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Effect of inorganic fertilizers and bio-stimulants on growth, yield and quality of okra (*Abelmoschus esculentus* L. Moench) cv. Kashi Lalima

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Abstract

This study was carried out during the year 2024-25 on Horticulture research farm Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh. The plant to plant and row to row spacing were maintained at 45x30 cm respectively. The experiment was carried under Randomized Block Design (RBD) with three replications. A single standard variety Kashi Lalima released from IIVR Varanasi is sown with the different treatment combinations. The treatment combinations were T₁ (RDF) 100%, T₂ *Azospirillum* (100%), T₃ *Azotobacter* (100%), T₄ PSB (100%), T₅ RDF (50%) + *Azospirillum* (50%), T₆ RDF (50%) + *Azotobacter* (50%), T₇ RDF (50%) + PSB (50%), T₈ *Azospirillum* (50%) + *Azotobacter* (50%), T₉ *Azotobacter* (50%) + PSB (50%), T₁₀ RDF (25%) + *Azospirillum* (25%) + *Azotobacter* (25%) + PSB (25%). On the basis of overall performance under the present investigation, it may be concluded that the application of T₁₀ RDF (25%) + *Azospirillum* (25%) + *Azotobacter* (25%) + PSB (25%) in Kashi Lalima increased the growth, yield and Quality of okra under Lucknow condition. On the basis of overall performance under the present investigation, it may be concluded that the application of 50%RDF+Vermicompost in Kashi Lalima increased the growth, yield and nutritional quality of okra under Lucknow condition.

Keywords: Okra, biofertilizers, integrated nutrient management, RDF, growth and yield, quality

Introduction

Vegetables occupy a crucial place in human nutrition due to their rich contents of vitamins minerals antioxidants and crude fibre and their consistent consumption is essential for a balanced diet. India's diverse agroclimatic conditions support year-round vegetable cultivation, among which okra (*Abelmoschus esculentus* L. Moench) 2n = 130 is one of the most important crops grown across tropical and subtropical regions. Okra is valued for its tender, nutritious pods and adaptability to a wide range of soil and climatic conditions (Khalid *et al.*, 2005) [7]. It is an excellent source of vitamins A, B and C minerals fibre and iodine, contributing significantly to dietary health (Kumar *et al.*, 2009) [8].

India is the world leader in okra production, cultivating 557 thousand hectares with a production of 7305 thousand MT, with major producing states including Gujarat, Madhya Pradesh, West Bengal, Bihar and Odisha (Ministry of Agriculture and Farmers Welfare, 2024) [14]. Okra is often-cross-pollinated, with insect-mediated cross-pollination reaching up to 19% and flowers exhibit anthesis between 8-10 AM, supporting reproductive efficiency and fruit set (Kumar *et al.*, 2009) [8]. Its high average nutritional value (ANV 3.21) makes okra superior to many other vegetable crops.

Fresh pods contain high moisture, essential minerals vitamin C and significant mucilage which is highly water-soluble and used in various industrial and food applications. Dried fruits contain up to 24% protein and 22% oil while stems and residual biomass serve as raw materials for fibre and paper industries (Kumar *et al.*, 2009) [8].

Sustainable okra cultivation depends heavily on balanced nutrient supply. Over-dependence on chemical fertilizers has resulted in nutrient imbalance, soil degradation reduced soil organic matter and disturbed microflora (Mal *et al.*, 2013) [10]. To counter these issues, Integrated Nutrient Management (INM) has emerged as a promising approach, combining

inorganic fertilizers with organic manures and biofertilizers. Biofertilizers such as *Azotobacter*, *Azospirillum* and phosphate-solubilizing bacteria enhance nitrogen fixation, phosphorus solubilization, growth hormone production and soil biological activity (Bahadur and Manohar, 2001; Gayathri and Reddy, 2013) ^[2, 4]. INM not only maintains soil fertility but also improves crop yield, quality and sustainability while reducing environmental pollution (Ipsita Das and Singh, 2014) ^[5]. Adopting INM in okra helps minimize chemical fertilizer dependency, supports long-term soil health and ensures stable productivity (Adilakshmi *et al.*, 2008) ^[1].

