



RESEARCH ARTICLE

Foliar nano urea and micronutrient effect on fruit quality and nutrient uptake in bhendi (*Abelmoschus esculentus* L. Moench)

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Received: 16 July 2025; Accepted: 27 October 2025; Available online: Version 1.0: 24 December 2025

Cite this article: Madhumitha M, Sundaram V. Foliar nano urea and micronutrient effect on foliar quality and nutrient uptake in bhendi (*Abelmoschus esculentus* L. Moench). Plant Science Today. 2025;12(sp4):01–06. <https://doi.org/10.14719/pst.10672>

Abstract

A field experiment was conducted in the Department of Horticulture, Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, U T of Puducherry, in okra [*Abelmoschus esculentus* (L.) Moench] during the summer of 2024 to investigate the effect of nano urea and micronutrients spray on fruit quality and nutrient uptake of okra. The experiment was laid out in a randomised block design (RBD) with 15 treatments, each replicated twice. The study materials included nano urea, 19:19:19 NPK WSF, zinc, boron and Arka vegetable special, besides recommended N, P, K fertilisers. Results revealed that the foliar application of Arka vegetable special 2 gm L⁻¹ as foliar spray thrice at 20, 40 and 60th days of sowing along with the recommended dose of fertilisers (RDF-200:100:100 kg NPK ha⁻¹) recorded the minimum crude fibre (11.57 %) and maximum crude protein (20.67 %) content. This treatment exhibited the highest uptake of N, P and K by okra fruits, recording 48.87 kg ha⁻¹, 1.49 kg ha⁻¹ and 44.80 kg ha⁻¹ as well as the highest uptake of N, P and K by okra plant (33.12 kg ha⁻¹, 2.43 kg ha⁻¹ and 64.78 kg ha⁻¹ respectively). Further, the maximum available N (150.94 kg ha⁻¹), P (11.08 kg ha⁻¹) and K (80.05 kg ha⁻¹) in post-harvest soil was observed in foliar spray of Arka Vegetable Special thrice as a supplement with the recommended dose of NPK (200:100:100 kg ha⁻¹). This is attributed to the better nutrient availability aided by basal and top dressing of fertilisers applied in soil, in addition to foliar application. In contrast, nano urea application showed a marginal effect and did not perform better than the control, indicating that its efficiency in okra under these conditions was limited when compared to conventional nutrient sources.

Keywords: fruit quality; nitrogen; nutrient uptake; okra; phosphorous; potassium

Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) is mostly cultivated as a vegetable crop in India during the summer and monsoon seasons due to its soft, green fruits. Tender fruits are nutritious and hence, they find an important place in the Indian diet. In India, it is cultivated in almost all the states throughout the year and consumed by the majority of the people. India ranks first in okra production, constituting 72 % of the total world production, with an area of 546000 ha, producing about 670000 MT. Generally, okra hybrids are known for their higher yield potential, early maturity, uniform fruit size and attractive as well as uniform colour of fruits. Due to high yield potential, okra hybrids require a constant supply of nutrients throughout their vegetative and reproductive stages of development.

Vegetable crops generally require both major and micronutrients to express their yield potential. The Indian farmers have applied all major nutrients to the vegetable crops since the green revolution, but efforts to supply micronutrients are rather poor. Further, due to the non-judicious application of inorganic fertilisers, results in micronutrient deficiencies. Hence, vegetable crops respond very well to micronutrient application and their use in vegetable cultivation could be of greater significance. The micronutrients, viz, Zn, B, Mn, Fe, Mo, Cl and Cu play an important

role in vegetable production as they play a catalytic role in nutrient absorption and balancing other nutrients, besides regulating various physiological functions (1). Regular depletion of nutrient resources from soil due to crop removal and other causes has led to increased nutrient deficiency disorders. A significant number of Indian soils are known to be largely lacking in micronutrients, particularly zinc, manganese, boron and iron. In most of the productive bowls of the world, the yield levels of various crops have started showing declining trends in spite of the addition of sufficient quantities of chemical fertilisers containing macro and micronutrients. Additionally, the effectiveness of the inorganic micronutrients used is quite limited because they can become fixed in the soil (2).

