vegetables are well-known for their nutritional richness and health-enhancing effects. Among them, broccoli (*Brassica oleracea* var. *italica*) is especially distinguished due to its high concentration of sulforaphane, a naturally occurring compound widely studied for its potential in cancer prevention. This vegetable may have originated in the eastern Mediterranean.

Italy later played a significant role in its development and genetic improvement (Maggioni, 2015). India's vegetable production for 2023–24 is estimated at 204.96 million tonnes, slightly lower than 212.55 million tonnes in 2022–23 (Ministry of Agriculture and Farmers Welfare, 2024).

Among cole crops, broccoli is particularly valued for its excellent nutritional composition. It contains minimal fat and cholesterol and is an abundant source of vital vitamins, minerals and proteins (Zhang and Hamauzu, 2004). The main edible parts are the young stems and immature flower heads, which are not only palatable but also dense in nutrients (Prashar, 2021).

Sulforaphane, a key phytochemical found in broccoli, has been linked to several health benefits, particularly its anti-carcinogenic potential (Thamburaj and Singh, 2001). Approximately 2500 IU of vitamin A, 113 mg of vitamin C, 3.6 grams of protein, and 5.9 grams of carbs are found in a 100-gram meal of broccoli. It also supplies essential minerals, including 103 mg of calcium, 1.1 mg of iron, 78 mg of phosphorus, 382 mg of potassium, and 15 mg of sodium (Tejaswini, 2018).

In addition to its vitamins and minerals, broccoli contains 3,3'-diindolylmethane, a compound known to support immune function and provide both antiviral and antibacterial effects (Riby *et al*., 2006). Another distinctive aspect of broccoli is its high glucosinolate

content—natural compounds stored in the plant as potassium salts. These substances contribute to broccoli's characteristic taste and aroma and are activated by the enzyme myrosinase during preparation (Zhao *et al*., 2008).

Among macronutrients, nitrogen plays a crucial role in vegetative growth, particularly in cole crops (Savei, 2012). Phosphorus is essential for establishing strong root systems, while potassium enhances enzyme function and carbohydrate metabolism (Shaheen *et al*., 2007). Hence, maintaining a balanced supply of nitrogen, phosphorus, potassium and essential micronutrients is vital for achieving optimal growth and improving both yield and quality across vegetable crops (Nai-hua *et al*., 1998).

Materials and Methods

The field experiment was carried at the Crop Research Centre (CRC-3), School of Agriculture, Department of Horticulture, ITM University, Gwalior (M.P.), during *rabi* season (2024-2025) from the beginning of September until the middle of March. The experimental design was a randomized block design with three replications at spacing of 60 cm × 45 cm and the plot size was 2 m×1.5 m (3 square meter). The experiment was consisting of twelve treatments Table 1. The study involved the application of a recommended dose of fertilizers (RDF) at the rate of 150:80:60 kg ha^{-1} of N, P and K, respectively, supplemented with Nano Urea and foliar application of Naphthalene Acetic Acid (NAA) at two concentrations-100 ppm (0.1 g L^{-1} and 150 ppm (0.15 g L^{-1}). NAA was administered as a foliar spray in two separate doses during the crop growth cycle. The applications were carried out on December 19, 2024 and January 3, 2025, aligning with critical physiological stages of plant growth to maximize treatment efficacy. For the foliar spray, NAA was accurately weighed and dissolved in water to prepare 100 ppm (0.1 g L^{-1}) and 150 ppm (0.15 g L^{-1}) solutions.

Table 1 : List of treatments used in field trail.

S. no.	Symbol used	Treatments
1	T_1	100 % RDF
2	T_2	75 % RDF + 25 % through nano urea
3	T_3	50 % RDF + 50 % through nano urea
4	T_4	25% RDF + 75 % through nano urea
5	T_5	100 % RDF + 100 ppm NAA
6	T_6	75% RDF + 25% through nano urea + 100 ppm NAA
7	T_7	50% RDF + 50% through nano urea + 100 ppm NAA
8	T_8	25% RDF + 75 % through nano urea + 100 ppm NAA
9	T_9	100% RDF + 150 ppm NAA
10	T_{10}	75 % RDF + 25 % through nano urea + 150 ppm NAA
11	T_{11}	50 % RDF + 50 % through nano urea + 150 ppm NAA
12	T_{12}	25% RDF + 75 % through nano urea + 150 ppm NAA

The process described by Panse and Sukhatme (1967) was followed in order to perform the analysis of variance for the design of experiment (RBD).

Results and Discussion

Different parameters related to growth and productivity of broccoli reflected a significant variation under different growing media (Table 2).

