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Influence of organic and inorganic fertilizers on the morphological growth and yield of broccoli in coastal regions of Bangladesh

Nishat Farabi[1], Mehedi Hasan[1], Mariha Rahman[1], Mostaque Ahmad[2], Nasiba Fatima[2], Md. Bayzid Sarker[3] and Gazi Md. Mohsin*[4]

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A B S T R A C T

A field study was conducted to assess the combined effects of organic and inorganic fertilizers on the growth and yield of broccoli (*Brassica oleracea* var. *italica*) under coastal conditions in Bangladesh, characterized by slightly saline soil (EC 1.67 mS cm^{-1}). Six treatment combinations were tested: T_0 – Control (no fertilizer application); T_1 – 100% recommended dose of inorganic fertilizers (Urea, TSP, MoP); T_2 – 100% recommended dose of inorganic fertilizers + 2.5 t ha^{-1} vermicompost; T_3 – 100% recommended dose of inorganic fertilizers + 5 t ha^{-1} vermicompost; T_4 – 2.5 t ha^{-1} vermicompost; and T_5 – 5 t ha^{-1} vermicompost. Results showed that the combined application of 100% RDF with 5 t ha^{-1} vermicompost (T_3) significantly improved all vegetative growth parameters, such as plant height, leaf number, leaf length, and leaf diameter, which subsequently enhanced curd diameter, net curd weight, and marketable curd weight, leading to the highest yield per plot. The strongest correlations (r = 0.946) were observed between yield and both net and marketable curd weight, indicating that curd biomass is the most direct determinant of yield. The study concludes that the integration of 100% RDF with 5 t ha^{-1} vermicompost (T_3) is the most effective and sustainable nutrient management practice for maximizing broccoli growth and yield under coastal agro-ecological conditions of Bangladesh.

Keywords: Broccoli, Vermicompost, Integrated fertilization, Soil nutrient management

[1]*Department of Soil, Water and Environmental Sciences, Noakhali Science and Technology University, Noakhali, Bangladesh*
[2]*Department of Soil, Water and Environment, Dhaka University, Bangladesh*
[3]*Research and Development, Lal Teer Seed Limited, Gazipur, Bangladesh*
[4]*Department of Agriculture, Noakhali Science and Technology University, Noakhali, Bangladesh*

*Corresponding author's email: gazimohsin@nstu.edu.bd (Gazi Md. Mohsin)

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Introduction

Broccoli (*Brassica oleracea* L. var. *italica*), an important cole crop vegetable belonging to the Brassicaceae (Cruciferae) or mustard family, is gaining popularity in Bangladesh and is known for being a rich source of sulforaphane - a compound with potent anti-carcinogenic properties (Kirsh *et al.*, 2007). In Bangladesh, broccoli is viewed as a promising crop with the potential to thrive in local markets and eventually enter the export sector. Despite this, organic cultivation remains limited in scale. Broccoli is widely recognized as a nutritious and flavorful addition to salads and other health-conscious meals. Broccoli is recognized for its rich composition of vitamins, minerals, dietary fiber, and antioxidants, which play essential roles in promoting overall human health (Cartea *et al.*, 2008; Faller and Fialho, 2009; Porter, 2012). It is a good source of carbohydrates, protein, vitamins A and C, vitamins B_1 and B_2, calcium, and phosphorus. Compared with cauliflower, broccoli contains approximately 4.0, 2.5, and 2.0 times higher amounts of riboflavin, calcium, and ascorbic acid, respectively

(Hazra and Som, 2009). Moreover, it has a low glycemic index (GI = 10), making it a suitable and safe vegetable option for individuals with diabetes (Nagraj *et al.*, 2020).

Farmers in Bangladesh have shown growing interest in broccoli cultivation due to its high economic value. The use of balanced and adequate fertilizer combinations is crucial for ensuring the production of high-quality broccoli and attaining maximum yield and profitability (Ahirwar and Nath, 2020). In Bangladesh, many farmers lack awareness of the benefits of balanced fertilization and often cultivate vegetables without following proper fertilizer rates or soil testing. To achieve higher yields, they frequently apply chemical fertilizers indiscriminately while neglecting adequate amounts of organic manure. Such irresponsible fertilizer practices can degrade soil health, reduce produce quality, and shorten shelf life (Mal *et al.*, 2014). Relying solely on chemical fertilizers may boost short-term crop yields, but over time they can harm soil health and crop performance (Gupta *et al.*, 2019). Organic manure can supply essential nutrients to plants, helping maintain crop quality while also enhancing the physical and chemical properties of the soil (Alam *et al.*, 2019). Organic manures can serve as a substitute for synthetic fertilizers (Hossain *et al.*, 2020). The use of locally available manures, such as cow dung and chicken manure, in vegetable cultivation can enhance crop yields while reducing reliance on chemical fertilizers. Additionally, consumers are increasingly seeking high-quality, safer foods and show a strong preference for organic products.