Nano urea, a novel technology in fertiliser designing, is expected to reduce the environmental pollution caused by the granular form of fertilisers by reducing their excessive application, leading to environmental pollution. The nano urea contains 40000 ppm of nitrogen in 500 mL, which is claimed to be equivalent to the impact provided by nitrogen from one bag of conventional urea and hence, could replace conventional urea by 50 % (3). Nano urea is gaining importance in Indian agriculture because of its ability to increase nutrient use efficiency, increasing crop yields and reducing excessive use of synthetic fertilisers. Nano urea boosts nitrogen availability to the crop by more than 80 %, resulting in increased nutrient use efficiency (4). Considering the aforementioned aspects,

the present study was conducted to assess the impact of foliar application of nano urea and micronutrients on the quality and nutrient uptake of the bhendi hybrid COBh H4.

Materials and Methods

The present study was carried out during 2024 in the Eastern farm of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, U T of Puducherry, India. The 'bhendi hybrid CO 4 (COBh H4) released by the Tamil Nadu Agricultural University with a crop duration of 110 days was experimented with in the present study. The treatment materials for the study comprised nano urea, zinc as zinc sulphate monohydrate (33 %), boron as di sodium tetra borate penta hydrate (20 %), Arka Vegetable Special, 19:19:19 NPK (WSF), besides recommended soil application of N, P, K (200: 100: 100 kg ha⁻¹) fertilisers. The experimental setup was organised using a RBD, consisting of 15 treatments (Table 1), with each treatment replicated 2 times. A plot size of 20 m² was maintained for each treatment to accommodate 48 plants in a plot at a spacing of 60 cm × 45 cm.

The soil of the experimental area belongs to the Surakudy series, having the textural class of sandy clay loam with a pH of 6.72 and an Electrical Conductivity of 0.07 dS m⁻¹. The organic carbon (0.217 %), available nitrogen (126.00 kg ha⁻¹), available phosphorus (8 kg ha⁻¹) and available potassium (73.30 kg ha⁻¹) were estimated and the soil of the experimental field was classified as low in nutrient status according to the soil nutrient estimate. A fertiliser application of 200:100:100 kg NPK ha⁻¹ as recommended in the Crop production guide - Horticulture crops (2020) was taken as the reference for soil application (5). All the treatment plots were uniformly applied with the recommended basal dose of 100 kg each of N, P and K. However,

top dressing of 100 kg of N was applied only to treatment plots T₁ to T₆. The quality parameters, viz., crude fibre and crude protein in okra fruit, were analysed following the standard procedures described in the respective methodologies, as shown in Table 2 (6, 7).

Statistical analysis

The AGRES software was used to perform statistical analysis of the data. After computing the analysis of variance (ANOVA), standard deviation (SE(d)) and least significant difference (LSD) values with the critical difference set at 5 % level of significance, the mean comparisons were performed.

Result and Discussion

Effect of nano urea and micronutrients on nutrient uptake in Bhnedi hybrid CO 4

The data on the influence of foliar nutrition of nano urea and micronutrients on various nutrient uptake is presented in Table 3.

Effect of nano urea and micronutrients on plant nutrient uptake

The variations observed in the uptake of nutrients by plants with different fertiliser combinations used were found statistically significant for all 3 major nutrients in the present study (Fig. 1-3). The highest nutrient absorption by plants, N (33.12 kg ha⁻¹), P (2.43 kg ha⁻¹) and K (64.78 kg ha⁻¹) in the research was achieved through the foliar application of Arka vegetable special 3 times in addition to the recommended NPK dosage (200:100:100 kg ha⁻¹). Similar findings have been reported in okra (8). While the lowest nutrient absorption by plants was recorded in basal NPK + Zn + B in T₉, N uptake (5.72 kg ha⁻¹), P uptake (0.09 kg ha⁻¹) and K uptake (8.43 kg ha⁻¹). The addition of NPK fertilisers along with foliar spray of Arka vegetable special could enhance the uptake of NPK by the

