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Impact of Integrated Nutrient Management on Vegetative Characteristics and Yield of Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl.] cv. Pusa Naveen

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation entitled "Impact of Integrated Nutrient Management on Growth and Yield of Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl.] cv. Pusa Naveen" was conducted during the *Kharif* season of 2024 at the Horticulture Experimental Field, College of Agriculture, RVSKVV, Gwalior (M.P.). The main objective of the study was to evaluate the influence of integrated nutrient management (INM) on growth, yield and quality attributes of bottle gourd. The experiment comprised thirteen treatments replicated thrice in a Randomized Block Design (RBD). Among the

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treatments, T_{13}- 75% RDF + Vermicompost (12 t/ha) + Azotobacter (5 kg/ha) + PSB (5 kg/ha) + KSB (5 lit/ha) recorded significantly superior performance across all observed parameters. In contrast, the control treatment T_1 (100% RDF alone) exhibited the least performance. Treatment T_{13} showed remarkable improvements in morphological parameters such as germination percentage, vine length, number of primary branches per vine, number of nodes per vine up to the first male and female flowers and internodal length. In terms of phenological traits, it also showed first appearance of male and female flower. Yield attributes including days to first picking, number of fruits per plant, fruit length and diameter, pedicel length and average fruit weight were significantly influenced by the application of different INM combinations. The highest values for all these yield parameters were observed in treatment T_{13}, while the lowest were recorded in the control (T_1), confirming the beneficial effects of integrated nutrient management in enhancing the overall performance of bottle gourd.

Keywords: Biofertilizers; bottle gourd; growth and yield attributes; morphological and phenological traits.

1. INTRODUCTION

Bottle gourd (*Lagenaria siceraria* [Mol.] Standl.), a member of the Cucurbitaceae family, originates from South Africa and is an annual, cross-pollinated vine (2n=22) grown in warm climates. Its tender fruits are widely used as vegetables, pickles and sweets, while the hard shells of mature fruits serve as containers, utensils and ornaments. Medicinally, it offers various benefits- fruit poultices heal wounds and parts of the plant are used in treatments for headaches and jaundice (Harika *et al*., 2012). In India, bottle gourd is mainly cultivated in Bihar, Madhya Pradesh, Haryana, West Bengal and Uttar Pradesh. During 2023-24, it was grown on 224 thousand hectares with a production of 3780 thousand MT. In Madhya Pradesh alone, 30.30 thousand hectares yielded 539.19 thousand MT (Anonymous, 2024). Nutritionally, it is low in calories and rich in vitamins and minerals, while its seeds are a good source of protein, oil and antioxidants (Leghari *et al*., 2014). Excessive and continuous use of chemical fertilizers degrades soil health and the environment (Dass *et al*., 2008). A shift toward integrated nutrient management (INM), combining organic and inorganic sources, supports sustainable productivity. Organic inputs like vermicompost, FYM and biofertilizers enhance soil fertility, plant growth and yield (Nagar *et al*., 2017). Vermicompost improves nutrient availability, microbial activity and plant growth via biologically active compounds (Mahale *et al*., 2018). FYM supplies essential nutrients and improves soil structure, supporting crop productivity (Baghel *et al*., 2017). Biofertilizers enhance nutrient cycling, particularly nitrogen fixation and carbon assimilation, promoting sustainable agriculture (Patle *et al*., 2018). Among essential nutrients, nitrogen is vital for protein synthesis and overall growth, phosphorus for root and reproductive development and potassium for improving fruit quality and stress resistance (Bhosale, 2016). Integrated nutrient management, therefore, ensures optimal yields while enhancing soil health through a balanced application of organic and inorganic sources tailored to specific crop and climatic conditions.

2. MATERIALS AND METHODS

The field experiment was Implemented during the rainy season of 2024-25 at the Experimental Field, Department of Horticulture, College of Agriculture, Gwalior, under the agro-climatic conditions of northern Madhya Pradesh. The experimental site is located at 26°13′ North latitude and 76°14′ East longitude, at an elevation of 211.52 meters above mean sea level. The Gwalior region receives an average annual rainfall of approximately 700 mm. The soil at the site was slightly alkaline (pH 7.6) with normal electrical conductivity (EC 0.32 dS m^{-1}). It had a medium organic carbon content (0.45 g kg^{-1}), low available nitrogen (197 kg ha^{-1}), medium phosphorus (19 kg ha^{-1}), and low available potassium (241 kg ha^{-1}). The aim of this study was to evaluate the effects of different nutrient management practices on the vegetative traits and yield of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] cv. Pusa Naveen. The experiment was dissipated in a Randomized Block Design (RBD) with thirteen treatments (Table 1.) replicated thrice. Each treatment was applied to plots size of 3×2 m^2. Nutrient management in the study involved using organic manures (FYM at 25 t/ha and vermicompost at 12 t/ha) and biofertilizers (Azotobacter at 5 kg/ha, PSB at 5 kg/ha and KSB at 5 liters/ha), along

