E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(9): 44-48
Received: 23-07-2025
Accepted: 27-08-2025

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Performance of okra (*Abelmoschus esculentus* (L.) Moench) under different fertilizer management

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DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i9a.3726

Abstract
Sustainable okra farming can be achieved by using precision nutrient management and advanced application methods to improve vegetative growth and overall productivity. A field investigation was carried out during the *rabi* 2024-25 season, at the Instructional Farm, Department of Agronomy, College of Agriculture, Dapoli, Maharashtra to evaluate the effect of different fertilizer application methods and doses on performance of okra (*Abelmoschus esculentus* L.). The experiment was arranged in a strip-plot design with three vertical strip treatments *viz*., soil application (M_1), fertigation (M_2) and soil test-based fertigation (M_3); and four horizontal strip treatments *viz*., absolute control (F_0), 60 per cent recommended dose of fertilizer (F_1), 80 per cent recommended dose of fertilizer (F_2) and 100 per cent recommended dose of fertilizer (F_3). The findings revealed that, the treatment soil test-based fertigation (M_3) significantly enhanced plant growth parameters *viz.*, plant height, number of functional leaves per plant, number of branches per plant and dry matter accumulation per plant and yield components i.e. number of fruits per plant, fruit yield per plant and fruit yield per hectare while maintaining post-harvest soil fertility. Among fertilizer doses, the treatment 100 per cent recommended dose of fertilizer (F_3) demonstrated superior performance in growth attributes and yield, often performing on par with the treatment 80 per cent recommended dose of fertilizer. Among all the treatment combinations, plants receiving soil test-based fertigation with 100 per cent fertilizer dose (M_3F_3) showed significantly higher growth parameters, number of fruits per plant, fruit yield per plant and maximum fruit yield per hectare compared to other treatment combinations under study. These results suggest that, precision fertigation based on soil testing coupled with balanced fertilization can significantly improve okra productivity while maintaining soil health.

Keywords: Okra, growth and yield, fertilizer application methods, fertilizer doses, fertigation, soil test-based fertigation

Introduction
Okra scientifically referred to as *Abelmoschus esculentus (L.)* Moench, is commonly called as "lady's finger". Okra is one of the oldest and most traditional vegetable crop as cultivated in tropical and subtropical lowland areas across Asia, Africa, America and the warmer regions of the Mediterranean (Martin *et al*., 1979) [8]. India is the largest producer of okra in the world, which contributes in the production of okra with 7.31 million tonnes of production obtained from an area of 5.57 lakh hectares with productivity of 13.12 tonnes per hectare during 2023-24. The area under the okra crop in Maharashtra during 2023- 24 was 0.13 lakh hectares with the production of 0.14 million tonnes (Anonymous, 2024) [1]. As a short-duration crop, okra requires precise nutrient management, as fertilization practices critically impact its growth, yield and quality. Among the essential plant nutrients nitrogen, phosphorus and potash play crucial roles in both the vegetative and reproductive phases of crops (Das *et al*., 2014; Lakra *et al*., 2017) [4, 7]. Indian farmers primarily rely on surface irrigation and manual fertilizer application for cultivating okra, which often results in low water use efficiency and reduced productivity. Adopting deficit irrigation through drip systems can expand the irrigated area, while the use of mulch helps retain soil moisture for extended periods, enhancing crop growth and yield. Fertilizer application via drip irrigation improves nutrient availability in the soil profile compared to traditional methods, promoting better plant growth (Mushar *et al*., 2020) [9].
The growth, yield and quality of crops are significantly affected by the soil's fertility status, in addition to the genetic potential of the variety. Enhancing crop productivity can be achieved by

modifying soil nutrients and fertility through the application of balanced and sufficient amounts of essential nutrients such as nitrogen, phosphorus and potassium, tailored to the specific needs of the crop (Rajaraman and Pugalendhi, 2013) [14].