Table 1. Treatment particulars

S. No.	Treatment	Treatment details
1.	T ₁	RDF
2.	T ₂	RDF + 19:19:19 NPK (WSF)
3.	T ₃	RDF + Zn + B
4.	T ₄	RDF + Arka vegetable special
5.	T ₅	RDF + 19:19:19 NPK (WSF) + Zn + B
6.	T ₆	RDF + 19:19:19 NPK (WSF) + Arka vegetable special
7.	T ₇	Basal NPK + 19:19:19 NPK (WSF)
8.	T ₈	Basal NPK + Nano urea
9.	T ₉	Basal NPK + Zn + B
10.	T ₁₀	Basal NPK + Arka vegetable special
11.	T ₁₁	Basal NPK + 19:19:19 NPK (WSF) + Nano urea
12.	T ₁₂	Basal NPK + 19:19:19 NPK (WSF) + Zn + B
13.	T ₁₃	Basal NPK + 19:19:19 NPK (WSF) + Nano urea + Zn + B
14.	T ₁₄	Basal NPK + 19:19:19 NPK (WSF) + Arka vegetable special
15.	T ₁₅	Basal NPK + 19:19:19 NPK (WSF) + Nano urea + Arka vegetable special

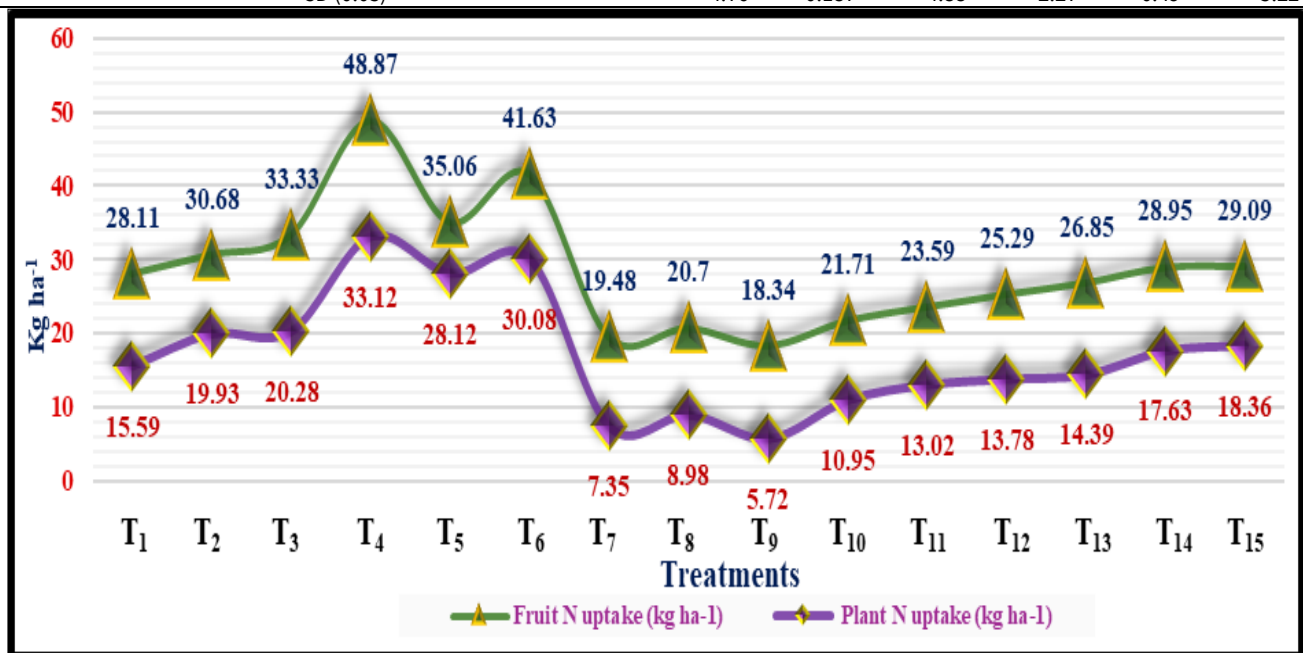
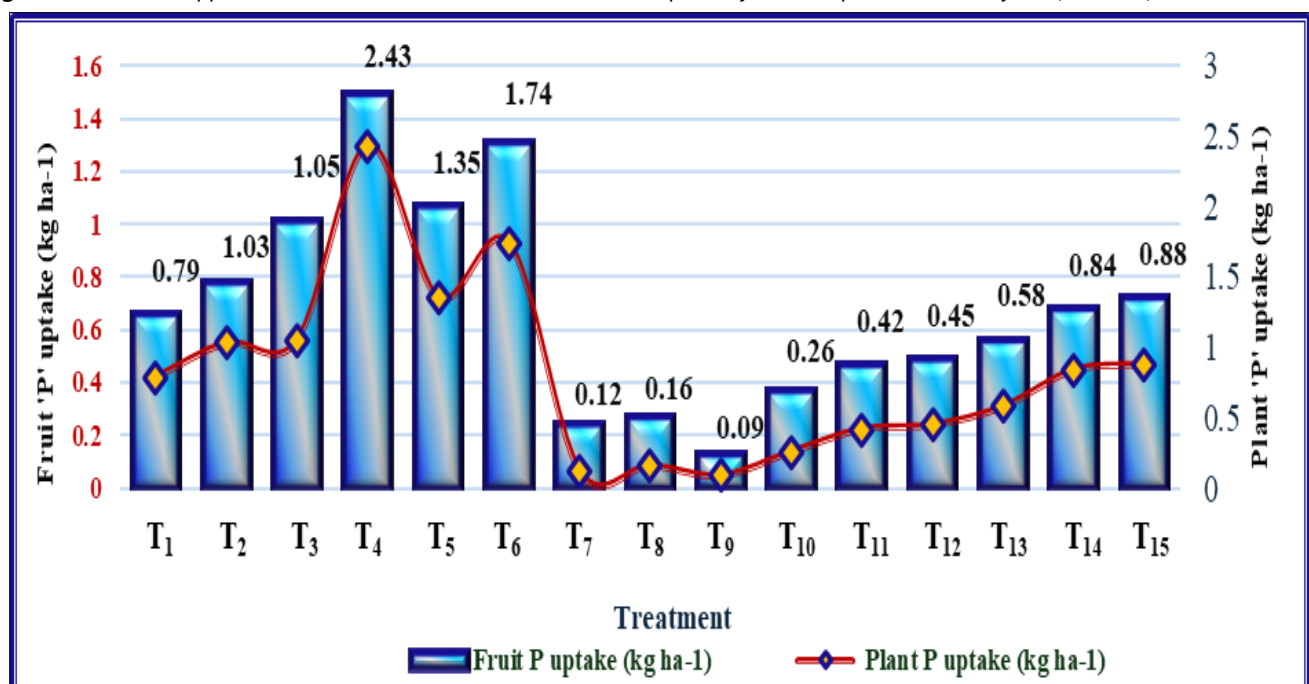
RDF- Recommended dose of fertiliser [N - 100 kg, P - 100 kg and K - 100 kg ha⁻¹ as basal and N - 100 kg ha⁻¹ as top dressing on 30 DAS (Days after sowing); WSF - Water soluble fertiliser

Table 2. Details of the analytical method employed for soil and plant analysis

S. No.	Analysis	Methodology	Reference
I. Soil analysis			
A. Physicochemical properties			
1.	Soil reaction (1:2.5)	Using a glass electrode in the ELICO (LI 120) pH meter	(12)
2.	Electrical conductivity (1:2.5)	Using the ELICO (CM 180) conductivity meter	(12)
B. Chemical properties			
1.	Organic carbon	Chromic acid wet digestion	(13)
2.	Available nitrogen	Alkaline KMnO ₄ method	(14)
3.	Available phosphorous	Extraction with the NH ₄ F method	(15)
4.	Available potassium	Flame photometer method	(16)
II. Plant analysis			
1.	Total nitrogen	Kjeldahl's method	(17)
2.	Total phosphorous	Vanadomolybdate yellow colour method (Triple acid extract)	(12)
3.	Total potassium	Flame photometric method (Triple acid extract)	(12)

