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Response of okra [*Abelmoschus esculentus* (L.) Moench] to different methods and levels of fertilizer application

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ABSTRACT

A field experiment was conducted during the rabi season of 2025–26 at the Instructional Farm, Department of Agronomy, College of Agriculture, Dapoli, Maharashtra, to study the response of okra [*Abelmoschus esculentus* (L.) Moench] to different methods and levels of fertilizer application. The experiment was laid out in a strip plot design with three vertical strip treatment involves fertilizer application methods, viz., soil application (M_1), fertigation (M_2) and conventional method (50%) + fertigation (50%) (M_3), and horizontal strip treatment involves four fertilizer doses, viz., 100% RDF (F_1), 125% RDF (F_2), 150% RDF (F_3) and soil-test-based fertilizer dose (F_4), resulting in 12 treatment combinations replicated three times. The variety Hybrid Indus-161 was grown at 45×30 cm spacing with drip irrigation and silver-black polythene mulch. Fertigation was imposed in 14 equal splits at seven-day intervals. The findings revealed that, the treatment fertigation (M_2) 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 fertility. Among fertilizer doses, treatment 150% recommended dose of fertilizer (F_3) demonstrated superior performance in growth attributes and yield, often performing on par with the treatment 125 % recommended dose of fertilizer. Among all the treatment combinations, plants receiving fertigation with 150 percent recommended dose of fertilizer (M_2F_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. Overall, the experiment demonstrated a strong response of okra to fertigation and increased fertilizer supply under the experimental conditions of the Konkan region.

Keywords: Okra, growth and yield, fertilizer application methods, fertilizer doses, fertigation

Introduction

Okra (*Abelmoschus esculentus* L.), commonly known as lady's finger or bhendi, is an important annual herbaceous vegetable crop belonging to the Malvaceae family. The crop is believed to have originated in Africa, particularly in Ethiopia (Singh *et al.*, 1967) [1]. The crop thrives well under hot and humid climatic conditions but is highly sensitive to frost and extremely low temperatures. An optimum temperature range of 24 °C to 28 °C is considered ideal for its growth and development. Although okra can be grown in a wide range of soil types, from sandy to clayey soils, it performs best in light-textured, well-drained, and fertile soils due to its deep taproot system. A soil pH ranging from 6.0 to 6.8 is regarded as optimum for successful cultivation. Okra is a rich source of essential nutrients. Every 100 g of edible portion of okra contains approximately 1.9–2.4 g of protein, appreciable amounts of dietary fiber, and important minerals such as calcium, phosphorus, iron, and potassium.

India is the world's leading producer of okra. The crop was cultivated over an area of 5.57 lakh hectares, producing 7.31 million tonnes with an average productivity of 13.12 tonnes per hectare, during 2023–24. The major okra-producing states in India are Andhra Pradesh, Bihar, Assam, and Gujarat. In Maharashtra, okra occupied an area of 0.13 lakh hectares during 2023–24, with a total production of 0.14 million tonnes. However, Maharashtra state average productivity of 10.79 tonnes per hectare remained below the national average of 13.12 tonnes per hectare (Anonymous, 2024) [2]. Okra possesses significant potential as an export-oriented fresh vegetable crop. India exports substantial quantities of okra to markets in West Asia, Western Europe, and the United States. Okra responds favorably to fertilizer application and is recognized as a nutrient-exhaustive crop with high requirements for nitrogen, phosphorus, and potassium. The efficient management of fertilizers and irrigation water is essential for sustaining agricultural productivity. Okra produced for a long time and therefore requires a continuous, balanced, and adequate supply of nutrients to achieve optimum yield and superior pod quality. The excessive and unregulated application of inorganic fertilizers have been associated with reduced nutrient-use efficiency, deterioration in vegetable quality, and degradation of soil health (Agrawal, 2003) [3]. Fertigation has emerged as a widely adopted and advanced nutrient manage

ment practice in vegetable cultivation, as it enables the application of nutrients in precise quantities and at critical stages of crop growth. This method promotes early crop maturity and enhances the quality of produce. Through fertigation, nutrients are delivered directly to the active root zone via drip emitters, resulting in improved nutrient availability and higher fertilizer use efficiency compared to conventional fertilizer application methods. The integration of fertigation with drip irrigation represents an innovative approach for maximizing crop productivity. Although the initial investment required for a drip irrigation system is relatively high, its long operational lifespan ensures that the benefits derived from the system can be realized over an extended period. Fertigation also involves additional expenditure on water-soluble fertilizers; however, this cost is generally offset by the increased yields, superior produce quality, and higher net returns obtained from the crop (Rajaraman *et al.*, 2013) [4].

