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Effect of Integrated Nutrient Management Practices on Enhancing Productivity in Brinjal (*Solanum melongena* L.)

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ABSTRACT

Brinjal is an important vegetable crop in the coastal districts of Odisha. To enhance yields, farmers often depend heavily on chemical fertilizers, which may not always deliver the desired results. To address this, a field experiment was conducted across seven farmer fields to evaluate the effectiveness of integrated nutrient management (INM), combining chemical fertilizers, organic manure, biofertilizers, and micronutrients, in improving brinjal productivity and farmer's income. The experiment followed a Randomized Block Design (RBD) with three treatments and seven replications. The treatments comprising Application of NPK: 120:60:60 kg/ha along with FYM-20t/ha and Biofertilizers like Azospirillum, PSB @ 5kg/ha and micronutrient application: Zn and B @ 0.1% twice before flowering (T3) indicated there is significant increase in yield and yield attributing characters over control. The influence of biofertilizer along with optimum dose of fertilizer increased microbial activity and uptake of nutrients which triggered the flowering behaviour and fruit yield in combination with Boron and Zn like micronutrients. The results revealed that Treatment T3 significantly improved yield and yield-attributing characters over the control. The synergistic effect of biofertilizers with the optimum fertilizer dose enhanced microbial activity and nutrient uptake, which in turn improved flowering, fruit set, and yield, further supported by the role of micronutrients such as boron and zinc. T3 recorded the highest fruit yield (428 q/ha) along with the maximum benefit-cost ratio (2.78), followed by T2 (382.2 q/ha; B:C ratio 2.50) and T1 (270 q/ha; B:C ratio 2.09). A similar trend was observed for other growth and yield parameters. Based on the findings, it can be concluded that the integrated application of NPK (120:60:60 kg/ha), FYM (20 t/ha), biofertilizers (Azospirillum and PSB @ 5 kg/ha) and foliar sprays of Zn and B (0.1%) significantly enhances brinjal productivity and farmers' income in a sustainable manner.

Keywords: Biofertilizers, Brinjal,Micronutrient, Integrated Nutrient Management, Vegetable.

INTRODUCTION

Eggplant (*Solanum melongena* L.), commonly known as brinjal, ranks among the widely cultivated vegetables in India. It is valued for its nutritional content, particularly as a source of vitamins A and B (Kumar and Kannaujia, 2017; Singh and Bisen, 2020). Brinjal, also known as aubergine or Guinea squash, belongs to the family Solanaceae and has a diploid chromosome number of 2n = 24 (Kapur *et al,* 2020). It is extensively grown throughout tropical and subtropical regions and is believed to have originated in India (Kataky, 2024). The fruits of Brinjal are used in various ways of cooking, sauting, grilling, backing and frying by both poor and rich in India. It is having high nutritive value and rich in vitamins and minerals. It is considered as one of the leading and the second major vegetable crops next to tomato (Kiran *et al,* 2010). It can be cultivated across a wide range of soil types and climatic conditions; however, the optimum temperature range for achieving maximum yield is between 21°C and 27°C. India ranks second to China in area and production in the world accounting 7.11 lakh hectares with annual production of 135.58 lakh tons and productivity of 19.1 metric tons per hectare. India contributes about 28% of the total world production (Daunay *et al,* 2001). It is highly productive and usually finds a place as "poor man's crop".

The growth and yield of brinjal depend on multiple interacting factors. As a long-duration and high-yielding crop, it extracts large amounts of nutrients from the soil. Along with macronutrients, micronutrients also play a critical role in plant nutrition. Therefore, balanced fertilization with both macro and micronutrients is essential, since micronutrients are involved in key metabolic processes of plants. Deficiency of these elements can lead to

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physiological stress due to the malfunctioning of enzymatic systems and other metabolic activities (Modi *et al,* 2019). Micronutrients aid nutrient uptake by acting as catalysts in plant metabolic processes and balancing other nutrients. They are required in small quantity for normal growth and development of plants. Zinc is an essential component of a number of enzymes, *i.e.,* dehydrogenase, aldolase, isomerases, proteinase, peptidase and phosphohydrolase. Boron helps in the absorption of water and carbohydrate metabolism, translocation of carbohydrates in plants, etc., and it also plays an important role in flowering and fruit formation. Iron helps in the synthesis of enzymes and chlorophyll. Foliar spraying of micronutrients such as ferrous sulfate, zinc sulfate, and borax significantly alters various metabolic activities in plants, thereby enhancing both growth and yield (Pandav *et al,* 2017).