Materials and Methods

An experiment was conducted at Horticulture Research Farm, Department of Horticulture, at Babasaheb Bhimrao Ambedkar University, Lucknow during March to June 2024-25. The experiment was laid out in randomized block design with 10 treatments replicated thrice. Total numbers of plots were 30 and the net plot size was (2.16 m²). The row to row and plant to plant distance of the experiment was maintained respectively 45 cm and 30 cm. The treatments involved were T₁ (RDF) 100%, T₂ *Azospirillum* (100%), T₃ *Azotobacter* (100%), T₄ PSB (100%), T₅ RDF (50%) + *Azospirillum* (50%), T₆ RDF (50%) + *Azotobacter* (50%), T₇ RDF (50%) + PSB (50%), T₈ *Azospirillum* (50%) + *Azotobacter* (50%), T₉ *Azotobacter* (50%) + PSB (50%), T₁₀ RDF (25%) + *Azospirillum* (25%) + *Azotobacter* (25%) + PSB (25%). 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 Department of Horticulture, at BBA University, Lucknow, 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 March 2023.

The inorganic manures were applied as basal dose before sowing, for proper decomposition, full dose of phosphorus and potassium and half dose of nitrogen as per treatment were applied just before the sowing. The remaining half dose of nitrogen was applied 30 days after sowing. All cultural practices were followed regularly during crop growth and observations were recorded on vegetative characters i.e. days to germination (50%), days to germination (100%), plant height, stem diameter, number of branches, number of leaves, number of flowers per plant, internodal length, Day to first flowering, fruiting and yield characters i.e. days to first flowering, days to 50% flowering, number of fruits per plant, fruit weight, fruit length, fruit diameter, days to first picking, fruit yield per

plant, number of seeds per fruits and bio-chemical parameters i.e. total soluble solids (⁰Brix), Titrable acidity, Ascorbic acid and Moisture content (%). The data on these parameters were subjected to statistical analysis to draw logical conclusions. The seeds were sown directly to the field. Light irrigation was given after sowing. Total of eight irrigations was done at 10 to 12 days intervals during the vegetative to reproductive phase. Crop harvesting starts from mid-April to the second fortnight of June at 2-3 days intervals.

Results and Discussion

Growth attributes

Plant height (cm)

At (30, 45 and 60 DAT) plant height varied noticeably among treatments. The highest growth was observed in T₁₀ (25% RDF + 25% *Azospirillum* + 25% *Azotobacter* + 25% PSB), which recorded (70.73 cm), indicating a strong synergistic effect of the combined biofertilizers. T₅ (50% RDF + 50% *Azospirillum*) produced the next tallest plants (67.71 cm), while the shortest plants (56.03 cm) were noted under the T₁ treatment receiving only the full recommended dose of fertilizers. This trend is also supported by Singh and Choudhary (2018) ^[19] and Meena *et al.* (2019) ^[12].

Number of leaves (cm)

A marked improvement in the number of leaves was evident across all observation stages (30, 45 and 60 DAT). The treatment T₁₀ recorded the highest leaf count (26.13 cm) leaves per plant, demonstrating the strong influence of combined biofertilizers with reduced RDF on foliage development. This was closely followed by T₅, which produced (25.20 cm) leaves per plant. In contrast, the lowest leaf number (19.01 cm) was observed in T₁, indicating that sole application of RDF was less effective in promoting leaf proliferation compared with integrated nutrient approaches.

Diameter of stem (cm)

Significant differences in stem diameter were observed among the treatments across all growth stages (30, 45 and 60 DAT). The maximum stem thickness (85.63mm) was obtained under T₁₀, highlighting the positive impact of integrating multiple biofertilizers with reduced RDF on stem robustness. This was followed by T₅ which recorded a stem diameter of (83.78mm). The minimum diameter (72.03mm) was noted in T₁ indicating that plants receiving only the recommended dose of fertilizers exhibited comparatively lower structural growth than those under integrated nutrient treatments a trend further supported by Jat *et al.* (2015) ^[6] and Reddy and Raghavendra (2017) ^[16].

Table 1: Effect of inorganic fertilizers and bio-stimulants on growth parameters of okra.