Table 1. Treatment details of the experiment (2024-25)

Treatments	Treatments Descriptions
T_1	100% RDF (Control)
T_2	75% RDF + Azotobacter (5 kg/ha) + PSB (5 kg/ha)
T_3	75% RDF + Azotobacter (5 kg/ha) + KSB (5 lit/ha)
T_4	75% RDF + PSB (5 kg/ha) + KSB (5 lit/ha)
T_5	75% RDF + Azotobacter (5 kg/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)
T_6	75% RDF + FYM (25 t/ha) + *Azotobacter* (5 kg/ha) + PSB (5 kg/ha)
T_7	75% RDF + FYM (25 t/ha) + *Azotobacter* (5 kg/ha) + KSB (5 lit/ha)
T_8	75% RDF + FYM (25 t/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)
T_9	75% RDF + FYM (25 t/ha) + *Azotobacter* (5 kg/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)
T_{10}	75% RDF + Vermicompost (12 t/ha) + *Azotobacter* (5 kg/ha) + PSB (5 kg/ha)
T_{11}	75% RDF + Vermicompost (12 t/ha) + *Azotobacter* (5 kg/ha) + KSB (5 lit/ha)
T_{12}	75% RDF + Vermicompost (12 t/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)
T_{13}	75% RDF + Vermicompost (12 t/ha) + *Azotobacter* (5 kg/ha)+ PSB (5 kg/ha) + KSB (5 lit/ha)

with different levels of the recommended NPK fertilizer dose (100:60:80 kg/ha). Before sowing, one-third of the nitrogen and the full amounts of phosphorus and potassium were mixed into the soil. The remaining nitrogen was applied in two equal portions at 30 and 60 days after sowing. All fertilizers and manures were properly incorporated into the soil using a hand hoe according to the treatment plan. From each treatment, five plants were randomly chosen to observe vegetative growth, flowering patterns, sex expression and yield traits. The collected data were analysed statistically using the Analysis of Variance (ANOVA) method and treatment differences were tested for significance using the t-test at the 5% level (P = 0.05).

3. RESULTS AND DISCUSSION

3.1 Effect of Integrated Nutrient Management on Morphological Parameters of Bottle gourd

The mean results presented in Table 2 revealed significant variations in vegetative parameters among the different nutrient and combination of biofertilizer sources. The application of organic manures and biofertilizers in combination with varying levels of recommended fertilizer doses significantly influenced seed germination in bottle gourd. The highest germination percentage was observed under treatment T_{13} (75% RDF + Vermicompost @ 12 t/ha + Azotobacter @ 5 kg/ha + PSB @ 5 kg/ha + KSB @ 5 lit/ha), while the lowest was recorded with T_1 (100% RDF alone). Enhanced germination under integrated nutrient treatments may be attributed to improved soil structure and microbial activity. These results are consistent with the findings of Patle *et al*. (2018), Shree *et al*. (2018), Shah *et al*. (2020) and Mandloi *et al*. (2022).

Treatment T_{13} (75% RDF + Vermicompost @ 12 t/ha + Azotobacter @ 5 kg/ha + PSB @ 5 kg/ha + KSB @ 5 lit/ha) significantly outperformed all other treatments in enhancing vine length at 30, 45, 60 DAS and at the final stage. In contrast, the shortest vines were recorded under T_1 (100% RDF). The superior performance of T_{13} may be attributed to improved soil physical and chemical properties resulting from the combined application of organic, inorganic and biofertilizer inputs, ensuring better nutrient availability and promoting vegetative growth. These findings are supported by Geethu *et al*. (2018), Patel *et al*. (2019) and Pathak *et al*. (2022).

