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Impact of integrated nutrient management on the growth, yield, and quality of Okra (*Abelmoschus esculentus* L. Moench)

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Abstract
The present investigation entitled Study of Integrated Nutrient Management on Growth, Yield and Quality of Okra [*Abelmoschus esculentus* (L.) Moench]" was conducted during *Kharif* season from July to November 2023 at College of Horticulture, Rama University, Kanpur. he experiment was laid out in Randomized Block Design with 10 treatments *viz*., T_1-Control (No use of fertilizers), T_2-100% Recommended dose of fertilizers (RDF), T_3-75% RDF + 25% RDN through FYM + Azotobacter+ Phosphorus solubilizing bacteria [PSB], T_4-50% RDF + 50% RDN through FYM, T_5-75% RDF + 25% RDN through vermicompost + Azotobacter + Phosphorus solubilizing bacteria [PSB], T_6-50% RDF + 50% RDN through vermicompost, T_7-75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter+ Phosphorus solubilizing bacteria [PSB], T_8-50% RDF + 25% RDN through FYM + 25% RDN through vermicompost + Azotobacter + Phosphorus solubilizing bacteria [PSB], T_9 -100% RDN through FYM and T_{10}-100% RDN through vermicompost. These treatments were replicated thrice. The growth attributes were significantly affected due to the different INM treatments. Application of inorganic fertilizers in combination with organic manures and biofertilizers i.e. 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter+ Phosphorus solubilizing bacteria [PSB] recorded significantly higher plant height (25.16, 78.68, and 125.64 cm), number of leaves (11.54, 45.55 and 55.50), number of branches (0, 2.19 and 4.41) and inter nodal length (2.41, 5.47 and 6.95 cm) at 30, 60 and at final harvest respectively.

Keywords: Azotobacter, PSB, okra, nitrogen, phosphorus and potash

1. Introduction

Bhindi, or Okra scientifically known as *Abelmoschus esculentus* L. Moench, belongs to the Malvaceae family, with a somatic chromosome count of 2n=130. Originating from tropical and subtropical regions of Africa, America, Turkey, and neighboring countries, it has also found prominence in India. Particularly popular in Uttar Pradesh, it goes by various names internationally: Lady's finger in England, Gumbo in the United States of America, and Bhindi in India.

As an economically significant vegetable crop, Okra thrives in tropical and subtropical climates worldwide. Its cultivation spans from small-scale garden plots to large commercial farms. Commercial cultivation of Okra is widespread in countries such as India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malaysia, Brazil, Ghana, Ethiopia, Cyprus, and the Southern United States. In the current landscape of dietary awareness, organic produce stands out as a prominent topic within modern agriculture. Additionally, concerns regarding climate variability have become paramount within the farming community, encompassing issues such as extreme weather patterns, desertification, and water scarcity, which all contribute to adverse health outcomes.

The excessive reliance on chemical fertilizers to achieve high yields has led to numerous detrimental effects on soil health, including the depletion of micronutrients (Balasubramani, 1997) [1], stunted growth in plant morphology such as root and shoot systems, as well as reproductive parts (Bharthy *et al*., 2016) [2], and nutrient imbalances (Gayathri and Krishnaveni, 2015) [3], ultimately resulting in diminished crop yields.

In light of these challenges, the adoption of organic farming practices emerges as a sustainable solution. By focusing on nutrient conservation, minimizing exploitation, and bolstering soil organic matter content, organic agriculture offers a pathway towards maintaining agricultural viability amidst contemporary agricultural challenges. The International Federation of Organic Agriculture Movements (IFOAM) defines organic agriculture as a production system designed to uphold the health of soils, ecosystems, and people. It operates on the principles of ecological processes, biodiversity, and locally adapted cycles, eschewing the sole reliance on costly chemical inputs that have detrimental effects. Organic agriculture blends traditional wisdom, innovative practices, and scientific knowledge to nurture the shared environment and foster equitable relationships, striving for a high quality of life for all involved stakeholders.

