RESEARCH ARTICLE

Enhancing Growth and Quality of Red Okra (*Abelmoschus esculentus* cv. Kashi Lalima) Using Nano Urea and Bio-enhancers

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DOI: 10.18811/ijpen.v11i01.23

Abstract

An investigation was carried out on red okra at Experimental Farm, Kharora, Mata Gujri College, Sri Fatehgarh Sahib, Punjab, India to check the nano urea and bio-enhancer's impact on quantitative and qualitative attributes of red okra cv. Kashi Lalima with various treatments under randomized block design. Eight treatments were evaluated out of these treatments T_6 (Nano Urea @0.4% + Panchgavya @3%) responded superior in yield parameters such as length of pod (10.44 cm), pod diameter (1.89 cm), pod weight (9.74 g), pod yield (9.82 q ha^{-1}), number of pods $plant^{-1}$ (18.44), biological yield (18.82 kg ha^{-1}) and harvest index (52.63%). The quality characters were significantly affected by T_6 in which maximum TSS content (7.70°Brix), crude protein (1.79%), crude fat (5.14 %), anthocyanin (3.49 mg $100g^{-1}$), vitamin A (0.62 mg $100g^{-1}$) and vitamin C (18.84 mg $100g^{-1}$), respectively. Additionally, treatment T_6 gives better results in higher B:C ratio (2.94), gross returns (₹ 5,23,770.83 ha^{-1}) and net returns (₹ 3,99,286.93 ha^{-1}), respectively.

Keywords: Red Okra, quantitative, Qualitative attributes, Bio-enhancers, Nano fertilizers.

International Journal of Plant and Environment (2025); **ISSN:** 2454-1117 (Print), 2455-202X (Online)

Introduction

Red okra (*Abelmoschus esculentus* L.) from the family Malvaceae which is also known as mallow family. Among the vegetable crops, the lady's finger has the highest chromosome no. (2n = 130). Geographically okra originated in Ethiopia (Simmone *et al.*, 2004 and Naveed *et al.*, 2009). Red okra is a fast-growing, erect, annual and herbaceous plant cultivated as a vegetable crop throughout the world. The most common names of okra in different regions are bhindi or bhendi in India, ochoro in Southeastern parts of Asia and gumbo in the United States of America. This crop thrives in long warm and humid climates. India leads 1st position by producing around 60% of okra in the world (Anonymous, 2023). It is consumed as raw vegetables, used as soups, salad stews and fresh/dried, boiled, or fried (Ndunguru and Rajabu, 2004). Okra pods contain gummy material which appears in the form of mucilage. Color of red okra is due to the presence of anthocyanin and phenolics (Anonymous, 2018). Anthocyanins are pigments present in vascular parts of plants.

Nano fertilizers is a novel strategy for sustainable agriculture that makes the effective use of every drop of fertilizer available in liquid form. One type of nano fertilizer that helps plants meet their nitrogen needs is called nano urea. India has become the first country which globally start commercial production of Nano Urea. The Government of India has notified you in accordance with the Fertilizer Control Order, 1985. The IFFCO Nano urea liquid specifies that the particle size is smaller than 100 nm. It has a two-year shelf life that contains 4% N. Their larger surface area and exact concentration make nutrients available to plants gradually and are very soluble in water (Johnson & Lee, 2018 and Smith *et al.*, 2020).

The organic manures known as bio-enhancers are available in powder or liquid form and serve as effective alternatives to chemical fertilizers when used at the right rate and time. They offer dual benefits by increasing soil productivity and crop yield. Bio-enhancers are usually produced from actively fermenting plants by using animal residues, which provide rich macronutrients (NPK), micronutrients, microbial communities, and compounds that support plant immunity and growth (Pathak and Ram, 2013). Single Indian cow dung and cow urine are enough to meet 12 hectares of land for organic cultivation (Aulakh *et al.*, 2013).

Panchgavya is a bio-enhancer composed of a blend of five elements obtained from cow waste, specifically cow dung, cow urine, cow curd, cow ghee and cow milk. Additionally, jaggery and ripened bananas are included in the mixture. These components are thoroughly combined and left covered for a period of 30 days, after which it becomes a fermented solution with beneficial effects on crops. The mixture is stirred both clockwise and anticlockwise for 15 minutes every day. After the fermentation period, the resulting product is abundant in plant growth nutrients such as gibberellins, auxins and microbial

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How to cite this article: Singh, A., Singh, S.K., Thakur, R., Kaur, H., Sejwal, A., Kaur, S., Kumar, A., Kaur, R. (2025). Enhancing Growth and Quality of Red Okra (*Abelmoschus esculentus* cv. Kashi Lalima) Using Nano Urea and Bio-enhancers. International Journal of Plant and Environment. 11(1), 213-218.