Application of different organic manures and biofertilizers significantly increased the number of primary branches per vine in bottle gourd. The highest number of primary branches was recorded under treatment T_{13} (75% RDF + Vermicompost @ 12 t/ha + Azotobacter @ 5 kg/ha + PSB @ 5 kg/ha + KSB@ 5 lit/ha), while the lowest was observed in T_1 (100% RDF). Enhanced branching could be attributed to improved soil chemical and physical properties resulting from the combined use of organic, inorganic, and biofertilizer inputs. These findings align with those of Rathod *et al*. (2018), Shree *et al*. (2018), Shah *et al*. (2020) and Mandloi *et al*. (2022).

Table 2. Effect of Integrated Nutrient Management on morphological parameters of bottle gourd

Treatments	Germination percentage (%)	Vine length (cm)				Number of primary branches /vine	Number of node/vine upto first female flower	Number of node/ vine upto first male flower	Length of internode /vine (cm)
		30 DAS	45 DAS	60 DAS	At final				
T_1- 100% RDF (Control)	70.19	7.03	85.24	155.26	175.26	7.00	10.00	6.00	6.50
T_2- 75% RDF + AB (5 kg/ha) + PSB (5 kg/ha)	76.59	8.51	92.15	172.12	191.41	8.00	11.33	7.00	7.35
T_3- 75% RDF + AB (5 kg/ha) + KSB (5 lit/ha)	75.03	8.22	90.06	169.66	189.66	7.67	11.00	6.67	7.29
T_4- 75% RDF + PSB (5 kg/ha) + KSB (5 lit/ha)	74.26	7.75	88.81	163.15	184.02	7.33	10.67	6.33	7.05
T_5- 75% RDF + AB (5 kg/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	77.90	8.95	95.42	178.59	199.72	8.33	11.67	7.33	7.65
T_6- 75% RDF + FYM (25 t/ha) + AB(5 kg/ha) + PSB (5 kg/ha)	82.51	10.30	104.55	190.49	210.49	9.67	13.00	8.00	8.52
T_7- 75% RDF + FYM (25 t/ha) + AB (5 kg/ha) + KSB (5 lit/ha)	79.31	9.56	99.49	184.82	206.15	9.00	12.33	7.67	8.06
T_8- 75% RDF + FYM (25 t/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	78.92	9.34	97.29	180.89	200.89	8.33	12.00	7.67	7.88
T_9- 75% RDF + FYM (25 t/ha) + AB (5 kg/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	85.45	11.06	107.04	192.52	212.77	10.00	13.67	8.67	9.06
T_{10}- 75% RDF + VC (12 t/ha) + AB (5 kg/ha) + PSB (5 kg/ha)	89.15	11.72	109.18	194.34	215.14	10.33	14.00	9.00	9.33
T_{11}- 75% RDF + VC (12 t/ha) + AB (5 kg/ha) + KSB (5 lit/ha)	84.04	10.51	106.09	190.66	211.69	9.67	13.33	8.33	8.90
T_{12}- 75% RDF + VC (12 t/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	80.39	9.88	100.27	188.72	209.21	9.33	12.67	8.00	8.18
T_{13}- 75% RDF + VC (12 t/ha) + AB (5 kg/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	91.26	12.36	110.14	195.00	215.75	11.00	14.67	9.33	9.51
SEm (±)	2.92	0.45	3.74	3.15	2.97	0.70	0.76	0.55	0.40
CD 5%	8.30	1.28	10.61	8.93	8.43	1.98	2.17	1.58	1.15

**RDF= Recommended dose of fertilizer, VC= Vermicompost, AB= Azotobacter, PSB= Phosphorus Solubilizing bacteria, KSB= Potassium Solubilizing Bacteria*
SEm= Standard Error of Mean CD= Critical Difference

Table 3. Effect of Integrated Nutrient Management on Phenological parameters of bottle gourd

Treatments	Days to first appearance of female flowers	Days to first appearance of male flowers
T_1- 100% RDF (Control)	54.00	48.33
T_2- 75% RDF + AB (5 kg/ha) + PSB (5 kg/ha)	52.33	47.33
T_3- 75% RDF + AB (5 kg/ha) + KSB (5 lit/ha)	53.00	47.33
T_4- 75% RDF + PSB (5 kg/ha) + KSB (5 lit/ha)	53.33	48.00
T_5- 75% RDF + AB (5 kg/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	52.33	47.00
T_6- 75% RDF + FYM (25 t/ha) + AB(5 kg/ha) + PSB (5 kg/ha)	50.33	46.33
T_7- 75% RDF + FYM (25 t/ha) + AB (5 kg/ha) + KSB (5 lit/ha)	51.33	46.67
T_8- 75% RDF + FYM (25 t/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	51.67	46.67
T_9- 75% RDF + FYM (25 t/ha) + AB (5 kg/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	49.67	46.00
T_{10}- 75% RDF + VC (12 t/ha) + AB (5 kg/ha) + PSB (5 kg/ha)	49.33	45.33
T_{11}- 75% RDF + VC (12 t/ha) + AB (5 kg/ha) + KSB (5 lit/ha)	50.00	46.00
T_{12}- 75% RDF + VC (12 t/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	50.67	46.33
T_{13}- 75% RDF + VC (12 t/ha) + AB (5 kg/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	49.00	45.00
SEm (±)	**0.86**	**0.51**
CD 5%	**2.44**	**1.43**