Bio-fertilizers have become essential parts of “Integrated Nutrient” Supply Systems and have the latent to increase productivity through improved nutrient supply (Hegde *et al,* 1999). These beneficial microorganisms help biological processes converting essential elements from insoluble to soluble forms. Similar to *Pseudomonas strata*, Phosphate Solubilizing Bacteria (PSB) are essential for solubilizing fixed phosphorus in soil so that plants can access it. Beneficial bacteria such as Azotobacter and PSB found in biofertilizers improve nutrient uptake by changing nutrients into soluble forms (Bhattacharya *et al,* 2000; Kumar *et al,* 2024). Phosphate Solubilizing Bacteria (PSB) are beneficial microbes known for their ability to convert insoluble forms of phosphorus into soluble forms by breaking down both organic and inorganic phosphorus compounds. This process is mainly facilitated through the secretion of low molecular weight organic acids. Similarly, *Azospirillum* is a well-known plant growth-promoting rhizobacterium that contributes to enhanced soil fertility. It is a heterotrophic nitrogen-fixing organism reported to be effective and cost-efficient across various crops. These microbes help in improving overall plant growth, yield and quality (Singh *et al,* 2013).

To address the challenges of nutrient deficiency and minimize the negative impacts of chemical fertilizers, it is important to utilize all available nutrient sources under the concept of integrated nutrient management (INM). This method involves combining chemical fertilizers with organic manures and biofertilizers in suitable proportions. INM plays a key role in maintaining soil health and fertility over time. Biofertilizers are a vital part of this system, as they support natural processes that help make nutrients available to plants. Alongside major nutrients and biofertilizers, micronutrients such as zinc and boron are also crucial for plant growth and metabolism. Applying these micronutrients through foliar sprays ensures efficient uptake through the leaves and can show quick results (Tawab *et al,* 2015). The present study was conducted with the objective of using biofertilizers and INM practices to access productivity, fertilizer use efficiency, cost of fertilizers, soil quality and brinjal yield.

MATERIALS AND METHODS

Experimental site and treatments applied

The study was carried out during 2020-21 across seven different farmer's fields in KVK Cuttack, under ICAR-Central Rice Research Institute to assess the impact of integrated nutrient management practices on brinjal productivity and farmer's income in the coastal districts of Odisha. Each trial covered an area of 0.4 hectares. The experimental soil was sandy loam in texture and deep and friable in nature. A Randomized Block Design (RBD) was used for the experiment. In line with the goal of sustainable vegetable production and environmental protection, On-Farm Trials (OFT) were carried out by KVK Cuttack during 2021-22 at seven locations in the district. The treatments were: T1 – farmer's conventional practice involving non-judicious use of chemical fertilizers; T2 - application of NPK at 120:60:60 kg/ha along with 20 t/ha of FYM and biofertilizers such as Azospirillum and PSB at 5 kg/ha; and T3 - similar to T2 with an added foliar spray of micronutrients (Zn and B) at 0.1% applied twice prior to flowering.

Observations recorded

Observations were recorded on different growth, yield and economic parameters. Farmers involved in the trials were trained in scientific crop management practices, covering aspects such as crop establishment, intercultural operations, water and nutrient management, weed control and proper harvesting. Standard agronomic practices were followed during crop cultivation. Weather data for the crop's growing period at the experimental site is presented in Table 1.

Field preparation, intercultural practices and treatment application

The experimental field was prepared to a fine tilth through repeated ploughing and harrowing,

Table 1. Meteorological data of the district during growing season of crop

Month	Average Temperature ^{0}C (Max)	Average Temperature ^{0}C (Min)	Relative humidity (%)
September 2021	32.96	25.13	89.66
October 2021	32.44	24.17	81.88
November 2021	29.65	19.52	81.62
December 2021	18.74	84.03	75.88
January 2022	14.87	86.90	98.96
February 2022	17.14	83.76	54.42
March 2022	22.74	82.03	53.46

Table 2. Effect of different treatments on growth, yield and yield-attributing traits of brinjal

Treatment	Plant Height (cm)	No. of Branches	Days to 1st Harvesting	Days to last harvesting	Fruit weight (g)	No. of fruits/plant	Fruit yield /plant (kg)	Fruit yield (q/ha)
T1	55	15.4	56	140.4	94	13.0	1.2	270
T2	65.8	19.0	52	148.8	100	17.0	1.7	382.2
T3	75	25.0	50	158.0	105	19.0	2.0	428
SE (m)	2.75	0.55	0.43	0.68	0.30	0.37	0.03	5.92
CD-5%	8.51	1.73	1.36	2.14	0.96	1.17	0.10	18.44

Table 3. Economic impact of nutrient management practices in brinjal.