The highest plant height was found in T_5: 100% RDF + 100 ppm NAA (44.67 cm). The lowest plant height was observed in T_7: 50 % RDF + 50 % through nano urea + 100 ppm NAA (36.86 cm). These findings are in agreement with the studies of Kaur and Mal (2018), Chanwala *et al*. (2019) and Mahmoud *et al*. (2019). Comparable results were also seen in broccoli (Atal *et al*., 2019) and cauliflower (Subedi *et al*., 2019).

The maximum number of leaves/plants found in the treatment T_2: 75% RDF + 25% through nano urea (19.61). According to Singh *et al*. (2015), the number of leaves per broccoli plant significantly increased with the combined application of nitrogen (N), phosphorus (P), potassium (K) and boron (B). The minimum leaf breadth was found in T_9: 100% RDF + 150 ppm NAA (14.13 cm). The maximum leaf breadth was found in T_1: 100% RDF (19.19 cm). Similar outcomes were reported by Peerzada *et al*. (2009) in cabbage and by Kachari and Korla (2012) in cauliflower. The minimum days to 1st curd initiation was found in T_6: 75 % RDF + 25% through nano urea + 100 ppm NAA (52.33 days). While, the maximum days to 1st curd initiation was found in T_1: 100% RDF (62.67 days). The maximum days to first curd harvest was found in T_1: 100 % RDF (73.92 days). The minimum days to first curd harvest was found in T_6: 75% RDF + 25% through nano urea + 100 ppm NAA (63.58 days). These results are in close conformity with those of Jakhar *et al*. (2018), Meena *et al*. (2018) and Chanwala *et al*. (2019).

The maximum stem length was found in T_2: 75% RDF + 25% through nano urea (25.96 cm). The shortest stem length was found T_1: 100 % RDF (20.49 cm). The

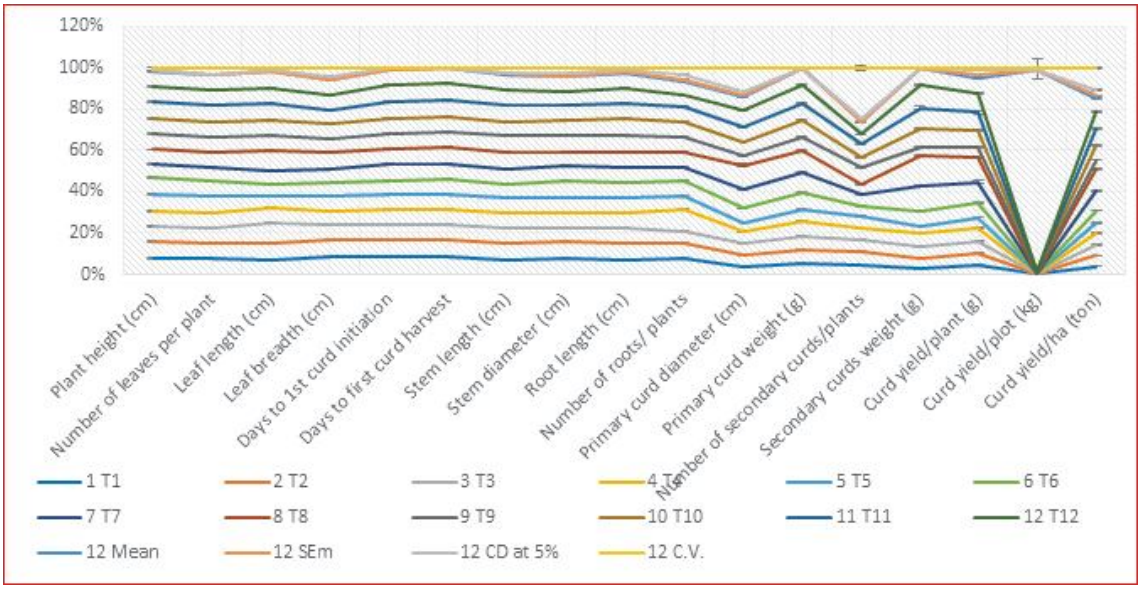

Fig 1: Graphical representation of Growth and yield traits of broccoli.

Table 2 : Analysis of variance of broccoli.