The fertilizer needs of crops differ based on their production potential and their capacity to extract nutrients from both natural and applied sources. Consequently, the amount of fertilizer required depends on the soil's initial nutrient levels, making soil testing a critical factor. Additionally, the fertilizer requirement is influenced by the desired yield target. To achieve a specific yield, a precise amount of nutrients must be supplied which can be determined by considering the contributions from both soil nutrients and applied fertilizers. This approach serves as the foundation for fertilizer recommendations aimed at achieving targeted crop yields (Subba-Rao and Srivastava, 2001) [17]. Ramesh *et al*., (2013) [15] found that, by using soil test-based fertilizer application in a castor-sorghum cropping system led to a 16-17% increase in system productivity and economic returns compared to applying standard recommended fertilizer doses.

The research titled "Performance of okra (*Abelmoschus esculentus* (L.) Moench) under different fertilizer management" focuses on evaluating the impact of various fertilizer application methods and doses on the growth and yield of okra. The research can offer region-specific insights into optimizing fertilizer management for okra which is a widely grown vegetable in this area. By evaluating different fertilizer application methods and doses, the study can help farmers in the Konkan region and across India enhance okra yield and productivity contributing to food security and economic growth. The study can promote balanced fertilization practices, reducing overuse or underuse of fertilizers, thereby improving soil health and sustainability in the long term.

Materials and Methods

The present study titled "Performance of okra (*Abelmoschus esculentus* (L.) Moench) under different fertilizer management" was carried out at the Instructional Farm of the Department of Agronomy, College of Agriculture, Dapoli, located in district Ratnagiri, Maharashtra during the *rabi* season 2024-25. The site is geographically located at 17°45' N latitude and 73°1' E longitude, with an elevation of approximately 250 m above mean sea level. The experimental field exhibited a well-drained sandy clay loam textured soil, categorized under Alfisol, with initial soil properties indicating low available nitrogen (188.16 kg ha^{-1}), medium in available phosphorus (15.51 kg ha^{-1}), medium in available potassium (266.67 kg ha^{-1}), high organic carbon (15.3 g kg^{-1}) and acidic in pH (5.3).

A strip-plot design was employed for this study, featuring a factorial arrangement of treatments. The vertical strip consisted of three fertilizer application methods: soil application (M_1), fertigation (M_2) and soil test-based fertigation (M_3). In the fertigation treatments (M_2 and M_3), nutrients were applied in 12 equal splits at weekly interval. The horizontal strip comprised four fertilizer doses: absolute control (F_0), 60 per cent recommended dose of fertilizer (F_1), 80 per cent recommended dose of fertilizer (F_2) and 100 per cent recommended dose of fertilizer (F_3). This design resulted in twelve treatment combinations, each replicated thrice. The gross plot size was 4.50 m x 3.60 m, with a net plot size of 3.60 m x 3.00 m. Common agronomic practices across all treatments included the use of silver-black polythene mulch, drip irrigation and raised bed cultivation.

The experiment utilized the high-yielding okra variety 'Hybrid Indus-161', selected for its upright growth habit, vigorous development and strong branching characteristics. Seeds were sown using the dibbling method at a spacing of 45 cm x 30 cm, with a single seed placed per hill. The seed rate was maintained at 4-4.5 kg per hectare. A recommended fertilizer dose of 100:50:50 kg N:P_2O_5: K_2O per hectare was used. In the treatment soil application (M_1), a basal dose consisting of 40% N, 100% P_2O_5 and 100% K_2O was applied using urea, single superphosphate (SSP) and muriate of potash (MOP). The remaining nitrogen was applied in two split applications: 40% through drip irrigation at 30 days after sowing (DAS) and the final 20% at 60 DAS. For the treatments fertigation (M_2) and soil test-based fertigation (M_3), water-soluble fertilizers (grade 19:19:19 and urea) were delivered via a venturi system. In the fertigation treatment (M_2), the full RDF was applied. In the treatment soil test-based fertigation (M_3), the nutrient dose was adjusted to 125:50:50 kg ha^{-1} of N:P_2O_5:K_2O based on initial soil analysis.

All collected data were subjected to Analysis of Variance (ANOVA) as per Fisher's method and the results were interpreted in accordance with the statistical procedures described by Gomez and Gomez (1984) [6].

