AGRICULTURAL SCIENCE AND TECHNOLOGY, VOL. 16, No 1, pp 54-62, 2024
Published by Faculty of Agriculture, Trakia University, Bulgaria
ISSN 1313-8820 (print)
ISSN 1314-412X (online)
http://www.agriscitech.eu
DOI: 10.15547/ast.2024.01.006

Influence of Vermicompost and Biofertilizer on growth, head yield and quality of Broccoli (*Brassica oleracea* L. var. *italica*)

M.J. Hasan[1*], K. Khatun[2], T. Mostarin[2], K.C. Karishma[2], M.K.A. Nadim[3], S.M.A. Chowdhury[4]

[1]Entomology Division, Bangladesh Institute of Nuclear Agriculture, BAU Campus, Mymensingh-2202, Bangladesh
[2]Department of Horticulture, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh
[3]Biotechnology Division, Bangladesh Institute of Nuclear Agriculture, BAU Campus, Mymensingh-2202, Bangladesh
[4]Agronomy Division, Bangladesh Institute of Nuclear Agriculture, BAU Campus, Mymensingh-2202, Bangladesh

(Manuscript received 27 September 2023; accepted for publication 1 February 2024)

Abstract. *The present experiment was conducted from November 2020 to March 2021 at Sher-e-Bangla Agricultural University's Horticulture Farm in Dhaka, Bangladesh. The investigation included four levels of vermicompost (T_0= control, T_1=3 t.ha^{-1}, T_2=6 t.ha^{-1} and T_3=9 t.ha^{-1}) and biofertilizer (F_0=control, F_1=3 kg.ha^{-1}, F_2=5 kg.ha^{-1} and F_3=7 kg.ha^{-1}) which was carried out by factorial randomized complete block design with three replications. The broccoli variety 'Green Carpet' was used as planting material. The application of the treatment T_3F_3 (vermicompost at 9 t.ha^{-1} and biofertilizer at 7 kg.ha^{-1}) resulted in the highest plant height (67.85 cm), number of leaves per plant (22.76), leaf length (60.57 cm), leaf breadth (23.23 cm) and chlorophyll (SPAD index) (54.90). However, statistically similar results were also observed for T_2F_3 in most cases (vermicompost at 6 t.ha^{-1} and biofertilizer at 7 kg.ha^{-1}). The maximum stem diameter (4.98 cm) was recorded in T_2F_3. Fewest days to achieve 100% curd initiation (54 days), maximum curd diameter (13.19 cm), yield (15.84 t.ha^{-1}) and vitamin C (64.34 mg 100 g^{-1}) content were recorded in T_3F_3. With the exception of the fewer days required to initiate curd formation, all other parameters were statistically similar to those observed in the T_2F_3 treatment combination.*

Keywords: Ascorbic acid; K-means clustering; Pearson's correlation; SPAD Index

Introduction

Broccoli (*Brassica oleracea* L. var. *italica*) as a biennial and herbaceous cole crop, is one of the most well-known exotic vegetable crops of the family Brassicaceae. Broccoli can be consumed cooked in soups, pickles, and curries, or raw in salads. It is richer in vitamins, minerals and antioxidants than other cole crops and is also free of fat and cholesterol (Zhang, 2004). Vermicompost is a type of organic manure that releases nutrients slowly and contains chelated forms of the majority of the macro and micronutrients necessary to meet the long-term nutrient requirements of plants. Additionally, organic manures reduce the C:N ratio, enhance humic acid content, and provide plants with nutrients including nitrate, exchangeable phosphorus, soluble potassium, magnesium and calcium in readily available form (Talashilkar et al., 1999). Biofertilizers are live microorganisms

* e-mail: jahidhasan1506603@gmail.com

that may convert inaccessible nutrients into usable forms through biological processes. Moreover, they also raise the levels of growth hormones including IAA and GA and thus stimulate the growth and development of plants (Asad et al., 2004). Biofertilizers, containing live microorganisms, play a crucial role in making nutrients accessible to plants. Biofertilizers promoting crop production are azotobacter, azospirillum, blue-green algae, azolla, phosphorus solubilizing microorganisms, mycorrhizae and sinorhizobium (Selvakumar et al., 2009). The gap between the supply and demand of nutrients can be greatly reduced with the incorporation of biofertilizers. Therefore, the goal was to investigate how vermicompost and biofertilizer together enhance both yield and nutritional quality of broccoli. The study aimed to evaluate the effects of vermicompost and biofertilizer on the growth, yield, and quality characteristics of broccoli.