Treatment	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	BCR
T1	175100	367520	192420	2.09
T2	177496	446380	268260	2.50
T3	179788	504000	323612	2.78

followed by the removal of clods and debris. The land was then leveled and raised beds were prepared. A spacing of 90 cm between ridges and 90 cm between plants was maintained. Before fertilizer application, random soil samples were taken from the experimental site and analyzed, revealing a pH below 5.5. For each hectare, 25 tons of well-decomposed FYM, 210 kg of urea, 130 kg of diammonium phosphate (DAP) and 96 kg of muriate of potash (MOP) were applied. Half of the recommended nitrogen, phosphorus and potassium were incorporated into the soil before transplanting, while the remaining nitrogen was applied in two equal split doses at one-month intervals. Biofertilizers were applied as a basal dose at the time of seedling transplanting. Micronutrients containing zinc and boron were applied as foliar sprays at one-month intervals after transplanting. Weed control was managed through 3-4 hoeings and the crop received 10-15 irrigations, including one immediately after transplanting. Harvesting was done at the immature and tender stage to meet market demand.

Data collection

Five plants were randomly selected from each plot to record observations on plant height (cm), number of branches per plant, days taken to first harvest, days taken to last harvest, fruit weight (g), number of fruits per plant, fruit yield per plant (kg/plant), and fruit yield per hectare (q/ha). The number of days to first harvest was noted from the day of transplanting to the initial harvest. Yield per hectare was derived from the average fruit yield per plant and expressed in quintal (q/ha).

Economic analysis

The cost of cultivation and gross returns were calculated based on the prevailing market prices of inputs during the study period. Labor charges and operational costs for activities such as ploughing, weeding, irrigation, planting, bed preparation and harvesting were included, along with the costs of seeds and fertilizers. Net returns (Rs./ha) and benefit-cost ratio (BCR) were determined using the formula:

Net Returns = Gross Returns - Cost of Cultivation

BCR = Gross Returns / Total Cost of Cultivation

Statistical analysis of the collected data was performed following the standard methodology outlined by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Plant height (cm)

The effect of different treatments on plant height was significant. The tallest plants were recorded in T3 (75.0 cm), followed by T2 (65.8 cm), while the shortest were in T1 (55.0 cm). The increase in plant height may be attributed to enhanced cell division and enlargement, driven by improved protein synthesis and metabolic activity. The combined application of micronutrients, chemical fertilizers, and biofertilizers ensured a continuous nutrient supply and promoted phytohormone production, which enhanced carbohydrate synthesis and supported overall plant growth. The superior plant height in T3 (75.0 cm) may thus be due to the steady supply of balanced nutrients throughout the crop cycle, leading to better vegetative development. Similar findings were reported by Pandav *et al* (2017) and Pinkee *et al* (2023).

Number of branches per plant

All treatments significantly influenced the number of branches per plant. The highest number was recorded in T3 (25.0), followed by T2 (19.0), while the lowest was in T1 (15.4). The increase in branching under T3 may be attributed to the combined application of fertilizers, biofertilizers, and micronutrients. Essential nutrients such as nitrogen and phosphorus play a key role in root and shoot development, as well as in the formation of phospholipids and phosphoproteins. These compounds enhance meristematic activity, thereby increasing branch production (Patidar and Bajpai, 2018). The present findings are in close agreement with those of Padhiary and Dubey (2020) and Pinkee *et al* (2023).

Days taken to firstharvest

The results in Table 2 show that all treatments significantly affected the number of days to the first harvest. The earliest harvest was observed in T3 (50.0 days), which was statistically at par with T2 (52.0 days), while T1 required the longest time (56.0 days) after transplanting. The delay in T1 may be due to poorer plant and soil conditions, whereas the earlier harvests in T2 and T3 can be attributed to better nutrient availability and improved physiological status, which supported faster growth and a smoother transition from vegetative to reproductive stages. Similar results were reported by Srivastava *et al* (2009) and Uikey *et al* (2018).

Days taken to last harvest

Table 2 shows that all treatments had significant effect on the number of days to the last harvest. The longest harvesting period was recorded in T3 (158.0 days), followed by T2 (148.8 days), while the shortest was in T1 (140.4 days). This indicates that T3 extended the harvesting duration compared to the other treatments. The prolonged harvest period in T3 may be attributed to healthier plant growth, better soil conditions, and improved plant vigor, which enhanced flowering and fruit development. These factors also promoted continued vegetative growth and efficient photosynthesis, thereby extending the flowering and fruiting stages. Similar results were reported by Kumar *et al* (2024).

Fruit weight (g)

All treatments significantly influenced average fruit weight. The highest weight was recorded under T3 (105 g), followed by T2 (100 g) and T1 (94 g). The superior fruit weight in T3 may be due to the combined application of NPK (100:60:60 kg/ha), biofertilizers (Azospirillum and PSB @ 5 kg/ha each), and foliar spray of micronutrients. This ensured a steady nutrient supply, especially phosphorus, which is crucial for plant growth. Phosphorus-solubilizing bacteria (PSB) further enhanced its availability by breaking down insoluble forms, while also producing growth-promoting substances and antibiotic-like compounds that supported healthy plant development. The improvement in fruit weight under T3 can be attributed to enhanced nutrient uptake, assimilate partitioning, and better fruit filling. Similar findings were reported by Prathyusha *et al* (2023).

