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Effect of integrated nutrient management on growth and yield of Okra

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Abstract
A field experiment entitled "Effect of integrated nutrient management on growth and yield of Okra" was conducted at Research cum Instructional farm of College of Horticulture and Research Station Saja, Bemetara (C.G.) during *Zaid* season of 2024-25. The experiment was laid out in Randomized Block Design with three replications. The treatments consisted of eight nutrient management practices viz., (T_0) Control, (T_1) 100% RDF (100:50:50 kg NPK/ha), (T_2) 70% RDF + 30% *Azospirillum*, (T_3) 50% RDF + 50% FYM, (T_4) 50% RDF + 50% Vermicompost, (T_5) 40% RDF + 30% *Azospirillum* + 30% FYM, (T_6) 40% RDF + 30% *Azospirillum* + 30% Vermicompost and (T_7) 40% RDF + 30% FYM + 30% Vermicompost. Observations on growth parameters *viz.,* plant height, number of branches, number of leaves, leaf area, intermodal length and yield parameters viz., number of flowers, number of fruits, fruit length, fruit diameter and fruit yield of okra crop were recorded at harvest and statistically analyzed were also worked out. The study revealed that integrated nutrient management significantly influenced the vegetative growth of okra. The highest plant height, number of leaves, leaf area, number of branches and internodal length were recorded under (T_1) 100% RDF (100:50:50 kg NPK/ha), which was statistically comparable to (T_2) 70% RDF + 30% *Azospirillum.* Treatments (T_4) 50% RDF + 50% Vermicompost and (T_3) 50% RDF + 50% FYM showed moderate improvements over the control (T_0). Similarly, reproductive growth and yield traits were maximized under (T_1) 100% RDF (100:50:50 kg NPK/ha) with the highest number of flowers, fruits per plant, fruit length, fruit diameter and fruit yield (320.54 g per plant), followed closely by (T_2) 70% RDF + 30% *Azospirillum*. Which was statistically significant superior with treatments (T_4) 50% RDF + 50% Vermicompost and (T_3) 50% RDF + 50% FYM, while the lowest yield was observed in the control (T_0).

Keywords: Okra, Vermicompost, *Azospirillum*, FYM, integrated and yield

Introduction
Okra (*Abelmoschus esculentus* L.), also referred to as lady's finger, is a significant vegetable crop of the Malvaceae family. It is extensively grown in tropical and subtropical areas due to its adaptability and nutritional benefits (Yadav *et al*., 2019) [34]. This vegetable is a rich source of vitamins A, B and C, essential minerals like calcium, potassium, and magnesium, as well as dietary fiber, making it an important part of the human diet (Kumar *et al.*, 2021) [11]. India is the world's leading producer of okra, cultivating it on about 547 thousand hectares, with an annual output of 7149 million metric tonnes and an average yield of 13.07 t ha^{-1} (Anonymous, 2023) [1]. In Chhattisgarh, okra is grown on around 32.77 thousand hectares, producing 364.22 thousand metric tonnes annually, with an average productivity of 11.11 tonnes per hectare. Specifically, in Bemetara district during 2022-23, okra cultivation covered about 1548.00 hectares, resulting in a total production of 21.959 metric tonnes (Anonymous, 2022) [1]. Although okra is economically and nutritionally valuable, its cultivation is challenged by issues such as declining soil fertility, unbalanced nutrient management, and heavy reliance on chemical fertilizers, which contribute to soil degradation and reduced productivity (Patel *et al*., 2021) [22]. Prolonged use of chemical fertilizers has been shown to reduce soil organic matter and microbial activity, negatively impacting long-term soil health and crop performance (Verma *et al*., 2020) [33]. Tackling these challenges is essential for sustainable vegetable production, as preserving soil health plays a key role in improving both yield and crop quality (Muqtadir *et al*., 2019) [18].