Material and methods

The experiment was conducted from November 2020 to March 2021 at Sher-e-Bangla Agricultural University's Horticulture Farm in Dhaka, Bangladesh. The Broccoli variety 'Green Carpet' was selected for this study. The experiment tested four levels each of vermicompost (0, 3, 6, 9 tonnes per hectare) and biofertilizer (0, 3, 5, 7 kilograms per hectare), resulting in 16 treatment combinations. Treatments were applied prior to the second ploughing, ensuring each treatment's uniform distribution. The experimental area was fertilized as presented in Table 1. The experimental design was a factorial Randomized Complete Block Design (RCBD) with three replications. Each unit plot measured 1.6 square meters (1.6m by 1m). Plants were spaced 60 cm apart in rows, with 40 cm between each plant. Blocks and plots were separated by 0.5 meter. Seedlings, aged 25 days, were transplanted into the field. The crop was grown with proper intercultural operations. Broccoli curds were harvested according to maturity indices, with an 8 cm stem attached. Data were collected on morphological traits, yield, and quality. Stem diameter was measured 8 cm below the head, and chlorophyll content was assessed using a SPAD 502 meter (Country of origin: Japan). By homogenizing 5 g of broccoli head with 50 ml meta-phosphoric acid solution, the vitamin C (Ascorbic acid) content was analyzed. The solution was then filtered. To get a light pink color, 2, 6-dichlorophenolindophenol solution was titrated with 10 ml of the filtrate. Vitamin C content was determined by titrating a meta-phosphoric acid solution of broccoli head with 2,6-dichlorophenolindophenol, calibrated against L-ascorbic acid (Uggla, 2004). Statistical analysis was performed using R software (Version 4.2.3), employing the Least Significant Difference (LSD) test to identify significant differences among treatments at a 5% significance level.

Table 1. Fertilizer doses with their nutrient composition

Fertilizers	Doses/ha	Nutrients
Vermicompost*	3 t	$N_{48kg}P_{30.6kg}K_{21.9kg}Mg_{9.915kg}Zn_{1.713kg}$
	6 t	$N_{96kg}P_{61.2kg}K_{43.8kg}Mg_{19.83kg}Zn_{3.416kg}$
	9 t	$N_{144kg}P_{91.8kg}K_{65.7kg}Mg_{29.74kg}Zn_{5.139kg}$
Biofertilizer**	3 kg	-
	5 kg	-
	7 kg	-

* Nitrogen 1.60%, Potassium 0.73%, Phosphorus 1.02%, Magnesium 0.33%, Zinc 0.057%

** Azotobacter, Rhizobium, Plant growth promoting bacteria, Phosphate and Silicate solubilizing microorganism all are at 10^8 CFU/g and Trichoderma at 10^9 CFU/g

Results and discussion

Effect of vermicompost

Vermicompost showed significant effect on growth, yield and quality parameters (Tables 2 and 3) over untreated plots. The plant height, number of leaves, leaf length, leaf breadth and curd diameter greatly increased with each subsequent increase in vermicompost levels while shortening the time to achieve full curd formation. The maximum stem diameter was recorded in T_2 (Vermicompost at 6 $t.ha^{-1}$) but the highest yield $plot^{-1}$ (2.26 kg) and subsequent yield (14.12 $t.ha^{-1}$) were found by the plants grown at vermicompost T_3 (9 $t.ha^{-1}$) which was statistically similar to the treatment T2 (6 $t.ha^{-1}$) (2.22 kg $plot^{-1}$ and 13.87 $t.ha^{-1}$). No significant differences were observed in leaf and curd dry weight (g). Vermicompost has a significant impact on the quality aspects as well. The amount of vermicompost greatly raised the leaf chlorophyll content and vitamin C content of the head (Table 3). Vermicompost may play a beneficial effect in the soil moisture content, porosity and other characteristics that promote plant growth, all of which influenced the broccoli's growth, yield and quality parameters.