Results and Discussion

1. Growth studies

Effect of methods of fertilizer application

The data given in the Table 1 indicates that, the plant height (cm), number of leaves $plant^{-1}$, number of branches $plant^{-1}$ and dry matter accumulation $plant^{-1}$ (g) were significantly influenced due to methods of fertilizer application at harvest. The treatment soil test based fertigation (M_3) recorded the significantly higher plant height (76.50 cm), number of functional leaves $plant^{-1}$ (20.00), number of branches $plant^{-1}$ (3.21) and dry matter accumulation $plant^{-1}$ (28.83 g) over rest of the treatments. These findings align with those reported by Nawghare *et al.* (2021) [12], who observed that, the soil test-based fertigation enhanced plant height, number of leaves $plant^{-1}$, number of branches $plant^{-1}$ and dry matter accumulation $plant^{-1}$ in okra. Additionally, Asawale *et al.* (2019) [2], who noted that, the fertigation with 100 per cent RDF recorded significantly higher plant height, number of leaves $plant^{-1}$, number of branches $plant^{-1}$ and dry matter accumulation $plant^{-1}$ of okra as compared to conventional soil application supporting the present findings.

Table 1: Plant height of okra as influenced periodically by methods of fertilizer application and fertilizer dose during *rabi season* 2024-25.

Treatments	Growth parameters at last harvest			
	Plant height (cm)	Number of functional leaves $plant^{-1}$	Number of branches $plant^{-1}$	Dry matter accumulation $plant^{-1}$ (g)
A] Methods of fertilizer application				
M_1 - Soil application	65.91	16.56	64.27	65.91
M_2 – Fertigation	69.93	17.60	67.33	69.93
M_3 - Soil test based fertigation	76.50	20.00	73.38	76.50
S.E.(m)±	1.54	0.51	1.34	1.54
C.D. at 5%	6.06	2.00	5.25	6.06

B] Fertilizer dose				
F_0- Absolute control	52.45	33.43	49.73	13.63
F_1- 60% Recommended dose of fertilizer	73.68	46.72	71.28	17.44
F_2- 80% Recommended dose of fertilizer	76.71	49.79	74.31	19.69
F_3- 100% Recommended dose of fertilizer	80.28	53.49	77.98	21.45
S.E.(m)±	4.17	2.91	4.23	1.13
C.D. at 5%	14.44	10.08	14.64	3.89
C] Interaction effect				
S.E.(m)±	1.51	1.01	1.55	0.87
C.D. at 5%	4.64	3.11	4.76	2.69
General mean	70.78	45.86	68.33	18.05

(**Note: M_3**: 125:50:50 kg $N:P_2O_5:K_2O$ ha^{-1})

Effect of fertilizer doses

The data given in the Table 1 indicates that, the plant height (cm), number of leaves $plant^{-1}$, number of branches $plant^{-1}$ and dry matter accumulation $plant^{-1}$ (g) were significantly influenced due to different fertilizer doses at harvest. The treatment 100 per cent fertilizer dose (F_3) recorded significantly higher plant height (80.28 cm), number of functional leaves $plant^{-1}$ (21.45), number of branches $plant^{-1}$ (3.35) and dry matter accumulation $plant^{-1}$ (30.61 g) over rest of the treatments. However, treatment 100 per cent RDF (F_3) was at par with treatments 80 per cent RDF (F_2) and 60 per cent RDF (F_1) in respect of plant height and number of branches per plant. In case of number of functional leaves per plant and dry matter production per plant, the treatment 100 per cent RDF (F_3) was statistically at par with the 80 per cent RDF (F_2) at all the growth stages. These findings align with the observations of Kumar *et al.* (2020) [6], who reported that, the 100 per cent recommended NPK dose resulted in the taller plants, higher leaf count, number of branches and dry matter accumulation per plant. The improved growth under higher fertilizer doses can be attributed to better nutrient availability, as supported by Singh *et al.* (2014) [16], who observed increased branching with elevated NPK application.