**RDF= Recommended dose of fertilizer, VC= Vermicompost, AB= Azotobacter, PSB= Phosphorus Solubilizing bacteria, KSB= Potassium Solubilizing Bacteria, SEm= Standard Error of Mean CD= Critical Difference*

Table 4. Effect of Integrated Nutrient Management on Yield Parameters of Bottle gourd

Treatments	Days to first picking	Number of fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Pedicel length (cm)	Average fruit weight (g)
T_1- 100% RDF (Control)	62.67	14.10	26.07	6.00	12.00	0.87
T_2- 75% RDF + AB (5 kg/ha) + PSB (5 kg/ha)	61.67	14.31	27.43	6.55	12.76	0.89
T_3- 75% RDF + AB (5 kg/ha) + KSB (5 lit/ha)	62.00	14.44	27.18	6.35	12.55	0.90
T_4- 75% RDF + PSB (5 kg/ha) + KSB (5 lit/ha)	62.33	14.60	26.98	6.09	12.23	0.91
T_5- 75% RDF + AB (5 kg/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	61.33	14.65	27.87	6.65	13.06	0.91
T_6- 75% RDF + FYM (25 t/ha) + AB(5 kg/ha) + PSB (5 kg/ha)	59.33	15.09	29.18	7.34	13.86	0.97
T_7- 75% RDF + FYM (25 t/ha) + AB (5 kg/ha) + KSB (5 lit/ha)	59.33	15.01	28.13	7.00	13.46	0.92
T_8- 75% RDF + FYM (25 t/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	60.00	15.08	28.02	6.80	13.19	0.92
T_9- 75% RDF + FYM (25 t/ha) + AB (5 kg/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	58.67	15.19	29.99	7.77	14.39	1.02
T_{10}- 75% RDF + VC (12 t/ha) + AB (5 kg/ha) + PSB (5 kg/ha)	58.33	16.40	30.36	7.90	14.64	1.05
T_{11}- 75% RDF + VC (12 t/ha) + AB (5 kg/ha) + KSB (5 lit/ha)	59.00	16.11	29.95	7.66	14.04	1.04
T_{12}- 75% RDF + VC (12 t/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	59.33	15.18	29.00	7.14	13.62	1.03
T_{13}- 75% RDF + VC (12 t/ha) + AB (5 kg/ha) + PSB (5 kg/ha) + KSB (5 lit/ha)	58.00	16.71	32.12	8.05	15.02	1.07
SEm (±)	0.94	0.62	0.97	0.15	0.23	0.06
CD 5%	2.67	1.81	2.75	0.42	0.66	0.17

**RDF= Recommended dose of fertilizer, VC= Vermicompost, AB= Azotobacter, PSB= Phosphorus Solubilizing bacteria, KSB= Potassium Solubilizing Bacteria*
SEm= Standard Error of Mean CD= Critical Difference

Treatment T_{13} (75% RDF + Vermicompost @ 12 t/ha + Azotobacter @ 5 kg/ha + PSB @ 5 kg/ha + KSB @ 5 lit/ha) recorded the highest number of nodes per vine up to the first male and female flowers, indicating its superiority in enhancing morphological traits of bottle gourd. In contrast, the minimum number of nodes was observed under T_1 (100% RDF). The improved node development may be attributed to better nutrient availability facilitating early flowering. Similarly, T_{13} also exhibited the maximum internode length, while T_1 showed the shortest. The enhanced growth parameters likely resulted from improved nutrient supply and soil health. These findings are consistent with the reports of Tirumalesh *et al*. (2016), Patle *et al*. (2018), Shree *et al*. (2018), Tripathi *et al*. (2018), Rabari *et al*. (2019), Kumar *et al*. (2020), Pathak *et al*. (2022) and Niharika *et al*. (2023).

