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Effect of different bio fertilizers on growth and yield of okra (*Abelmoschus esculentus* L.)

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Abstract
An experiment was conducted during Zaid 2024-25 at the Government Nursery, Mohgaon, Saja, Bemetara (Chhattisgarh) to evaluate integrated biofertilizer-vermicompost packages on okra (*Abelmoschus esculentus* L. cv. Radhika). The study employed a completely randomized design with 12 × 12 in. growbags (120 bags; eight treatments; three replications). Treatments included control (T_0), 100% RDF (T_1), and combinations of 75% or 50% RDF with vermicompost and biofertilizers (Azotobacter and PSB) (T_2-T_7). Growth and yield attributes recorded were days to germination, plant height, leaves per plant, branches per plant, days to first flowering, internodal length, fruits per plant, fruit size, individual fruit weight, per-plant yield, and total plot yield. Data were analyzed using ANOVA. Treatment T_4 (75% RDF + vermicompost + Azotobacter + PSB) produced the best results: shortest germination (5.54 d), tallest plants (100.12 cm), highest leaf number (12.74) and branching (5.07), earliest flowering (36.92 d), longest internodes (7.12 cm), largest and heaviest fruits (14.02 cm; 15.63 g), highest fruit count (22.38 plant^{-1}), and maximum yields (346.21 g plant^{-1}; 5183.60 g plot^{-1}). T_7 (50% RDF + vermicompost + Azotobacter + PSB) was a promising low-input alternative. Validation across seasons and locations is recommended.

Keywords: Okra, biofertilizers, vermicompost, integrated nutrient management, yield

Introduction
Okra (*Abelmoschus esculentus* L.) is a warm-season vegetable of the Malvaceae family, cultivated globally on over 2 million ha with annual production exceeding 10 million t. India ranks among its top producers, harvesting 6.3 million t from 0.6 million ha—yet average national yields (10.5 t ha^{-1}) remain below the crop's genetic potential. In Chhattisgarh, okra covers 12 500 ha and yields 120 000 t (9.6 t ha^{-1}), supporting rural livelihoods and small-scale processing industries. The pods' high-water content (88-90%), low caloric density (30 kcal 100 g^{-1}), and rich micronutrient profile—including vitamin C (21 mg 100 g^{-1}), vitamin A (375 IU 100 g^{-1}), B-complex vitamins, and minerals such as potassium (299 mg 100 g^{-1}), calcium (82 mg 100 g^{-1}) and magnesium (57 mg 100 g^{-1})—underscore okra's dietary importance. Despite this nutritional richness, productivity is constrained by physiological disorders—excessive vegetative growth, flower drop, poor pod set, and uneven maturation—caused by unbalanced fertilization, erratic rainfall, and high temperatures during critical reproductive stages. Integrated nutrient management (INM), replacing 25-50% of recommended NPK with vermicompost plus inoculation of biofertilizers (Azotobacter and phosphate-solubilizing bacteria, PSB), has demonstrated synergistic benefits: vermicompost improves soil structure, moisture retention, and nutrient release, while Azotobacter fixes atmospheric nitrogen and PSB enhances phosphorus availability and synthesizes growth-promoting phytohormones such as indole-3-acetic acid and gibberellins. Field trials under open-field conditions, using 50-75% of the recommended NPK dose combined with vermicompost and these microbial inoculants, have reported significant gains in okra growth, yield, and profitability. However, these INM strategies have not been systematically evaluated in protected-cultivation grow-bag systems—which provide precise control over root-zone media and drainage—particularly under Chhattisgarh's tropical wet-dry climate. To address this gap, the present study—conducted during the 2024-25 Zaid season at the Government Nursery, Mohgaon, Saja, Bemetara (Chhattisgarh)—evaluated eight treatments in a completely randomized design using 12 × 12 in. grow bags: untreated control; 100% RDF; and 75% or 50% RDF each combined with vermicompost and single or dual

Azotobacter/PSB inoculations. Germination, vegetative, and reproductive parameters were recorded, and economic performance was assessed via cost-benefit analysis to identify the most efficient INM package for maximizing okra cv. Radhika's productivity and profitability under local protected-cultivation conditions.