Interaction effect

The data presented in Tables 2 and 3 indicates a interaction effect between fertilizer application methods and fertilizer doses. This interaction effect between fertilizer application methods and fertilizer doses significantly influenced plant height (cm), number of leaves $plant^{-1}$, number of branches $plant^{-1}$ and dry matter accumulation $plant^{-1}$ (g) of the okra crop at the harvest stage. The treatment combination of soil test-based fertigation with 100 per cent fertilizer dose (M_3F_3) recorded significantly higher values for different growth parameters compared to all other treatment combinations. The higher plant height (80.28 cm), number of functional leaves $plant^{-1}$ (21.45), number of branches $plant^{-1}$ (3.35) and dry matter accumulation $plant^{-1}$ (30.61 g) were observed. However, the treatment combination of soil test-based fertigation with 100 per cent fertilizer dose (M_3F_3) was at par with soil test-based fertigation with 80 per cent dose (M_3F_2) at last harvest in respect to plant height and number of branches $plant^{-1}$. These results are in accordance with those of Venkadeswaran *et al.* (2016) [18], Nagegowda *et al.* (2020) [10] in okra crop.

Table 2: Interaction effect of methods of fertilizer application and fertilizer dose at last harvest on plant height and number of functional leaves per plant of okra during *rabi* 2024-25.

Treatment	Plant height (cm)				Number of functional leaves $plant^{-1}$			
	F_0	F_1	F_2	F_3	F_0	F_1	F_2	F_3
M_1	51.28	68.36	70.54	73.44	14.19	15.31	17.65	19.08
M_2	51.80	72.71	75.59	79.62	13.45	17.05	19.32	20.56
M_3	54.26	79.96	84.00	87.78	13.24	19.95	22.10	24.72
S.E.(m)±	1.51				0.87			
C.D. 5%	4.64				2.69			

Table 3: Interaction effect of methods of fertilizer application and fertilizer dose at last harvest on number of branches per plant and dry matter accumulation per plant of okra during *rabi* 2024-25.

Treatment	Number of branches $plant^{-1}$				Dry matter accumulation $plant^{-1}$			
	F_0	F_1	F_2	F_3	F_0	F_1	F_2	F_3
M_1	1.23	1.93	2.52	2.91	16.77	20.23	22.15	26.85
M_2	1.33	2.69	2.95	3.33	21.23	23.33	25.66	28.29
M_3	1.90	3.46	3.68	3.82	18.13	29.63	30.87	36.69
S.E.(m)±	0.11				1.55			
C.D. 5%	0.35				4.76			

2. Yield studies

Effect of methods of fertilizer application

The data pertaining to the yield parameters *viz.*, number of fruits per plant, fruit yield per plant (g) and fruit yield (kg ha^{-1}) as influenced by the different fertilizer application methods and fertilizer doses are presented in Table 4. The statistical analysis of the data revealed that, the treatment soil test-based fertigation (M_3) produced significantly higher fruit number per plant (22.98), fruit yield per plant (260.04 g) and fruit yield (20,528.24 kg ha^{-1}) as compared to rest of the treatments under the study. These findings align with Venkadeswaran *et al.* (2014) [19], observed that, the fertigation with water-soluble fertilizers significantly increased fruit yield of okra over conventional soil application of fertilizers. Similarly, Nawghare *et al.* (2021) [12], who reported that, the drip fertigation based on soil test values resulted in the higher number of fruits per plant and fruit yield of okra as compared to conventional methods.

Effect of fertilizer doses

The number of fruits per plant, fruit yield per plant (g) and fruit

yield (kg ha^{-1}) was significantly influenced by the different fertilizer doses under study. Among the four fertilizer dose treatments, the treatment 100 per cent RDF (F_3) produces significantly higher number of fruits per plant (24.89), fruit yield per plant (278.36 g) and fruit yield (23237.65 kg ha^{-1}). In case of number of fruits per plant and fruit yield per plant, the treatment 100 per cent RDF (F_3) was at par with treatments 80 per cent RDF (23.61 and 267.01 g, respectively) and 60 per cent RDF (F_1) (22.76 and 257.05 g, respectively) during the *rabi*, 2024-25 season. These findings align with previous studies. Bhatt *et al.* (2022) [3], observed higher fruit counts with full-dose water-soluble fertilizers in *summer* okra. Padmanabha *et al.* (2018) [13], noted that, 100 per cent RDF through fertigation enhanced fruit weight per plant in okra, corroborating the present results. The superior yield under treatment 100 per cent RDF (F_3) is supported by Nair *et al.* (2017) [11], who recorded maximum okra yield with full-dose of fertigation.

