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Impact of integrated Nutrient Management on Yield and Quality of Okra (*Abelmoschus esculentus* Moench.)

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ABSTRACT: The present experiment was carried out with aim to find out the optimum combination of organic and inorganic fertilizers in relation to growth of Okra and to find out the best source of organic manure in relation to yield of okra or Lady finger at Horticultural Research Farm, Department of Horticulture, Sardar Patel University Balaghat (M.P.) during *Kharif* season 2021. The details of treatment combination used are T_1(Control)); T_2(100% RDF* (Recommended Dose of Fertilizer)); T_3(75% RDF + 25% *Azospirillum*); T_4(50% RDF + 50% FYM); T_5(50% RDF + 50% Vermicompost); T_6(50% RDF + 25% *Azospirillum* + 25% FYM); T_7(50% RDF + 25% *Azospirillum* + 25% Vermicompost) and T_8(50% RDF + 25% FYM + 25% Vermicompost). The experiment was laid in Randomized block design with 8 treatments and 3 replications with different treatment combination of nutrients mentioned. The overall results obtained from this present investigation clearly revealed that the application of T_7((50% RDF + 25% *Azosprillum* +25% vermicompost) showed the better performance for vegetative growth (plant height, number of branch per plant, number of leaves per plant ,leaf area, days to 50% flowering), yield attributes (number of fruit per plant, fruit yield per plant (kg), fruit yield per plot (kg), Single pod weight (g), of okra except fruit length and fruit diameter) were would be useful to enhance the productivity of okra. The key challenge of study is high cost of organic nutrient sources and microbial inoculants, maintaining optimum dosage recommendations, and scaling integrated nutrient management for widespread adoption of okra.

Keywords: RDF, Lady finger, INM, FYM, Fruit Yield, *Azospirillum.*

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) commonly known as Bhindi or lady finger belongs to family Malvaceae bearing chromosome number 2n=130 (Skovsted, 1935) and is a fast-growing annual vegetable crop grown in tropical and sub-tropical regions of world. It is considered as an important vegetable crop cultivated almost across the country under various agro -climatic conditions. India is the major producer of okra (73.2%) in the world followed by Nigeria (12.1%) and Sudan (3.2%), respectively. It is a widely adopted and popular vegetable in Indian households and can be grown in summer and rainy seasons throughout the country. (Paul *et al.,* 2022). Being a great source of vitamins, vegetable protein, and minerals, it continues to hold a prestigious position among vegetables. The plant's mucilaginous seed pods, which contain soluble fibre, produce the distinctive "goo" or slime when they are boiled. By cooking okra with an acidic food, such as tomatoes, the mucilage can be removed, reducing its viscosity. Okra is an allopolyploid of uncertain parentage. The geographical origin of okra is disputed, with supporters of Southeast Asian, South Asian, Ethiopian, and West African origins. It originated from Ethiopia (Vavilov, 1935). Fruits and vegetables have historically held a place in dietary guidance because of their concentrations of vitamins, especially vitamin A and C; minerals, especially electrolytes; and more recently phytochemicals especially antioxidant. India is world's second largest fruit and vegetable producer, produced around 107.10 million metric tonnes fruits and 204.61 million metric tonnes of vegetables which accounts for nearly 16.38% of country's share in the world production of vegetables in the year 2020-21 (APEDA, 2020-21). India, being the second largest producer of vegetable in the world, next only to China, shares about 15 per cent of the world output of vegetables from about 3 per cent of total cropped area in the country (NHB, 2021). India ranks first in Okra production producing 60% of world's okra production alone followed by Nigeria and Sudan (FAOSTAT, 2020). The area under Okra production in India accounts to 498.12 thousand ha with production of 54.45 metric tonnes in year 2020-21. Gujarat ranks first in area and production of Okra in year 2020-21 followed by West Bengal and Bihar. In Uttar Pradesh area under production is 1.18 thousand hectares while production is estimated to be 3.35 million tonnes for year 2020-21. (Source: NHB, Ministry of Agriculture & Farmers Welfare, Government of India, 2021-22.). To get a good financial return and healthy soil for the ensuing crop yield, it might be helpful to combine organic and inorganic sources of nutrients. All kinds of micronutrients and macronutrients that promote plant elongation are released by organic fertilizers. Since organic fertilizers typically have lower nutrient contents, solubilities, and release rates than inorganic fertilizers, the latter are preferred. This is because organic fertilizers have lower nutrient contents, solubilities, and release rates than inorganic fertilizers. By implementing integrated fertilizer management, which helps to improve various physical, chemical, and biological properties of soil leading to improved soil fertility and also to increase fertilizer use efficiency, it is possible to sustainably increase production (Dick and Greegorich 2009). Organic fertilizers enhanced the physical characteristics of the soil, supplied vital plant nutrients for greater plant growth, protected the soil from erosion, provided the cementing substance for desired aggregate soil formation, and helped to loosen the soil. By providing all necessary nutrients and sustaining cropping systems through improved nutrient recycling, manure application enhances the soils physical and biological qualities (Shahriazzaman *et al.*, 2014). Okra is one of the most important crops and it has a rich economic importance. Organic manures like Vermicompost, Poultry manure and Farmyard manure when supplemented with inorganic fertilizers not only promote to produce higher yield and increase harvest quality but also maximizes plant genetic potential and the presence of nutrients impact on root development, fruit setting, plant vigor and health but also increases the quality of soil and upgrade its biological span. Nutrients are fundamental for balanced nutrition and a tremendous tool to help farmers in increasing crop yield and quality. Therefore, the present experiment was conducted with aim to study the effect of integrated nutrient management on growth and development of okra and economics of crop.