Number of fruits per plant

All the treatments had significant effects on fruit yield for plant. T3 treatment was having maximum number of fruits per plants (19.0) followed by T2 (17.0) and T1 (13.0). This may be due to more no of flowers and more fruit retention due to optimum growth and development which could attributed for better flower and fruit retention in the plant. The significant increase in fruit number under T3 may be attributed to better growth and reproductive efficiency, enhanced nutrient utilization, and improved physiological processes leading to more effective flowering and fruit setting.

Fruit yield/Plant (kg/plant)

All the treatments had significant effects on fruit yield per plant (Kg/plant). T3 recorded the highest fruit yield per plant (2.0 kg), followed by T2 (1.7 kg), whereas T1 registered the lowest yield (1.2 kg). The superiority of T3 may be attributed to its higher fruit weight and greater number of fruits per plant, which together contributed to enhanced yield.

Fruit yield/ha (q/ha)

Fruit yield per hectare varied significantly among the treatments. The highest yield was recorded in T3 (428 q/ha), followed by T2 (382.2 q/ha), while the lowest was in T1 (270 q/ha). The superiority of T3 may be attributed to the combined positive effects of greater plant height, more branches, higher fruit weight, and a larger number of fruits per plant, which collectively enhanced yield per plant and translated into higher yield per hectare. In addition, the use of organic manure in T3 not only supplied nutrients but also improved the soil's physical, chemical, and biological properties. Upon decomposition and mineralization, organic manure directly released nutrients and facilitated the solubilization of otherwise fixed nutrients, making them more available for plant uptake. These results confirm that Treatment 3 is the most promising option for maximizing fruit yield at the field level (Bhattarai *et al*, 2021; Modi *et al,* 2019).

It was observed that treatments performing well in unit areas also maintained their superiority on a larger scale, since yield per hectare was estimated by multiplying plot yield with the hectare factor. Similar observations were reported by Suryanto *et al* (2017) and Tandel *et al* (2018). The combined use of organic manures, biofertilizers, chemical fertilizers, and multi-micronutrients enhanced nutrient-use efficiency and improved soil physical, chemical, and biological properties by narrowing the gap between nutrient removal and supply. Similar findings were reported by Chumei *et al* (2014). Overall, fruit yield under T3 showed a 58.51% increase over the control (T1) and a 11.9 % increase over T2.

Economics

The economic analysis was conducted using prevailing market prices of inputs and outputs during the study year to calculate cost of cultivation, gross return, net return, and the benefit-cost ratio (BCR). Net profit per hectare also depends on factors such as labor availability and market access. As shown in Table 3, treatment T3 achieved the highest net return (₹3,23,612/ha) with a BCR of 2.78, followed by T2 (₹2,68,260/ha; BCR 2.50) and T1 (₹1,92,420/ha; BCR 2.09). The cost of cultivation was maximum under T3 (₹1,79,788/ha), followed by T2 (₹1,77,496/ha) and T1 (₹1,75,100/ha). Gross returns were also highest in T3 (₹5,04,000/ha), compared with T2 (₹4,46,380/ha) and T1 (₹3,67,520/ha). The higher net return in T3 was primarily due to its greater gross return relative to the cost of cultivation. Cost reduction through balanced nutrient integration, rather than excessive and imbalanced use of chemical fertilizers, contributed to improved plant growth, development, and yield. The BCR, being a key indicator of profitability, strongly influences farmers' decisions to adopt a particular production practice. For any horticultural practice to gain acceptance, it must demonstrate a favorable cost-benefit ratio. Similar economic benefits of integrated nutrient management have been reported by Paswan *et al* (2022), Singh *et al* (2020), Srivastava *et al* (2009), and Sharma and Khadda (2023).

CONCLUSION

The study demonstrated that integrated nutrient management (INM), involving the combined use of chemical fertilizers, farmyard manure (FYM), biofertilizers (Azospirillum and PSB), and micronutrients (Zn and B), significantly enhanced the growth, yield, and economic returns of brinjal in the coastal districts of Odisha. Among all treatments, T3 consistently outperformed others in plant height, branching, fruit weight, fruit number, and overall productivity (428 q/ha), while also recording the highest net return (₹3,23,612/ha) and benefit-cost ratio (2.78). The superior yield and profitability under T3 can be attributed to improved nutrient availability, better soil health, and efficient resource utilization. These findings strongly support the adoption of INM as a sustainable and economically viable strategy for brinjal cultivation under similar Agro-climatic conditions.

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