The drip fertigation is considered a highly efficient method of nutrient delivery, as it facilitates accurate placement and controlled application of water-soluble fertilizers. Additionally, it helps minimize nutrient losses through leaching, thereby reducing the risk of groundwater contamination and promoting environmentally sustainable crop production (Pawar *et al.*, 2013) [5]. In okra, the application of nitrogen, phosphorus, and potassium through irrigation water has been reported to result in higher yields compared to the conventional soil application of the recommended fertilizer dose (Venkadeswaran *et al.*, 2014) [6].

The research entitled “Response of okra [*Abelmoschus esculentus* (L.) moench] to different methods and levels of fertilizer application” focuses on evaluating the impact of various fertilizer application methods and doses on the growth and yield of okra. The study can help by evaluating different fertilizer application methods and doses to farmers in the Konkan region and across India to enhance okra yield and productivity contributing to food security and economic growth.

Materials and Methods

The present study entitled “Response of okra (*Abelmoschus esculentus* (L.) Moench) to different methods and levels of fertilizer application” 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 2025-26. 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 (229 kg ha⁻¹), medium in available phosphorus (16 kg ha⁻¹), medium in available potassium (225.9 kg ha⁻¹), organic carbon (11.6 g kg⁻¹) and acidic in pH (5.5). A strip-plot design was employed for this study. The vertical strip consisted of three fertilizer application methods: soil application (M₁), fertigation (M₂) and conventional method (50%) + fertigation (50%) (M₃). In the fertigation treatments (M₂ and M₃), nutrients were applied in 14 equal splits at weekly interval. The horizontal strip comprised four fertilizer doses: 100 per cent recommended dose of fertilizer (F₁), 125 per cent recommended dose of fertilizer (F₂), 150 per cent recommended dose of fertilizer (F₃) and soil test based fertilizer dose (F₄). 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. The 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 hybrid variety of okra ‘Hybrid Indus-161’, selected for its upright growth habit, vigorous development and strong branching characteristics. The 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:P₂O₅:K₂O per hectare was used.

In the treatment soil application (M₁), a basal dose consisting of 40% N, 100% P₂O₅ and 100% K₂O was applied using urea, single super-phosphate (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. The water-soluble fertilizers (grade 19:19:19 and urea) were delivered via a venturi system for treatments fertigation (M₂) and conventional method (50%) + fertigation (50%) (M₃). The fertilizer application for treatment conventional method (50%) + fertigation (50%) (M₃) was done by applying 50 per cent dose by soil application method and 50 per cent through fertigation by using urea and 19:19:19 water-soluble fertilizer. In the treatment soil test-based fertilizer dose (F₄), the nutrient dose was adjusted to 125:50:45 kg ha⁻¹ of N:P₂O₅:K₂O 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) [7].

Results and Discussion

Growth studies

Table 1. Growth parameters of okra as influenced by methods of fertilizer application and fertilizer dose during rabi season 2025-26.

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	56.01	8.28	3.06	17.67
M ₂ - Fertigation	61.14	9.23	3.52	19.58
M ₃ - Conventional method (50%) + fertigation (50%)	57.58	8.65	3.21	18.17
S.E. (m) ±	0.78	0.14	0.07	0.29
C.D. at 5%	3.06	0.53	0.27	1.13
B] Fertilizer dose				
F ₁ - 100% RDF	47.74	7.20	2.66	16.22
F ₂ - 125% RDF	61.53	9.11	3.42	18.89
F ₃ - 150 % RDF	71.36	10.11	4.03	21.00
F ₄ - Soil test based fertilizer dose	52.34	8.47	2.93	17.78
S.E. (m) ±	3.50	0.41	0.20	0.67
C.D. at 5%	12.10	1.41	0.69	2.32
C] Interaction effect				

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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)
S.E. (m) ±	1.02	0.17	0.06	0.65
C.D. at 5%	3.15	0.53	0.18	2.01
General mean	58.19	8.71	3.26	18.47

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 fertigation (M₂) recorded the significantly higher plant height (61.14 cm), number of functional leaves plant⁻¹ (9.23), number of branches plant⁻¹ (3.52) and dry matter accumulation plant⁻¹ (19.58 g) over treatment soil application (M₁) and was at par with treatment conventional method (50%) + fertigation (50%) (M₃) in respect of number of branches per plant at last harvest during rabi season 2025-26. The present findings are in agreement with the observations of Adawadkar (2018) [8], who reported that the drip fertigation with 150 % RDF significantly improved plant growth parameters such as increased plant height, more branches per plant and canopy cover compared to traditional method in brinjal. Similar findings were reported by Padmanabha *et al.* (2018) [9] and Hadole *et al.* (2020) [10], who observed that fertigation resulted in a greater number of leaves and branches per plant in okra. Venkadeswaran *et al.* (2014) [6], who reported that fertigation with water soluble fertilizers significantly enhances key growth attributes of okra including plant height, and dry matter production compared to conventional fertilization methods.