Table 2. Effect of vermicompost and biofertilizer on growth and yield of broccoli

Treatment	Plant height (cm)	No of leaves per plant	Leaf length (cm)	Leaf breadth (cm)	100% curd initiation (Days)	Stem diameter (cm)	Curd diameter (cm)
Vermicompost level							
T_0	58.86d	17.78c	54.23d	20.31d	60.08a	4.24d	10.28d
T_1	60.77c	19.52b	56.99c	21.38c	58.58b	4.46c	11.15c
T_2	62.86b	20.93a	57.68b	21.97b	56.75c	4.73a	11.73b
T_3	65.44a	21.32a	58.61a	22.32a	55.42d	4.66b	12.09a
CV (%)	8.25	6.45	5.02	4.25	5.58	4.82	7.21
Biofertilizer level							
F_0	60.24 d	18.88 d	55.58c	20.89 d	58.83a	4.30d	10.61c
F_1	61.56 c	19.62 c	56.83b	21.33 c	58.00b	4.39c	11.20b
F_2	62.55 b	20.19 b	56.96b	21.64 b	57.42c	4.67b	11.47b
F_3	63.58 a	20.86 a	58.13a	22.12 a	56.58d	4.72a	11.98a
CV (%)	8.25	6.45	5.02	4.25	5.58	4.82	7.21

Similar letter(s) in a column signifies that they are statistically similar, whereas dissimilar letter(s) means that they differ significantly by LSD at 0.05 levels of probability. Note: T_0 = 0 $t.ha^{-1}$ vermicompost (control), T_1 = 3 $t.ha^{-1}$ vermicompost, T_2 = 6 $t.ha^{-1}$ vermicompost and T_3 = 9 $t.ha^{-1}$ vermicompost, F_0 = 0 $kg.ha^{-1}$ biofertilizer (control), F_1 = 3$kg.ha^{-1}$ biofertilizer, F_2 = 5 $kg.ha^{-1}$ biofertilizer and F_3 = 7 $kg.ha^{-1}$ biofertilizer

Table 3. Effect of vermicompost and biofertilizer on growth, yield and quality attributes of broccoli

Treatment*	Leaf dry weight per 100g	Curd dry weight per 100g	Yield per plot (kg)	Yield ($t.ha^{-1}$)	Leaf chlorophyll content (SPAD value)	Vitamin C (mg/100g of fresh head)
Vermicompost level						
T_0	15.34	12.05	1.82c	11.37c	31.78d	55.02d
T_1	15.96	12.34	2.18b	13.65b	39.47c	57.82c
T_2	16.66	13.06	2.22ab	13.87ab	49.71b	60.35b
T_3	16.54	13.26	2.26a	14.12a	52.57a	62.99a
CV (%)	6.84	5.24	5.24	5.24	1.65	2.85
Biofertilizer level						
F_0	15.47	11.99	1.96d	12.27d	40.26d	57.61b
F_1	15.92	12.63	2.03c	12.68c	42.78c	58.90ab
F_2	16.33	12.85	2.17b	13.55b	44.71b	59.53a
F_3	16.79	13.24	2.32a	14.51a	45.80a	60.14a
CV (%)	6.84	5.24	5.24	5.24	1.65	2.85

*Treatment details are given in Table 2

Rabbee et al. (2020) found a significant effect of vermicompost on the growth and yield-contributing characteristics of broccoli. Recorded data regarding plant height, number of leaves per plant, leaf length, leaf diameter, 50% curd initiation, curd diameter, net curd weight, and yield per plot were superior to vermicompost compared to farmyard manure and control.

Singh et al. (2020) investigated that 10 $t.ha^{-1}$ Vermicompost + 50% RDF was the best treatment for more growth and high yield of broccoli. The results of the current study support those of Rabbee et al. (2020) and Singh et al. (2020).