Soil nutrient availability is often limited due to insufficient application of both inorganic and organic fertilizers, as well as nutrient losses caused by erosion and leaching. Many smallholder farmers are unable to access synthetic fertilizers because of high costs, lack of credit, poor distribution networks, and other socio-economic constraints. As a result, crop yields remain low—or are even declining in several regions—putting the sustainability of current farming practices at risk. The continuous use of high doses of chemical fertilizers without incorporating organic manures or biofertilizers has resulted in the deterioration of soil health. This includes adverse effects on the soil's physical and chemical properties, a decline in microbial activity, reduction in soil organic matter, and increased pollution of soil, water and air. Modern nutrient management strategies have increasingly emphasized sustainability and environmental friendliness. The integrated use of different soil fertility amendments seeks to address nutrient deficiencies and enhance the availability of essential nutrients. Numerous studies have indicated that neither inorganic fertilizers nor organic sources or biofertilizers alone can sustain long-term crop productivity. Additionally, the rising cost of inorganic fertilizers has made them increasingly unaffordable for small and marginal farmers. The most effective approach to soil fertility management is therefore the combined use of inorganic and organic fertilizers, where inorganic fertilizers supply essential nutrients, while organic fertilizers enhance soil organic matter, improve soil structure, and increase the soil's buffering capacity. The joint application of inorganic fertilizers, organic amendments and biofertilizers commonly referred to as integrated nutrient management (INM)—is widely recognized for its ability to boost crop yield and maintain soil productivity sustainably. Several studies have also highlighted the effectiveness of INM in addressing deficiencies of secondary and micronutrients. The advantages of combining chemical fertilizers with organic manures such as farmyard manure, compost, vermicompost, poultry manure, and biofertilizers are well established. A balanced application of organic and inorganic fertilizers, along with biofertilizers, is considered an ideal approach to fulfill the nutrient requirements of most horticultural crops. Implementing integrated nutrient management practices in okra is particularly important for achieving higher yields, improved quality and better economic returns. The continuous application of organic manures gradually enhances soil nutrient content, thereby allowing a reduction in the use of synthetic fertilizers. Integrated nutrient management (INM) is a key component of sustainable agriculture, focusing on the efficient management of resources to meet evolving human needs while preserving environmental quality and conserving essential natural resources.

Integrated Nutrient Management (INM) is an effective strategy to tackle these challenges by combining organic and inorganic nutrient sources to boost crop yield while maintaining soil fertility (Mariam *et al*., 2018) [16]. The application of farmyard manure (FYM), vermicompost, and NPK fertilizers has been shown to enhance soil fertility, increase nutrient availability, and promote healthier plant growth (Meena and Meena, 2018) [17]. Research demonstrates that integrating FYM and vermicompost with NPK fertilizers significantly improves plant height, branch number, and leaf area index in okra, while also enhancing fruit yield and pod quality (Mandal *et al*., 2020 and Kumawat *et al*., 2023) [14, 13]. A balanced use of organic manures alongside chemical fertilizers supports sustainable soil health management, improves nutrient uptake efficiency, and ultimately results in higher productivity and better crop quality. Biofertilizers are a crucial and cost-effective component of the integrated nutrient management system. When applied to seeds, roots, or soil, they help fix atmospheric nitrogen, enhance nutrient availability, and promote the growth of beneficial microflora. The combined use of organic manures with nitrogen-fixing biofertilizers and phosphate-solubilizing bacteria further improves nutrient accessibility (Khan *et al*., 2019) [10]. In recent years, the widespread adoption of biofertilizers has emerged as an eco-friendly, low-cost technology in crop production. Scientific studies have consistently demonstrated that the combined application of nitrogen-fixing, phosphate-solubilizing, and nutrient-mobilizing microbes positively influences crop growth and yield. The main components of Integrated Nutrient Management (INM) include organic manure, biofertilizers, and chemical fertilizers. Organic manures not only help balance nutrient supply but also enhance the soil's physical and chemical properties. In the context of Indian agriculture, given the limited availability of organic nutrient sources and the potential for yield reduction, especially in the initial years, complete replacement of chemical fertilizers is not advisable. Instead, organic sources should be used to partially supplement chemical fertilizers. Therefore, a judicious combination of organic and inorganic nutrient sources represents the most practical strategy for nutrient management, offering economic benefits while promoting sustainable production, maintaining soil health, and protecting the environment.