Okra stands out as a nutritional powerhouse, boasting a wealth of iodine and other essential minerals and vitamins. Its mucilage contains polysaccharides such as galacturonic and glucuronic acids. Furthermore, okra possesses medicinal properties, serving as a plasma replacement or blood volume expander, and effectively binding cholesterol and bile acid toxins excreted by the liver. The seeds of okra are particularly rich in protein and unsaturated fatty acids like linoleic acid (Mal *et al.*, 2013) [4], while also serving as excellent sources of calcium and potassium.

Various endeavors have been undertaken to boost okra productivity without compromising soil nutrient levels. These efforts involve the use of biofertilizers alongside organic and inorganic nutrient inputs. The outcomes have been promising, including increased biological nitrogen fixation, enhanced nutrient availability through phosphate solubilization, improved nutrient absorption capacity, stimulation of plant growth, and higher yields attributed to rapid organic residue decomposition. A comprehensive review is underway to elucidate the impact of integrated nutrient management on okra yield in recent years.

2. Materials and Methods

The experiment took place at the Agriculture Research Farm, Department of Horticulture, Rama University, Kanpur (Uttar Pradesh), under the agroclimatic conditions of Kanpur, from August to October 2023. The soil in the experimental field was sandy loam, deficient in nitrogen, relatively rich in phosphorus, and medium in potash, with a slightly alkaline pH. To prepare the soil for sowing, one round of cross-cultivation was conducted using a tractor-drawn cultivator, followed by two rounds of harrowing and one round of planking. Thinning of the plants was performed two weeks after sowing to maintain a distance of 45 cm between plants and 60 cm between rows. In this experiment, ten treatment groups were established. The first group, labeled T_1, served as the control group where no fertilizers were applied. The second group, T_2, received 100% of the recommended dose of fertilizers (RDF). Group T_3 was treated with 75% of RDF along with 25% of the recommended dose of nitrogen (RDN) supplied through Farm Yard Manure (FYM), Azotobacter, and Phosphate Solubilizing Bacteria (PSB). T_4 received 50% of RDF combined with 50% of RDN from FYM. In T_5, 75% of RDF was supplemented with 25% of RDN from vermicompost, along with Azotobacter and PSB. T_6 received 50% of RDF and 50% of RDN from vermicompost. T_7 was treated with 75% of RDF, with 12.5% of RDN from FYM, 12.5% of RDN from vermicompost, and supplemented with Azotobacter and PSB. Group T_8 received 50% of RDF, with 25% of RDN from FYM, 25% of RDN from vermicompost, and supplemented with Azotobacter and PSB. T_9 received 100% of RDN from FYM, while T_{10} received 100% of RDN from vermicompost. The plants were randomly arranged, and observations were recorded at regular intervals from the experimental field. All parameter characteristics were analyzed using the analysis of variance (ANOVA) technique. Critical difference values were calculated at a significance level of 5%.

3. Results and Discussion

The experimental results of the present investigation are presented, with the findings regarding growth, yield, and quality parameters of various treatments discussed in the following pages under relevant headings.

Table 1: Effect of integrated nutrient management on plant height (cm) and number of leaves per plant of okra at 30 DAS, 60DAS and at final harvest

Treatments	30 DAS	60 DAS	At final harvest	30DAS	60 DAS	At final harvest
T_1	20.80	66.53	109.69	6.62	31.53	38.52
T_2	24.52	75.8	123.72	11.38	44.53	53.53
T_3	23.96	75.12	119.7	10.53	41.58	48.54
T_4	23.13	69.74	114.53	9.54	36.73	42.58
T_5	24.72	75.32	122.74	10.57	42.53	51.56
T_6	23.28	71.82	115.6	9.56	37.57	44.56
T_7	25.16	78.68	125.64	11.54	45.55	55.5
T_8	22.35	73.53	117.95	9.58	39.55	46.62
T_9	23.78	69.32	110.58	7.56	34.53	41.53
T_{10}	22.85	69.53	112.58	8.54	35.57	42.31
SEM ±	0.67	1.09	2.47	0.15	0.83	1.21
CD at 5%	2.02	3.27	7.39	0.46	2.49	3.64