Effect of biofertilizer

Tables 2 and 3 show how broccoli's growth, yield and quality characteristics were considerably impacted by increasing biofertilizer levels. Plot treated with biofertilizer at 7 $kg.ha^{-1}$ (F_3) had maximum plant height (63.58 cm), number of leaves per plant (20.86), leaf length (58.13 cm), leaf breadth (22.12 cm), stem diameter (4.72 cm) and curd diameter (11.98 cm) as well as minimum days for curd initiation (56.58). The same treatment resulted in highest yield $plot^{-1}$ (2.32 kg) and yield (14.51 $t.ha^{-1}$). Leaf and curd dry weight (g) values did not differ significantly among the treatments. Table 3 shows that as the amount of biofertilizer increased, so did the leaf chlorophyll and vitamin C content. The maximum values were observed for the F_3 treatment. This could be explained by an increase in nitrogen availability for the activity of nitrogen-solubilizing microorganisms in biofertilizer which is an essential component of chlorophyll and protein, leading to greater growth and yield. Application of biofertilizers aids in the production of growth-promoting substances, which improves root development, transportation of water, nutrient uptake and decomposition.

Lateef et al. (2019) and Mohamed et al. (2021) observed that broccoli growth, yield, and quality parameters, as well as the maximum utilization efficiency of other fertilizer sources, improved while using biofertilizer in combination with other fertilizers, which is consistent with the findings of the results of this study.

Effect of interaction of vermicompost and biofertilizer

Combined effect of different vermicompost

and biofertilizer doses indicated a significant interaction on various attributes (Tables 4 and 5) of broccoli. Treatment (T_3F_3) comprising vermicompost (9 $t.ha^{-1}$) and biofertilizer (7 $kg.ha^{-1}$) had the highest plant height (67.85 cm), while the shortest plant height (57.52 cm) was from T_0F_0. Because of the beneficial soil conditions provided by the vermicompost and biofertilizer, this may be ascribed to increased water holding capacity, supply of micronutrients and availability of major nutrients (Chaudhary et al., 2012). Magd et al. (2006) and Sharma et al. (2008) also found that organic manure and biofertilizer promote the growth-attributing characteristics of broccoli, which results in better plant height.

Table 4. Interaction effect of vermicompost and biofertilizer on growth and yield of broccoli

Treatment*	Plant height (cm)	No of leaves per plant	Leaf length (cm)	Leaf breadth (cm)	100% curd initiation (Days)	Stem diameter (cm)
T_0F_0	57.52l	17.19i	53.39f	19.96h	61.33a	4.09i
T_0F_1	58.44kl	17.60hi	54.38ef	20.09gh	60.67a	4.22h
T_0F_2	59.30jk	18.08h	54.46e	20.64fg	59.33b	4.43fg
T_0F_3	60.17hij	18.28h	54.69e	20.60fgh	59.00bc	4.23h
T_1F_0	59.86ij	18.21h	56.94cd	20.95ef	59.00 bc	4.16hi
T_1F_1	60.81ghi	19.34g	57.47c	21.14ef	58.67bc	4.38g
T_1F_2	60.74ghi	20.36def	56.34d	21.45de	58.33c	4.51e
T_1F_3	61.67efg	20.15efg	57.21cd	21.99cd	58.33c	4.79d
T_2F_0	61.18fgh	19.73fg	54.88e	21.13ef	58.33c	4.54e
T_2F_1	61.90ef	21.04cd	56.34d	21.87cd	57.00d	4.49ef
T_2F_2	63.72d	20.69de	59.43b	22.18bc	56.67d	4.93ab
T_2F_3	64.64cd	22.25ab	60.04ab	22.72ab	55.00e	4.98a
T_3F_0	62.38e	20.39def	57.09cd	21.52de	56.67d	4.43fg
T_3F_1	65.08c	20.48def	59.14b	22.22bc	55.67e	4.52e
T_3F_2	66.45b	21.65bc	57.63c	22.29bc	55.33e	4.82cd
T_3F_3	67.85a	22.76a	60.57a	23.23a	54.00f	4.89bc
CV (%)	8.25	6.45	5.02	4.25	5.58	4.82

*Treatment details are given in Table 2

Table 5. Interaction effect of vermicompost and biofertilizer on growth, yield and quality attributes of broccoli