Table 3. Effect of foliar application of nano urea and micronutrients on N, P and K uptake by fruit and plant (kg ha⁻¹) in bhendi hybrid (COBh H4)

Treatment details	Nutrient uptake by fruit			Nutrient uptake by plant		
	'N' uptake (kg ha ⁻¹)	'P' uptake (kg ha ⁻¹)	'K' uptake (kg ha ⁻¹)	'N' uptake (kg ha ⁻¹)	'P' uptake (kg ha ⁻¹)	'K' uptake (kg ha ⁻¹)
T ₁ RDF	28.11	0.66	27.11	15.59	0.79	32.24
T ₂ RDF + 19:19:19 NPK (WSF)	30.68	0.78	29.25	19.93	1.03	41.33
T ₃ RDF + Zn + B	33.33	1.01	30.49	20.28	1.05	42.08
T ₄ RDF + Arka Vegetable Special	48.87	1.49	44.80	33.12	2.43	64.78
T ₅ RDF + 19:19:19 NPK (WSF)+ Zn + B	35.06	1.07	34.14	28.12	1.35	52.66
T ₆ RDF + 19:19:19 NPK (WSF)+ Arka vegetable special	41.63	1.31	38.69	30.08	1.74	61.58
T ₇ Basal NPK + 19:19:19 NPK (WSF)	19.48	0.24	17.78	7.35	0.12	12.64
T ₈ Basal NPK + Nano urea	20.70	0.27	19.05	8.98	0.16	15.37
T ₉ Basal NPK + Zn + B	18.34	0.13	16.19	5.72	0.09	8.43
T ₁₀ Basal NPK + Arka vegetable special	21.71	0.37	20.65	10.95	0.26	18.95
T ₁₁ Basal NPK + 19:19:19 NPK (WSF)+ Nano urea	23.59	0.47	22.53	13.02	0.42	21.85
T ₁₂ Basal NPK + 19:19:19 NPK (WSF)+ Zn + B	25.29	0.49	24.18	13.78	0.45	23.78
T ₁₃ Basal NPK + 19:19:19 NPK (WSF)+ Nano urea + Zn + B	26.85	0.56	25.70	14.39	0.58	24.87
T ₁₄ Basal NPK + 19:19:19 NPK (WSF)+ Arka vegetable special	28.95	0.68	27.67	17.63	0.84	33.28
T ₁₅ Basal NPK + 19:19:19 NPK (WSF)+ Nano urea + Arka vegetable special	29.09	0.72	27.81	18.36	0.88	35.49
Mean	28.78	0.68	27.07	17.15	0.81	32.62
SEd	2.22	0.09	2.27	1.06	0.23	2.43
CD (0.05)	4.76	0.187	4.88	2.27	0.49	5.22

**Fig. 1.** Effect of foliar application of nano urea and micronutrients on N uptake by fruit and plant in bhendi hybrid (COBh H4).**Fig. 2.** Effect of foliar application of nano urea and micronutrients on P uptake by fruit and plant in bhendi hybrid (COBh H4).

