**Comparative Performance of Different Organic Nutrient Management Schedules on Growth, Physiological and Yield Attributes of Sprouting Broccoli (*Brassica oleracea* var. *italica*)**

**ABSTRACT**

Farmers rely on conventional farming methods and lack knowledge of organic farming. However, conventional methods undoubtedly produce good yields, and there is a scope for improving the quantity and quality of broccoli through the use of organic manures and biofertilizers. This study was carried out to improve the productivity of organic sprouting broccoli by assessing the response of various organic nutrient schedules containing enriched farmyard manure, vermicompost and poultry manure as basal and top-dressing during the winter seasons of 2018-19 and 2019-20 at Uttar Banga Krishi Viswavidyalaya, Pundibari, West Bengal, India. The experiment consisted of 8 treatment combinations and included a randomized block design with 3 replications. The results of the study showed that the use of enriched poultry manure @ 5 t/ha as basal fertilizer + enriched poultry manure @ 1 t/ha as top dressing (T4) significantly enhanced broccoli plant growth in terms of the greatest plant height (58.04 cm) and number of leaves per plant (19.83), and leaf chlorophyll content (86.61). However, the application of enriched vermicompost @ 2.5 t/ha along with enriched poultry manure @ 2.5 t/ha as basal + top dressing of enriched vermicompost @ 0.5 t/ha along with enriched poultry manure @ 0.5 t/ha each (T7) significantly improved the head yield (20.47 t/ha) of organic broccoli.

***Keywords:*** *Azospirillum; biofertilizers; enriched organic manure; sprouting broccoli; vegetative growth; yield*

**INTRODUCTION**

Sprouting broccoli (*Brassica oleracea* var. *italica*) is one of the most popular cole group vegetables. It belongs to the Brassicaceae family and has chromosome number 2n= 18. Broccoli is more nutritious vegetable than any other vegetable of the same genus (Yoldas et al. 2008). It contains vitamin A (22 times and 130 times more abundant than cabbage and cauliflower), thiamine, riboflavin, niacin, vitamin C and minerals such as calcium, iron and phosphorous (Acharya et al. 2015). The crop forms a head with green buds and a thick fleshy floret stalk, unlike cauliflower. Broccoli is a cool season crop of three different types, viz., white, green and purple. Broccoli is similar to cauliflower in its upright structure, leaf habit and head formation, with major differences in inflorescence (Thamburaj & Singh 2001).

Farmers rely on conventional farming methods and lack knowledge of organic farming. However, conventional methods undoubtedly produce good yields, and there is ample potential for improving the quantity and quality of broccoli through the use of organic manures (Sen et al. 2023) as well as biofertilizers. Biofertilizers are modern agricultural tools that improve soil fertility and quality. Biofertilizers provide an ecologically sound means of reducing the use of external inputs and enhancing the quality and quantity of produce in vegetables (Joseph et al. 2015; Ruiz & Sanjuan 2022). The use of biofertilizers improves soil properties (El-yazeid et al. 2007). *Azotobacter* species can produce antifungal compounds that fight against various plant pathogens. They improve seed germination and plant vigor, resulting in the improvement of crop stands (Siddique et al. 2014). Several studies have confirmed the role of *Azotobacter* in nitrogen fixation. *Azospirillum* also provides N nutrients to vegetable crops through fixation and supplementation with expensive inorganic fertilizers (Bhattacharjee & Dey 2014; Geddes et al. 2015; Chauhan et al. 2015). The use of biofertilizers such as 5% *Azotobacter* spp. and *Azospirillum* spp.in sprouting broccoli resulted in the maximum plant height, biomass yield per plant, number of sprouts per head, number of slips per sprout, head diameter, plant spread and yield of plants (Manivannan & Singh 2004). PSB (phosphate-solubilizing bacteria) solubilizes both native and applied phosphorus and synthesizes growth-promoting substances such as auxin, IAA, GA, cytokinin and vitamins which augment plant growth (Ponmurugan et al. 2012; Ahemad & Kibret 2014). The use of biofertilizers in crop production can reduce the use of agro-chemicals and support eco-friendly sustainable food production.

The enrichment of organic manures with biofertilizers provides several advantages including increases in essential nutrient content, microbial load, enzyme activity, decomposition and mineralization, which increase the availability of nutrients for a longer period. The use of FYM and seed inoculation with biofertilizer (VAM) significantly improved the fresh weight of leaves, stem diameter, dry weight of the head, diameter of the head and yield (Bahadur et al. 2003). Considering the growing demand for organic sprouting broccoli, there is an urgent need to standardize the nutrient management schedule for organic broccoli cultivation. Information on the comparative performance of different enriched organic manure-based broccoli cultivations is still limited. Therefore, an attempt was made to evaluate different nutrient management schedules and examine their effects on the growth, yield and quality of organic broccoli.