Treatment*	Curd diameter (cm)	Leaf dry weight per 100g	Curd dry weight per 100g	Yield per plot (kg)	Yield ($t.ha^{-1}$)	Leaf chlorophyll content (SPAD value)
T_0F_0	9.77i	15.17	11.66	1.73i	10.82i	29.54l
T_0F_1	10.20hi	15.25	11.84	1.80hi	11.28hi	31.30k
T_0F_2	10.49gh	15.37	12.17	1.85h	11.57h	32.76j
T_0F_3	10.64fgh	15.57	12.52	1.88gh	11.80gh	33.54j
T_1F_0	10.58fgh	15.67	11.86	2.06ef	12.90ef	36.22i
T_1F_1	11.16ef	15.73	12.48	2.16de	13.48de	38.93h
T_1F_2	11.45de	15.99	12.26	2.16de	13.51de	40.65g
T_1F_3	11.40de	16.45	12.75	2.35c	14.70c	42.10f
T_2F_0	11.13efg	15.33	12.35	2.16de	13.51de	46.95e
T_2F_1	11.19ef	16.53	12.94	1.97fg	12.29fg	48.32d
T_2F_2	11.94cd	16.65	13.16	2.24d	13.99d	50.92c
T_2F_3	12.66ab	18.12	13.80	2.51ab	15.71ab	52.64b
T_3F_0	10.94efg	15.69	12.09	1.89gh	11.87gh	48.33d
T_3F_1	12.25bc	16.16	13.27	2.19d	13.67d	52.58b
T_3F_2	11.98cd	17.29	13.80	2.42bc	15.12bc	54.48a
T_3F_3	13.19a	17.02	13.88	2.53a	15.84a	54.90a
CV (%)	7.21	6.84	5.24	5.24	5.24	1.65

*Treatment details are given in Table 2

Number of leaves per plant was statistically significant at 5% level and the highest value (22.76) was obtained from T_3F_3 which was statistically similar to T_2F_3 (22.25). Lowest number of leaves per plant (17.19) was observed from T_0F_0. The highest leaf length (60.57 cm), leaf breadth (23.23 cm) and lowest days to 100% curd initiation (54.00) was obtained from T_3F_3 which all are also statistically similar to that of T_2F_3. In addition to fixing nitrogen, biofertilizer contains plant growth-promoting bacteria, and vermicompost contains amylase, lipase, cellulase, chitinase enzymes, and plant growth hormones like gibberellic acid, cytokinins, and auxins that are directly known as plant growth promoters. As a result, the plant has displayed opulent growth that shortens the curd initiation period. This result is consistent with what Lal et al. (2015) and Lalnunmawii and Simon (2022) found: better growth and early initiation of curd due to the application of organic manures and biofertilizers in broccoli.

The maximum stem diameter (4.89 cm) was obtained from T_2F_3 but a statistically similar result was obtained in case of curd diameter from T_3F_3 (13.19 cm) and T_2F_3 (12.66 cm) treatment combination. Statistically, there was no discernible difference in the broccoli curd and leaf dry weights of 100g each. The highest yield per plot (2.53 kg) and yield (15.84 $t.ha^{-1}$) (Table 5) was obtained from T_3F_3 treatment combination which was statistically similar to T_2F_3 (2.51 kg per plot and 15.71 $t.ha^{-1}$). The lowest yield (10.82 $t.ha^{-1}$) was observed from T_0F_0. Higher microbial loads and growth hormones due to the effects of vermicompost and biofertilizer may have enhanced soil biomass, maintaining the availability and uptake of applied and native soil nutrients, leading in better crop growth and yield. This result is in accordance with findings of Riba et al. (2018) and Singh et al. (2020). The highest chlorophyll content of leaf (54.90, SPAD 502 value) was recorded from T_3F_3. It is possible that the greatest vermicompost and biofertilizer levels encouraged the formation of chlorophyll which would account for the rise in chlorophyll content. Results showed that there were no significant differences detected in terms of vitamin C content (Figure 1) in broccoli head. The highest level of both sources of nutrients (T_3F_3) contained the highest amount of ascorbic

acid followed by T_3F_2 and the lowest ascorbic acid content was in the T_0F_0 treatment. The higher level of vermicompost and biofertilizer may have mobilized the biosynthesis of ascorbic acid due to the increased availability of nutrients in the soil, which may have resulted in the synthesis and accumulation of more photosynthates. Bahadur et al. (2003) and Wang et al. (2010) observed earlier improvements in ascorbic acid concentration with increased amounts of organic manures.