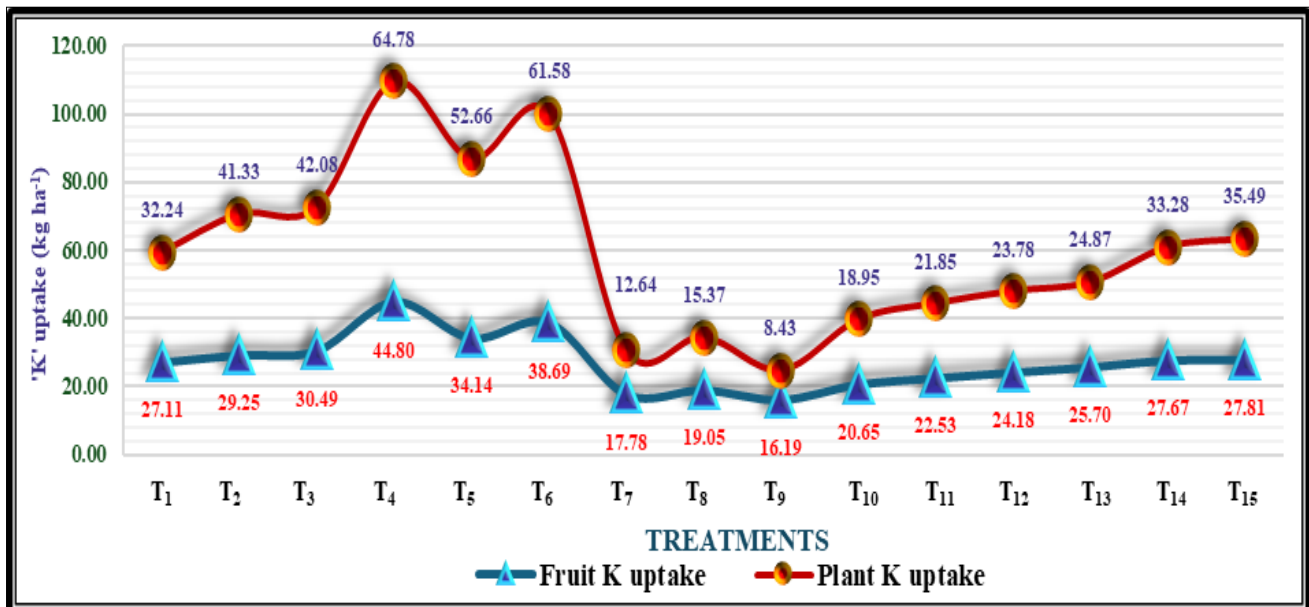


Fig. 3. Effect of foliar application of nano urea and micronutrients on K uptake by fruit and plant in the bhendi hybrid (COBh H4).

plant and this might be due to the increased availability of these nutrients released from applied fertilisers. Further, micronutrients applied through foliage would have been easily absorbed and translocated in the plants without any loss, which would have resulted in enhanced nutrient uptake by the crop.

The increased N uptake by plants could have been the result of applied micronutrients like zinc, which has resulted in nitrogen fixation and translocation into plant parts, ultimately increasing the N content of plants. The higher nitrogen absorption may also be due to the stimulatory effect of zinc on nitrogen uptake. Further, the applied NPK fertiliser could have resulted in better root growth and increased physiological activity of roots to absorb more phosphorus. Further, the highest uptake of K, which showed enhanced micronutrient-stimulated metabolic functions and facilitated absorption and translocation of nutrients (9).

Effect of nano urea and micronutrients on nutrient uptake by bhendi fruit

The maximum nutrient uptake by okra fruits N (48.87 kg ha⁻¹), P (1.49 kg ha⁻¹) and K (44.80 kg ha⁻¹) in the present study was obtained by the foliar spray of Arka vegetable special should be applied 3 times in addition to the suggested dosage of NPK (200: 100: 100 kg ha⁻¹). This supports the previous results regarding okra

(8). The nutrient uptake observed was the least in basal NPK + Zn + B (T₉) N - 0.13 kg ha⁻¹, P - 0.13 kg ha⁻¹, K - 16.19 kg ha⁻¹. In okra, reported significant increase in nutrient uptake was reported by the combined application of the recommended dose of NPK with micronutrients (10). The enhanced nutrient absorption following the application of a micronutrient mixture was primarily due to its easy absorption through the leaves and subsequent movement within the plant when dissolved in water and applied as a spray, leading to an increase in dry matter production (11). Application of NPK fertilisers would show an increased uptake of nutrients. Nitrogen has been known to enhance leaf production, while phosphorus enhances flowering, fruiting and seed formation. Potash is a quality element offering tolerance to plants for adverse growth factors. Therefore, increasing the rate of NPK uptake leads to higher metabolic activities and consequently higher yield.