Interaction effect

The data pertaining interaction between methods of fertilizer application and fertilizer dose are presented in Table 5 and 6 revealed that, the combination of treatment soil test-based fertigation with 100 per cent fertilizer dose (M_3F_3) produced significantly higher number of fruits per plant (27.04), fruit yield per plant (310.84 g) and fruit yield (28780.86 kg ha^{-1}) demonstrating superior performance over all other treatment combinations. However, the treatment combination of soil test-based fertigation with 100 per cent fertilizer dose (M_3F_3) was at par with soil test-based fertigation with 80 per cent fertilizer dose (M_3F_2) over rest of the treatment combinations under study with respect to fruit yield per plant. These outcomes align with previous findings by Padmanabha *et al.* (2018) [13] and Nawghare *et al.* (2021) [12] regarding efficient nutrient management in okra production.

Table 4: Yield parameters of okra as influenced periodically by methods of fertilizer application and fertilizer dose during *rabi* season 2024-25.

Treatments	Number of fruits plant^{-1}	Fruit yield plant^{-1} (g)	Fruit yield (kg ha^{-1})
A] Methods of fertilizer application			
M_1 – Soil application	19.98	223.91	15432.10
M_2 – Fertigation	21.21	236.17	16169.75
M_3 – Soil test based fertigation	22.98	260.04	20528.24
S.E.(m)±	0.44	5.30	795.05
C.D. at 5%	1.71	20.82	3121.27
B] Fertilizer dose			
F_0– Absolute control	14.29	157.75	5275.31
F_1– 60% Recommended dose of fertilizer	22.76	257.05	19890.12
F_2– 80% Recommended dose of fertilizer	23.61	267.01	21103.70
F_3–100% Recommended dose of fertilizer	24.89	278.36	23237.65
S.E.(m)±	1.60	18.52	2728.47
C.D. at 5%	5.55	64.07	9440.31
C] Interaction effect			
S.E.(m)±	0.44	6.86	968.37
C.D. at 5%	1.37	21.14	2983.41
General mean	21.39	240.04	17376.70

(**Note: M_3**: 125:50:50 kg N:P_2O_5:K_2O ha^{-1})

Table 5: Interaction effect of methods of fertilizer application and fertilizer dose on number of fruits per plant and fruit yield per plant (g) of okra crop during *rabi* season 2024-25.

Treatment	Number of fruits plant^{-1}				Fruit yield plant^{-1} (g)			
	F_0	F_1	F_2	F_3	F_0	F_1	F_2	F_3
M_1	13.68	20.82	22.47	22.95	150.85	242.50	248.58	253.72
M_2	14.49	22.58	23.06	24.70	163.75	250.42	260.01	270.52
M_3	14.71	24.89	25.28	27.04	158.64	278.23	292.45	310.84
S.E.(m)±	0.44				6.86			
C.D. 5%	1.37				21.14			

Table 6: Interaction effect of methods of fertilizer application and fertilizer dose on fruit yield per hectare (kg ha^{-1}) of okra crop during *rabi* season 2024-25.

Treatment	Fruit yield (kg ha^{-1})			
	F_0	F_1	F_2	F_3
M_1	5006.17	18104.94	18456.79	20160.49
M_2	4265.43	19364.81	20277.16	20771.60
M_3	6554.32	22200.62	24577.16	28780.86
S.E.(m)±	968.37			
C.D. 5%	2983.41			

Conclusion

The experiment revealed that, among the different fertilizer application methods and fertilizer doses, the treatment soil test-based fertigation with 100 per cent fertilizer dose demonstrated significantly superior performance in terms of growth and yield of okra crop. It is concluded that, soil test-based fertigation with 100 per cent fertilizer dose (125:50:50 kg N:P_2O_5:K_2O ha^{-1}) with raised bed and polythene mulch be used for obtaining higher growth and yield through okra cultivation under Konkan condition.

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