***Original Research Article***

**Optimizing okra growth, productivity and profitability using nanourea along with conventional fertilization**

**ABSTRACT**

This study investigated the impact of nanourea along with varying fertilizer doses on the growth, productivity and profitability of okra (cv. Hisar Unnat) during spring-summer season of the year 2023 at the Regional Research Centre, Raiya (Jhajjar) of MHU, Karnal. The experiment followed a randomized block design with ten treatment combinations, each replicated three times. The treatments included various fertilizer doses (control, 50% RDF, 75% RDF and 100% RDF) along with nanourea @ 4ml/l (applicationed once at 25 DAS or twice at 25 and 40 DAS). The results revealed that the application of 100% RDF alongside nanourea application twice (T4) resulted in the tallest plant height at all observed growth stages (30, 60, 90 days after sowing and at final harvesting), as well as notable increases in the quantity of fruits per plant (31.94%) compared to the control. Treatment T4 and T3 maximized yield per plant, surpassing 100% RDF (T2: 217.44 g) by 4.9–5.1%. Treatment T4 also provided highest economic efficiency with B: C ratio of 1.85. Reducing the RDF to 75% or 50% alongside nanourea applications (T5-T8) resulted in moderate growth and yield attributes, suggesting that while nanourea supplementation improves productivity, it may not fully compensate for the reduction in the primary fertilizer dose under the experimental conditions. These findings suggest that optimal okra production requires balanced fertilizer application combined with strategic nanourea supplementation.

**Keywords:** Okra, Fertilizer, Nanourea, growth, yield and flowering

**INTRODUCTION**

*Abelmoschus esculentus* a member of the Malvaceae family is an amphidiploid species with chromosome number 2n=130. It is a vegetable of tropical or sub tropical regions commonly called okra or lady’s finger. It prefers temperature ranges of 20-35°C for optimal growth and development. Globally, India stands as the leading producer of okra, harvesting approximately 7157.64 thousand metric tons from 548.95 thousand hectare area in the year 2022-23. On the other hand, okra covers 11.93 thousand hectares of area in Haryana, with 100.71 thousand metric tons of production and 8.44 metric tons per hectare of productivity (Anonymous, 2023). Okra cultivation is particularly prominent in Haryana's Karnal, Panipat, Sonipat and Hansi regions. Farmers in these key Haryana regions often adopt practices that deviate from standard recommendations. They commonly plant 4 to 5 seeds per hill along ridge sides closely. This translates to an elevated seed rate of 50-60 kg per hectare, surpassing the advised 40-45 kg ha-1. Furthermore, nitrogen application rates are often three to four times higher than the suggested 100 kg ha-1 (Kumar *et al.,* 2016) to enhance seed germination for crops sown early, typically in late February or early March and to boost the yield of small, thin and tender fruits that fetch better prices in the market. However, excessive fertilization not only increases cost of production but may also lead to undesirable environmental outcomes such as eutrophication and pollution of water sources.

Nitrogen, one of the 17 essential elements necessary for plant development, plays a crucial role in synthesizing numerous essential substances and compounds within plants, including chlorophyll, enzymes, amino acids, RNA and DNA (Khalil *et al.,* 2016). Adequate availability of nitrogen is imperative for plant growth. The majority of nitrogen is typically supplied through inorganic fertilizers (Bloom, 2015). After nitrogen fertilizer is applied to soil, it is first converted to ammonium and then transformed by soil bacteria into nitrate through nitrification. Plants absorb these nitrogen forms for growth, but nitrate can also leach into groundwater or be lost as gases through denitrification. This nitrogen cycling is influenced by soil conditions like moisture, temperature and pH (Sharma *et al.,* 2022a) which make it challenging to enhance a crop's nitrogen-use efficiency (NUE). Recognizing this challenge, researchers have explored various strategies to improve nitrogen utilization in crops. Recent innovations in nanotechnology have shown particular results, with nano-fertilizers emerging as a potential solution to reduce the environmental footprint of conventional nitrogen fertilization (Zulfiqar *et al.,* 2019) while maintaining crop productivity (Singh *et al.,* 2021).

A significant advancement in agricultural inputs is the introduction of nanourea fertilizer by the Indian Farmers’ Fertilizer Cooperative Limited. It has a shelf life of two years and contains 4% (w/v) nitrogen. Remarkably, it's proposed that just one 500 ml bottle of nanourea can fulfill a crop's nitrogen requirements as effectively as a 50 kg bag of traditional prilled urea (Mandal *et al.,* 2023; Frank and Husted, 2024). However, it is crucial to evaluate its impact on crop growth parameters under field conditions before recommending its utilization in the field conditions. Therefore, in light to thoroughly understand the potential of this new technology, investigated the impact of nanourea along with varying fertilizer doses on the growth and yield of okra (cv. Hisar Unnat) during spring-summer season of the year 2023.