3.2 Effect of Integrated Nutrient Management on Phenological Parameters of Bottle gourd

The mean results in Table 3 indicated significant differences in phenological parameters across various nutrient sources and biofertilizer combinations. The earliest appearance of male and female flowers was recorded under treatment T_{13} (75% RDF + Vermicompost @ 12 t/ha + Azotobacter @ 5 kg/ha + PSB @ 5 kg/ha + KSB @ 5 lit/ha), whereas the maximum number of days to flowering was observed in T_1 (100% RDF). The earliness in flowering with T_{13} may be attributed to improved nutrient translocation and availability, promoting faster reproductive development. These findings are consistent with those reported by Tripathi *et al*. (2018), Rabari *et al*. (2019), Shah *et al*. (2020) and Niharika *et al*. (2023).

3.3 Effect of Integrated Nutrient Management on Yield Parameters of Bottle gourd

The mean results presented in Table 4 showed significant variations in yield parameters among the different nutrient sources and biofertilizer treatments. The earliest fruit picking was recorded under treatment T_{13} (75% RDF + Vermicompost @ 12 t/ha + Azotobacter @ 5 kg/ha + PSB @ 5 kg/ha + KSB @ 5 lit/ha), while T_1 (100% RDF) exhibited the longest duration to first picking. Early fruiting in T_{13} may be attributed to enhanced nutrient availability and uptake. These findings are supported by Mandloi *et al*. (2022) and Pathak *et al*. (2022).

Treatment T_{13} (75% RDF + Vermicompost @ 12 t/ha + Azotobacter @ 5 kg/ha + PSB @ 5 kg/ha + KSB @ 5 lit/ha) produced the maximum number of fruits per plant, significantly outperforming other treatments. In contrast, the minimum number of fruits per plant was recorded under T_1 (100% RDF). The superior fruit setting under T_{13} may be attributed to improved nutrient availability, enhanced soil fertility, and better physiological activity due to the combined effect of organic manures, inorganic fertilizers, and biofertilizers. These results are in line with the findings of Rathod *et al*. (2018), Patel *et al*. (2019), Mandloi *et al*. (2022) and Pathak *et al*. (2022).

Application of different organic manures and biofertilizers significantly improved yield parameters in bottle gourd. Treatment T_{13} (75% RDF + Vermicompost @ 12 t/ha + Azotobacter @ 5 kg/ha + PSB @ 5 kg/ha + KSB @ 5 lit/ha) recorded the maximum pedicel length, fruit length and fruit diameter, while the minimum values were observed in T_1 (100% RDF). The increase in fruit length may be attributed to enhanced diversion of photosynthates towards reproductive organs (Shree *et al*., 2018), whereas improved fruit diameter could be due to better nitrogen availability promoting protein synthesis, meristematic activity, and cell division. These findings are consistent with those of Patle *et al*. (2018), Singh *et al*. (2018), Shah *et al*. (2020) and Mandloi *et al*. (2022).

Different organic manure and biofertilizer treatments significantly enhanced average fruit weight of bottle gourd. The highest average fruit weight was recorded in treatment T_{13} (75% RDF + Vermicompost @ 12 t/ha + Azotobacter @ 5 kg/ha + PSB @ 5 kg/ha + KSB @ 5 lit/ha), while the lowest was observed under T_1 (100% RDF). The increase in fruit weight may be attributed to improved phosphorus uptake, promoting nucleic acid synthesis, enhanced cell division and continuous nutrient supply throughout the growth period. These results are in agreement with the findings of Patel *et al*. (2019), Rabari *et al*. (2019) and Pathak *et al*. (2022).

4. CONCLUSION

In conclusion, this study highlights the effectiveness of using different organic manures and biofertilizers in combination with varying recommended doses of fertilizers. The findings demonstrate that treatment T_{13} - 75% RDF + Vermicompost (12 t/ha) + Azotobacter (5 kg/ha) +

PSB (5 kg/ha) + KSB (5 lit/ha) significantly outperforms other treatments in terms of morphological, phenological and yield parameters of bottle gourd plants. In contrast, T_1 (100% RDF) exhibited the least favourable results. Furthermore, the use of such materials contributes to environmental protection by reducing chemical pollution. It is therefore recommended that vegetable growers adopt integrated nutrient management practices, combining biofertilizers with reduced chemical fertilizers, for sustainable bottle gourd production.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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