Submitted: 30/08/2024 **Accepted:** 06/03/2025 **Published:** 28/03/2025

fauna, serving as a tonic to improve soil quality and stimulate the vigor of plants, leading to the production of high-quality yields (Swarnam *et al.*, 2016).

Jivamrita is a liquid bio-enhancer, consisting of biological waste material such as cow urine, dung, pulse flour, jaggery and virgin soil. It took 5-7 days for the proper fermentation of solution. It helps to progress the microbial activities and microbial community in the soil (Borairah *et al.*, 2017).

The main objective of this study is to check the impact of bio-enhancers and nano-fertilizers on the quality, yield and economics of red okra and to compute the economics of different treatments applied to crops. Enhancing growth and quality of red okra (*Abelmoschus esculentus* cv. Kashi Lalima) using nano urea and bio-enhancers (Kumar *et al.*, 2023, Mehta & Gupta, 2023, Choudhary & Mishra, 2024, Patel *et al.*, 2024 and Singh *et al.*, 2024).

Materials and Methods

The experiment was carried out at Experimental Farm, Mata Gujri College, Kharora, District Sri Fatehgarh Sahib, Punjab, India during the summer season of 2023. Various soil samples were analyzed from different spots at a depth of 15 cm before laying out an experiment. Soil texture was sandy loam estimated using (Piper, 1996) and a pH value (7.8) neutral to slightly basic soil was calculated using (Jackson, 1973). The experiment consisted of nine treatments with three replications *viz.* T_0 (Control), T_1 (Nano urea @0.2%), T_2 (Nano urea @0.4%), T_3 (Panchgavya @3%), T_4 (Jivamrita @10%), T_5 (Nano urea @0.2% + Panchgavya @3%), T_6 (Nano urea @0.4% + Panchgavya @3%), T_7 (Nano urea @0.2% + Jivamrita @10%) and T_8 (Nano urea @0.4% + Jivamrita @10%) under randomized block design (RBD). The dimensions of each plot size were measured as 2.4 m×2.4 m. Proper spacing was maintained at 45×15 cm. The cultivar used was Kashi Lalima (VROR-157) which was purchased from the Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, India. As per the recommendations of Punjab Agricultural University, Ludhiana, Punjab, India recommended dose of fertilizers is added to all plots equally. Seeds were sown using the dibbling method at a depth of 1 to 2 cm on the ridges in the last week of February 2023. A total of eight irrigations were done at 10 to 12 days intervals during the vegetative to reproductive phase. Crop harvesting starts from mid-April to the second fortnight of May at 2-3 days intervals.

Panchgavya

A mixture of fresh cow urine and 5 L of water was added, followed by mixing and 1 L of cow milk and 6 bananas were added and stirred for a month for proper decomposition and results in the initiation of the fermentation process. The mixture was stirred twice daily in both clockwise and anti-clockwise directions The plots were treated with a 3% dose of panchgavya at 30, 45, and 60 days after sowing. A 3% solution of panchgavya was created by mixing 30 mL of panchgavya in 1000 mL of water (Verma *et al.*, 2019).

Jivamrita

To make the solution of jivamrita, 10 kg of fresh cow dung and 10 L of cow urine were mixed with jaggery solution. Then, pulse flour @2 kg was added to the solution with @1-kg live soil. The mixture was stirred twice daily and left for fermentation for 7 days to create the final solution. A 10% dose of Jivamrita was used for foliar application at 30, 45, and 60 days after sowing in the treatment. Jivamrita @10% solution was created by mixing 100 mL of Jivamrita with 1000 ml of water (Kaur *et al.*, 2021).

Nano -urea

The IFFCO nano urea bottle was bought from a nearby market and applied at rates of 0.2 and 0.4% on plots 30, 45 and 60 days after planting. A mixture of 2 and 4 mL of nano urea was prepared in 1000 mL of water at concentrations of 0.2 and 0.4%, respectively (Goud *et al.*, 2022).