Materials and methods

A field experiment entitled "Effect of integrated nutrient management on growth and yield of Okra" was conducted at Research cum Instructional farm of College of Horticulture and Research Station Saja, Bemetara (C.G.) during *Zaid* season of 2024-25. The location of the Bemetara district is latitude 22.09˚N and longitude 82.15˚E. This area is classified as India's Eastern Plateau and Hill Region (Agro-climatic zone VII). The state of Chhattisgarh is divided into three agro-climatic zones; Bemetara is located in the state's plains zone. The experiment was laid out in Randomized Block Design with three replications. The treatments consisted of eight nutrient management practices *viz.*, (T_0) Control, (T_1) 100% RDF (100:50:50 kg NPK/ha), (T_2) 70% RDF + 30% *Azospirillum*, (T_3) 50% RDF + 50% FYM, (T_4) 50% RDF + 50% Vermicompost, (T_5) 40% RDF + 30% *Azospirillum* + 30% FYM, (T_6) 40% RDF + 30% *Azospirillum* + 30% Vermicompost and (T_7) 40% RDF + 30% FYM + 30% Vermicompost. Observations on growth parameters *viz*., plant height, number of branches, number of leaves, leaf area, intermodal length and yield parameters *viz*., number of flowers, number of fruits, fruit length, fruit diameter and fruit yield of okra crop were recorded at harvest and statistically analyzed were also worked out.

Results and discussions

Growth parameters

The maximum plant height was observed under (T_1) 100% RDF (100:50:50 kg NPK/ha) at all growth stages (30, 45, and 60 DAS), which was statistically at par with (T_2) 70% RDF + 30% *Azospirillum*. Treatments with organic supplementation (T_3 and T_4) recorded moderate growth, whereas the lowest plant height was noted under the (T_0) Control. A similar trend was recorded for the number of leaves. The highest numbers of leaves was observed under (T_1) 100% RDF (100:50:50 kg NPK/ha), followed by (T_2) 70% RDF + 30% *Azospirillum*, while the minimum number of leaves was registered under the (T_0) Control. Leaf area was markedly influenced by nutrient management. The largest leaf area was recorded under (T_1) 100% RDF (100:50:50 kg NPK/ha), statistically comparable with (T_2) 70% RDF + 30% *Azospirillum*, while organic treatments (T_4) 50% RDF + 50% Vermicompost and (T_3) 50% RDF + 50% FYM showed moderate effects. The lowest leaf area was observed under the (T_0) Control. Branching was also enhanced by nutrient management. (T_1) 100% RDF (100:50:50 kg NPK/ha) produced the maximum number of branches, statistically at par with (T_2) 70% RDF + 30% *Azospirillum*, while the (T_0) Control recorded the lowest. Internodal length was significantly affected by nutrient treatments. The shortest internodes were recorded under (T_1) 100% RDF (100:50:50 kg NPK/ha) followed by (T_2) 70% RDF + 30% *Azospirillum*, indicating compact plant growth. In contrast, the (T_0) Control plants exhibited longer internodes, which is undesirable for yield.

Yield parameters

The longest fruits and widest diameters were produced under (T_1) 100% RDF (100:50:50 kg NPK/ha), which was comparable with (T_2) 70% RDF + 30% *Azospirillum*. Other organic and integrated treatments recorded intermediate values, whereas the (T_0) Control produced the smallest fruits. The heaviest fruits and maximum number of fruits per plant were obtained under (T_1) 100% RDF (100:50:50 kg NPK/ha), followed by (T_2) 70% RDF + 30% *Azospirillum*. Integrated treatments (T_3 and T_4) showed moderate improvements, while the (T_0) Control consistently lagged behind. The highest fruit yield (320.54 g per plant) was recorded under (T_1) 100% RDF (100:50:50 kg NPK/ha), statistically similar to (T_2) 70% RDF + 30% *Azospirillum* (303.65 g per plant). Organic and integrated treatments produced moderate yields, while the lowest yield (112.86 g per plant) was obtained under the (T_0) Control.

