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RESEARCH ARTICLE

Effect of Integrated Nutrient Management (INM) on Growth and Yield of Broccoli (*Brassica oleracea* var. *italica*)

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ABSTRACT

The present investigation was conducted at Research Farm, Agricultural Research Institute, Patna, Bihar, India, during the Rabi season 2023-2024 to investigate "Effect of Integrated Nutrient Management (INM) on the growth and yield of Broccoli". This study investigated the effects of integrated nutrient management on broccoli's growth, development and yield. Among various treatments, T9 [50% recommended dose of fertilizers (RDF) through chemical fertilizer + 25% nitrogen (N) through Neem cake + Biofertilizers (Azotobacter + PSB)] recorded the maximum plant height (54.08 cm) due to enhanced nutrient availability and favorable soil conditions. The maximum number of leaves (21.00) was observed in T10 [50% RDF through chemical fertilizer + 12.5% N through FYM + 12.5% N through Vermicompost + 12.5% N through Neem cake + Biofertilizers (Azotobacter + PSB)], attributed to improved soil aeration and moisture retention. Treatment T10 also required the shortest time to reach 50% heading (61.00 days) and marketable maturity (81.00 days), likely due to the balanced nutrient supply from organic and inorganic sources. Yield parameters demonstrated superior performance for T10, which achieved the highest head weight (372.03 g) and yield (187.81 q/ha), followed by T9 and T8. The enhanced yield in T10 can be attributed to the synergistic effects of organic and inorganic fertilizers and biofertilizers, which improved nutrient availability, root development, and overall plant growth. Conversely, the lowest values for growth and yield attributes were consistently recorded in T2 (100% N through farmyard manure). These findings underline the significance of integrated nutrient management in improving broccoli production by optimizing plant growth and yield.

Keywords: *Azotobacter, Broccoli, INM, Neem cake, Vermicompost, Yield*

INTRODUCTION

Broccoli (*Brassica oleracea* var. *italica*) is one of the most nutrient-rich vegetables among the cole crops cultivated for its delicate heads. It is a member of the Brassicaceae family and originates in the Mediterranean region. The United States of America is the foremost global producer of broccoli. Broccoli

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is available in three distinct colors: green, yellow, and purple, with the green kind being the most commonly favored.

In recent years, broccoli has gained appeal among growers in India, primarily due to rising demand in cosmopolitan areas and increased knowledge of its nutritional benefits. Broccoli holds a significant position as a cool-season vegetable. Farmers are obtaining profitable returns in Bihar by marketing their produce in adjacent marketplaces. Its cultivation has gained momentum in India. With the implementation of integrated nutrient management in broccoli around 16–22 t/ha yield can be obtained under Indian conditions (Singh *et al*., 2021). The study highlights improved nutrient management as key for yield enhancement..

Broccoli includes indole-3-carbinol, which helps to combat breast and lung cancer. Its sprouts are a rich source of glucosinolate, particularly glucoraphanin, the substance associated with reducing cancer. Besides its anticarcinogenic properties, broccoli is an excellent source of vitamins, minerals and proteins. It contains roughly 130 times more vitamin A than cauliflower and 22 times more than cabbage. It is the richest source of sulphoraphane, a chemical related to lowering the risk of cancer in humans (Singh *et al*., 2021). Consumption of 150 g of broccoli aids in fulfilling the requirement of adults for vitamins E, A, B1, and C, and boosts the immune system (Sai *et al*., 2024).

Neem cake, a slow-release organic fertilizer, supplies essential nutrients such as nitrogen, phosphorus, and potassium while improving soil quality and microbial activity. Similarly, organic matter like farm-yard manure and vermicompost enhances soil physical and chemical properties, increasing water-holding capacity, nutrient mineralization, and overall fertility.