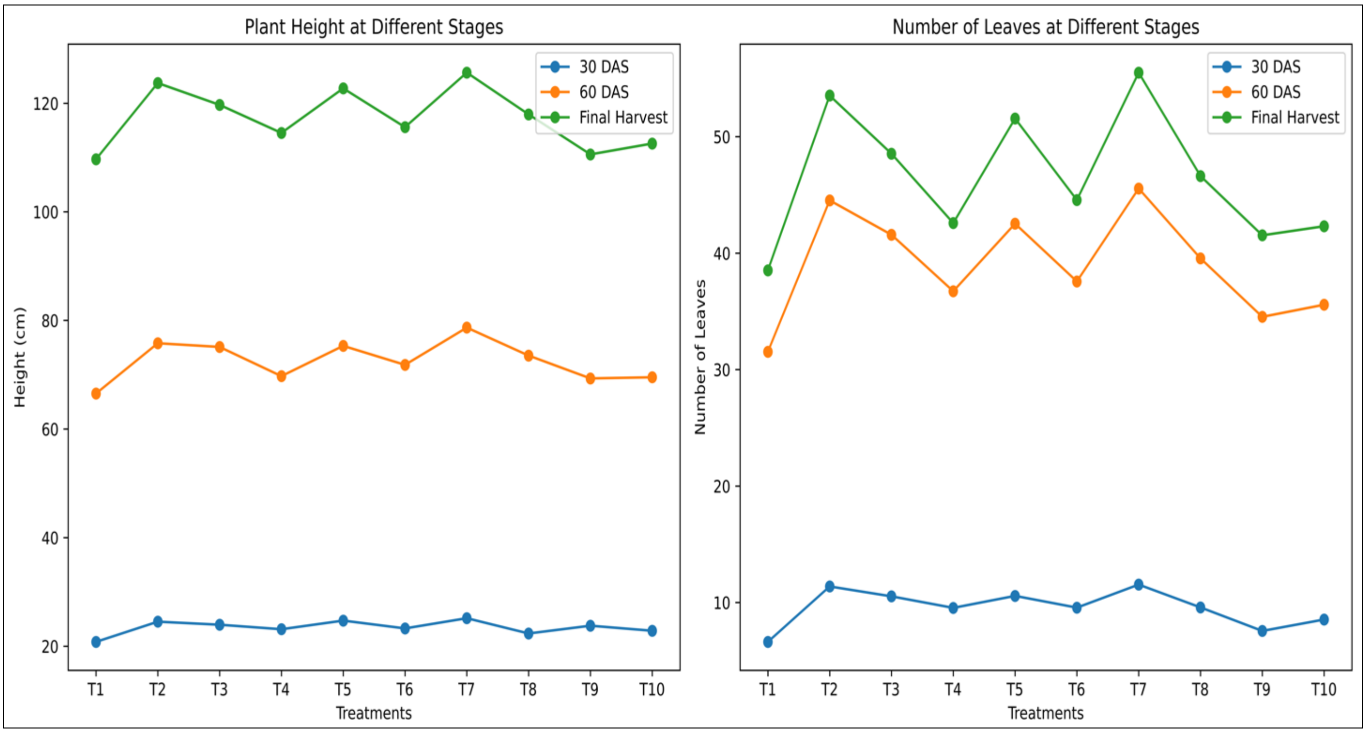

Fig 1: Effect of integrated nutrient management on plant height (cm) and number of leaves per plant

The information regarding the effect of integrated nutrient management on plant height at 30 and 60 days after sowing, as well as at the final harvest stage, is presented in Table 1. Additionally, it is graphically depicted in Figure 1. Significant differences in plant height were observed across integrated nutrient management treatments at 30 days after sowing (DAS), 60 DAS, and at harvest time. Treatment 1, serving as the Control for comparison, recorded plant heights of 20.80 cm, 66.53 cm, and 109.69 cm, respectively. Among other treatments, Treatment 7 displayed the tallest plants at all stages, with heights of 25.16 cm (30 DAS), 78.68 cm (60 DAS), and 125.64 cm (final harvest). Overall, Treatment 7 exhibited the most significant growth enhancement. This can also be attributed to the favorable effects of vermicompost, Azotobacter, and PSB (organic sources) on microbial activity and root proliferation in the soil, leading to a solubilizing effect on native nitrogen, phosphorus, potassium, and other nutrients. The reduced dosage of chemical fertilizers supplemented with organic manures also decreases the exploitation of micronutrients. The results further demonstrate that the soil application of balanced fertilizers with Azotobacter and PSB significantly improved growth parameters such as plant height of okra compared to chemical fertilization alone. These findings align closely with previous studies by Nambiar (1994) [5], Biswas and Benbi (1997) [7], Santhy *et al.* (2001) [6], and Hegde (1996) [8], which emphasized the benefits of combined fertilizer and organic manure usage on crop growth.