The main objectives of the proposed research are to examine the effects of organic and inorganic fertilizers on the growth and yield performance of broccoli and to determine the optimal level of organic fertilizer application under coastal conditions. Additionally, the study aims to assess the impact of inorganic fertilizers and their combined use on the yield, quality, and economic returns of broccoli.

Materials and Methods

Selection of site

The study was conducted at the Agricultural Research Field, Noakhali Science and Technology University (NSTU), Noakhali, Bangladesh, located in Agro-Ecological Zone 18 (AEZ-18), which is characterized by normal seasonal flooding and well-drained soils.

Selection of test plant material

A certified high-yielding broccoli variety, Lidia F1, was used for this study, and the seeds were sourced from Siddique Bazar, Dhaka.

Land preparation

The field was thoroughly prepared using a power tiller, followed by harrowing and leveling with a ladder. Individual plots were constructed to a height of 7 cm and a depth of 8 cm, with drainage channels around each plot to prevent lateral runoff from irrigation or rainfall.

Crop establishment and management

Broccoli (*Brassica oleracea* var. *italica*) seedlings were grown in a nursery and later transplanted to the experimental plots at 30 days after sowing when seedlings had 4–5 true leaves. Each plot measured 1.5 m × 1.0 m with a spacing of 50 cm × 50 cm between plants. Uniform agronomic practices, including irrigation, weeding, and pest control, were implemented across all treatments to reduce variation not associated with fertilizer effects.

Design of the experiment and treatments

The experiment followed a Randomized Complete Block Design (RCBD) with three replications. There were eighteen experimental plots. The treatments comprised different combinations of organic and inorganic fertilizers, including:

T_0: Control (no fertilizer application)
T_1: 100% recommended dose of inorganic fertilizers (Urea, TSP, MoP)
T_2: 100% recommended dose of inorganic fertilizers + 2.5 t ha^{-1} vermicompost
T_3: 100% recommended dose of inorganic fertilizers + 5 t ha^{-1} vermicompost
T_4: 2.5 t ha^{-1} vermicompost

Fertilizer application

Organic fertilizers (vermicompost) were incorporated into the soil one week prior to transplanting. The recommended dose of inorganic fertilizers consisted of Urea, Triple Super Phosphate (TSP), and Muriate of Potash (MoP) at the rates of 37.5, 22.5, and 30.0 g $plot^{-1}$, respectively. Inorganic fertilizers were applied in split doses: nitrogen at half rate, and the full amounts of phosphorus and potassium were incorporated into the soil during final land preparation, while the remaining nitrogen was side-dressed at 30 and 45 days after transplanting.

Data collection

Data were collected from three randomly chosen plants per plot to measure plant height (cm), number of leaves, length of leaves (cm), diameter of leaves (cm), curd diameter (cm), net curd weight (g), marketable curd weight (g), and yield per plot (kg plot^{-1}).

Statistical analysis

All raw data were checked for normality and homoscedasticity (equal variance). The data were compared using one-way ANOVA, and Tukey's post hoc test was applied to identify significant differences among treatments. The data were transformed as required before performing the one-way ANOVA. Microsoft Excel was used to create graphs, while MINITAB 17 was used to perform one-way ANOVA and Tukey's pairwise comparisons.

Growth parameters as affected by organic and inorganic fertilizer application

Vegetative growth parameters of broccoli, including plant height, leaf number, leaf length, and leaf diameter, were significantly influenced by different fertilizer treatments. The highest values for all vegetative traits were recorded in T_3 (100% RDF + 5 t ha^{-1} vermicompost), whereas the control treatment (T_0) showed the lowest performance. The superior growth observed under integrated nutrient management might be attributed to improved nutrient availability, enhanced microbial activity, and better soil physical conditions resulting from vermicompost application. The balanced supply of nutrients from both organic and inorganic sources likely promoted cell division, chlorophyll synthesis, and leaf expansion, ultimately enhancing overall vegetative growth.