Biofertilizers provide a sustainable alternative by utilizing microorganisms to convert nutrients into plant-available forms, improving soil fertility and combating harmful pathogens. Their use enhances vegetable yield and quality while reducing the need for external inputs. However, more research is needed to optimize nutrient combinations for cultivating unique vegetables like sprouting broccoli.

The main objective of this study is to examine the effect of integrated nutrient management on the growth and yield of broccoli.

MATERIALS AND METHODS

Experimental site

The present investigation was conducted at the Agricultural Research Institute, Patna, Bihar, India, during the *Rabi* season 2023-2024. The details of the experimental material used and the methodology followed during the investigation have been described below:

Table 1: Treatment details

Notations	Treatments
T_1	Control -100 % RDF (RDF: 125 kg N + 65 kg P_2O_5 + 65 Kg K_2O)
T_2	100 % N through Farmyard manure
T_3	50 % RDF through chemical fertilizer + 50 % N through FYM
T_4	50 % RDF through chemical fertilizer + 50 % N through Vermicompost
T_5	50 % RDF through chemical fertilizer + 50 % N through Neem cake
T_6	50 % RDF through chemical fertilizer + Biofertilizers (Azotobacter +PSB)
T_7	50 % RDF through chemical fertilizer + 25 % N through FYM+ Biofertilizers (Azotobacter +PSB)
T_8	50 % RDF through chemical fertilizer + 25 % N through Vermicompost + Biofertilizers (Azotobacter + PSB)
T_9	50 % RDF through chemical fertilizer + 25 % N through Neem cake + Biofertilizers (Azotobacter +PSB)
T_{10}	50 % RDF through chemical fertilizer + 12.5 % through FYM+ 12.5 % N through Vermicompost + 12.5 % N through Neem cake + Biofertilizers (Azotobacter +PSB)

Design of Experiment

The experiment was laid out in a randomized block design (RBD) with ten treatments and three replications. Every replication has ten treatments. In every replication, every treatment was randomized in isolation.

Experimental Design : Randomized Block Design (RBD)
Replication (s) : 3
No. of Treatments : 10
No. of plots : 30
Variety : Green Magic
Plot size : 3m x 3m
Spacing : 45 cm X 45 cm

Growth parameters

Plant height (cm)

Plant height was measured at the time of harvesting from the soil level to the highest tip of the plant with the help of a measuring scale. The height of five randomly selected plants was measured, and the average value was expressed in centimeters.

Number of leaves per plant

The number of leaves per plant was recorded under each treatment at the harvesting time. All the fully grown leaves were counted except those that were attached to the heads. The number of leaves was counted from five randomly selected plants and averaged to get a number of leaves per plant.

Days taken to reached 50 % heading

This observation was recorded by visiting the experimental field daily, and numbers of days were counted right from the date of transplanting of seedlings to the date when heads matured in 50 per cent of the plants per plot.

Days to marketable maturity

Marketable maturity in broccoli refers to the stage when the heads are fully developed, compact, and have tightly closed buds, indicating they are ready for harvest.

Yield parameters

Terminal head weight (g)

Randomly, five heads from different plants were selected from each plot, their weight was recorded, and the average value was expressed in grams.

Polar diameter of head (cm)

The diameter of curd from randomly selected plants was measured with the help of a meter scale, and then the mean value was calculated.

Yield per hectare (q/ha)

The curd of each plot was harvested at the proper stage, and the number of curds and their weight per plot in kg were recorded. The average was calculated from which the yield per hectare was calculated.

RESULTS AND DISCUSSION

Growth parameters

The plant height is one of the key factors in predicting crop productivity. Among all the treatments, the maximum plant height (54.08 cm) was recorded in treatment T9-50 % RDF through chemical fertilizer + 25 % N through Neem cake + Biofertilizers (Azotobacter +PSB). This might be explained by the enhanced water-holding capacity, micronutrient supply, and major nutrient availability brought about by the favorable soil conditions that farmyard trash supplies.) The present findings are congruent with those of Dash *et al.* (2019) and Sharma *et al.* (2005) in broccoli. According to Sai *et al.* (2024), using biofertilizers also assists in producing compounds that encourage growth, enhancing root development, water transportation, nutrient absorption and decomposition in broccoli. The present results also coincide with those of Tyagi *et al.* (2022)in cauliflower and Bahadur *et al.* (2011) in Chinese cabbage. However, treatment T2 (100 percent N via farmyard manure) had the lowest plant height at maturity, measuring 39.11 cm.