**MATERIALS AND METHODS**

Okra (*Abelmoschus esculentus*) cv. Hisar Unnat was sown for the experiment at the Regional Research Centre, Raiya (Jhajjar), of Maharana Pratap Horticultural University in Haryana in randomized block design with ten treatment combinations, each replicated three times. The seeds were obtained from CCS HAU’s Vegetable seed processing unit at Hisar. The maximum mean weekly temperature fluctuated from 26.7 ºC to 39.6 ºC and minimum from 14.7 ºC to 28.3 ºC during the cropping period (spring summer) from march 14th 2023. The relative humidity ranged from 14% to 92%. This period also received some light showers of rains.

**Table 1: treatment details**

|  |  |
| --- | --- |
| **T1**  | Control  |
| **T2**  | 100% RDF (100 kg/ha N and 60 kg/ha P2O5) |
| **T3** | 100% RDF + nanourea application @ 4ml/l at 25 DAS |
| **T4** | 100% RDF + nanourea application @ 4ml/l at 25 and 40 DAS |
| **T5** | 75% RDF + nanourea application @ 4ml/l at 25 DAS |
| **T6** | 75% RDF + nanourea application @ 4ml/l at 25 and 40 DAS |
| **T7** | 50% RDF + nanourea application @ 4ml/l at 25 DAS |
| **T8** | 50% RDF + nanourea application @ 4ml/l at 25 and 40 DAS |
| **T9** | Single nanourea application @ 4ml/l at 25 DAS |
| **T10** | Two nanourea application @ 4ml/l at 25 and 40 DAS |

Recommended dose of nitrogen and phosphorous *i.e.* 100 kg ha-1 of N and 60 kg ha-1 of P2O5 were given as per treatment using inorganic fertilizers: granular Urea and DAP. Full dose of phosphorous and 1/3rd nitrogen was given at sowing; remaining was provided in two equal applications at 21 and 45 DAS. IFFCO nanourea was used for foliar applications of nitrogen @ 4 ml/l. Single application of nanourea was given at 25 DAS while in treatments involving two applications, nanourea was applied on 25 and 40 DAS.

For each 3 m×3 m experimental plot, data on critical plant growth and yield parameters were meticulously collected. These included plant height (measured at 30 days interval from date of sowing and at final harvest), fruit length and diameter; weight of each fruit, number of pickings, number of fruits per plant, fruit yield and benefit cost ratio. Measurements were taken from five randomly selected plants within each plot to ensure representativeness. To draw meaningful conclusions from this data, a rigorous statistical analysis was performed. The collected data was subjected to the statistical analysis by ANOVA (analysis of variance) utilizing the OPStat software developed by CCS HAU. To precisely identify significant differences between treatment means, Duncan's Multiple Range Test was subsequently applied at *P* = 0.05.

 **RESULTS**

**Table 2: Impact of different fertilizer doses and nanourea applications on height of plants (cm) at thirty, sixty and ninety days after sowing and on final harvest of okra**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. |  Treatments | Height on 30 DAS (cm) | Height on 60 DAS (cm) | Height on 90 DAS (cm) | Height on final harvest(cm) |
| T1 | Control | 24.79d | 44.71g | 66.98g | 72.98f |
| T2 | 100% RDF | 28.10b | 60.92b | 88.55bc | 91.53c |
| T3 | 100% RDF + nanourea application @ 4ml/l at 25 DAS | 29.96a | 62.53b | 89.59b | 97.07b |
| T4 | 100% RDF + nanourea application @ 4ml/l at 25 and 40 DAS | 30.05a | 66.28a | 94.10a | 102.01a |
| T5 | 75% RDF + nanourea application @ 4ml/l at 25 DAS | 27.16bc | 57.81cd | 81.07d | 87.71d |
| T6 | 75% RDF + nanourea application @ 4ml/l at 25 and 40 DAS | 27.19bc | 60.49bc | 86.17c | 89.59cd |
| T7 | 50% RDF + nanourea application @ 4ml/l at 25 DAS | 27.03bc | 53.21e | 77.41e | 82.79e |
| T8 | 50% RDF + nanourea application @ 4ml/l at 25 and 40 DAS | 27.00bc | 56.21d | 79.04de | 86.33d |
| T9 | Single nanourea application @ 4ml/l at 25 DAS | 25.98cd | 49.12f | 68.25g | 75.2f |
| T10 | Two nanourea application @ 4ml/l at 25 and 40 DAS | 25.97cd | 51.75ef | 72.11f | 82.16e |
| . | S.E.(m)± | 0.40 | 0.96 | 1.01 | 1.13 |
| . | C.D. (*P* = 0.05) | 1.21 | 2.88 | 3.02 | 3.38 |

means denoted by the same letter(s) within each column, are not significantly different (DMRT, *P* = 0.05).