Results and Discussion

Fruiting Attributes

Pod diameter (cm)

The recorded pod diameter (cm) was maximum in T_6 (1.89 cm) shown in Table 1 and was statically at par with T_5 (1.78 cm). This may be the outcome of nano urea's effect on enzymatic activity, which produces organic acids and converts energy for fruit development and growth. Additionally, panchgavya application promotes growth enhancers in a plant like an auxin and gibberellins (Panda *et al.*, 2020). Similar results were found by Panda *et al.*, (2020), Subraamani *et al.*, (2023) and Meena *et al.*, (2023).

Pod length (cm)

Pod length was found maximum in T_6 treated plots in which the average value of pods was (10.44 cm) recorded which was statistically at par with T_5 (9.90 cm) and T_8 (9.71 cm) represented in Table 1. The potential cause of the longer pods might be nano urea, which strengthens and stretches cell walls to aid in fruit form alteration. Growth is aided by panchgavya application because it produces hormones. Similar results were found by Panda *et al.*, (2020), Meena *et al.,* (2023), Subramani *et al.*, (2023) and Balyan *et al.*, (2024).

Number of pods plant^{-1}

Data recorded on a number of pods plant^{-1} showed significant results with application of T_6 that was (18.44) respectively which was statistically at par with T_5 (18.10) and T_8 (17.46) and shown in Table 1. This finding might be the result of the application of panchgavya, which builds up auxin and cytokinins in plants and may increase the number of fruits produced per plant (Swain *et al.*, 2015). Nano urea responds to cell growth due to better absorption that leads to accumulation and translocation of nutrients to whole plants (Kumawat *et al.*, 2013, Bhawariya *et al.*, 2022 and Mirji *et al.*, 2023).

Pod weight (g)

Pod weight (g) was significantly influenced by the T6 treated plot that showed maximum weight (9.74 g) and was statistically at par with T_5 (9.19 g) represented in Table 1. The impact of panchgavya on pod weight is a result of enhanced photosynthetic activity translocation to economically important regions. This is because more chlorophyll is formed, which facilitates the translocation of more carbohydrates towards fruit (Yadav *et al.*, 2019). Nano urea

Table 1: Fruiting attributes of red okra

Treatments	*Pod diameter (cm)*	*Pod length (cm)*	*No. of pods plant^{-1}*	*Pod weight (g)*
T_0	1.37	7.40	12.30	6.45
T_1	1.61	8.12	14.64	6.69
T_2	1.67	9.47	15.38	7.40
T_3	1.62	8.49	14.96	7.15
T_4	1.53	7.61	13.95	6.68
T_5	1.78	9.90	18.10	9.19
T_6	1.89	10.44	18.44	9.74
T_7	1.68	9.34	16.11	7.72
T_8	1.70	9.71	17.46	8.10
SEm (±)	0.04	0.31	0.66	0.27
$CD_{(0.05)}$	0.11	0.93	1.98	0.80

contributes to the development of plant parts by increasing pod weight by making nitrogen available. Similar results were found by Vennila and Jayanthi (2008), Adeyeye *et al.* (2017), Davarpanah *et al.*, (2017), Devanda *et al.*, (2021) and Madhvi *et al.*, (2022).

Pod yield

The superior outcomes for pod yield were observed in treatment T_6 in which maximum pod yield (130.99 g plant^{-1}), (9.82 kg plot^{-1}) and (174.59 q ha^{-1}) were recorded and represented in Table 2. According to Swain *et al.*, (2015), plant yield may be impacted by panchgavya enhancing photosynthetic activity and improving the source-sink relationship, while nano urea promotes proper photosynthesis and boosts microbial activity for increased yield (Sharada and Sujathamma, 2018). Similar findings were observed (Lekshmi *et al.*, 2022) and (Ojha *et al.*, 2023).

Biological yield

The biological yield was recorded maximum under the treatment T_6 in which data showed (18.82 kg plot^{-1}), respectively and statistically at par with T_5 (18.70 kg plot^{-1}) shown in Table 2. The translocation of nutrients and growth regulators like IAA and GA to plants can be easily influenced by the foliar application of panchgavya, which may have a positive impact on plants (Choudhary *et al.*, 2017). Similar findings were observed by Kumawat *et al.*, (2013).

Harvest index (%)

The data recorded showed a maximum harvest index (52.63%) in treatment T6 and was statistically at par with T_5 (50.95%) and T_8 (50.82%) represented in Table 2. The use of panchgavya improves the harvest index by enhancing photosynthesis and hormonal characteristics, while nano nitrogen enhances transportation through foliar application based on demand. Similar findings were observed by Shivaprasad and Chittapur (2009), Midde *et al.*, (2022) and Reddy *et al.*, (2022).