The maximum number of leaves (21.00) was documented in treatment T10 [50 % RDF through chemical fertilizer + 12.5 % through FYM + 12.5 % N through Vermicompost + 12.5 % N through Neem cake + Biofertilizers (Azotobacter + PSB)], which was statistically comparable to treatment T8 [50 % RDF through chemical fertilizer + 25 % N through Vermicompost + Biofertilizers (Azotobacter + PSB)] (19.00) and T9 [50 % RDF through chemical fertilizer + 25 % N through Neem cake + Biofertilizers (Azotobacter + PSB)] (20.00). In contrast, the lowest number of leaves (15.00) was observed in treatment T2 (100 % N through Farmyard manure). This phenomenon may be related to the application of organic manures, which promote greater air circulation and soil moisture retention, hence supporting improved soil health. The findings of the present research coincide

with the results published by Sharma *et al.* (2005) and Singh *et al.* (2023)..Treatment T10 (50 % RDF through chemical fertilizer + 12.5% N through FYM+ 12.5% N through Vermicompost + 12.5% N through Neem cake + Biofertilizers (Azotobacter + PSB)) had the lowest number of days (61.00) required to reach 50% heading among the various treatments. This was found to be statistically equivalent to treatment T8 (50 % RDF through chemical fertilizer + 25% N through Vermicompost + Biofertilizers (Azotobacter + PSB)) 64.00 days, T7 (50 % RDF through chemical fertilizer + 25 % N through FYM+ Biofertilizers (Azotobacter +PSB)) 64.00 and T9 (50 % RDF through chemical fertilizer + 25 % N through Neem cake + Biofertilizers (Azotobacter +PSB) 64.00 days. However, treatment T2 (100 % N by farmyard manure) had the highest number of days required to reach 50% heading, which was 71 days. This may occur because the nutrient needs are satisfied from organic and inorganic fertilizer sources, making nutrients accessible throughout the cultivation and their efficiencies are also greater. Present findings align with those reported by Singh *et al.* (2023) and Netwal et al. (2023) in broccoli. Tyagi *et al.* (2022) in cauliflower.

Among different treatments, the minimum number of days to marketable maturity was recorded in treatment T10 (50 % RDF through chemical fertilizer + 12.5 % through FYM+ 12.5 % N through Vermicompost + 12.5 % N through Neem cake + Bio-fertilizers (Azotobacter +PSB) 81.00 days, followed by T9 (50

Table 4.2: Effect of integrated nutrient management on Plant height (cm), No. of leaves, Days taken to 50% heading, and days to marketable maturity of broccoli