Materials and Methods

The trial was conducted during Zaid 2024-25, with sowing on 9 April 2025, at the Government Nursery, Mohgaon, Saja, Bemetara (21°36′ N, 81°17′ E; 290 m elevation) using a completely randomized design (CRD) comprising eight treatments, three replications, and five growbags (12 × 12 in., HDPE) per replication. The treatments included: T_0—control; T_1—100% RDF (100 kg N, 50 kg P_2O_5, 40 kg K_2O ha^{-1}); T_2—75% RDF + vermicompost + Azotobacter; T_3—75% RDF + vermicompost + PSB; T_4—75% RDF + vermicompost + Azotobacter + PSB; T_5—50% RDF + vermicompost + PSB; T_6—50% RDF + vermicompost + Azotobacter; and T_7—50% RDF + vermicompost + Azotobacter + PSB. The growth media consisted of field soil, vermicompost, and sand in a 3:1:1 ratio, with 68% coarse sand, 20% fine sand, 7% silt, 5% clay, pH 7.8, EC 0.24 dS m^{-1}, organic carbon 0.31%, available N 213 kg ha^{-1}, P_2O_5 7.12 kg ha^{-1}, and K_2O 115.4 kg ha^{-1}. Vermicompost was applied at 2.5 t ha^{-1} (10 g bag^{-1}), while RDF was supplied through urea, DAP, and MOP. Seed inoculation was performed using Azotobacter and PSB cultures (10 mL culture per 125 g jaggery). Observations recorded included days to germination, plant height, number of branches, internode length (30, 60, 90 DAS), number of leaves, days to first flowering, number of fruits per plant, fruit length, diameter, weight, yield per plant, and total yield. The data were analyzed using ANOVA for CRD at $p \leq 0.05$ (Panse & Sukhatme 1967) [7] employing SAS/STAT® 9.4.

Results and Discussion

Growth performance

Integrated application of 75% RDF with vermicompost, Azotobacter, and PSB (T_4) significantly improved germination and vegetative growth. Seeds germinated in 5.54 d under T_4, 15% earlier than control (6.53 d). Plant height at harvest reached 100.12 cm under T_4 compared with 55.28 cm in control (Fig. 1). Leaves per plant (12.74) and branches per plant (5.07) doubled relative to control (6.28 and 0.83, respectively). Internodal length was 7.12 cm in T_4 versus 4.26 cm in control. Days to first flowering were reduced to 36.92 d under T_4 compared with 45.34 d in control (Table 1).

Yield attributes

Yield traits followed the same trend. Fruits per plant increased to 22.38 under T_4 compared with 8.67 in control (Fig. 2). Fruit length reached 14.02 cm, diameter 1.64 cm, and weight 15.63 g compared with 7.38 cm, 1.42 cm, and 7.62 g in control (Table 2). Per-plant yield and plot yield were 346.21 g and 5183.60 g under T_4 compared with 64.72 g and 967.90 g in control. These improvements reflect synergistic effects: vermicompost enhanced soil aeration and nutrient release, while microbial inoculants improved N fixation, P solubilization, and phytohormone production. The results agree with earlier findings (Choudhary *et al.* 2015; Dutta *et al.* 2020; Singh *et al.* 2018) [3, 4, 13]. Treatment T_7 (50% RDF + vermicompost + Azotobacter + PSB) also showed promising results, suggesting input savings with minor yield reduction.