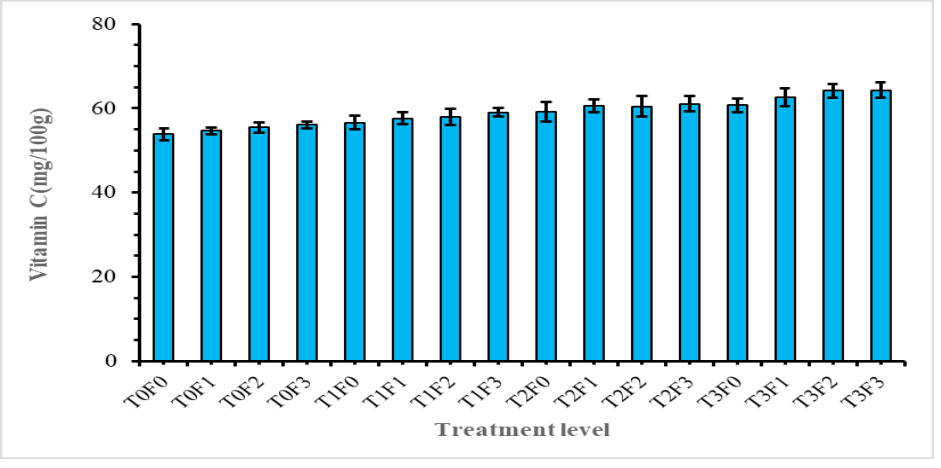

Figure 1. Effect of interaction between vermicompost and biofertilizer on vitamin C (ascorbic acid) content of broccoli head

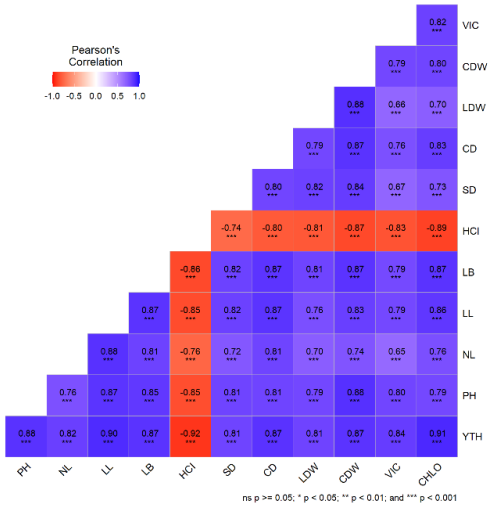

Figure 2. Correlation coefficients for growth, yield and quality contributing characters of broccoli (*Brassica oleracea* L. var. *italica*)

(**Note:** YTH=Yield t.ha^{-1}, PH=Plant height, NL=No of leaves, LL=Leaf length, LB=Leaf breadth, HCI=Hundred percent curd initiation (Days), SD=Stem diameter, CD=Curd diameter, LDW=Leaf dry weight, CDW=Curd dry weight, VIC=Vitamin C content, CHLO=Leaf chlorophyll content.)

Correlation analysis among parameters

A correlation analysis was conducted for twelve different parameters derived from the study component of this research. The results (Figure 2) showed a substantial positive correlation between yield (t.ha^{-1}) and plant height, leaf length, curd diameter, curd dry weight and chlorophyll content as well as a positive correlation between number of leaves, leaf breadth, stem diameter, leaf dry weight and vitamin C content. But it is significantly negatively correlated with hundred percent curd initiation (days). Hundred percent curd initiation (days) showed significantly negative correlation with curd dry weight and leaf chlorophyll content. Vitamin C content positively correlated with all the attributes. The same trend is followed by number of leaves and stem diameter.