Treatment	Plant Height (cm)	Number of leaves (cm)	Diameter of stem (mm)
T ₁ -RDF (100%)	56.03	19.01	72.03
T ₂ - <i>Azospirillum</i> (100%)	61.44	21.15	76.38
T ₃ - <i>Azotobacter</i> (100%)	59.54	20.62	75.14
T ₄ -PSB (100%)	58.02	20.03	73.07
T ₅ -RDF (50%) + <i>Azospirillum</i> (50%)	67.71	25.20	83.78
T ₆ -RDF (50%) + <i>Azotobacter</i> (50%)	67.91	24.02	81.72
T ₇ -RDF (50%) + PSB (50%)	66.76	22.57	78.49
T ₈ - <i>Azospirillum</i> (50%) + <i>Azotobacter</i> (50%)	65.02	21.77	80.00
T ₉ - <i>Azotobacter</i> (50%) + PSB (50%)	63.27	21.32	76.59
T ₁₀ -RDF (25%) + <i>Azospirillum</i> (25%) + <i>Azotobacter</i> (25%) + PSB (25%)	70.73	26.13	85.63
C.D.	1.51	0.76	1.23
SE(m)	4.54	2.27	3.70

Yield attributes**Number of flowers, Number of days to first fruit and Length of fruit (cm)**

Clear and significant variation was recorded among the treatments with respect to the number of flowers, days to first fruiting and fruit length. The maximum number of flowers observed at 30, 60 and 90 DAT was produced under T₁₀ (25% RDF + 25% *Azospirillum* + 25% *Azotobacter* + 25% PSB), which recorded (11.82) flowers per plant, followed by T₅ (50% RDF + 50% *Azospirillum*) with (10.78) flowers per plant. The lowest flower count (6.63) was noted under T₁ (100% RDF), indicating comparatively weaker reproductive growth under sole inorganic fertilization. similar to trends noted by (Sarkar and Chakraborty 2017) [17]

A similar trend was observed in the earliness of fruit initiation. The earliest first fruit appearance occurred in T₅ (34.20 days), followed by T₁₀ (38.21 days), whereas the longest duration to first fruiting was recorded in T₁ (46.06 days), reflecting delayed reproductive development under this treatment. Report present by (Patel and Rana 2016) [15]

Fruit length also varied significantly among treatments. The longest fruits (12.93 cm) were produced under T₁₀, demonstrating the superior impact of combined biofertilizers with reduced RDF. This was closely followed by T₅, which recorded a fruit length of (12.81 cm). The shortest fruits (8.30 cm) were obtained from T₁, indicating that exclusive use of RDF was less supportive for optimum fruit development compared to integrated nutrient management. Similar enhancement report under integrated nutrient strategies has been documented by (Chauhan *et al.* 2021) [3].

Girth of fruit (cm) and weight of fruit (g)

Significant differences were recorded among the treatments with respect to fruit girth and fruit weight. The maximum fruit girth (1.88 cm) was obtained under T₁₀ (25% RDF + 25% *Azospirillum* + 25% *Azotobacter* + 25% PSB), indicating the strong promotive effect of integrating multiple biofertilizers with reduced chemical fertilization. This was followed by T₅ (50% RDF + 50% *Azospirillum*), which recorded a girth of (1.78 cm), while the minimum

girth (0.98 cm) was observed under T₁ (100% RDF).

A similar trend was reflected in fruit weight. The highest fruit weight (9.18 g) was achieved in T₁₀, demonstrating the superior influence of the combined nutrient application on pod development and biomass accumulation. The treatment T₅ ranked next with (8.97 g), whereas the lowest fruit weight (7.35 g) was recorded in T₁, indicating that exclusive reliance on inorganic fertilizers was comparatively less effective in enhancing fruit growth.

Fruit yield per plant (g), Fruit yield per plot (kg) and Fruit yield (q/ha)

A significant influence of inorganic fertilizers and bio-stimulants was observed on fruit yield per plant in okra. Fruit yield showed considerable variation among treatments. The highest yield (188.5 g per plant) was obtained under T₁₀, where a balanced combination of (25% RDF + 25% *Azospirillum* + 25% *Azotobacter* + 25% PSB), followed by T₅ recorded (169.3 g per plant) respectively. In contrast, the sole application of 100% RDF T₁ produced comparatively lower fruit yield Per plant (116.9 g per plant), indicating the superior effectiveness of integrated nutrient sources over chemical fertilizers alone.