Table 1 illustrates the impact of integrated nutrient management on the number of leaves per okra plant at 30 days after sowing (DAS), 60 DAS, and final harvest. Treatment 1, serving as the control for comparison, exhibited an average of 6.62 leaves per plant at 30 DAS, increasing to 31.53 leaves at 60 DAS, and reaching 38.52 leaves at final harvest. Among other treatments, Treatment 7 displayed the highest number of leaves per plant at all stages, with counts of 11.54 leaves (30 DAS), 45.55 leaves (60 DAS), and 55.5 leaves (final harvest). The results also indicate that the application of balanced fertilization with Azotobacter and PSB significantly enhanced the growth parameters of okra compared to chemical fertilization alone. Improvement in crop growth attributed to Azotobacter, the microbial inoculants, is due to their ability to fix atmospheric nitrogen through free-living N2 fixers in the rhizosphere. Additionally, they produce various growth substances such as indole acetic acid, gibberellins, vitamin-B, and antifungal substances. The superior efficiency of organic manures in combination with inorganic fertilizers may stem from their ability to provide micronutrients like zinc, iron, copper, manganese, etc., at optimal levels. Application of organic manures could have facilitated plant metabolism by supplying essential micronutrients during the early growth phase, thereby promoting vigorous growth, including the number of leaves per plant of okra cv. Arka Anamika (Barani and Anburani, 2004).

3.1.1 Number of branches per plant

The data regarding the number of branches per plant at 60 days after sowing and at the final harvest stage, influenced by integrated nutrient management, is presented in Table 2.

Table 2: Effect of integrated nutrient management on number of branches and internodal length (cm) of okra at 30 DAS, 60 DAS and at final harvest

Treatments	30 DAS	60 DAS	At final harvest	30DAS	60 DAS	At final harvest
T_1	0.00	0.97	2.45	0.86	4.6	6.08
T_2	0.00	1.65	4.40	1.49	5.45	6.77
T_3	0.00	1.90	4.17	1.46	5.42	6.47
T_4	0.00	1.65	3.43	1.41	4.46	6.7
T_5	0.00	1.93	3.47	1.48	5.44	6.8
T_6	0.00	1.43	3.45	1.42	4.48	6.78
T_7	0.00	2.19	4.41	2.41	5.47	6.95
T_8	0.00	1.44	3.46	1.44	5.4	6.42
T_9	0.00	1.50	3.4	1.38	4.68	6.49
T_{10}	0.00	1.61	3.42	1.39	4.44	6.62
SEM ±	00.00	0.04	0.09	0.03	.015	0.013
CD at 5%	00.00	.013	.027	0.13	0.44	0.038