Tr. No.	Treatments	Plant height at maturity (cm)	Number of leaves per plant	Days taken to reach 50 % heading	Days to marketable maturity
T_1	Control -100 % RDF (RDF: 125 kg N + 65 kg P_2O_5 + 65 Kg K_2O)	49.56	19.00	66.00	88.00
T_2	100 % N through Farmyard manure	39.11	15.00	71.00	99.00
T_3	50 % RDF through chemical fertilizer + 50 % N through FYM	44.79	16.00	68.00	94.00
T_4	50 % RDF through chemical fertilizer + 50 % N through Vermicompost	46.65	16.00	71.00	98.00
T_5	50 % RDF through chemical fertilizer + 50 % N through Neem cake	48.24	16.00	67.00	95.00
T_6	50 % RDF through chemical fertilizer + Biofertilizers (Azotobacter +PSB)	49.65	18.00	66.00	94.00
T_7	50 % RDF through chemical fertilizer + 25 % N through FYM+ Biofertilizers (Azotobacter +PSB)	50.61	19.00	64.00	91.00
T_8	50 % RDF through chemical fertilizer + 25 % N through Vermicompost + Biofertilizers (Azotobacter + PSB)	52.11	19.00	64.00	90.00
T_9	50 % RDF through chemical fertilizer + 25 % N through Neem cake + Biofertilizers (Azotobacter +PSB)	54.08	20.00	64.00	87.00
T_{10}	50 % RDF through chemical fertilizer + 12.5 % through FYM+ 12.5 % N through Vermicompost + 12.5 % N through Neem cake + Biofertilizers (Azotobacter +PSB)	53.33	21.00	61.00	81.00
	SEm±	1.47	0.68	1.63	2.95
	CD (0.05)	4.39	2.02	4.84	8.78
	CV (%)	5.60	7.16	4.13	5.39

% RDF through chemical fertilizer + 25 % N through Neem cake + Biofertilizers (Azotobacter +PSB) 87.00 days, T8 (50 % RDF through chemical fertilizer + 25 % N through Vermicompost + Biofertilizers (Azotobacter + PSB) 90.00 days and T7 (50 % RDF through chemical fertilizer + 25 % N through FYM+ Biofertilizers (Azotobacter +PSB) 91.00 days. This could be due to the increased availability of nitrogen owing to the activity of Azotobacter, a significant ingredient of chlorophyll and protein, therefore driving greater growth. FYM assists in promoting soil health and provides optimum aeration in the soil, and enhances the water-holding capacity of the soil. The current findings are in accordance with the results of Sharma *et al.* (2008) and Singh *et al.* (2021) in broccoli In cabbage, Zargar *et al.* (2022) showed that a greater fertility level promoted the maturity time, but the process of growth and development was slower at a lower fertility level. On the other hand, a Maximum number of days to marketable maturity was obtained in treatment T2 (100 % N through Farmyard manure). Comparable findings have been documented by Netwal et al. (2023) in sprouting broccoli; Zagar *et al.* (2022) in cabbage and Bahadur *et al.* (2011) in Chinese cabbage. Moreover, being a medium duration crop, broccoli's fast release of nutrients promoted both vegetative and reproductive development stages.

Yield parameters

Maximum head weight was recorded in treatment T10 (50 % RDF through chemical fertilizer + 12.5 % through FYM+ 12.5 % N through Vermicompost + 12.5 % N through Neem cake + Biofertilizers (Azotobacter +PSB)) 372.03 g. It was followed by T9-50 % RDF through chemical fertilizer + 25 % N through Neem cake + Biofertilizers (Azotobacter + PSB) 333.48 g, T8-50 % RDF through chemical fertilizer + 25 % N through Vermicompost + Biofertilizers (Azotobacter + PSB) 310 g. The minimum head weight was recorded in treatment T2 (100% N from farmyard manure) at 210 g. The microbes' increased root development and hormone production caused the application of vermicompost to promote the formation of carbohydrates and organic structures, which were then transferred to the head and increased their weight. These findings are in good agreement with those of Bahadur *et al.* (2011), Sai *et al.* (2024) and Tyagi *et al*. (2022) .

The largest polar diameter of the head was observed in treatment T10 (50% RDF from chemical fertilizers + 12.5% N from FYM + 12.5% N from vermicompost + 12.5% N from neem cake + biofertilizers, specifically Azotobacter and PSB), measuring 15.12 cm. The smallest polar diameter was recorded in T2 (100% N from farmyard manure), measuring 10.06 cm. The combined impact of the numerous food sources and biofertilizers may be the reason for T10's increased head size. A more balanced nutritional profile was presumably achieved by mixing organic and inorganic fertilizers, which promoted plant growth and development. Furthermore, the biofertilizers (PSB and Azotobacter) could have boosted nutrient intake and availability, promoting bigger heads (Kumar and Sharma, 2014). In another experiment, a bigger plant photosynthetic capability may be the source of the cauliflower curd's bigger polar and equatorial diameters (in centimeters).