K-means Clustering of the treatment combination

K-means is a well-liked partitioning and

clustering technique. K-means clustering aims to form segregated groups with similar traits and assign them to clusters. The purpose of K-means clustering in this context was to find out the similar treatment combinations that had similar data points on the growth, yield, and quality characteristics of broccoli, although the treatments had dose variation among them. This was actually done for the precision of the study. As the price of vermicompost is comparatively higher than that of other organic manure, considering the cost, there was a demand to find out the treatment combination that contained lower dose but had the same potential as the highest dose combination for both of the factors used. Parameters such as plant height, number of leaves per plant, leaf length, leaf breadth, hundred percent curd initiation (days), stem diameter, curd diameter, yield t.ha^{-1}, leaf chlorophyll content, and vitamin C content were used for clustering.

The data set was divided into k clusters with the greatest potential difference between them (Burns and Burns, 2008). By applying k-means clustering, five group of clusters (Figure 3) were identified according to their closeness or similarities. Cluster-I was composed of the treatments T_2F_2, T_2F_3 and T_3F_1. T_3F_2 and T_3F_3 belonged to the same cluster (Cluster-II). Treatments T_0F_0, T_0F_1, T_0F_2 and T_0F_3 plotted on the same cluster. Clusters-IV and V represent three and four treatment combinations which showed similar growth, yield and quality characteristics during the study.

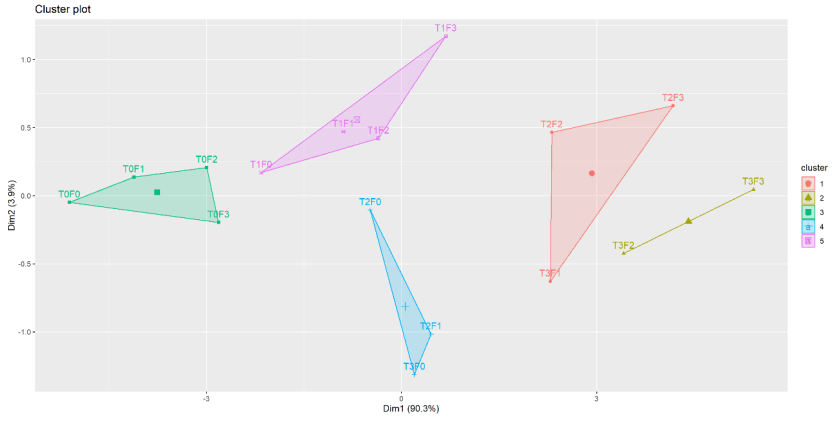

Figure 3. K-means clustering of the treatments

(**Note:** Using Euclidean distance and Ward.D2 method using parameters: Plant height, No of leaves, Leaf length, Leaf breadth, Hundred percent curd initiation (Days), Stem diameter, Curd diameter, Yield (t.ha^{-1}), Leaf chlorophyll content and Vitamin C content)

Conclusion

An excellent option to sustainable agriculture practices that does not sacrifice plant growth, yield, quality or soil health is the use of organic and biofertilizer in place of chemical fertilizers. The overall results revealed that among various combinations of vermicompost and biofertilizer, the treatment combination T_3F_3 (vermicompost at 9 t.ha^{-1} and biofertilizer at 7 kg.ha^{-1}) responded well as substitute to sole fertilizer considering vegetative growth of plant, higher yield and vitamin C from broccoli under complete organic production of broccoli. But considering most of the growth, quality and yield parameters, it was statistically similar to T_2F_3 (vermicompost at 6 t.ha^{-1} and biofertilizer at 7 kg.ha^{-1}). So, application of the treatment T_2F_3 was found as the best treatment combination regarding cost of production as well as higher yield.

Conflicts of Interest: There is no conflict of interest stated by the authors.

Acknowledgements

The authors are obliged to the Department of Horticulture of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh. The Ministry of Science and Technology, Government of the People's Republic of Bangladesh has been applauded by the authors for providing financial support.

References

Asad SA, Bano A, Farooq M, Aslam M and Afzal A, 2004. Comparative study of the effects of biofertilizers on nodulation and yield characteristics of mungbean (*Phaseolus vulgaris* L.). International Journal of Agriculture and Biology, 6, 837-843.