Quality Attributes

TSS content (°Brix)

The data recorded from various treatments shows a non-significant effect on TSS values while the maximum value was recorded in T_6 (7.70 °Brix) and statistically at par with T_5 (7.67 °Brix) represented in Table 3. This could be attributed to the key function in the chloroplast's formation, CO_2 absorption and enzyme activation related to enhanced photosynthesis and carbohydrate storage, leading to an increase in the total soluble solids (TSS) in pomegranates (Davarpanah *et al.*, 2017). Another possible explanation could be the use of panchgavya, which may increase the nitrogen levels available for the production of secondary metabolites such as phenols. These phenols act as a natural defense mechanism for plants (Bhadauria *et al.*, 2023) that improves the TSS level in fruit.

Crude fat (%)

Crude fat was recorded as maximum in T_6 which was (5.14 %) which was statistically at par with T_5 (5.10 %) represented in Table 3. Panchgavya application resulted in the highest findings possibly due to its foliar application, which impacts nutrient availability and boosts microbial activity (Dhanushkodi and Nageswari, 2022)

Crude protein (%)

Observed data revealed that the maximum value of crude protein was recorded in T6 (1.79%) and was followed by T_5

Table 2: Fruiting attributes of red okra

Treatments	*Pod yield (g plant^{-1})*	*Pod yield (kg plot^{-1})*	*Pod yield (q ha^{-1})*	*Biological yield (kg plot^{-1})*	*Harvest index (%)*
T_0	82.45	6.18	109.92	16.79	37.10
T_1	100.01	7.49	132.94	16.97	44.17
T_2	110.61	8.29	147.50	17.20	48.22
T_3	108.04	8.10	144.13	17.08	47.45
T_4	94.94	7.12	126.58	16.93	41.95
T_5	127.14	9.53	169.88	18.70	50.95
T_6	130.99	9.82	174.59	18.82	52.63
T_7	115.59	8.66	154.09	17.61	49.19
T_8	121.09	9.11	161.46	17.78	50.82
SEm (±)	1.38	0.28	1.66	0.12	0.67
$CD_{(0.05)}$	4.14	0.85	4.97	0.36	2.01

Table 3: Quality attributes of red okra

Treatments	*TSS (ºBrix)*	*Crude fat (%)*	*Crude protein (%)*	*Crude fibre (%)*	*Anthocyanin (mg 100 g^{-1})*	*Vitamin C (mg 100 g^{-1})*	*Vitamin A (mg 100 g^{-1})*	*Ash content (%)*
T_0	7.47	4.65	1.29	8.84	2.97	15.34	0.49	1.16
T_1	7.63	4.77	1.48	9.00	3.20	15.88	0.54	1.34
T_2	7.64	4.67	1.53	8.87	3.25	16.54	0.56	1.37
T_3	7.57	4.86	1.58	9.10	3.22	18.53	0.55	1.25
T_4	7.60	4.77	1.55	9.18	36	15.40	0.53	1.26
T_5	7.67	5.10	1.72	9.97	3.29	18.70	0.60	1.41
T_6	7.70	5.14	1.79	10.01	3.49	18.84	0.62	1.46
T_7	7.63	4.67	1.69	9.60	33	17.10	0.57	1.31
T_8	7.37	5.06	1.45	9.91	3.23	16.89	0.58	1.23
SEm (±)	NS	NS	NS	NS	NS	0.53	0.01	NS
$CD_{(0.05)}$						1.59	0.04	

(1.72%) represented in Table 3. Jakhar *et al*., (2022) suggest that the positive results could be linked to panchgavya increasing nitrogen uptake, boosting photosynthesis and enhancing protoplasm and protein synthesis during the growth phase. An additional factor for the rise in crude protein levels from nano urea could be linked to enhanced plant growth through the application of higher doses of nano fertilizers (Kannoj *et al*., 2022), as well as the increased surface area and nutrient accessibility to the crops which enhance the quality of crude protein (Burhan and Al-Hassan, 2019).

Crude fibre (%)

The data recorded on crude fiber content showed a non-significant effect of various treatments and the following results revealed that maximum crude fiber content (10.01%) was recorded in the treatment T_6 which was statistically at par with T_5 (9.97%) represented in Table 3.