Plant height exhibited notable variations across treatments at different growth stages (Table 2). The tallest plants were obtained with T4 (100% RDF + nanourea application @ 4ml/l at 25 and 40 DAS) which were 30.05 cm, 66.28 cm, 94.1 cm and 102.01 cm tall at 30, 60, 90 DAS and at final harvest, respectively. They were significantly taller than other treatments except T3 (100% RDF + nanourea application @ 4ml/l at 25 DAS) at 30 DAS. In contrast, the shortest plants were recorded in T1 (control) with 24.79 cm, 44.71 cm, 66.98 cm and 72.98 cm height at (measured at 30 days interval from date of sowing and at final harvest), respectively. Our findings align with previous research by Ojha *et al.* (2022), Kumar *et al.* (2023), and Subramani *et al.* (2023), who also reported positive influences of nano urea on plant height in okra.

**Table 3: Impact of different fertilizer doses and nanourea applications on fruit length (cm), fruit diameter (cm), fruit weight (g) and number of picking of okra**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. |  Treatments | Fruit length (cm) | Fruit diameter (cm) | Fruit weight (g) | Number of pickings |
| T1 | Control | 9.01e | 1.16f | 8.11f | 13.33 |
| T2 | 100% RDF | 12.27ab | 1.48b | 10.34ab | 15.00 |
| T3 | 100% RDF + nanourea application @ 4ml/l at 25 DAS | 12.64a | 1.61a | 10.42a | 15.33 |
| T4 | 100% RDF + nanourea application @ 4ml/l at 25 and 40 DAS | 13.03a | 1.67a | 10.48a | 15.33 |
| T5 | 75% RDF + nanourea application @ 4ml/l at 25 DAS | 10.54c | 1.43bc | 10.04c | 13.67 |
| T6 | 75% RDF + nanourea application @ 4ml/l at 25 and 40 DAS | 11.49b | 1.45b | 10.16bc | 14.00 |
| T7 | 50% RDF + nanourea application @ 4ml/l at 25 DAS | 9.84cde | 1.33cde | 9.56d | 13.67 |
| T8 | 50% RDF + nanourea application @ 4ml/l at 25 and 40 DAS | 10.14cd | 1.41bcd | 9.65d | 13.67 |
| T9 | Single nanourea application @ 4ml/l at 25 DAS | 9.3de | 1.23ef | 8.33ef | 13.33 |
| T10 | Two nanourea application @ 4ml/l at 25 and 40 DAS | 9.53de | 1.3de | 8.48e | 13.67 |
| . | S.E.(m)± | 0.30 | 0.03 | 0.07 | 0.52 |
| . | C.D. (*P* = 0.05) | 0.91 | 0.10 | 0.22 | NS |

means denoted by the same letter(s) within each column, are not significantly different (DMRT, *P* = 0.05).

Treatment effects on fruit attributes were significant (*P* = 0.05). Nanourea (NU) synergized with inorganic fertilizers significantly enhanced fruit length and diameter (Table 3). The 100% RDF + two NU applications (T4) produced the longest fruits (13.03 cm), outperforming 100% RDF alone (T2: 12.27 cm). Even at reduced RDF levels, NU applications improved fruit length: 75% RDF + two applications (T6: 11.49 cm) surpassed 75% RDF + single application (T5: 10.54 cm). However, NU-only treatments (T9: 9.30 cm; T10: 9.53 cm) and 50% RDF combinations (T7, T8: 9.84, 10.14 cm) showed minimal improvement over the control (9.01 cm). A similar trend emerged for fruit diameter. Full RDF + two NU applications (T4: 1.67 cm) and single application (T3: 1.61 cm) yielded the thickest fruits, significantly exceeding 100% RDF alone (T2: 1.48 cm). The highest fruit weight was recorded in T4 (100% RDF + two NU applications) at 10.48 g, followed closely by T3 (100% RDF + single NU application) at 10.42 g, both statistically superior to 100% RDF alone (T2: 10.34 g; *P* = 0.05) (Table 3). Similar findings were also recorded by Parmar *et al.* (2015), Lekshmi *et al.* (2022), Ojha *et al.* (2022) and Subramani *et al.* (2023). The maximum number of pickings (15.33) was noted under treatment T4 (100% RDF + nanourea application @ 4ml/l at 25 and 40 DAS) and T3 (100% RDF + nanourea application @ 4ml/l at 25 DAS). While, the minimum pickings (13.33) were recorded under treatments T1 (control) and T9 (single application of nanourea at the rate of 4 ml/l at 25 DAS). However, after statistically analyzing the data, it was revealed that this difference was not significant.