**MATERIALS AND METHODS**

The experiment was carried out at Uttar Banga Krishi Viswavidyalaya (UBKV), West Bengal, India (89°23′ E longitude and 26°19' N latitude at an elevation of 43 meters above MSL), during the winter seasons of 2018-19 and 2019-20. The initial soil pH and soil organic carbon content were 5.78 and 0.76%, respectively. The available nitrogen, phosphorous and potassium contents in the soil were 117.60, 14.98 and 104.26 kg/ha, respectively. The climatic conditions of the region are subtropical with high rainfall, high humidity and prolonged winters, which is ideal for organic broccoli cultivation during the winter months.

The field experiment consisted of eight treatments viz., FYM @ 20 t/ha as basal + FYM @ 5 t/ha as top dressing as control (T1); enriched FYM @ 20 t/ha as basal + enriched FYM @ 5 t/ha as top dressing (T2); enriched vermicompost @ 5 t/ha as basal + enriched vermicompost @ 1 t/ha as top dressing (T3); enriched poultry manure @ 5 t/ha as basal + enriched poultry manure @ 1 t/ha as top dressing (T4); enriched FYM @ 10 t/ha and enriched vermicompost @ 2.5 t/ha as basal + top dressing of enriched FYM @ 2.5 t/ha and enriched vermicompost @ 0.5 t/ha (T5); enriched FYM @ 10 t/ha and enriched poultry manure @ 2.5 t/ha as basal + top dressing of enriched FYM @ 2.5 t/ha and enriched poultry manure @ 0.5 t/ha (T6); enriched vermicompost @ 2.5 t/ha along with enriched poultry manure @ 2.5 t/ha as basal + top dressing of enriched vermicompost @ 0.5 t/ha along with enriched poultry manure @ 0.5 t/ha each (T7); enriched FYM @ 7 t/ha, enriched poultry manure @ 2 t/ha and enriched vermicompost @ 2 t/ha as basal + top dressing of enriched FYM @ 2 t/ha, enriched vermicompost @ 0.25 t/ha and enriched poultry manure @ 0.25 t/ha (T8), were laid out in RBD (Randomized Block Design) which were replicated thrice.

Basal and top dressings of organic manures were applied at 30 and 45 days after transplanting. The organic manures were enriched by mixing well decomposed organic manures, viz., farmyard manure, vermicompost, poultry manure) with *Azotobacter chroococcum* and phosphate-solubilizing bacteria (*Acinetobacter sp*.) containing *Azophos* biofertilizer with a standard microbial population of 5 × 108 at 2 kg/t of organic manure and stored under shaded conditions for approximately 20 days before field application. Broccoli seedlings of the variety Green Magic were transplanted to 3 m × 3 m plots spaced at 60 cm × 60 cm during the 2nd week of November for both years. The crop was raised by following standard cultural practices. Neem cake @ 2 t/ha was used as the basal treatment, and neem oil at 5 ml/l was sprayed as needed for all the treatments. Hand weeding was performed to keep the crop weed free. Observations of various growth, yield and quality traits were made by selecting ten random plants from each plot.

**STATISTICAL ANALYSIS**

Two years of data were collected from various treatments which were subjected to statistical analysis by adopting the randomized block design suggested by Panse & Sukhatme (1985) with the help of the OPSTAT statistical package. The data for individual years were used for pooled analysis over two years, and the means were compared at the 0.05 level for statistical significance (Gomez & Gomez 1984).

**RESULTS AND DISCUSSION**

**GROWTH AND PHYSIOLOGICAL ATTRIBUTES OF SPROUTING BROCCOLI**

The mean pooled data on the plant height of broccoli as affected by organic nutrient sources are depicted in Table 1 and Figure 1. Compared with those in the control treatment (T1), all the treatments resulted in increased plant height. The maximum plant height was recorded in T4 (58.04 cm), which was significantly greater than the other organic nutrient sources, and the minimum plant height was observed in T1 (52.54 cm). The number of leaves per broccoli plant increased significantly due to the increase in organic manures. This was observed at every stage of observations. The greatest number of leaves per plant (19.83 and 19.55) was observed under T4 and T3, respectively. The number of leaves was minimal under the treatment T1 (17.63). The earliest head formation was observed in the T3 treatment, which took 34.19 days followed by that in the T4 treatment (34.97 days), and the longest time to head formation was observed in the T1 treatment (40.95 days). The pooled data on days taken to marketable head maturity was influenced by different enriched organic manures are presented in Table 1. The earliest marketable head maturity was observed in the T3 treatment, which took 46.47 days, followed by that in the T4 treatment (48.48 days). The chlorophyll content in leaves was recorded at 30 and 60 days after transplanting by using a SPAD meter. The plants grown under different enriched organic manure compositions had the greatest leaf chlorophyll content according to the SPAD value of T4 (86.61) and the lowest leaf chlorophyll content according to the SPAD value of T1 (80.64). The leaf area index was significantly influenced by enriched organic manures. The maximum leaf area index (1.95) was recorded for T4,followed by T3 (1.94).