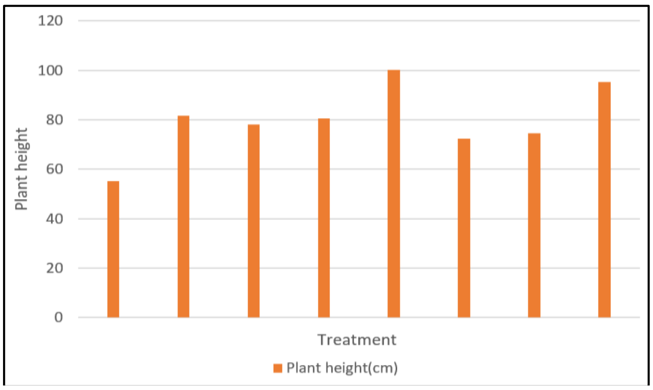

Fig 1: Effect of Biofertilizer Application on Plant Height of Okra

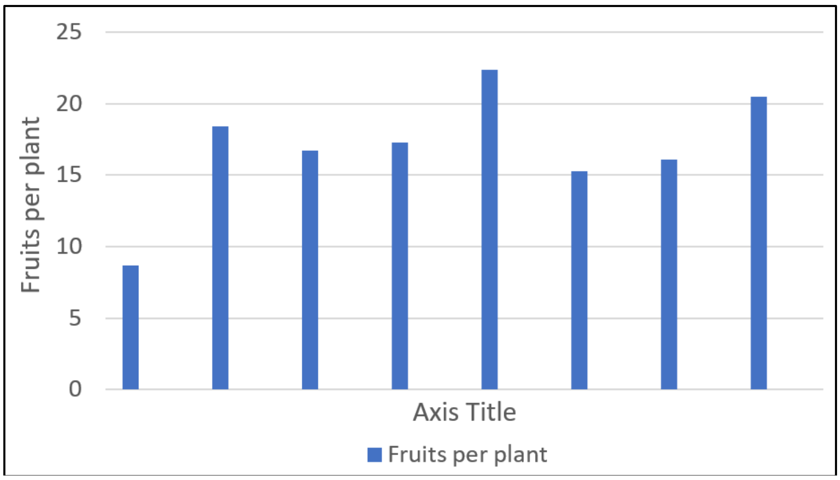

Fig 2: Fruits per Plant of Okra under Different Biofertilizer Treatments

Table 1: Effect of different biofertilizers on growth parameters of okra (*Abelmoschus esculentus* L.)

Treatments	Days taken to initiate germination	Plant height (cm)	No. of leaves per plant at flowering stage	No. of branches per plant	Days to first flower appearance	Internodal length
Control	6.53	55.28	6.28	0.83	45.34	4.26
100% RDF	6.07	81.76	11.43	3.56	38.67	6.12
75% RDF + vermicompost + *Azotobacter*	5.82	78.23	10.86	3.24	39.81	5.76
75% RDF + vermicompost + PSB	5.85	80.61	11.07	3.38	39.43	6.18
75% RDF + vermicompost + *Azotobacter* + PSB	5.54	100.12	12.74	5.07	36.92	7.12
50% RDF + vermicompost + PSB	6.02	72.45	9.62	2.94	41.29	5.63
50% RDF + vermicompost + *Azotobacter*	5.91	74.68	10.14	3.15	40.78	5.74
50% RDF + vermicompost + *Azotobacter* + PSB	5.63	95.33	12.09	4.63	37.64	6.62
SEm±	0.19	3.36	0.56	0.17	1.20	0.23
CD (0.05)	0.58	10.08	1.69	0.50	3.61	0.70

Table 2: Effect of different biofertilizers on yield parameters of okra (*Abelmoschus esculentus* L.)

Treatments	Fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit yield per plant (g)	Total yield (g)
Control	8.67	7.38	1.42	7.62	64.72	967.90
100% RDF	18.43	11.57	1.50	12.41	226.89	3394.10
75% RDF + vermicompost + *Azotobacter*	16.75	10.66	1.48	11.53	191.47	2873.00
75% RDF + vermicompost + PSB	17.31	10.25	1.49	11.67	203.84	3044.80
75% RDF + vermicompost + *Azotobacter* + PSB	22.38	14.02	1.64	15.63	346.21	5183.60
50% RDF + vermicompost + PSB	15.27	9.17	1.46	10.17	154.11	2317.10
50% RDF + vermicompost + *Azotobacter*	16.08	10.73	1.47	10.92	174.38	2608.10
50% RDF + vermicompost + *Azotobacter* + PSB	20.47	13.44	1.57	13.34	269.77	4039.00
SEm±	0.90	0.40	0.05	0.60	11.58	127.62
CD (0.05)	2.70	1.19	0.16	1.80	34.73	382.60

Conclusion
Application of 75% RDF with vermicompost, Azotobacter, and PSB (T_4) accelerated germination, improved vegetative growth, advanced flowering, and more than quintupled yield compared with the unfertilized control. By achieving high yields with 25% reduced chemical fertilizer, T_4 offers a resource-efficient and sustainable strategy for okra production. Validation across seasons and agroecological zones is needed to confirm adaptability.

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