**Table 4: Influence of fertilizer doses and nanourea on nodes, fruits per plant and yield (kg/plot) of okra**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No. | Treatment combinations  | Number of fruits (per plant) | Fruit yield per plant (g) | Fruit yield (q/ha) |
| T1 | Control | 16.47e | 133.67e | 70.55e |
| T2 | 100% RDF | 21.07ab | 217.44ab | 114.76ab |
| T3 | 100% RDF + nanourea application @ 4ml/l at 25 DAS | 21.4ab | 222.77a | 117.57a |
| T4 | 100% RDF + nanourea application @ 4ml/l at 25 and 40 DAS | 21.73a | 228.53a | 120.61a |
| T5 | 75% RDF + nanourea application @ 4ml/l at 25 DAS | 19.2bcd | 193.15cd | 101.94cd |
| T6 | 75% RDF + nanourea application @ 4ml/l at 25 and 40 DAS | 19.67abc | 200.03bc | 105.57bc |
| T7 | 50% RDF + nanourea application @ 4ml/l at 25 DAS | 18.33cde | 175.48d | 92.61d |
| T8 | 50% RDF + nanourea application @ 4ml/l at 25 and 40 DAS | 18.8cde | 181.11cd | 95.58cd |
| T9 | Single nanourea application @ 4ml/l at 25 DAS | 17de | 141.71e | 74.79e |
| T10 | Two nanourea application @ 4ml/l at 25 and 40 DAS | 17.73cde | 150.02e | 79.18e |
| . | S.E.(m)± | 0.69 | 6.30 | 0.07 |
| . | C.D. (5%) | 2.07 | 18.86 | 0.22 |

means denoted by the same letter(s) within each column, are not significantly different (DMRT, *P* = 0.05).

The maximum fruits per plant (21.73) were obtained with T4 (100% RDF + nanourea application @ 4ml/l at 25 and 40 DAS). It was significantly more than other treatments except T3 (100 % RDF + nanourea application @ 4ml/l at 25 DAS) and T2 (100% RDF) which produced 21.4 and 21.07 fruits per plant, respectively. The minimum fruits per plant (16.47) were recorded in T1 (control). Treatment T4 (228.53 g) and T3 (222.77 g) maximized yield per plant, surpassing 100% RDF (T2: 217.44 g) by 4.9–5.1%. T6 (75% RDF + two NU applications) yielded 200.03 g, achieving 92% of T2’s performance, demonstrating partial substitution potential. Sole reliance on NU (T9–T10) yielded 30–32% less than T2, reinforcing its supplemental role. Similar findings were also recorded by Firoz (2009), Jana *et al.* (2010) Chudhari *et al.* (2020), Khanal *et al.* (2020) and Mandal *et al.* (2023) in okra.

**Table 5: Influence of fertilizer doses and nanourea on economics of okra cv. Hisar Unnat in spring summer season**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatments | Common Cost | Treatment cost | Total cost of production | Gross return | Net return | B:C ratio |
| T1. | ₹ 59,448 | ₹ 0 | ₹ 59,448 | ₹ 1,26,986 | ₹ 67,538 | ₹ 1.14 |
| T2. | ₹ 59,448 | ₹ 14,509 | ₹ 73,957 | ₹ 2,06,570 | ₹ 1,32,614 | ₹ 1.79 |
| T3. | ₹ 59,448 | ₹ 15,684 | ₹ 75,132 | ₹ 2,11,631 | ₹ 1,36,499 | ₹ 1.82 |
| T4. | ₹ 59,448 | ₹ 16,859 | ₹ 76,307 | ₹ 2,17,105 | ₹ 1,40,798 | ₹ 1.85 |
| T5. | ₹ 59,448 | ₹ 11,369 | ₹ 70,817 | ₹ 1,83,490 | ₹ 1,12,673 | ₹ 1.59 |
| T6. | ₹ 59,448 | ₹ 12,544 | ₹ 71,992 | ₹ 1,90,024 | ₹ 1,18,032 | ₹ 1.64 |
| T7. | ₹ 59,448 | ₹ 8,054 | ₹ 67,502 | ₹ 1,66,702 | ₹ 99,199 | ₹ 1.47 |
| T8. | ₹ 59,448 | ₹ 9,229 | ₹ 68,677 | ₹ 1,72,050 | ₹ 1,03,373 | ₹ 1.51 |
| T9. | ₹ 59,448 | ₹ 1,175 | ₹ 60,623 | ₹ 1,34,626 | ₹ 74,003 | ₹ 1.22 |
| T10. | ₹ 59,448 | ₹ 2,350 | ₹ 61,798 | ₹ 1,42,516 | ₹ 80,718 | ₹ 1.31 |