The effects of biofertilizers on the production of various phytohormones such as IAA (indole-3-acetic acid), cytokinin and gibberellic acid, likely led to improved root development and nutrient uptake and translocation, ultimately resulting in improved plant growth (Mohapatra et al. 2013). The effect of biofertilizers can be attributed to the mutually beneficial effects of played by each of the two biofertilizer groups. Similar findings were reported by Yadav et al. (2012) and Mohapatra et al. (2013) and Banotra et al. (2021).

**YIELD ATTRIBUTES OF SPROUTING BROCCOLI**

Pooled data on head weight as influenced by enriched organic manures are furnished in Table 2. The maximum head weight was recorded in T7 (774.93 g), which was significantly greater than that in other treatments, and the minimum head weight was observed in T1 (541.41 g). The average highest head yield per hectare was recorded in T7 (20.47 t), followed by T4 (20.15 t), and the lowest head yield per hectare from T1 (16.83 t) is presented in Table 2 and Figure 1. The percentage of the harvest index was highest in the T7 treatment (68.10%), and the lowest was observed in the T1 treatment (59.52%). With increasing plant growth and dry matter accumulation, plants develop better heads and ultimately have higher head yield. These results are in accordance with those of Mohapatra et al. (2013) and Sarker et al. (2021).

**CONCLUSION**

Based on the present investigation, it can be concluded that *Azophos* biofertilizer enriched poultry manure (5 t/ha) as a basal dressing along with enriched poultry manure (1 t/ha) as a top dressing at 30 and 45 days after transplanting had a pronounced influence on plant growth whereas, basal application of *Azophos* biofertilizer- enriched vermicompost (2.5 t/ha) and poultry manure (2.5 t/ha) along with top dressing of enriched vermicompost (0.5 t/ha) and poultry manure (0.5 t/ha) at 30 and 45 days after transplanting exerted maximum head yield of organic broccoli, therefore this biofertilizer can be successfully utilized in organic broccoli cultivation.

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**COMPETING INTERESTS**

All the authors declare that there is no competing interests exist.

**AUTHOR’S CONTRIBUTION**

This work was carried out in collaboration among all authors. The first author designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. The second author is the major guide and chairman of the advisory committee of the first author. The third author and fourth author managed the literature searches and helped in the data analysis.

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**Table 1. Effects of different organic nutrient sources on growth and physiological attributes of broccoli**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments\*** | **Plant height (cm)** | **Number of leaves/ plant** | **Days to head formation (DAT)** | **Days to marketable head maturity (DAT)** | **Leaf chlorophyll content**  **(SPAD value)** | **Leaf area** **index (LAI)** |
| T1 | 52.54 | 17.63 | 40.95 | 52.91 | 80.64 | 1.73 |
| T2 | 53.66 | 17.83 | 39.99 | 52.39 | 81.41 | 1.79 |
| T3 | 57.44 | 19.55 | 34.19 | 46.47 | 85.55 | 1.94 |
| T4 | 58.04 | 19.83 | 34.97 | 48.48 | 86.61 | 1.95 |
| T5 | 54.70 | 18.40 | 36.95 | 50.10 | 81.52 | 1.85 |
| T6 | 55.31 | 18.73 | 39.03 | 52.28 | 82.46 | 1.87 |
| T7 | 56.93 | 19.35 | 36.15 | 49.72 | 83.51 | 1.92 |
| T8 | 56.63 | 18.98 | 37.56 | 50.84 | 83.05 | 1.91 |
| S.Em.± | 0.22 | 0.25 | 0.39 | 0.44 | 0.80 | 0.03 |
| CD (0.05) | 0.76 | 0.86 | 1.31 | 1.48 | 2.73 | 0.12 |

\*Treatment details are mentioned in materials and methods

S.Em. = standard error of mean; CD = critical difference

**Table 2. Effects of different organic nutrient sources on yield and yield attributes of broccoli**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments\*** | **Average** **head weight (g)** | **Harvest index (%)** | **Head yield/ hectare (ton)** |
| T1 | 541.41 | 59.52 | 16.83 |
| T2 | 608.16 | 61.01 | 17.49 |
| T3 | 728.51 | 65.00 | 19.81 |
| T4 | 767.80 | 67.01 | 20.15 |
| T5 | 643.40 | 63.05 | 18.05 |
| T6 | 698.79 | 62.68 | 18.38 |
| T7 | 774.93 | 68.10 | 20.47 |
| T8 | 717.93 | 63.83 | 19.24 |
| S.Em.± | 0.01 | 0.36 | 0.32 |
| CD (0.05) | 0.02 | 1.23 | 1.10 |

\*Treatment details are mentioned in materials and methods

S.Em. = standard error of mean; CD = critical difference

**Figure 1. Effects of different organic nutrient sources on growth, physiological and yield attributes of sprouting broccoli**