Bahadur A, Singh J, Upadhyay AK and Singh KP, 2003. Effect of organic manures and biofertilizers on growth, yield and quality attributes of broccoli. Vegetable Science, 30, 192-194.

Burns R and Burns R, 2008. Cluster analysis. In: Business Research Methods and Statistics Using SPSS. SAGE, London, pp. 552-567.

Chaudhary S, Chaudhary AK and Jat NK, 2012. Effect of organic and inorganic sources of nutrients on growth, yield and quality of sprouting broccoli cv. CBH-1. Indian Journal of Horticulture, 69, 550-554.

Lal S, Singh SP, Yadav TV and Meena AK, 2015. Effect of biofertilizers and zinc on growth, yield and quality of sprouting broccoli (*Brassica oleraceae* L. var. *italica*). Progressive Horticulture, 47, 90-96. https://doi.org/10.5958/2249-5258.2015.00016.0

Lalnunmawii B and Simon S, 2022. Effect of bio-resources against alternaria leaf spot (*Alternaria brassicae*) of broccoli (*Brassica oleracea* L. var. *italica*). The Pharma Innovation Journal, 11, 131-135.

Lateef SM, Alamery AA, Alhassaany MH, Almosawy AN and Almosawy MM, 2019. Role of bio fertilizers and phosphate levels on growth and yield properties of broccoli (*Brassica oleracea* L. var. *italica*). Plant Archives, 19, 1564-1568.

Magd MA, Bassiony AM and Fawzy ZF, 2006. Effect of organic manure with or without chemical fertilizers on growth, yield and quality of some varieties of broccoli plants. Journal of Applied Sciences Research, 2, 791- 798.

Mohamed MH, Ali M, Eid RS, El-Desouky HS, Petropoulos SA, Sami R and Zewail RM, 2021. Phosphorus and biofertilizer application effects on growth parameters, yield and chemical constituents of broccoli. Agronomy, 11, 2210. https://doi.org/10.3390/agronomy11112210

Rabbee HE, Methela NJ, Hossain B and Suhel MRI, 2020. Growth and yield response of Broccoli to vermicompost and farmyard manure. Journal of Bioscience and Agriculture Research, 25, 2107-2113. https://doi.org/10.18801/jbar.250120.251

Riba D, Hasan A, Swaroop N, Thomas T, David AA and Rao S, 2018. Effects of organic and inorganic source of nutrients on physio-chemical properties of soil and yield of cabbage (*Brassica oleracea* L.). International Journal of Chemical Studies, 6, 2196-2200.

Selvakumar G, Lenin M, Thamizhiniyan P and Ravimycin T, 2009. Response of biofertilizers on the growth and yield of blackgram (*Vigna mungo* L.). Recent Research in Science and Technology, 1, 169-175.

Sharma A, Parmar DK, Kumar P, Singh Y and Sharma RP, 2008. Azotobacter soil amendment integrated with cow manure reduces need for NPK fertilizers in sprouting broccoli. International Journal of Vegetable Science, 14, 273-285. https://doi.org/10.1080/19315260802165209

Singh S, Chamroy T, Malik S and Kundu S, 2020. Integrated nutrient management (INM) studies on growth and yield of Broccoli (*Brassica oleracea* var. *italica*). Plant archives, 20, 9651-9654.

Talashilkar SC, Bhangarath PP and Mehta VB, 1999. Changes in chemical properties during composting of organic residues as influenced by earthworm activity. Journal of the Indian Society of Soil Science, 47, 50-53.

Uggla M, 2004. Domestication of Wild Roses for fruit production. Thesis for DSc, Swedish University of Agricultural Sciences, Alnarp, Sweden. https://res.slu.se/id/publ/12364

Wang D, Shi Q, Wang X, Wei M, Hu J, Liu J and Yang F, 2010. Influence of cow manure vermicompost on the growth, metabolite contents and antioxidant activities of Chinese cabbage (*Brassica campestris* ssp. *chinensis*). Biology and Fertility of Soils, 46, 689-696. https://doi.org/10.1007/s00374-010-0473-9

Zhang YHD, 2004. Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. Food chemistry, 88, 503-509. https://doi.org/10.1016/j.foodchem.2004.01.065