International Journal of Horticultural Science and Technology (2023) Vol. 10, , No. 1, pp. 87-96

International Journal of Horticultural Science and Technology
Journal homepage: http://ijhst.ut.ac.ir

The Effects of Organic Nutrient Sources on Yield and Shelf life of Broccoli

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ARTICLE INFO

Article history:

Received: 19 Feb 2022,
Received in revised form: 1 May 2022,
Accepted: 5 May 2022

Article type:

Research paper

Keywords:

Broccoli,
Shelf life,
Tricho-compost,
Vermicompost,
Yield

ABSTRACT

The study was conducted in Polashi, Manirampur Upazila, Jashore, Bangladesh, during Rabi seasons of 2020-2021 and 2021-2022 to evaluate the effects of organic nutrient sources on yield and shelf life of broccoli. The experimental layout was a Randomized Complete Block Design (RCBD) with three replications and six treatments which were: T_1= Vermicompost 3 t ha^{-1}, T_2 = Vermicompost 4 t ha^{-1}, T_3 = Trichocompost 3 t ha^{-1}, T_4 = Trichocompost 4 t ha^{-1}, T_5 = FYM 12 t ha^{-1}, T_6 = (control). A Completely Randomized Design (CRD) was designed to determine the shelf life of broccoli with three replications, considering three factors, (i) the effects of organic sources of nutrient, (ii) storage materials at room temperature and (iii) storage materials at cold storage condition. The findings revealed that the effects of organic nutrient sources significantly influenced the yield and shelf life of broccoli. The treatment T_2 (vermicompost 4 t ha^{-1}) produced significant ($p \leq 0.05$) amounts of marketable curd yield of broccoli (22.33 t ha-1 and 21.27 t ha^{-1}), followed by T4 (Trichocompost 4 t ha^{-1}) with marketable curd yield (19.76 t ha-1, 18.78 t ha^{-1}). In contrast, the minimum marketable curd yield (7.76 t ha^{-1} and 7.29 t ha^{-1}) occurred in T6 (control) in the respective years. The treatment of T2 led to the highest shelf life (7.33 and 7.55 days) at room temperature (14-220C with RH 60-65%). At cold storage (40C with RH 90-95%), using High-Density Polyethylene (HDP;15 micron) vacuum pack, the shelf life was also significant (24.75 & 25.19 days) during the years of 2020-2021 and 2021-2022, respectively.

Introduction

Broccoli is one of the most important, nutrient-rich vegetables among cole crops which belong to the family Brassicaceae. Broccoli has a reputation as a supplementary vegetable in salads and in supper food. It is known to be a healthy and delectable vegetable which is rich in many nutrients. Broccoli is rich in vitamins, minerals, fibers and antioxidants that support many dimensions of human health (Cartea et al., 2008; Faller and Fialho, 2009; Yvette, 2012). It is characterized by a low Glycemic Index (GI=10) for diabetics (Nagraj et al., 2020). The global production of broccoli was 27 million tons in 2019, of which 73% was produced by China and India. The rest was produced by USA, Mexico, Spain, Italy, Turkey, Bangladesh, Poland and France (FAOSTAT, 2020). Farmers in Bangladesh are very much interested to produce broccoli for

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its high value. The application of a balanced portion of fertilizers is essential to produce high-quality vegetables, including broccoli, and for getting maximum returns (Ahirwar and Nath, 2020). Most of the farmers in Bangladesh are not aware of the use of balanced fertilizers and they produce different vegetables without maintaining proper doses of fertilizers to test the soil. Generally, to get higher yields, the farmers indiscriminately use chemical fertilizers without addition of sufficient quantities of organic manures. The irresponsible use of fertilizers can lead to the deterioration of soil health and, at the same time, reduce the quality and shelf life of the products (Mal et al., 2014). Only chemical fertilizers may accelerate the crops yield initially, but they eventually have adverse effects (Gupta et al., 2019). On the other hand, organic manure has the capability to meet up demands for plant nutrients in maintaining quality attributes, as well as improved properties of soil health (Alam et al., 2019). Organic manures, Vermicompost, Tricho-compost, and FarmYard Manure (FYM) are able to maximize the crop's yield and protect from devastating pests and environmental pollution. This has resulted in research interest on the use of organic manures and the avoidance of synthetic chemicals. Thus, it is essential to adopt an appropriate organic nutrient management practice in broccoli for boosting safe production as well as quality and shelf life.