Table 1: Effect of integrated nutrient management on plant height of Okra.

Treatment No.	Treatment details	Plant height (cm)		
		30 DAS	45 DAS	60 DAS
T_0	Control	15.53	28.82	53.51
T_1	100% RDF (100:50:50 kg NPK/ha)	25.76**	50.46**	91.42**
T_2	70% RDF + 30% *Azospirillum*	25.09*	49.17*	89.07*
T_3	50% RDF + 50% FYM	22.21	42.64	77.96
T_4	50% RDF + 50% Vermicompost	22.95	44.06	80.55
T_5	40% RDF + 30% *Azospirillum* + 30% FYM	17.76	34.10	62.34
T_6	40% RDF + 30% *Azospirillum* + 30% Vermicompost	18.43	35.39	64.69
T_7	40% RDF + 30% FYM + 30% Vermicompost	18.87	36.23	66.23
SEm (±)		0.71	2.11	3.86
CD (5%)		2.14	6.39	11.71
CV (5%)		10.86	10.09	10.13

Table 2: Effect of integrated nutrient management on number of branches of Okra.

Treatment No.	Treatment details	Number of branches per plant	
		45 DAS	60 DAS
T_0	Control	1.18	1.33
T_1	100% RDF (100:50:50 kg NPK/ha	3.81**	4.31**
T_2	70% RDF + 30% *Azospirillum*	3.76*	4.25*
T_3	50% RDF + 50% FYM	2.93	3.31
T_4	50% RDF + 50% Vermicompost	3.01	3.40
T_5	40% RDF + 30% *Azospirillum* + 30% FYM	1.97	2.23
T_6	40% RDF + 30% *Azospirillum* + 30% Vermicompost	2.09	2.36
T_7	40% RDF + 30% FYM + 30% Vermicompost	2.16	2.44
SEm (±)		0.18	0.21
CD (5%)		0.56	0.64
CV (5%)		12.23	12.37

Table 3: Effect of integrated nutrient management on number of leaves of Okra.

Treatment No.	Treatment details	Number of leaves per plant		
		30 DAS	45 DAS	60 DAS
T_0	Control	5.64	7.22	9.36
T_1	100% RDF (100:50:50 kg NPK/ha	12.44**	15.92**	20.65**
T_2	70% RDF + 30% *Azospirillum*	11.93*	15.27*	19.80*
T_3	50% RDF + 50% FYM	9.83	12.58	16.32
T_4	50% RDF + 50% Vermicompost	10.15	12.99	16.85
T_5	40% RDF + 30% *Azospirillum* + 30% FYM	7.53	9.64	12.50
T_6	40% RDF + 30% *Azospirillum* + 30% Vermicompost	7.89	10.10	13.10
T_7	40% RDF + 30% FYM + 30% Vermicompost	8.05	10.30	13.36
SEm (±)		0.55	0.71	0.91
CD (5%)		1.68	2.13	2.75
CV (5%)		10.44	10.34	10.30

Table 4: Effect of integrated nutrient management on leaf area of Okra.

Treatment No.	Treatment details	Leaf area (cm^2)		
		30 DAS	45 DAS	60 DAS
T_0	Control	252.06	441.11	562.09
T_1	100% RDF (100:50:50 kg NPK/ha	582.43**	1019.25**	1298.82**
T_2	70% RDF + 30% *Azospirillum*	559.29*	978.76*	1247.22*
T_3	50% RDF + 50% FYM	445.36	779.38	993.15
T_4	50% RDF + 50% Vermicompost	479.74	839.55	1069.82
T_5	40% RDF + 30% *Azospirillum* + 30% FYM	337.65	590.89	752.96
T_6	40% RDF + 30% *Azospirillum* + 30% Vermicompost	352.84	617.47	786.83
T_7	40% RDF + 30% FYM + 30% Vermicompost	361.31	632.29	805.72
SEm (±)		23.55	40.32	54.99
CD (5%)		71.45	122.29	166.82
CV (5%)		9.68	9.48	10.15

Table 5: Effect of integrated nutrient management on intermodal length of Okra.