Results and Discussion

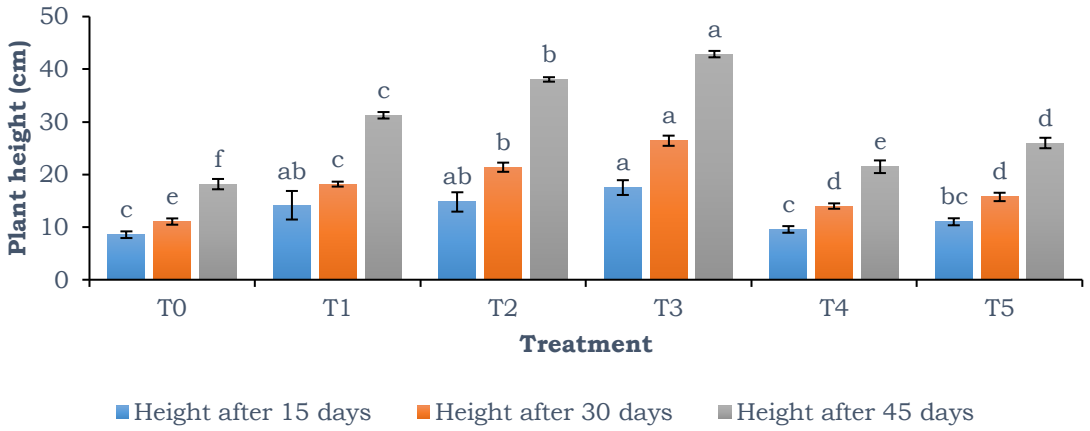

Fig. 1. Plant height after 15, 30 and 45 days as affected by different treatments. Letters above each bar show which treatment groups are statistically different from one another.

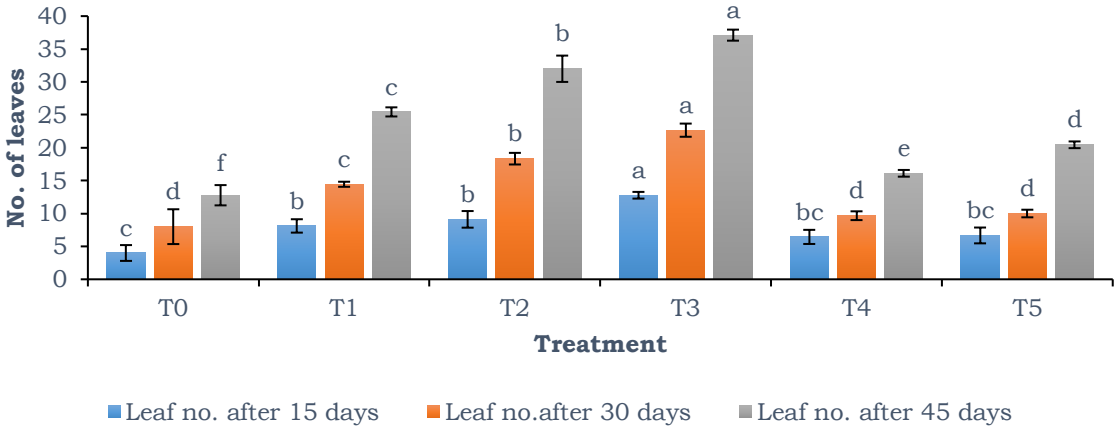

Fig. 2. Leaf number after 15, 30 and 45 days as affected by different treatments. Letters above each bar show which treatment groups are statistically different from one another.