MATERIAL AND METHODS

A. Research area

The present experiment was carried out at Horticultural Research Farm, Department of Horticulture, Sardar Patel University Balaghat (M.P.) during *Rabi* season 2021-22. The experimental materials in the form of seeds were bought from the department of horticulture, College of Agriculture, Sardar Patel University Balaghat (M.P.). Okra variety used in the experiment was Ankur Sidhhi. It is a yellow vein mosaic virus and leaf curl virus resistant variety. This variety is tall and erect growth habit. Dark green fruit colour elongated, shiny and slender. Fruit size medium, length and weight.

B. Experimental details

The experiment was laid in Randomized block design with 8 treatments and 3 replications with different treatment combination of nutrients mentioned. The details of treatment combination used are T_1(Control)); T_2(100% RDF* (Recommended Dose of Fertilizer)); T_3(75% RDF + 25% *Azospirillum*); T_4(50% RDF + 50% FYM); T_5(50% RDF + 50% Vermicompost); T_6(50% RDF + 25% *Azospirillum* + 25% FYM); T_7(50% RDF + 25% *Azospirillum* + 25% Vermicompost) and T_8(50% RDF + 25% FYM + 25% Vermicompost). The standard recommended dose of RDF (NPK i.e., 100:60:60 kg/ha); *Azospirillum* @ 3kg/ha; FYM @ 25mt/ha and vermicompost @ 15 mt/ha was used. Observations were recorded at different stages of growth periods and studied for growth parameters like plant height, number of branches per plant, earliness parameters like days to first flowering, days to 50% flowering, days to 1st fruiting, yield parameters like number of fruits per plant, fruit length, diameter and weight and fruit yield per plant and plot. The data were analyzed by the method suggested by Fisher and Yates (1963). The height of five randomly selected plants from each plot was measured in cm with of a 100 cm meter scale from ground level to tip of the shoot at 30, 60 and 90 DAS stage. The numbers of branches per plant (plant) of five randomly selected plants arising from main shoot were counted and were averaged to represent numbers of primary branches per plant. Number of branches per plant basis was counted at harvest stage. The numbers of days taken from the date of sowing to the date at which first flower appeared in plants or date at which plants start flowering in whole plot were recorded as days to first flowering, similarly, was taken for days to first flowering and days to final fruit harvest.

RESULTS AND DISCUSSION

A. Effect of integrated nutrient management on plant height, number of primary branches and number of leaves

The application of various mixes of organic and inorganic fertiliser resulted in a noticeable difference in plant height. The T_7 treatment (50% RDF + 25% *Azospirillum* + 25% vermicompost) had the tallest plants at 30 DAS (38.48 cm), followed by the T_3-75% RDF + 25% *Azospirillum* (36.53) and the T_2- 100% RDF (36.53), while the T_1 control had the shortest plants at 30 DAS (27.43 cm). The maximum plant height i.e. 83.85 cm were noted by the application of T_7- 50% RDF +25% *Azospirillum* + 25% vermicompost closely followed by T_3- 75% RDF + 25 % *Azospirillum i.e.* 82.37 cm and T_2– 100% RDF i.e.,81.45 cm, respectivelyand this improvement was significantly highest then rest of the treatment, however, minimum values i.e. 66.68 cm and 69.33 cm were in control where plots were deprived off by the use of any organic and inorganic fertilizers. The maximum plant height i.e., 138.37 cm were noted by the application of T_7- 50% RDF + 25% *Azospirillum* + 25% vermicompost closely followed by T_3- 75% RDF + 25% Azospirillium i.e., 137.65 cm and T_2- 100% RDF i.e. 136.55 cm, respectively and this improvement was significantly highest then rest of the treatment, however, minimum values i.e. 117.65 cm and 123.54 cm were in control where plots were deprived off by the use of any organic and inorganic fertilizers. The application of organic nutrients along with RDF might have improved the soil physical and chemical properties and leading to the adequate supply of nutrients to the plants which might have promoted the maximum vegetative growth while the minimum plant growth was due to non-availability of nutrients. Similar findings were reported by Tensingh and Muthulakshmi (2017); Samar (2018); Abbas *et al.* (2019); Singh and Tiwari (2020); Singh *et al.* (2021) in Okra.