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 150 per cent fertilizer dose (F₃) recorded significantly higher plant height (71.36 cm), number of functional leaves plant⁻¹ (10.11), number of branches plant⁻¹ (4.03) and dry matter accumulation plant⁻¹ (21.00 g) over rest of the treatments under study except treatments 125 per cent RDF (F₂). The treatments 125 per cent RDF (F₂) was at par with treatment 150 per cent RDF (F₃) in respect of plant height, number of functional leaves and dry matter accumulation per plant. These findings align with Adawadkar (2018) [8], who reported that the application of 150 per cent RDF resulted in higher plant growth and more number of branches in brinjal. Similarly, Aseffa *et al.* (2020) [11] reported that the maximum (150 kg ha⁻¹) Nitrogen rate resulted in luxuriant vegetative growth. The improved vegetative growth under higher fertilizer doses may be attributed to the greater availability of essential nutrients required for cell division, cell elongation and overall plant development. Supporting this explanation, Singh *et al.* (2014) and Hadole *et al.* (2020) [10] reported increased branching in okra with increasing levels of NPK application.

Interaction effect

Table 2. Interaction effect of methods of fertilizer application and fertilizer dose at last harvest on plant height of okra during rabi 2025-26.

Treatment	Plant height (cm)			
	F ₁	F ₂	F ₃	F ₄
M ₁	47.57	59.40	67.87	48.53
M ₂	48.07	65.13	75.73	55.63
M ₃	47.60	60.07	70.47	52.20
S.E. (m) ±	1.02			
C.D. at 5%	3.15			

Table 3. Interaction effect of methods of fertilizer application and fertilizer dose at last harvest on Number of functional leaves plant⁻¹ of okra during rabi 2025-26.

Treatment	Number of functional leaves plant ⁻¹			
	F ₁	F ₂	F ₃	F ₄
M ₁	6.40	8.73	9.73	8.27
M ₂	8.07	9.47	10.73	8.67
M ₃	7.13	9.13	9.87	8.47
S.E. (m) ±	0.17			
C.D. at 5%	0.53			

Table 4. Interaction effect of methods of fertilizer application and fertilizer dose at last harvest on Number of branches plant⁻¹ of okra during rabi 2025-26.

Treatment	Number of branches plant ⁻¹			
	F ₁	F ₂	F ₃	F ₄
M ₁	2.49	3.23	3.74	2.79
M ₂	2.79	3.74	4.40	3.15
M ₃	2.71	3.30	3.96	2.86
S.E. (m) ±	0.06			

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Treatment	Number of branches plant ⁻¹			
	F ₁	F ₂	F ₃	F ₄
C.D. at 5%		0.18		

Table 5. Interaction effect of methods of fertilizer application and fertilizer dose at last harvest on Dry matter accumulation plant⁻¹ of okra during rabi 2025-26.

Treatment	Dry matter accumulation plant ⁻¹			
	F ₁	F ₂	F ₃	F ₄
M ₁	15.33	18.67	19.33	17.33
M ₂	17.00	19.00	24.00	18.33
M ₃	16.33	19.00	19.67	17.67
S.E. (m) ±		0.65		
C.D. at 5%		2.01		

The data presented in Tables 2, 3, 4 and 5 indicates that the 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 harvest stage. The treatment combination of fertigation with 150 per cent fertilizer dose (M₂F₃) recorded significantly higher values for plant height (75.73 cm), number of functional leaves

plant⁻¹ (10.73), number of branches plant⁻¹ (4.40) and dry matter accumulation plant⁻¹ (24 g) growth parameters compared to all other treatment combinations under study. These results are in accordance with those of Venkadeswaran *et al.* (2016) [12], Nagegowda *et al.* (2020) [13] and Adawadkar (2018) [8].

2. Yield studies

Table 6. Yield parameters of okra as influenced periodically by methods of fertilizer application and fertilizer dose during rabi season 2025-26.