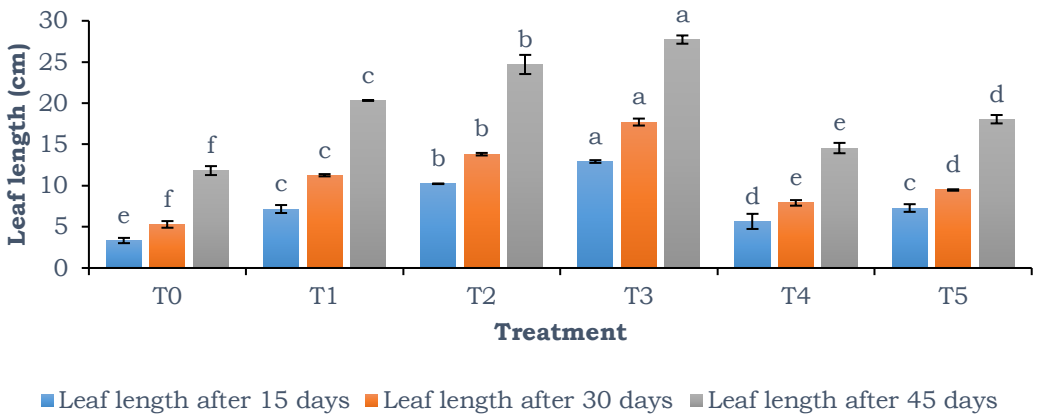

Fig. 3. Leaf length after 15, 30 and 45 days as affected by different treatments. Letters above each bar show which treatment groups are statistically different from one another.

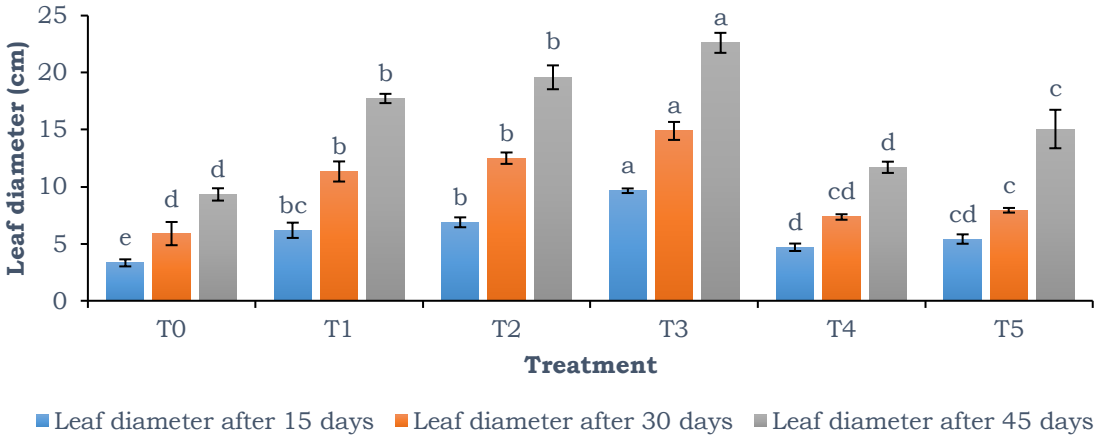

Fig. 4. Leaf diameter after 15, 30 and 45 days as affected by different treatments. Letters above each bar show which treatment groups are statistically different from one another.

Curd diameter

The data on curd diameter revealed that the largest curd diameter (10.03 cm) was recorded in the soil treated with T_3. This was followed by the T_2 treatment, which showed a slightly smaller curd diameter (8.83 cm). In contrast, the smallest curd diameter (5.47 cm) was observed in the soil treated with T_0.

These findings indicate that organic and inorganic fertilizer application, particularly the T_3 treatment, had a significant positive effect on the development of curd diameter. The influence of different fertilizer treatments on curd diameter is illustrated in Figure 5.

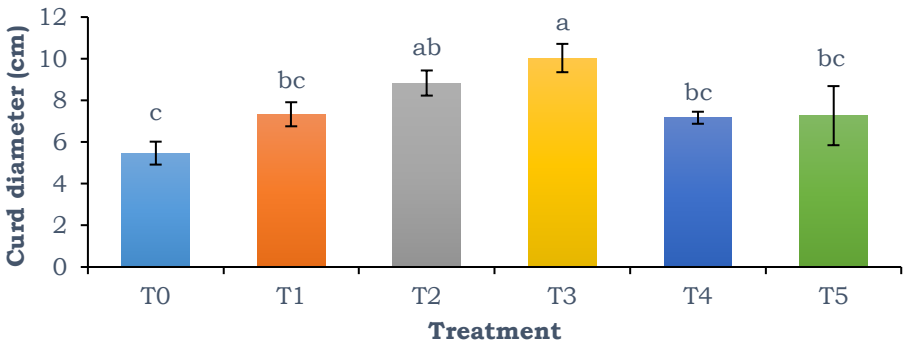

Fig. 5. Curd diameter as affected by different treatments. Letters above each bar show which treatment groups are statistically different from one another.