Anthocyanin content (mg 100g^{-1})

The maximum anthocyanin content was recorded in T_6 (3.49 mg 100 g^{-1}) and statistically at par with T_5 (3.29 mg) represented in Table 3. Results were found to be non-significant due to the application of treatments on anthocyanin.

Vitamin C (mg 100 g^{-1})

Data recorded on vitamin C show significant results in T_6 which was (18.84 mg) followed by T_5 (18.70 mg) and T_3 (18.53 mg) represented in Table 3. Observations in favor of panchgavya may be attributed to its gradual yet steady supply of essential nutrients, aiding in carbohydrate assimilation and the production of ascorbic acid. Additionally, panchgavya acts as a reservoir solution, causing a decrease and promoting cosmic ray penetration to harmonize basic growth elements, revitalizing the growth process in bitter gourd (Anuja and Archana, 2012).

Vitamin A (mg 100 g^{-1})

Vitamin A content showed a significant effect of various treatments and results revealed that maximum vitamin A (0.62 mg) was recorded in the treatment T6 and statistically at par with T_5 (0.60 mg) and T_8 (0.58 mg) represented in Table 3. This could lead to higher levels of vitamin A as a result of the mineral nutrients present (Panda *et al*., 2020). The potential benefits of

Table 4: Economics of red okra

Treatments		*Cost of cultivation (₹ ha^{-1})*	*Gross income (₹ ha^{-1})*	*Net returns (₹ ha^{-1})*	*Benefit: Cost ratio*
T_0	Control	121102.88	329760.12	206992.24	1.72 (RDF)
T_1	Nano urea @0.2%	123552.63	398820.37	275602.74	2.23
T_2	Nano urea @0.4%	127002.39	442500.61	318830.22	2.51
T_3	Panchagavya @3%	129600.95	432390.05	308806.1	2.38
T_4	Jivamrita @10%	125586.96	379740.04	255082.08	2.03
T_5	Nano urea @0.2% + Panchagavya @3%	134050.66	509640.34	385606.68	2.87
T_6	Nano urea @0.4% + Panchagavya @3%	135501.17	523770.83	399286.83	2.94
T_7	Nano urea @0.2% + Jivamrita @10%	131036.81	462270.19	338062.38	2.57
T_8	Nano urea @0.4% + Jivamrita @10%	131486.59	484380.41	359722.82	2.73

using panchgavya in agriculture include promoting crop growth and strength, increasing resistance to pests and disease, and preserving the quality of fruits and vegetables (Natarajan, 2003).

Ash content (%)

Data recorded on ash content show non-significant results and were found maximum in T6 (1.46 %) and followed by T_5 (1.41 %) represented in Table 3. Maximum observations may be due to panchgavya, which raised the mineral content in the plant (Kala and Eswari, 2019). Bogacz *et al*., (2021) found that nitrogen fertilizers resulted in increased ash content uptake in various plant parts during vegetative growth. Similar findings were also observed (Abd El-Rahman and Abd-Elkarim, 2022).

Economics

One of the most crucial parameters is the economic value of the crop in the market. The market sold red okra pods with total earnings of (₹ 523770.83 ha^{-1}) and cultivation expenses of ₹ 135501.17 per hectare mentioned in table 3.3. The treatment T_6 had the highest total net returns (₹ 399286.93 ha^{-1}) and also achieved the highest benefit: cost ratio (2.94). In comparison to T6, T_0 had the lowest net returns recorded at (₹ 206992.24 ha^{-1}) represented in Table 4.

Conclusion

The study suggests that treatment T_6 (nano urea @0.4%+Panchgavya @3%) should be chosen for cultivation of red okra, at farmer fields because it provides greater net returns and a higher B:C ratio as well as improves the quality of the produce including vitamins, protein and fats, etc parameters. Behalf of this, it enhances the yield of crops resulting in good income generation. Reducing nitrogen losses in the environment and managing nitrogen sites specifically is advantageous for preserving ecological balance. Furthermore, integrating home-based items like panchgavya can greatly benefit the organic growth of vegetable crops at a low cost.

Acknowledgments

The authors want to thank the institute that provided us with the opportunity to conduct our research project. We would like to extend our gratitude to Dr. Sandeep Kumar Singh, our supervisor, for providing us with precise guidance and motivation throughout the entire research. Finally, we are grateful to our parents and all family members for their valuable and financial assistance.

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