A higher yield quintal per hectare was found in treatment T10 (50 % RDF through chemical fertilizer + 12.5 % through FYM+ 12.5 % N through Vermicompost + 12.5 % N through Neem cake + Biofertilizers (Azotobacter +PSB)) 187.81 q/ha, which was followed by T9 (50 % RDF through chemical fertilizer + 25 % N through Neem cake + Biofertilizers (Azotobacter +PSB)) 166.74 q/ha. The lower yield was reported in treatment T2 (100 % N through Farmyard manure @ 25t/ha), 104.99 q/ha. Following the application of organic manure, such as farmyard manure, the combination of biofertilizers and organic manure yielded the highest yield per hectare, quintal. This might be due to proper nitrogen levels, essential for various substances, such as chlorophyll and enzymes that are vital for plants to utilize carbohydrates. This might be because the combined application of the biofertilizers and vermicompost significantly boosted the growth. Due to favorable soil conditions, vermicompost treatment may improve this development characteristic by increasing the availability of water, micronutrients, and key nutrients (Sharma *et al.et al.,* 2008). Additionally, the presence of vermicompost and organic fertilizers substantially impacted the qualitative features of broccoli heads. The current findings are in line with the findings of Kumar and Sharma (2014); Netwal et al. (2023) and Ankita *et al.* (2024) in broccoli, and Tyagi *et al.* (2022) in cauliflower..

CONCLUSION

The study concludes that integrating organic and inorganic nutrient sources significantly enhances broccoli's growth, development,

Table 4.3: Effect of integrated nutrient management on Terminal head weight, Polar diameter, and yield (q/ha) of broccoli

Tr. No.	Treatments	Terminal head weight (g)	Polar diameter of head (cm)	Yield quintal per hectare (q/ha)
T1	Control -100 % RDF (RDF: 125 kg N + 65 kg P2O5 + 65 Kg K2O)	286.97	13.18	144.15
T2	100 % N through Farmyard manure	210.00	10.06	104.99
T3	50 % RDF through chemical fertilizer + 50 % N through FYM	224.09	11.38	112.05
T4	50 % RDF through chemical fertilizer + 50 % N through Vermicompost	242.06	12.44	121.03
T5	50 % RDF through chemical fertilizer + 50 % N through Neem cake	263.51	13.35	131.75
T6	50 % RDF through chemical fertilizer + Biofertilizers (Azotobacter +PSB)	288.33	13.82	144.17
T7	50 % RDF through chemical fertilizer + 25 % N through FYM+ Biofertilizers (Azotobacter +PSB)	302.00	14.15	151.00
T8	50 % RDF through chemical fertilizer + 25 % N through Vermicompost + Biofertilizers (Azotobacter + PSB)	310.00	14.38	155.00
T9	50 % RDF through chemical fertilizer + 25 % N through Neem cake + Biofertilizers (Azotobacter +PSB)	333.48	14.86	166.74
T10	50 % RDF through chemical fertilizer + 12.5 % through FYM+ 12.5 % N through Vermicompost + 12.5 % N through Neem cake + Biofertilizers (Azotobacter +PSB)	372.03	15.12	187.81
	SEm±	7.20	0.79	4.74
	CD (0.05)	21.39	2.37	14.07
	CV (%)	5.08	11.44	6.68

and yield parameters. Among all treatments, T10 (50% RDF through chemical fertilizer + 12.5% N through FYM + 12.5% N through vermicompost + 12.5% N through neem cake + biofertilizers) consistently outperformed others, demonstrating the highest plant height, number of leaves, head weight, polar diameter, and yield per hectare while requiring the least time to reach 50% heading and marketable maturity.

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