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	16.35	164.57	11327.08
M ₂ - Fertigation	18.58	196.77	12476.41
M ₃ - Conventional method (50%) + fertigation (50%)	17.27	172.25	12033.29
S.E. (m) ±	0.32	4.85	167.33
C.D. at 5%	1.27	19.06	656.94
B] Fertilizer dose			
F ₁ - 100% RDF	14.29	135.02	9839.73
F ₂ - 125% RDF	18.76	190.29	11956.69
F ₃ - 150 % RDF	19.46	215.22	14945.68
F ₄ - Soil test based fertilizer dose	17.09	170.91	11040.26
S.E. (m) ±	0.77	11.28	726.61
C.D. at 5%	2.65	39.02	2514.02
C] Interaction effect			
S.E. (m) ±	0.52	6.56	273.59
C.D. at 5%	1.60	20.21	842.87
General mean	17.40	177.86	11945.59

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 6. The statistical analysis of the data revealed that, the treatment fertigation (M₂) produced significantly higher fruit number per plant (18.58), fruit yield per plant (196.77 g) and fruit yield (12476.41 kg ha⁻¹) as compared to rest of the treatments under the study except treatment conventional method (50%) + fertigation (50%) (M₃) with respect to fruit yield (kg ha⁻¹). The treatment conventional method (50%) + fertigation (50%) (M₃) was at par with treatment fertigation (M₂) in respect of fruit yield (kg ha⁻¹). The present findings are in accordance with Adawadkar (2018) [8], who reported that fertigation significantly increased fruit yield of okra compared with traditional method of fertilizer application. Similarly, Agrawal *et al.* (2018) [14] observed that applying different grades of water-soluble fertilizers with fertigation method yielded better results compared to non-fertigation methods.

Effect of fertilizer doses

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 different fertilizer doses are presented in Table 6. The statistical analysis of the data revealed that 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 150 per cent RDF (F₃) produces significantly higher number of fruits per plant (19.46), fruit yield per plant (215.22 g) and fruit yield (14945.68 kg ha⁻¹) over rest of the treatments under study except treatment 125 % recommended dose of fertilizer (F₂) with respect to number of fruits per plant and fruit yield per plant (g). The treatment 125 % recommended dose of fertilizer (F₂) was at par with treatment 150 percent recommended dose of fertilizer (F₃) with respect to number of fruits per plant and fruit yield per plant (g). These findings align with Adawadkar (2018) [8], who reported that fertigation with 150 per cent RDF increased the number of fruits per plant, yield per plant and total brinjal yield.

Similarly, Philip *et al.* (2010) [15] observed that the application of 150 kg NPK ha⁻¹ resulted in higher number of fruits per plant of okra.

Interaction effect

Table 7. Interaction effect of methods of fertilizer application and fertilizer dose on number of fruits per plant of okra crop during rabi season 2025-26.

Treatment	Number of fruits plant ⁻¹			
	F ₁	F ₂	F ₃	F ₄
M ₁	12.93	17.20	18.27	17.00
M ₂	15.67	20.53	21.30	16.80
M ₃	14.27	18.53	18.80	17.47
S.E. (m) ±	0.52			
C.D. at 5%	1.60			

Table 8. Interaction effect of methods of fertilizer application and fertilizer dose on fruit yield per plant (g) of okra crop during rabi season 2025-26.

Treatment	Fruit yield plant ⁻¹ (g)			
	F ₁	F ₂	F ₃	F ₄
M ₁	115.87	176.60	196.67	169.13
M ₂	148.67	217.40	244.27	176.73
M ₃	140.53	176.87	204.73	166.87
S.E. (m) ±	6.56			
C.D. at 5%	20.21			

Table 9. Interaction effect of methods of fertilizer application and fertilizer dose on fruit yield per hectare (kg ha⁻¹) of okra crop during rabi season 2025-26.

Treatment	Fruit yield (kg ha ⁻¹)			
	F ₁	F ₂	F ₃	F ₄
M ₁	9129.26	11456.48	13775.93	10946.64
M ₂	10231.79	12812.96	15752.78	11108.10
M ₃	10158.15	11600.62	15308.33	11066.05
S.E. (m) ±	273.59			
C.D. at 5%	842.87			

The data pertaining interaction between methods of fertilizer application and fertilizer dose are presented in Table 7, 8 and 9 revealed that, the combination of treatment fertigation with 150 per cent fertilizer dose (M₂F₃) produced significantly higher number of fruits per plant (21.30), fruit yield per plant (244.27 g) and fruit yield (15752.78 kg ha⁻¹) demonstrating superior performance over all other treatment combinations under study except treatment fertigation with 125 per cent fertilizer dose (M₂F₂) in respect of number of fruits per plant. The treatment combination of fertigation with 125 per cent fertilizer dose (M₂F₂) was at par with treatment combination of fertigation with 150 per cent fertilizer dose (M₂F₃) with respect to number of fruits per plant. These outcomes align with previous findings by Padmanabha *et al.* (2018) [9], Adawadkar (2018) [8] regarding efficient nutrient management in okra production.

Conclusion

The experiment revealed that, among the different fertilizer application methods and fertilizer doses, the treatment fertigation with 150 per cent fertilizer dose demonstrated significantly superior performance in terms of growth and yield of okra crop. It is concluded that, Okra performs best when 150% recommended dose of fertilizer applied through fertigation, ensuring higher growth and yield. 21-23.

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