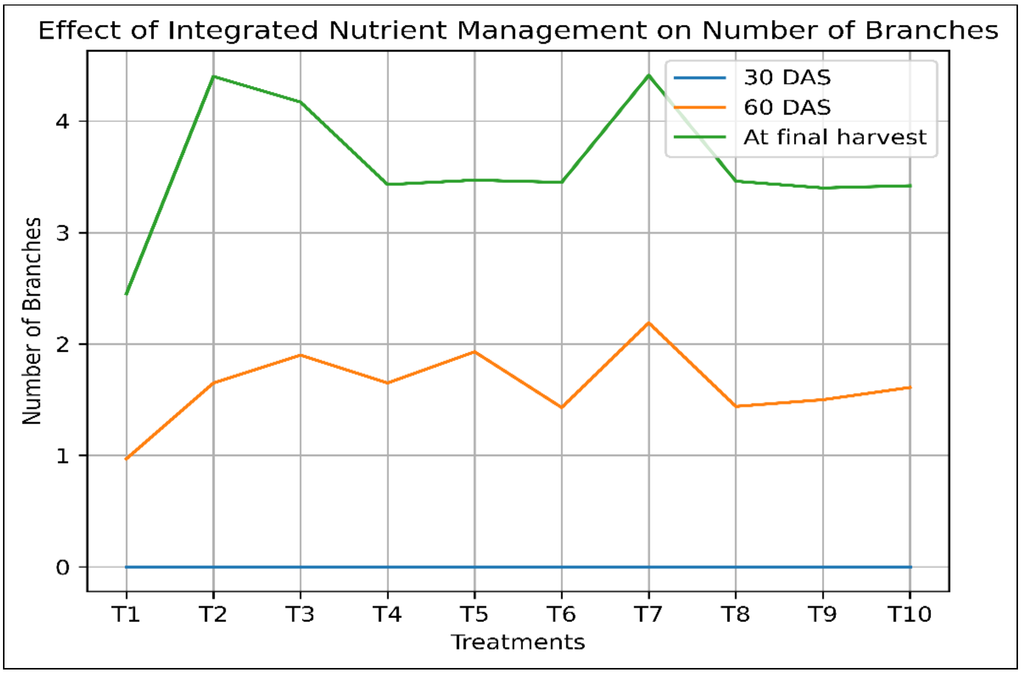

Fig 2: Effect of integrated nutrient management on number of branched of okra at 30 DAS, 60DAS and at final harvest

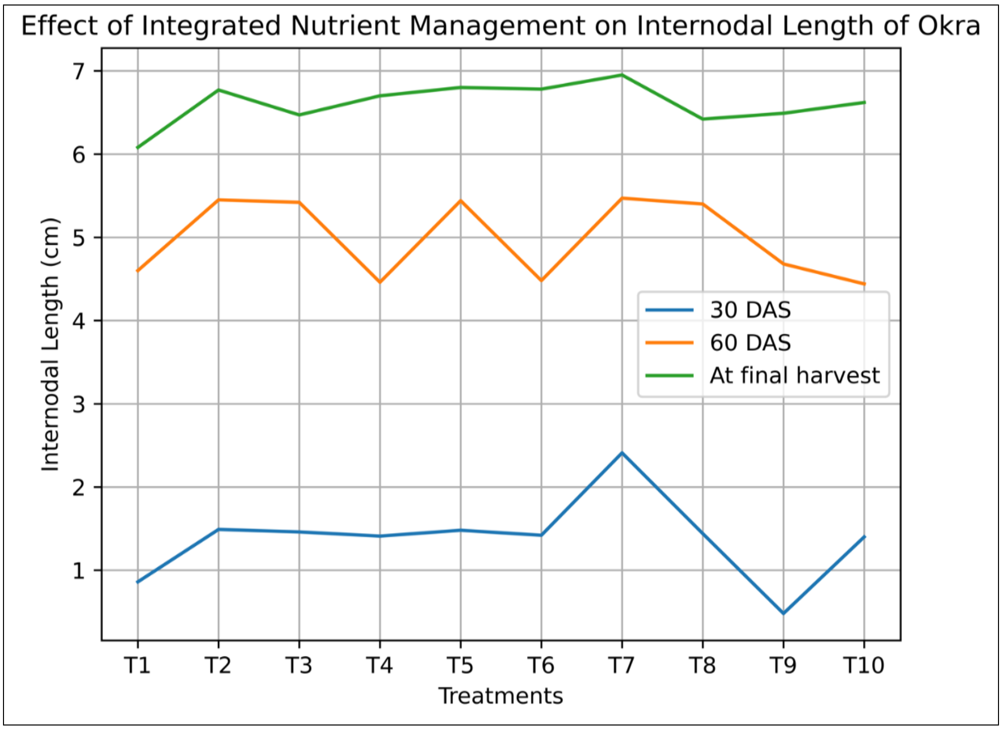

Fig 3: Effect of integrated nutrient management on internodal length (cm) of okra at 30 DAS, 60DAS and at final harvest