Preservation capability of broccoli is comparatively poor than other Cole crops like cauliflower. Yellowing is the main problem in post-harvest life of broccoli which leads to unmarketability due to consumer dislike (Chingtham Chanbisana and AK Banik, 2019). Farmers are not aware about the shelf life of broccoli. They apply huge amounts of chemical fertilizers and pesticides, often in overdoses, more frequencies and even mixing of two or more chemicals as cocktail formulation to achieve better yield during production (Shamsunnahar, 2016). Consequently, the storage longevity of broccoli decreases spontaneously. Under such circumstances, it is essential to improve post-harvest quality and to extend the shelf life of the said crop. The application of appropriate organic manures viz. Vermicompost, Tricho-compost and Farm Yard Manure (FYM) instead of chemical fertilizers is one of the best options to increase the shelf life of broccoli. Packaging materials help not only to keep these vegetables from drying out but also to preserve nutritive value, flavour, texture and color (Raseetha et al., 2018). Polyethylene bags can delay color change due to synchronized effects of increased humidity and fluctuated atmosphere composition (Rao and Shivashankara, 2015). Vacuum packs with low temperatures (storage at 40C with 95% RH) make an effective technique to maintain the shelf life of broccoli (Jadhav et al., 2018). Thus, this study focused on low-cost technology, i.e. Low-Density Polyethylene (LDP; 35 micron) bags, High-Density Polyethylene (HDP; 15 micron) vacuum packs, 2% egg shell powder and 2% ascorbic acid solution to sustain the shelf life of broccoli at room temperature and cold storage conditions. Since there have been small amounts of research on the above context, the current research dealt with the effects of oganic nutrient sources on yield and shelf life of broccoli.

Materials and Methods

The field experiment was conducted in Polashi, Manirampur Upazila, Jashore, Bangladesh, at Rabi seasons during the years 2020-2021 and 2021-2022. A Randomized Complete Block Design (RCBD) included six treatments in three replications, i.e. T_1=Vermicompost 3 t ha^{-1}, T_2 = Vermicompost 4t ha^{-1}, T_3 = Tricho-compost 3 t ha^{-1}, T_4 =Tricho-compost 4 t ha^{-1}, T_5 = FYM 12 t ha^{-1}, T_6 = (control). The above mentioned treatments were assigned according to Chanu et al. 2018. The hybrid variety of broccoli "Green Crown" was used for conducting the field experiment as planting material. Hybrid seeds were produced by SAKATA SEED CORPORATION, JAPAN and collected from East Bengal Seed Co. 174, Siddique Bazar, Dhaka-1000, Bangladesh. Before sowing them on the nursery bed, the seeds were treated by Thiram @ 2.5g per kg of seeds. Healthy and appropriate-aged seedlings (21 days) were transplanted to the experimental plots (3m×2m) with spacing of 50cm×40cm as per layout on the 16th November 2020 during the first year and 3rd November 2021 during the second year. According to the treatments, half of the organic manure (Vermicompost: N 1.55%, P 0.85%, K 1.53%, S 0.10%, Zn 0.005%, Tricho-compost : N 1.52%, P 0.77%, K 1.52%, S 0.10%, Zn 0.006% and Farm Yard Manure (FYM) : N 0.55%, P 0.29%, K 0.54%, S 0.10%, Zn 0.003%; SRDI, Jashore, 2019) were applied in the respective plots during final land preparation, after considering the soil test report (SRDI, Jashore, Bangladesh). Remaining organic manures were applied before planting the seedlings. Improved intercultural operations were pursued well in all experimental plots. The crop was irrigated and pests were managed through biological methods meticulously. Broccoli curds were harvested before the buds opened on 21 - 26 January 2021 during the first year and 08 - 14 January 2022, during the second year, respectively. The observation associated with yield and its contributing characteristics involved curd length and diameter, marketable curd weight per plant, and marketable yield ton per hectare. Three plants were randomly sampled in each experimental plot.