Fruit yield per plot showed significant variation in response to the combined use of biofertilizers and inorganic nutrients. The highest yield per plot (3.03kg) was recorded under T₁₀ (25% RDF + 25% *Azospirillum* + 25% *Azotobacter* + 25% PSB), confirming the strong synergistic influence of integrated nutrient management on yield enhancement. This was followed by (2.72kg) T₅ (50% RDF + 50% *Azospirillum*), while the lowest plot yield (1.89kg) was obtained under T₁ (100% RDF), indicating the limited effectiveness of sole chemical fertilization.

A similar pattern was observed when yield was expressed on a per-hectare basis. Treatment T₁₀ registered the maximum yield (139.6q/ha), followed by T₅ with (125.3q/ha) respectively. In contrast, T₁ produced the lowest yield (87.15 q/ha), further demonstrating that integrated use of biofertilizers with reduced RDF is more effective in increasing okra productivity than the exclusive application of inorganic fertilizers.

Table 2: Effect of inorganic fertilizers and bio-stimulants on yield parameters of Okra.

Treatment	Number of flowers p/plant	Number of days to first fruit	Length of fruit (cm)	Girth of fruit (cm)	Weight of fruit (g)	Fruit yield per plant (g)	Fruit yield per plot (kg)	Fruit yield (q/ha)
T ₁ -RDF (100%)	6.63	46.06	8.30	0.98	7.35	116.9	1.89	87.15
T ₂ - <i>Azospirillum</i> (100%)	8.29	39.04	10.25	1.47	8.43	151.4	2.44	112.3
T ₃ - <i>Azotobacter</i> (100%)	7.83	39.82	9.83	1.34	8.39	148.2	2.39	106.0
T ₄ -PSB (100%)	7.21	41.39	9.21	1.21	7.45	120.6	1.95	89.92
T ₅ -RDF (50%) + <i>Azospirillum</i> (50%)	10.78	34.20	12.81	1.78	8.97	169.3	2.72	125.3
T ₆ -RDF (50%) + <i>Azotobacter</i> (50%)	10.31	39.45	10.77	1.61	8.78	159.4	2.56	117.9
T ₇ -RDF (50%) + PSB (50%)	9.19	39.74	10.51	1.56	8.55	154.2	2.48	114.3
T ₈ - <i>Azospirillum</i> (50%) + <i>Azotobacter</i> (50%)	9.76	39.33	10.62	1.58	8.61	155.1	2.49	114.8
T ₉ - <i>Azotobacter</i> (50%) + PSB (50%)	8.67	40.28	10.39	1.51	8.51	153.4	2.44	112.7
T ₁₀ -RDF (25%) + <i>Azospirillum</i> (25%) + <i>Azotobacter</i> (25%) + PSB (25%)	11.82	38.21	12.93	1.88	9.18	188.5	3.03	139.6
C.D.	0.65	1.25	0.10	0.02	0.10	0.52	0.02	0.25
SE(m)	1.94	3.76	0.31	0.06	0.31	0.17	0.08	0.08

Quality Attributes**Titrate acidity (%)**

Titrate acidity differed markedly among the treatments. The lowest acidity content (0.20%) was recorded in T₁₀ (25% RDF + 25% *Azospirillum* + 25% *Azotobacter* + 25%

PSB), indicating better biochemical quality under integrated nutrient application. This was followed by T₅ (50% RDF + 50% *Azospirillum*) with 0.31%, while T₂ (100% *Azospirillum*) and T₈ (50% *Azospirillum* + 50% *Azotobacter*) recorded 0.38% and 0.43%, respectively. In

contrast, the highest acidity (0.75%) was observed in T₁ (100% RDF), suggesting that exclusive use of chemical fertilizers resulted in comparatively poorer fruit quality, which aligns with findings reported by (Singh and Devi 2020) [20].

TSS (°Brix)

The observations revealed that the treatments exerted a non-significant influence on TSS content; however, numerical differences were evident among the nutrient combinations. The highest TSS value (3.06 °Brix) was obtained under T₁₀ (25% RDF + 25% *Azospirillum* + 25% *Azotobacter* + 25% PSB), indicating a slight improvement in soluble solids with integrated nutrient application. This was followed by T₈ (50% *Azospirillum* + 50% *Azotobacter*) and T₅ (50% RDF + 50% *Azospirillum*), which recorded 2.67 °Brix and 2.54 °Brix, respectively. In contrast, the lowest TSS (1.11 °Brix) was observed in T₁ (100% RDF), reflecting comparatively poorer fruit quality under sole inorganic fertilization. similar to trends noted by (Meena and Khatik 2018) [13].