Marketable and net curd weight

Analysis of variance revealed that fertilizer treatments had a significant effect ($p < 0.05$) on both marketable and net curd weights of broccoli. The highest marketable curd weight (430.48 g plant^{-1}) was obtained from the T_3 treatment, followed by T_2 (368.00 g plant^{-1}), while the lowest value (206.23 g plant^{-1}) was recorded in the control T_0. A similar pattern was observed for net curd weight, where T_3 produced the maximum trimmed curd weight (374.33 g plant^{-1}). The T_2 treatment ranked second (320.00 g plant^{-1}), whereas T_0 recorded the minimum (179.33 g plant^{-1}). These results indicate that the integrated application of fertilizers (T_3) substantially improved both marketable and edible curd yields compared with individual or no-fertilizer applications. The impacts of different fertilizer treatments on net and marketable curd weights are shown in Figure 6.

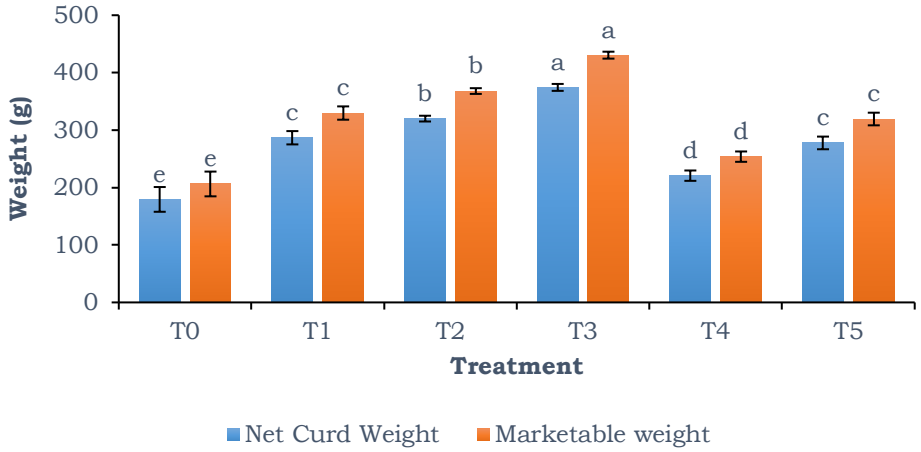

Fig. 6. Net curd weight and marketable curd weight as affected by different treatments. Letters above each bar show which treatment groups are statistically different from one another.

Yield Plot[1]

The highest yield (3.5 kg plot^{-1}) was obtained from treatment T_3, which was statistically similar to T_2 and T_1, but significantly higher than the control T_0 and T_4. This result suggests that the fertilizer combination used in T_3 provided an optimum nutrient balance that enhanced vegetative growth and curd development. Similar findings were reported by several researchers, who observed that balanced application of organic and inorganic fertilizers improved yield attributes and total yield of broccoli. The lower yield in the control plot may be attributed to soil nutrient deficiency, which restricted plant growth and curd formation. Overall, the positive response of yield to increased fertilizer application up to T_3 indicates that proper nutrient supplementation is essential to achieve maximum yield potential in broccoli under coastal conditions. The impacts of different fertilizer treatments on yield per plot are shown in Figure 7.

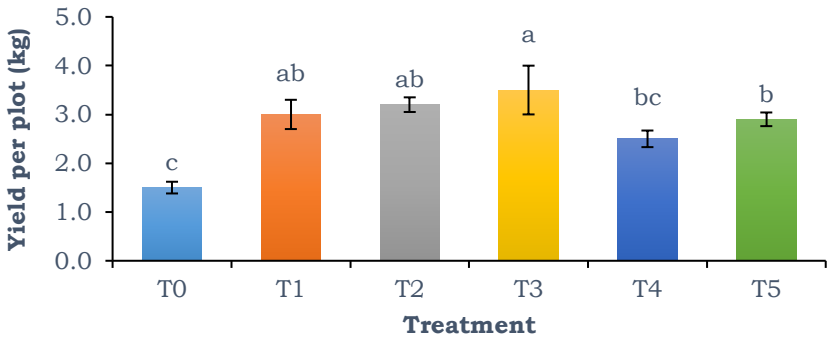

Fig. 7. Yield per plot as affected by different treatments. Letters above each bar show which treatment groups are statistically different from one another.