Critical analysis of the data revealed that different treatments significantly increased the number of branches per plant at all stages of growth, with T_7-50% RDF + 25% *Azospirillum* + 25% vermicompost recording the highest number of branches per plant, 4.28 and 5.66 at 60 and 90 DAS respectively while the lowest number of branches per plant, 3.12 and 4.22 were recorded with T_1 (control) for 60 and 90 DAS respectively.

The results of the data analysis showed that different treatments significantly increased the number of leaves per plant at 45 DAS of growth. The highest number of leaves per plant, 10.35, was recorded with T_7-50% RDF + 25% *Azospirillum* + 25% vermicompost, followed by T_3- 75% RDF + 25% Azospirillium, which was 10.29, and the lowest number of leaves per plant, 7.24, was recorded with T_1 (control) during, respectively. At 90 DAS The maximum number of leaves per plant, 20.52 a, were recorded with T_7-50% RDF + 25% *Azospirillum* + 25% vermicompost, followed closely by T_3- 75% RDF + 25% Azospirillium, with a minimum number of leaves per plant, 15.78, with T_1 (control), respectively. The application of integrated nutrients might have improved the soil physical and chemical properties and leading to the adequate supply of nutrients to the plants which might have promoted the maximum vegetative growth enhancing the number of branches and leaves per plant while the minimum plant growth was due to non-availability of nutrients. Similar findings were reported by Adekunle (2013); Tensingh and Muthulakshmi (2017); Samar (2018); Abbas *et al.* (2019) in Okra.

B. Days to first flowering, days to 50% flowering, days to first fruiting, fruit set percent and number of fruits per plant

The maximum number of days to the first flowering, or 47.67, was noted during, with the application of T_1-(Control) coming in second at 46.89, closely followed by T_2 - 100% RDF. The treatment T_7 (50% RDF + 25% *Azospirillum* + 25% Vermicompost) was found to have the shortest minimum time to first flowering (44.22 days). The application of T_1 (Control) was closely followed by T_3- 75% RDF + 25% *Azospirillum,* i.e., 55.33%, and T_8-50% RDF + 25% FYM + 25% Vermicompost, i.e. 55.67% for the maximum days to 50% flowering, respectively. The treatment T_7 (50% RDF + 25% *Azospirillum* + 25% Vermicompost) was found to have the shortest time (53.67) to 50% flowering. The application of T_7- 50% RDF + 25% *Azospirillum* + 25% vermicompost, which was followed closely by T_3- 75% RDF + 25% Azospirillium, resulting in a minimum day to first fruiting of 66.32, was recorded. The treatment T_1 (control) was found to have the longest time (68.32 days) until the first fruiting. Integration of organic nutrition with fertilizers favored vigorous growth and synthesized more these hormones in plants, which might have helped to the translocation as well as more quantity of available phosphorus through the xylem vessels and their accumulation in the axillary buds that would have favored the plant to enter reproductive phase comparatively earlier. Similar findings were reported by Tensingh and Muthulakshmi (2017); Samar (2018); Abbas *et al.* (2019); Abha *et al.* (2019); Singh *et al.* (2021) in Okra.

The maximum number of fruits per plant was noticed under treatment T_7-50 % RDF + 25% Azospirillium + 25% vermicompost i.e. 15.30 closely followed by T_3- 75 % RDF +25% Azospirillium i.e. 14.98 and 14.60 being at par with T_2 and it was significantly superior over remaining treatments, however, minimum values i.e. 11.78 were in control where plots were deprived off by the use of organic and inorganic fertilizer in the years.