Ascorbic acid (mg/100 g)

Ascorbic acid content varied significantly across the treatments, indicating a clear influence of inorganic fertilizers and biofertilizers on the vitamin C concentration of okra. The maximum ascorbic acid content (17.14 mg/100

g) was recorded under T₁₀ (25% RDF + 25% *Azospirillum* + 25% *Azotobacter* + 25% PSB), highlighting the positive impact of integrated nutrient management on enhancing nutritional quality. This was followed by T₅ (50% RDF + 50% *Azospirillum*) which recorded (16.60mg/100 g) respectively. The treatment T₈ (50% *Azospirillum* + 50% *Azotobacter*) also showed a moderate vitamin C level (13.62 mg/100 g). In contrast, the lowest ascorbic acid content (10.62 mg/100 g) was observed in T₁ (100% RDF), indicating comparatively reduced nutritional quality under sole inorganic fertilization. as supported by (Kumar and Thakur 2018) [9].

Moisture content in fruit (%)

Moisture content in okra fruits showed noticeable variation among the different nutrient treatments. The highest moisture percentage (87.63%) was recorded under T₁₀ (25% RDF + 25% *Azospirillum* + 25% *Azotobacter* + 25% PSB), indicating improved water retention and enhanced physiological activity due to integrated nutrient application. This was followed by T₅ (50% RDF + 50% *Azospirillum*) with (83.52%), recorded respectively. The lowest moisture content (82.50%) was observed in T₁ (100% RDF), suggesting comparatively reduced hydration levels under exclusive chemical fertilization. similar to trends noted by (Sharma and Verma 2019) [18].

Table 3: Effect of inorganic fertilizers and bio-stimulants on Quality parameters of Okra.

Treatment	Titration acidity (%)	TSS (°Brix)	Ascorbic acid (mg/100 g)	Moisture content in fruit (%)
T ₁ -RDF (100%)	0.75	1.11	10.62	82.50
T ₂ - <i>Azospirillum</i> (100%)	0.38	2.00	16.47	83.77
T ₃ - <i>Azotobacter</i> (100%)	0.60	1.73	11.79	86.67
T ₄ -PSB (100%)	0.64	1.44	11.32	87.44
T ₅ -RDF (50%) + <i>Azospirillum</i> (50%)	0.31	2.54	16.60	83.52
T ₆ -RDF (50%) + <i>Azotobacter</i> (50%)	0.53	2.53	13.21	85.50
T ₇ -RDF (50%) + PSB (50%)	0.49	1.99	12.31	85.46
T ₈ - <i>Azospirillum</i> (50%) + <i>Azotobacter</i> (50%)	0.43	2.67	13.62	84.36
T ₉ - <i>Azotobacter</i> (50%) + PSB (50%)	0.61	2.22	11.66	68.58
T ₁₀ -RDF (25%) + <i>Azospirillum</i> (25%) + <i>Azotobacter</i> (25%) + PSB (25%)	0.20	3.06	17.14	87.63
C.D.	0.02	0.03	0.15	0.31
SE(m)	0.08	0.09	0.45	0.93

Conclusion

The present study demonstrates that the combined application of inorganic fertilizers and bio-stimulants significantly improved the growth, yield and quality of okra cv. Kashi Lalima. Among the treatments, T₁₀ (25% RDF + 25% *Azospirillum* + 25% *Azotobacter* + 25% PSB) consistently produced the highest plant height, number of leaves, stem diameter, number of flowers, early fruiting, fruit size, fruit girth, fruit weight, number of fruits per plot, yield per hectare and quality parameters including ascorbic acid, moisture content and lower titratable acidity. Treatments T₅ (50% RDF + 50% *Azospirillum*) and T₈ (50% *Azospirillum* + 50% *Azotobacter*) also showed positive effects but were comparatively less effective than T₁₀. Sole application of inorganic fertilizers T₁ (100% RDF) was consistently the least effective in enhancing growth, yield and quality. The findings highlight that integrated nutrient management, combining reduced doses of chemical fertilizers with suitable bio-stimulants is a sustainable and efficient strategy to maximize okra productivity and improve fruit quality.

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