Analysis of variance		
Characters	**Treatments**	**Error**
d.f.	**11**	**22**
Plant height (cm)	17.76*	6.028
Number of leaves per plant	1.23	2.035
Leaf length (cm)	150.23**	4.612
Leaf breadth (cm)	8.27**	2.269
Days to 1st curd initiation	31.78**	2.713
Days to first curd harvest	32.98**	0.104
Stem length (cm)	8.88	4.069
Stem diameter (cm)	8.53**	2.090
Root length (cm)	9.30**	1.780
Number of roots/ plants	66.66**	19.18
Primary curd diameter (cm)	24.50**	1.575
Primary curd weight (g)	7435.83**	5.512
Number of secondary curds/plants	0.9744**	0.183
Secondary curds weight (g)	9456.80**	4.052
Curd yield/plant (g)	35369.79**	247.924
Curd yield/plot (kg)	9816625.41**	77405.192
Curd yield/ha (ton)	109.08**	0.854

maximum stem diameter was found in T_6: 75% RDF + 25% through nano urea + 100 ppm NAA (22.34 cm). The shortest stem diameter was found T_8: 25% RDF + 75% through nano urea + 100 ppm NAA (17.61 cm). The maximum root length was noted in T_2: 75% RDF + 25% through nano urea (29.92 cm). The minimum root length was found in T_3: 50% RDF + 50% through nano urea (24.57 cm). The maximum number of roots per plants were found in T_4: 25% RDF + 75% through nano urea (42.67). The lowest number of roots were found in T_{12}: 25% RDF + 75% through nano urea + 150 ppm NAA (22.73). These findings are consistent with those of Moniruzzaman *et al*. (2007). The highest primary curd diameter was found in T_8: 25% RDF + 75% through nano urea + 100 ppm NAA (14.92 cm). The lowest primary curd diameter was observed in T_1: 100% RDF (5.10 cm) and T_5: 100% RDF + 100 ppm NAA (5.72 cm), as supported by previous research from Jakhar *et al*. (2018), Mohanta *et al*. (2018) and Chanwala *et al*. (2019). The observation of data regarding to plant growth parameters are represented in Table 3 and Fig. 1.

The maximum primary curd weight was found in T_8: 25% RDF + 75 % through nano urea + 100 ppm NAA (317.67 g). The minimum value of primary curd weight was observed in T_1: 100% RDF (157.67 g). The maximum number of secondary curds/plants were found in T_9: 100% RDF + 150 ppm NAA (4.35) followed by T_2: 75% RDF + 25% through nano urea (3.72) and T_{11}: 50% RDF + 50% through nano urea + 150 ppm NAA (3.56). The minimum number of secondary curds/plants observed in T_1: 100 % RDF (2.3). The maximum secondary curds weight was found in T_8: 25% RDF + 75% through nano urea + 100 ppm NAA (234.67 g). The minimum secondary curds weight was observed in T_1: 100% RDF (50.15 g). These observations are in agreement with the findings of Singh *et al*. (2005) and Kumar *et al*. (2013).

The maximum Curd yield/plant found in T_8: 25% RDF + 75% through nano urea + 100 ppm NAA (552.34g). The minimum Curd yield/plant found in T_1: 100% RDF (207.81g). The maximum Curd yield/plot found in T_8: 25% RDF + 75% through nano urea + 100 ppm NAA (9.20kg). The minimum Curd yield/plot found in T_1: 100% RDF (3.46 g). These results align with the findings of Pankaj

Table 3 : Effect of foliar application of nano urea and NAA on Plant growth and yield of broccoli.

S. no.	Treatments notation	Plant height (cm)	Number of leaves per plant	Leaf length (cm)	Leaf breadth (cm)	Days to 1st curd initiation	Days to first curd harvest	Stem length (cm)	Stem diameter (cm)	Root length (cm)
1	T_1	43.75	18.27	38.96	19.19	62.67	73.92	20.49	21.44	26.88
2	T_2	41.74	19.60	43.60	17.69	60.33	71.58	25.96	21.71	29.92
3	T_3	40.71	17.80	52.08	16.63	54.00	65.25	22.03	17.79	24.57
4	T_4	40.01	18.67	39.72	15.21	56.33	67.58	24.74	19.03	28.72
5	T_5	44.67	18.53	26.86	15.37	53.33	64.58	21.08	20.46	27.13
6	T_6	43.56	18.00	32.17	14.22	52.33	63.58	22.05	22.34	25.04
7	T_7	36.86	17.33	36.12	15.93	60.00	63.92	23.05	19.63	28.99
8	T_8	38.15	17.80	51.04	18.60	55.67	68.92	25.39	17.61	27.24
9	T_9	42.04	18.73	41.88	14.13	53.33	64.58	23.25	22.29	29.48
10	T_{10}	41.82	18.00	38.92	15.40	56.33	69.25	21.87	19.50	27.81
11	T_{11}	43.35	19.23	43.94	15.40	56.94	68.19	23.61	19.52	27.82
12	T_{12}	40.12	18.28	38.97	15.71	59.24	70.49	24.36	18.33	27.48
	Mean	**41.40**	**18.35**	**40.36**	**16.12**	**56.71**	**67.65**	**23.16**	**19.97**	**27.59**
	SEm (±)	1.42	0.82	1.24	0.87	0.95	0.19	1.16	0.83	0.77
	CD at 5%	NS	NS	4.94	3.47	3.79	0.75	NS	3.33	3.07
	C.V.	6.05	7.77	5.32	9.31	2.90	0.48	8.71	7.10	4.68

Table 3 continued...