C. Fruit length, diameter and weight, Fruit yield per plant and fruit yield per hectare

The treatment T_7- 50% RDF + 25% *Azospirillum* + 25% vermicompost produced the longest fruit, measuring 12.58 cm, followed by T_3- 75% RDF + 25% Azospirillium, which was on par with T_7 and significantly better than the other treatments (12.27 cm). During the experimentation year, the T_1 (control) treatment had the shortest fruit length (8.47 cm). Treatment T_7- 50% RDF + 25% *Azospirillum* + 25% vermicompost had the largest fruit diameter, measuring 3.16 cm, followed by Treatment T_3- 75% RDF + 25% Azospirillium, measuring 3.11 cm, which was on par with T_7 and significantly better than the other treatments. However, Treatment T_1 (control) had the smallest fruit diameter, measuring 1.98 cm. The treatment T_7- -50 % RDF + 25% *Azospirillum* + 25% vermicompost i.e. (13.85gm) closely followed by T_3- 75 % RDF + 25% Azospirillium i.e. (13.77gm) closely followed by T_2 -100 % RDF i.e. (13.65gm) during, respectively. The values recorded being at parwith T_7 and it was significantly superior over remaining treatments. The minimum values (11.76 gm) fruit fresh weight were recorded in T_1 (control) treatment during the year of experimentation.

Treatment T_7- 50% RDF + 25% yielded the most fruit per plant, according to data. *Azospirillum* + 25% vermicompost, or 0.206 kg, came in second place, followed by T_3- 75% RDF + 25% Azospirillium, or 0.200 kg, which was on par with T_7 and significantly better than other treatments. However, the control plots, where organic and inorganic fertilizer was not used, had the lowest values, or 0.134 kg.

The more fruit yield per plot (4.296kg) was recorded under the treatment T7- - 50 % RDF +25% *Azospirillum* +25% vermicompost closely followed by T_3- 75 % RDF + 25% Azospirillium i.e., 3.200 kg being at par with T7 and it was significantly superior over remaining treatments. The lower (2.149 kg) fruit yield per plot were observed in T_1 (control) treatment during the year of experimentation. Integrated Nutrient Management (INM) significantly enhances okra yields and fruit characteristics. By combining organic and inorganic fertilizers, INM ensures a balanced nutrient supply, promoting healthy plant growth and increased yield per plant. It supports longer fruit length and larger diameters due to improved cell expansion and development. Additionally, INM enhances fruit weight, resulting in more substantial okra pods. This holistic approach enhances overall crop health, reduces nutrient imbalances, and minimizes environmental impact, ultimately leading to improved okra production and quality. Similar findings were reported by Sundari and Gandhi (2013); Sharma *et al.* (2014); Miglani *et al.* (2017); Bamboriya *et al.* (2018); Samar (2018); Devanda *et al.* (2021) in Okra.

D. Economic parameter

The treatment T_3 (75% RDF+ 25% *Azospirillum*), which yielded 14.81 t/ha and recorded the benefit: cost ratio of 3.72, was closely followed by the treatment T_7, which achieved the more fruit yield of 15.26 t/ha and recorded the higher benefit-cost ratio of 4.25. The treatment T_1 (Control) had the lowest benefit-to-cost ratio (2.67).

Table 1: Effect of Integrated Nutrient Management on different growth parameters of okra.

Treatment	Plant Height (cm)			No. of branches per plant		No of leaves per plant	
	30 DAS	60 DAS	90 DAS	60 DAS	90 DAS	45 DAS	90 DAS
T_1 - Control	27.43	66.68	117.65	3.12	4.22	7.24	15.78
T_2 - 100% RDF	36.53	81.45	136.55	4.15	4.56	9.31	18.53
T_3- 75% RDF + 25% *Azospirillum*	37.63	82.37	137.65	4.22	5.01	10.29	19.73
T_4 -50% RDF + 50%FYM	30.47	69.33	121.25	3.33	4.89	9.12	18.23
T_5- 50% RDF + 50% Vermicompost	32.65	73.15	124.82	3.65	5. 12	8.23	16.43
T_6- 50% RDF + 25% *Azospirillum* + 25% FYM	31.17	70.56	122.43	3.43	4.98	9.23	18.57
T_7- 50% RDF + 25% *Azospirillum* + 25% Vermicompost	38.48	83.85	138.37	4.28	5.66	10.35	20.52
T_8- 50% RDF + 25% FYM + 25% Vermicompost	31.85	72.02	123.54	3.57	4.34	9.17	18.33
CD@5%	**4.477**	**2.039**	**2.220**	**0.292**	**1.345**	**0.263**	**0.431**
S.E.(d)	**1.555**	**0.708**	**0.771**	**0.101**	**2.674**	**0.106**	**0.208**

Table 2: Effect of Integrated Nutrient Management on different earliness and yield parameters of okra.