Treatment No.	Treatment details	Internodal length (cm)		
		30 DAS	45 DAS	60 DAS
T_0	Control	1.13	1.89	2.41
T_1	100% RDF (100:50:50 kg NPK/ha	3.11**	5.19**	6.62**
T_2	70% RDF + 30% *Azospirillum*	3.03*	5.06*	6.45*
T_3	50% RDF + 50% FYM	2.49	4.16	5.30
T_4	50% RDF + 50% Vermicompost	2.56	4.28	5.45
T_5	40% RDF + 30% *Azospirillum* + 30% FYM	1.82	3.04	3.88
T_6	40% RDF + 30% *Azospirillum* + 30% Vermicompost	1.96	3.27	4.17
T_7	40% RDF + 30% FYM + 30% Vermicompost	2.04	3.41	4.35
SEm (±)		0.14	0.22	0.28
CD (5%)		0.41	0.67	0.84
CV (5%)		10.32	10.18	10.06

Table 6: Effect of integrated nutrient management on number of flower, number of fruit, fruit length, fruit diameter and fruit yield of Okra.

Treatment No.	Treatment details	Number of flowers per plant	Number of fruit per plant	Fruit length (cm)	Fruit diameter (mm)	Fruit yield (g per plant)
T_0	Control	15.36	8.76	6.52	11.23	112.86
T_1	100% RDF (100:50:50 kg NPK/ha	22.49**	18.95**	16.81**	17.98**	320.54**
T_2	70% RDF + 30% *Azospirillum*	22.16*	18.07*	15.92*	17.34*	303.65*
T_3	50% RDF + 50% FYM	20.25	14.96	12.78	15.22	239.34
T_4	50% RDF + 50% Vermicompost	20.56	15.43	13.25	15.78	248.62
T_5	40% RDF + 30% *Azospirillum* + 30% FYM	17.98	11.58	9.36	12.79	167.49
T_6	40% RDF + 30% *Azospirillum* + 30% Vermicompost	18.34	11.96	9.75	13.35	179.28
T_7	40% RDF + 30% FYM + 30% Vermicompost	18.68	12.38	10.17	13.63	186.71
SEm (±)		0.49	0.83	0.69	0.49	15.78
CD (5%)		1.48	2.52	2.09	1.49	47.87
CV (5%)		10.34	10.27	10.13	10.8	12.43

Conclusion

The study revealed that integrated nutrient management significantly influenced the vegetative growth of okra. The highest plant height (91.42. cm at 90 DAS), number of leaves (20.65 per plant at 90 DAS), leaf area (1298.82 cm^2), number of branches (3. 81 and 4.31 per plant) and internodal length (6.62 cm at 90 DAS) were recorded under (T_1) 100% RDF (100:50:50 kg NPK/ha), which was statistically comparable to (T_2) 70% RDF + 30% *Azospirillum.* Treatments (T_4) 50% RDF + 50% Vermicompost and (T_3) 50% RDF + 50% FYM showed moderate improvements over the control (T_0). Similarly, reproductive growth and yield traits were maximized under (T_1) 100% RDF (100:50:50 kg NPK/ha) with the highest number of flowers (22.49), fruits per plant (18.95), fruit length (16.81 cm), fruit diameter (17.98 cm) and fruit yield (320.54 g per plant), followed closely by (T_2) 70% RDF + 30% *Azospirillum*. Which was statistically significant superior with treatments (T_4) 50% RDF + 50% Vermicompost and (T_3) 50% RDF + 50% FYM, while the lowest yield was observed in the control (T_0).

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