S. no.	Treatments notation	Number of roots/ plants	Primary curd diameter (cm)	Primary curd weight (g)	Number of secondary curds/ plants	Secondary curds weight (g)	Curd yield/plant (g)	Curd yield/plot (kg)	Curd yield/ha (ton)
1	T_1	32.73	5.10	157.67	2.30	50.15	207.81	3.46	11.54
2	T_2	30.93	6.89	191.67	3.72	77.36	269.02	4.47	14.91
3	T_3	26.40	7.31	196.67	3.34	86.61	283.28	4.72	15.72
4	T_4	42.67	7.90	207.00	2.96	95.10	302.10	5.02	16.73
5	T_5	28.73	5.72	179.00	3.22	62.03	241.03	4.02	13.40
6	T_6	30.20	8.51	218.33	2.78	107.29	325.62	5.43	18.10
7	T_7	29.33	12.50	295.00	3.42	192.11	487.11	8.11	27.03
8	T_8	30.60	14.92	317.67	2.63	234.67	552.34	9.20	30.68
9	T_9	31.07	6.31	180.33	4.35	65.01	245.35	4.09	13.62
10	T_{10}	33.60	8.74	236.00	2.91	142.89	378.89	6.32	21.06
11	T_{11}	29.93	9.12	247.67	3.56	155.53	403.19	6.71	22.37
12	T_{12}	22.73	10.46	271.33	2.61	176.68	448.01	7.46	24.87
	Mean	**30.74**	**8.62**	**224.86**	**3.15**	**120.45**	**345.31**	**5751.08**	**19.17**
	SEm (±)	2.53	0.72	1.36	0.25	1.16	62.69	1.04	3.48
	CD at 5%	10.08	2.89	5.40	0.99	4.63	137.98	2.30	7.66
	C.V.	14.25	14.55	1.04	13.59	1.69	31.44	31.45	31.46

et al. (2018), Singh *et al*. (2018) and Mahmoud *et al*. (2019). The maximum Curd yield/ha was found in T_8: 25% RDF + 75% through nano urea + 100 ppm NAA (30.68 ton). The minimum Curd yield/ha was found in T_1: 100 % RDF (11.54 ton). Similarly, studies by Singh *et al*. (2018b), Kaur *et al*. (2020) and Neupane *et al*. (2020). They also reported that the combined use of organic and inorganic nutrient sources led to higher yields in cauliflower, primarily due to enhancements in soil structure and microbial activity. The observation of data regarding to plant yield parameters are represented in Table 3 and Fig. 1.

Conclusion

With respect to the research made, it is concluded that the T_5: 100 % RDF + 100 ppm NAA, T_2: 75 % RDF + 25% through nano urea and T_3: 50% RDF + 50% through nano urea responded well in terms of the Growth parameters. Whereas, T_6: 75% RDF + 25% through nano urea + 100 ppm NAA and T_1: 100% RDF responded well in terms of the Phenological parameters. It was observed that, T_8: 25% RDF + 75% through nano urea + 100 ppm NAA and T_9: 100% RDF + 150 ppm NAA responded well in terms of the Yield parameters. The treatments recorded the best values for growth parameters (i.e., plant height, Size of leaves and number of leaves per plant) Phenological Parameters i.e., (days to first curd emergence and days to first curd harvest) and for Yield attributing parameters (primary curd diameter, primary curd weight, secondary curds weight, curd yield/plant (g), curd yield/plot (kg) and curd yield (q/ha). Thus, it is cleared from the data procured that under the field condition at Gwalior the variety "Pusa KTS -1" performed better with the package, T_8: 25% RDF + 75 % through nano urea + 100 ppm NAA to obtain maximum yield per plot.

Author's contribution

The authors involved in the study have made remarkable contributions towards enhancing the scientific understanding of tomato. Their cooperative efforts comprehended all stages of the research process, including the formulation of the research proposal, executive of experiments, systematic data collection, statistical analysis and drafting, reviewing and final editing of the manuscript. Each phase of study reflects their dedicated involvement and shared commitment to the quality and completeness of the research work.

Declaration

The authors contributed significantly to the research. The authors are thankful to the Dean of the School of Agriculture, ITM University, Gwalior (M.P.), 474 001, for providing all the necessary facilities required for conducting the research work.

Competing interests

Authors have declared that no competing interests exist.

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