Table 2 displays the impact of integrated nutrient management on the number of branches of okra plants at 30 days after sowing (DAS), 60 DAS, and final harvest. Treatment 1 exhibited no branches at 30 DAS, gradually increasing to 0.97 branches at 60 DAS, and further to 2.45 branches at final harvest. Significant differences in number of branches per plant at harvest stage were recorded. Highest number of branches per plant was recorded in T_7 - 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter+ Phosphorus solubilizing bacteria [PSB] Treatment 7 recorded no branches at 30 days after sowing (DAS), followed by an increase to 2.19 branches at 60 DAS, and reaching 4.41 branches at final harvest. Following Treatment 7, Treatment 8 displayed no branches at 30 DAS, 1.44 branches at 60 DAS, and 3.46 branches at final harvest. Treatment 9 exhibited no branches at 30 DAS, 1.50 branches at 60 DAS, and 3.40 branches at final harvest. Lastly, Treatment 10 showed no branches at 30 DAS, 1.61 branches at 60 DAS, and 3.42 branches at final harvest. The enhanced efficiency of organic manures and biofertilizers in conjunction with inorganic fertilizers may be attributed to the provision of micronutrients such as zinc, iron, copper, manganese, etc., at optimal levels by organic manures. Application of organic manures could have facilitated plant metabolism by supplying these essential micronutrients during the early growth phase, thereby promoting vigorous growth of okra cv. Arka Anamika. These findings align closely with previous studies by Nambiar (1994) [5], Biswas and Benbi (1997) [7], Santhy *et al.* (2001) [6], and Hegde (1996) [8], which also emphasized the beneficial effects of combined fertilizer and organic manure usage on crop growth.

The information regarding internodal length (in centimeters) at 30, 60 days after sowing, and at the final harvest stage, affected by integrated nutrient management, is displayed in Table 2, the effects of integrated nutrient management on the internodal length (in centimeters) of okra plants at 30 days after sowing (DAS), 60 DAS, and final harvest. At 30 DAS, the internodal lengths ranged from 0.86 cm to 2.41 cm. By 60 DAS, the lengths increased, varying between 4.44 cm and 5.47 cm. At final harvest, the internodal lengths ranged from 6.08 cm to 6.95 cm. These results highlight the impact of different nutrient management strategies on the elongation of internodes in okra plants throughout their growth stages. The significant impact on internodal length (in centimeters) due to vermicompost, biofertilizers, and chemical fertilization can be attributed to the improved nutritional status of the soil, leading to enhanced crop growth. This improvement may also be credited to the beneficial effects of farmyard manure (FYM), vermicompost, Azotobacter, and PSB (organic sources) on soil microbial activity and root proliferation, resulting in the solubilization of native nitrogen, phosphorus, potassium, and other nutrients. Additionally, the reduced application of chemical fertilizers supplemented with organic manures helps mitigate the depletion of micronutrients. These findings align closely with previous studies by Nambiar (1994) [5], Biswas and Benbi (1997) [7], Santhy *et al.* (2001) [6], and Hegde (1996) [8], highlighting the agreement regarding the combined use of fertilizers and organic manures in enhancing crop growth.

Conclusion

The findings of this study indicate that employing a combination of 75% recommended dose of fertilizer (RDF), 12.5% RDF via farmyard manure (FYM), 12.5% RDF through vermicompost, along with Azotobacter and phosphorus-solubilizing bacteria (PSB) resulted in significant improvements in the growth, yield, quality, and uptake of major nutrients in okra. Additionally, this approach contributed to enhancing soil fertility. The inclusion of FYM, vermicompost, and biofertilizers alongside reduced chemical fertilizer levels demonstrated a positive impact on soil fertility. Therefore, for optimal okra production and sustainable yield, it is advisable to adopt an integrated approach, combining inorganic (75% RDF), organic (12.5% RDF via FYM + 12.5% RDF via vermicompost), and biofertilizers (Azotobacter + PSB) during cultivation. The results clearly underscored the significance of combining inorganic fertilizers with organic manure and biofertilizers, highlighting the efficacy of integrated nutrient management in okra production

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