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

 **Abstract**

The present investigation was conducted at Research Farm, Agricultural Research Institute, Patna, Bihar, India during *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 the growth, development and yield of broccoli. 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. *italic*) 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 (Thamburaj and Singh, 2001). The United States of America is the foremost global producer of broccoli. Broccoli 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. Presently in Bihar, farmers are obtaining profitable returns by marketing their produce in adjacent marketplaces. Its cultivation has gained momentum in India. It is grown in an area of 3,776 acres with annual production of 26,612(000 lbs) and productivity of 7.04000 lbs per acre. (Anonymous, 2015).

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 the reduction of cancer (Maurya et al., 2008). Besides its anticarcinogenic properties, broccoli is a great source of vitamins, minerals and proteins. It contains roughly 130 times more vitamin A content 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 human beings (Thamburaj and Singh, 2001). Consumption of 150 gm of broccoli aids in fulfilling the requirement of adults for vitamins E, A, B1 and C and boosts the immune system (Michaud et al., 2002).

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 the effect of integrated nutrient management on growth and yield of broccoli.

**Materials and Methods**

**Experimental site**

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

 **Table 1**: Treatment details

|  |  |
| --- | --- |
| **Notations** |  **Treatments** |
| T1 | Control -100 % RDF (RDF: 125 kg N + 65 kg P2O5 + 65 Kg K2O) |
| T2 | 100 % N through Farmyard manure |
| T3 | 50 % RDF through chemical fertilizer + 50 % N through FYM |
| T4 | 50 % RDF through chemical fertilizer + 50 % N through Vermicompost |
| T5 | 50 % RDF through chemical fertilizer + 50 % N through Neem cake |
| T6 | 50 % RDF through chemical fertilizer + Biofertilizers (Azotobacter +PSB) |
| T7 | 50 % RDF through chemical fertilizer + 25 % N through FYM+ Biofertilizers (Azotobacter +PSB) |
| T8 | 50 % RDF through chemical fertilizer + 25 % N through Vermicompost + Biofertilizers (Azotobacter + PSB) |
| T9 | 50 % RDF through chemical fertilizer + 25 % N through Neem cake + Biofertilizers (Azotobacter +PSB) |
| T10 | 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 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 centimeter.

**Number of leaves per plant**

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

**Days taken to 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 head were 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 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 meter scale and then mean value was calculated.

**Yield per hectare (q/ha)**

 The curd of each plot was harvested at proper stage and number of curds and their weight per plot in kg were recorded. The average was calculated and from which 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. Choudhary and associates (2012). The present findings are congruent with those of Pandey et al. (2008) and Chaterjee et al. (2005) in broccoli. According to Bhardwaj et al. (2007), the usage of biofertilizers also assists in the production of compounds that encourage growth, which enhances root development, water transportation, nutrient absorption, and decomposition. The present results also coincide with those of Magd et al. (2006) in broccoli and Sharma (2002) in 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), whereas the lowest number of leaves (15.00) was observed in treatment T2 (100 % N through Farmyard manure). This phenomena may be related to the application of organic manures, which promotes greater air circulation and soil moisture retention, hence supporting improved soil health. The findings of the present research coincide with the results published by Singh et al. (2022), Biswas et al. (2021) and Faysal et al. (2006).

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 take place because the nutrient needs are satisfied from organic and inorganic fertilizer sources, which makes nutrients accessible throughout the cultivation and their efficiencies are also greater. Present findings are in line with those reported by Kumar et al. (2013) in brocooli. Chatterjee et al. (2014) in cabbage.

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 % 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 which is a major ingredient of chlorophyll and protein therefore driving greater growth. FYM assists in promoting soil health and provides optimum aeration in soil and enhances the water holding capacity of soil. The current findings are in accordance with the results of Chatterjee et al. (2005) on broccoli, Mal et al. (2015) in broccoli, Kumar et al. (2013) in broccoli. In cabbage, Chaubey et al. (2006) showed that greater fertility level promoted the maturity time but the process of growth and development was slower at lower fertility level. On the other hand, Maximum number of days to marketable maturity was obtained in treatment T2 (100 % N through Farmyard manure) comparable findings have been documented by Chatterjee et al. (2014) in cabbage. Moreover, broccoli being a medium duration crop, fast release of nutrients promoted both vegetative and reproductive development stages.

**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 50 % heading** | **Days to marketable maturity** |
| T1 | Control -100 % RDF (RDF: 125 kg N + 65 kg P2O5 + 65 Kg K2O) | 49.56 | 19.00 | 66.00 | 88.00 |
| T2 | 100 % N through Farmyard manure | 39.11 | 15.00 | 71.00 | 99.00 |
| T3 | 50 % RDF through chemical fertilizer + 50 % N through FYM | 44.79 | 16.00 | 68.00 | 94.00 |
| T4 | 50 % RDF through chemical fertilizer + 50 % N through Vermicompost | 46.65 | 16.00 | 71.00 | 98.00 |
| T5 | 50 % RDF through chemical fertilizer + 50 % N through Neem cake | 48.24 | 16.00 | 67.00 | 95.00 |
| T6 | 50 % RDF through chemical fertilizer + Biofertilizers (Azotobacter +PSB) | 49.65 | 18.00 | 66.00 | 94.00 |
| T7 | 50 % RDF through chemical fertilizer + 25 % N through FYM+ Biofertilizers (Azotobacter +PSB) | 50.61 | 19.00 | 64.00 | 91.00 |
| T8 | 50 % RDF through chemical fertilizer + 25 % N through Vermicompost + Biofertilizers (Azotobacter + PSB) | 52.11 | 19.00 | 64.00 | 90.00 |
| T9 | 50 % RDF through chemical fertilizer + 25 % N through Neem cake + Biofertilizers (Azotobacter +PSB) | 54.08 | 20.00 | 64.00 | 87.00 |
| T10 | 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 |

**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 Ola et al. (2019), Mohanta et al. (2018), and Singh et al. (2018).

 The largest polar diameter of 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 of 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. Bigger plant photosynthetic capability may be the source of the cauliflower curd's bigger polar and equatorial diameters (in centimeters) in another experiment. (Kumar and others, 2021).

 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 of 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 manures yielded the highest yield per hectare, quintal. This might be due to proper nitrogen levels, which are essential for various substances, such as chlorophyll and enzymes that are vital for plants to utilize carbohydrates. This might be because the growth was significantly boosted by the combined application of the biofertilizers and vermicompost. Due to favorable soil conditions, vermicompost treatment may improve this development characteristic by increasing the availability of water, micronutrients, and key nutrients (Choudhary et al., 2012). Additionally, the presence of vermicompost and organic fertilizers had a substantial impact on the qualitative features of broccoli heads. The current findings are in line with the findings of Sharma (2000), and Sharma et al. (2002) in sprouting broccoli, as well as Pandey et al. (2008), Sharma et al. (2008), and Magd et al. (2010) in sprouting broccoli, Bahadur et al. (2003) in cabbage, Sharma et al. (2005) in broccoli, Singh et al. (2022) in broccoli, and Kalabandi et al. (2007) in cabbage.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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 |

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

**Conclusions**

 The study concludes that integrating organic and inorganic nutrient sources significantly enhances the growth, development, and yield parameters of broccoli. 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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