The benefit-cost (B:C) ratio of okra cultivation differed significantly as a result of different treatments, reflecting clear differences in economic efficiency among fertilizer and nanourea (NU) regimes (table 4). The highest B:C ratios were recorded in treatments that combined 100% recommended dose of fertilizers (RDF) with nanourea applications. Specifically, the application of 100% RDF alone (T₂) resulted in a B:C ratio of 1.79, while supplementing 100% RDF with a single (T₃) or two (T₄) NU applications further improved the B:C ratio to 1.82 and 1.85, respectively, with T₄ achieving the maximum economic return. Reducing the RDF to 75% and supplementing with NU applications (T₅ and T₆) led to moderate declines in the B:C ratio, with values of 1.59 and 1.64, respectively, yet these remained superior to the control. Further reduction to 50% RDF with NU (T₇ and T₈) resulted in B:C ratios of 1.47 and 1.51, indicating a progressive decrease in profitability as the RDF level was lowered, even when nano urea was applied. Overall, the results highlight that maximum economic efficiency in okra production was achieved with the integration of 100% RDF and two NU applications, while reduced fertilizer regimes, even with NU supplementation, compromised profitability.

These results are in conformity with the findings of Meena and Bhati (2016) and Chawla *et al.* (2018). Brar and Singh (2016) also revealed that the gross and net returns were higher at higher doses of nitrogen. However, Subramani *et al.* (2023) observed that utilizing nano application with N66PK and 0.4% nano urea resulted in higher net return (Rs. 541876 ha-1) and B:C ratio (4.64), which was followed by N100PK with net return of Rs. 476315 ha-1 and 4.21 B:C ratio.

**DISCUSSION**

Nitrogen (N) is a cornerstone of plant life, serving as the main component of chlorophyll and plays a vital role in synthesizing carbohydrates and proteins. It actively drives essential developmental processes such as division of cells, their enlargement, internodal elongation, photosynthesis, branching and other metabolic processes, which are vital for energy production (Chandra, 1990). The effectiveness of nanourea, particularly when applied *via* foliar application, stems from its minute particle size and vast surface area. These properties allow for rapid penetration into plant tissues, significantly boosting nitrogen use efficiency (Rajasekar *et al.,* 2015; Sharma *et al.,* 2022b). Furthermore, nano fertilizers improve the solubility and dispersion of otherwise insoluble nutrients, facilitating efficient absorption by plants (Veronica *et al.,* 2015). Some research also suggests that nano fertilizers release nutrients slowly and steadily into the soil, sustaining the plant's nutrient supply and thereby improving overall growth (Subramaniain and Sharmila, 2009). Therefore, an additional application of nitrogen *via* IFFCO Nanourea over 100% RDF helps to enhance growth parameters in okra. These findings align with previous research in okra by Ojha *et al.* (2022), Kumar *et al.* (2023) and Subramani *et al.* (2023).

However, it is worth mentioning that reducing the RDF to 75% or 50% along with nanourea application (T5, T6, T7 and T8) resulted in intermediate growth and yield attributes, suggesting that while nanourea can improve nutrient use efficiency, it may not fully compensate for the reduction in the primary fertilizer dose under the experimental conditions. The reduced performance of treatments with lower RDF levels highlights the importance of balanced nutrition for seed development.

**CONCLUSION**

This study conclusively demonstrates that combining fertilizer doses with nanourea applications significantly enhance the growth of okra cv. 'Hisar Unnat' under spring-summer conditions. Our findings suggest that treatment T4, which included 100% recommended fertilizer dose (100 kg Nitrogen per hectare and 60 kg P2O5 per hectare) alongside two applications of nanourea at 4 ml/l at 25 and 40 DAS, is the most effective approach. This specific combination can be confidently recommended to farmers for boosting the growth, productivity and profitability of okra under field conditions.

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