Treatments	Days to 1st flowering	Days to 50% flowering	Days to first fruiting	No of fruits per plant	Fruit yield per plant (kg/plant)	Fruit yield per plot (kg/plot)
T_1 - Control	47.67	56.33	68.32	11.78	0.134	2.149
T_2 - 100% RDF	46.89	55.67	67.22	14.60	0.195	3.120
T_3- 75% RDF + 25% *Azospirillum*	47.00	55.33	66.89	14.98	0.200	3.200
T_4 -50% RDF + 50%FYM	44.56	54.67	67.54	12.33	0.148	2.373
T_5- 50% RDF + 50% Vermicompost	46.33	55.67	68	12.95	0.165	2.645
T_6- 50% RDF + 25% *Azospirillum* + 25% FYM	44.78	53.67	69.00	12.47	0.155	2.475
T_7- 50% RDF + 25% *Azospirillum* + 25% Vermicompost	44.22	53.38	66.32	15.30	0.206	4.296
T_8- 50% RDF + 25% FYM + 25% Vermicompost	45.56	54.00	67.25	12.65	0.160	2.560
CD@5%	**0.38**	**0.44**	**0.292**	**1.449**	**0.019**	**0.309**
S.E.(d)	**1.24**	**1.31**	**0.101**	**0.503**	**0.007**	**0.107**

Table 3: Effect of Integrated Nutrient Management on different fruit parameters of okra.

Treatments	Fruit length (cm)	Fruit diameter (cm)	Single Pod weight (g)
T_1- Control	8.47	1.98	11.76
T_2- 100% RDF	10.05	2.25	13.65
T_3- 75% RDF + 25% *Azospirillum*	12.27	3.11	13.77
T_4 -50% RDF + 50%FYM	9.73	2.37	12.15
T_5- 50% RDF + 50% Vermicompost	10.23	2.20	12.50
T_6- 50% RDF + 25% *Azospirillum*+ 25% FYM	9.33	2.18	12.21
T_7- 50% RDF + 25% *Azospirillum* + 25% Vermicompost	12.58	3.16	13.85
T_8- 50% RDF + 25% FYM + 25% Vermicompost	11.96	2.95	12.34
CD@5%	0.155	0.507	1.190
S.E.(d)	0.054	0.176	0.413

Table 4: Effect of Integrated Nutrient Management on economics of okra.

Treatment	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
T_1 - Control	36800	98160	61360	2.67
T_2 - 100% RDF	36600	132954	90340	3.63
T_3- 75% RDF + 25% *Azospirillum*	38200	142320	104120	3.72
T_4 -50% RDF + 50% FYM	38400	119280	80880	3.10
T_5- 50% RDF + 50% Vermicompost	38300	113400	75100	2.96
T_6- 50% RDF + 25% *Azospirillum* + 25% FYM	35350	123220	82700	3.48
T_7- 50% RDF + 25% *Azospirillum* +25% Vermicompost	38500	163920	125420	4.25
T_8- 50% RDF + 25% FYM + 25% Vermicompost	37800	119250	84200	3.15

CONCLUSIONS

The overall results obtained from this present investigation clearly revealed that the application of T_7 ((50% RDF + 25% *Azosprillum* + 25% vermicompost) showed the better performance for vegetative growth (plant height, number of branch per plant, number of leaves per plant ,leaf area, days to 50% flowering), yield attributes [number of fruit per plant, fruit yield per plant (kg), fruit yield per plot (kg), single pod weight (g), of okra except fruit length and fruit diameter and would be useful to enhance the productivity of okra.

FUTURE SCOPE

1. Conduct long-term field experiments to study the sustained effects of integrated nutrient management on soil health, yield and quality over several cropping seasons.
2. Evaluate different combinations and proportions of organic and inorganic sources to optimize the nutrient supply for higher productivity.
3. Study the residual effects of treatments on the succeeding crops in a crop rotation system.
4. Analyze the changes in soil biological, chemical and physical properties under different treatments over time.
5. Analyze the nutrient uptake, use efficiency and balance in the soil-plant system under integrated nutrient management.
6. Study the interaction effects of integrated nutrient management with other agronomic practices like irrigation, mulching etc.

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Conflict of Interest. None.

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