Effect of nano urea and micronutrients on post-harvest soil properties of the bhendi field

No significant differences among the treatments imposed in the experimental field with respect to pH, EC and organic carbon could be observed in the present study (Table 4). However slight increase in pH, EC and organic carbon content of the post-harvest soil was observed, compared to initial soil values, which confirms the

Table 4. Effect of foliar application of nano urea and micronutrients on post-harvest soil pH, EC, organic carbon (%) and nitrogen, phosphorus and potassium in bhendi field

Treatment details	pH	EC (dS m ⁻¹)	Organic carbon (%)	Nitrogen (kg ha ⁻¹)	Phosphorus (kg ha ⁻¹)	Potassium (kg ha ⁻¹)
T ₁ RDF	6.80	0.08	0.21	137.72	10.67	78.90
T ₂ RDF + 19:19:19 NPK (WSF)	6.65	0.10	0.22	138.65	9.50	73.07
T ₃ RDF + Zn + B	6.60	0.09	0.23	145.09	10.24	79.39
T ₄ RDF + Arka vegetable special	6.65	0.08	0.25	150.94	11.08	80.05
T ₅ RDF + 19:19:19 NPK (WSF)+ Zn + B	6.65	0.09	0.24	143.31	10.85	74.89
T ₆ RDF + 19:19:19 NPK (WSF)+ Arka vegetable special	6.85	0.08	0.24	146.15	10.61	78.34
T ₇ Basal NPK + 19:19:19 NPK (WSF)	6.70	0.10	0.21	132.69	9.17	79.03
T ₈ Basal NPK + Nano urea	6.85	0.07	0.22	140.25	10.33	74.56
T ₉ Basal NPK + Zn + B	6.60	0.08	0.21	130.05	8.20	72.34
T ₁₀ Basal NPK + Arka vegetable special	6.90	0.08	0.24	133.97	8.94	76.11
T ₁₁ Basal NPK + 19:19:19 NPK (WSF)+ Nano urea	6.50	0.11	0.22	139.14	9.75	75.19
T ₁₂ Basal NPK + 19:19:19 NPK (WSF)+ Zn + B	6.85	0.07	0.23	132.52	8.34	77.63
T ₁₃ Basal NPK + 19:19:19 NPK (WSF)+ Nano urea + Zn + B	6.85	0.10	0.23	134.63	9.22	73.24
T ₁₄ Basal NPK + 19:19:19 NPK (WSF)+ Arka vegetable special	6.95	0.14	0.24	134.97	10.11	74.33
T ₁₅ Basal NPK + 19:19:19 NPK (WSF)+ Nano urea + Arka vegetable special	6.65	0.11	0.25	135.59	8.56	77.58
Mean	6.74	0.09	0.23	138.38	9.70	76.31
SED	0.17	0.03	0.05	3.56	0.96	2.78
CD (0.05)	NS	NS	NS	7.63	NS	NS

findings in okra (12). The presence of significant variations for post-harvest available N content of the soil was observed among the treatments imposed in the experimental field, while the post-harvest available P and K content of the soil was found non-significant for different fertiliser combinations tried. The maximum available N ($150.94 \text{ kg ha}^{-1}$), P (11.08 kg ha^{-1}), and K (80.05 kg ha^{-1}), was observed in foliar spray of Arka vegetable special thrice as a supplement to recommended dose of NPK (200: 100: 100 kg ha^{-1}) and this is attributed to the better nutrient availability aided by basal and top dressing of fertilisers applied in soil in addition to foliar application.

The enhanced availability of post-harvest soil phosphorus and potassium content in T₄ (RDF + Arka vegetable special) might be attributed to the supply of recommended phosphatic and potassic fertilisers along with FYM in soil, leading to a continuous and sustained supply of P and K through solubilisation by the organic acids released from FYM (13). The increased 'P' availability and uptake could have further promoted root growth and uptake of other micro elements, especially Zinc, ultimately resulting in better growth and yield attributes of okra (9). The rise in potassium availability is also a result of the equilibrium shift among the different forms of potassium, moving from more exchangeable potassium to more soluble forms in the soil.

Effect of nano urea and micronutrients on quality parameters in bhendi hybrid CO4

The data on the influence of foliar nutrition of nano urea and micronutrients on various quality parameters is presented in Table 5.