The results of the current study revealed that both vegetative growth and yield per plot of broccoli increased progressively with higher rates of vermicompost, and the best performance was obtained from the treatment receiving the highest level of vermicompost in combination with the RDF. This finding demonstrates the synergistic impact of organic and inorganic nutrient sources on soil fertility, nutrient uptake, and plant growth in broccoli. The results are in close agreement with those reported by Hasan *et al.* (2024), who observed that increasing vermicompost levels significantly enhanced head yield and quality of broccoli under field conditions. Similarly, the factorial investigation conducted by Mal *et al.* (2014) showed that the highest vermicompost rate (10 t ha^{-1}) combined with 100 % RDF produced the maximum curd yield and improved morphological traits. In addition, Meena *et al.* (2017) reported that integrating 75% RDF with higher organic compost levels significantly improved curd weight, plant height, and marketable yield compared with sole inorganic fertilization. The consistency of these results with the current findings strongly supports the conclusion that the combined application of chemical fertilizers and large doses of vermicompost creates an ideal nutrient balance that sustains soil health while maximizing broccoli yield under coastal agro-ecological conditions. Therefore, the present results are fully consistent with previous research, confirming that a high vermicompost rate, together with the recommended inorganic fertilizer dose, yields the most favorable outcome for broccoli production.

Relationship between morphological traits and the yield of broccoli

Vegetative characteristics of broccoli (*Brassica oleracea* L. var. *italica*) and yield per plot were tested for relationships. A Spearman correlation analysis was conducted to examine the relationships among these traits (Table 1). Significant correlations with r ≥ 0.5 were considered for further discussion. Statistical significance was assessed by considering p-values ≤0.05.

Table 1. Correlation coefficient (r) of growth parameters and yield of broccoli.

Properties	Height	Leaf number	Leaf length	Leaf diameter	Curd diameter	Net curd weight	Marketable curd weight
Leaf number	0.998***						
Leaf length	0.994***	0.992***					
Leaf diameter	0.997***	0.992***	0.990***				
Curd diameter	0.953**	0.959**	0.975**	0.948**			
Net curd weight	0.977**	0.967**	0.988***	0.983***	0.954**		
Marketable curd weight	0.977**	0.967**	0.988***	0.983***	0.954**	1.000***	
Yield per plot	0.891*	0.874*	0.914*	0.912*	0.911*	0.946**	0.946**

****, **, * Marked correlations are significant at P≤0.001, 0.01 and 0.05, respectively.*

The correlation matrix demonstrates strong and significant positive associations among the vegetative growth traits and curd-related parameters. For instance, plant height correlates almost perfectly with leaf number (r = 0.998***), leaf length (r = 0.994***), and leaf diameter (r = 0.997***), indicating that increased vertical growth is tightly linked with enhanced leaf productivity. These vegetative attributes also show very high intercorrelations (r > 0.99***), underscoring that canopy development is a coordinated process. The close relationships between growth traits and curd traits (e.g., leaf length vs net curd weight r = 0.988***; leaf diameter vs marketable curd weight r = 0.983***) suggest that improved foliage structure likely supports assimilate partitioning into the curd.

Yield per plot also exhibits significant positive correlations with all growth and curd parameters (e.g., r = 0.946** with net curd weight / marketable curd weight), and somewhat lower but still significant correlations with height (r = 0.891*) and leaf number (r = 0.874*). This implies that although basic vegetative growth contributes to yield, the mass and quality of curd formation are more directly influential for final yield. These findings are consistent with prior studies in broccoli showing that stronger vegetative growth often leads to higher curd yield (e.g., in nitrogen response trials) (Giri *et al.*, 2013).

Conclusions

The present study clearly demonstrated that the combined application of organic and inorganic fertilizers had a pronounced influence on the growth and yield performance of broccoli. Among the different treatments, the combination containing 100% (RDF) along with the highest level of vermicompost resulted in superior vegetative growth and maximum curd yield. This integrated nutrient management approach enhanced plant height, leaf production, and curd development more effectively than sole or lower-dose applications, indicating improved nutrient availability and uptake efficiency.

Correlation analysis further revealed that broccoli yield was strongly and positively associated with major growth attributes and curd-related parameters. The strongest correlations ($r > 0.946$) were observed between yield and both net and marketable curd weight, suggesting that curd mass is the most direct determinant of overall productivity. These findings confirm that vigorous vegetative growth supports better curd development, ultimately enhancing yield. Therefore, the integration of 100% RDF with vermicompost can be recommended as an effective and sustainable nutrient management practice to maximize broccoli production under the coastal conditions of Bangladesh.

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