Crude protein

The data on crude protein content of the fruits as influenced by foliar application of nano urea and micronutrients. The treatment which received basal NPK + Zn + B (T₉) recorded the lowest crude protein content (15.05 %) and was found to be on par with T₇ (15.40 %), T₈ and T₁₀ (15.93 %), while there was a significant increase in the crude protein content of the fruits harvested from plants of foliar treatment of Arka vegetable special on the 20th, 40th and 60th DAS along with recommended dose of fertiliser (T₄ - 20.65 %). The application of an optimal quantity of micronutrients might have enhanced the nutrient availability and absorption, leading to increased assimilation and translocation of primary and secondary metabolites in plants (14).

Crude fibre

The crude fibre content of okra fruits showed significant variation among treatments. The minimum crude fibre content (11.57 %) was observed in fruits of the plants that were treated with Arka vegetable special as foliar application on 20, 40 and 60 DAS (T₄) and this was statistically on par with T₆ (RDF + 19:19:19 NPK (WSF) + Arka vegetable special) with 11.62 % and T₅ recording 11.73 %. But, the fruit crude fibre content was the maximum (15.22 %) in the plot applied with basal NPK + Zn + B on 20 and 40 DAS (T₉), followed by T₇ (15.08 %). The increased metabolic activity due to macro and micronutrients prompted the fruits to produce protein, starch and mucilage, which decreased the amount of metabolites available for the formation of crude fibre in okra (11).

Conclusion

The study also revealed the importance of top dressing nitrogen in soil for hybrid bhendi, as the treatments where top dressing of nitrogen was substituted with foliar spraying of nano urea could not show better performance and their yields were found to be low compared to treatments receiving top dressing of nitrogenous fertiliser. It is concluded that the application of the recommended dose of NPK (200: 100: 100 kg ha^{-1}) in addition to Arka vegetable special thrice at 20, 40 and 60 DAS as foliar spray could ensure a continuous and stable supply of nutrients to meet the quality and nutrient uptake of hybrid bhendi. Moreover, the uptake and assimilation of micronutrients through foliar application is faster than soil application, thus proves beneficial in the long run in sustaining crop productivity.

Acknowledgements

All the authors acknowledge the esteemed organisation PAJANOCOA & RI for the support and facilities provided for the successful conduct of the research.

Authors' contributions

MM experimented on nano urea and micronutrients on okra, collected and analysed the data and drafted the manuscript. VS formulated the ideas of the research, monitored the conduct of the experiment and fine-tuned the writing. All authors read and approved the final manuscript.

Table 5. Effect of nano urea and micronutrients on quality parameters in COBH H4 hybrid bhendi

	Treatment details	Crude protein (%)	Crude fibre (%)
T ₁	RDF	17.15	12.50
T ₂	RDF + 19:19:19 NPK (WSF)	17.85	12.33
T ₃	RDF + Zn + B	18.38	12.16
T ₄	RDF + Arka vegetable special	20.65	11.57
T ₅	RDF + 19:19:19 NPK (WSF)+ Zn + B	19.08	11.73
T ₆	RDF + 19:19:19 NPK (WSF)+ Arka vegetable special	19.95	11.62
T ₇	Basal NPK + 19:19:19 NPK (WSF)	15.40	15.08
T ₈	Basal NPK + Nano urea	15.93	14.80
T ₉	Basal NPK + Zn + B	15.05	15.22
T ₁₀	Basal NPK + Arka vegetable special	15.93	13.83
T ₁₁	Basal NPK + 19:19:19 NPK (WSF)+ Nano urea	16.63	13.31
T ₁₂	Basal NPK + 19:19:19 NPK (WSF)+ Zn + B	16.80	13.00
T ₁₃	Basal NPK + 19:19:19 NPK (WSF)+ Nano urea + Zn + B	17.15	12.63
T ₁₄	Basal NPK + 19:19:19 NPK (WSF)+ Arka vegetable special	17.50	12.49
T ₁₅	Basal NPK + 19:19:19 NPK (WSF)+ Nano urea + Arka vegetable special	17.50	12.43
	Mean	17.40	12.98
	SEd	0.48	0.20
	CD (0.05)	1.03	0.44

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process: During the preparation of this work, the authors used the Grammarly tool to improve the language and readability of the content. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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