Design and methodology for shelf life assessment of broccoli

To ascertain the shelf life for broccoli, the following experimental design and methodology was followed (Fig. 1).

Statistical design : Completely Randomized Design (CRD).
Number of replications : 03

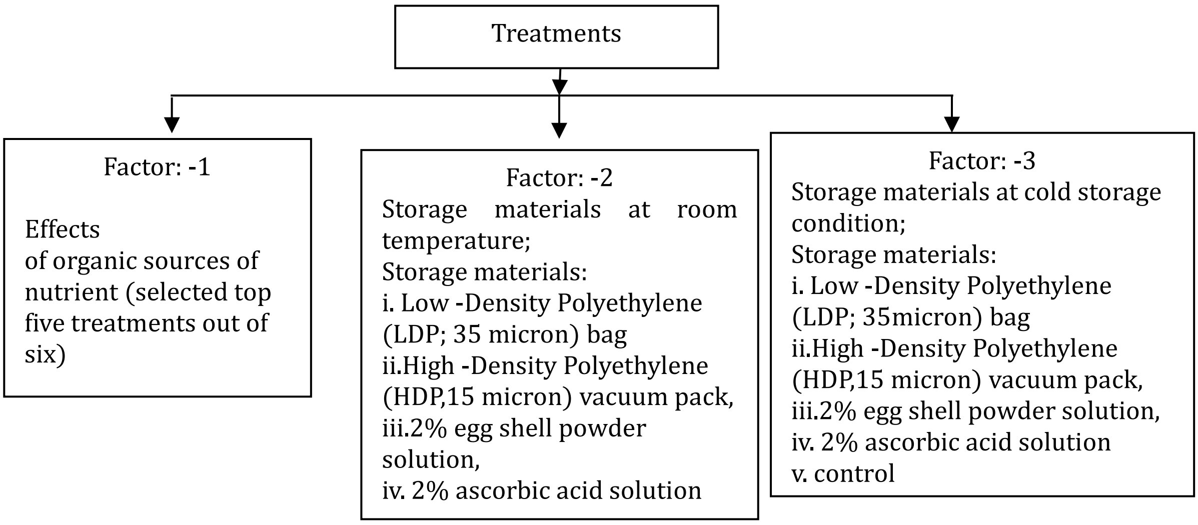

Fig. 1. Flow chart of the details of the experimental design for shelf life assessment of broccoli

In the case of shelf life assessment of broccoli, treatment-wise matured broccoli curd from each replication had been collected and placed in the selective storage materials (Low-Density Polyethylene (LDP; 35 micron) bag, High-Density Polyethylene (HDP;15 micron) vacuum pack, treated with 2% egg shell powder solution for five minutes, treated with 2% ascorbic acid solution for one minute and control). These were conducted either at room temperature or in cold storage. The change of curds color (just started to yellowing) was observed by eye estimation and was aimed to ascertain the shelf life of broccoli using each selective storage materials both at room temperature and cold storage.

The recorded data of various characteristics were analyzed with the help of Statistical Tool for Agricultural Research (STAR) Program and the mean values of all treatment groups were adjudged by Tukey's test at 5% level of probability for interpretation. Benefit Cost Ratio (BCR) for each treatment under evaluation had been calculated based on the present market prices of inputs and outputs in order to determine the maximum profitable treatment.

Results

Yield-related characteristics and yield

Curd length and diameter

The data in Table 1 revealed that significantly maximum curd length 16.36 cm and 16.75cm, curd diameter 19.53 cm and 19.27cm were observed in response to the T_2 treatment (Vermicompost 4t ha^{-1}) followed by T_4 (Tricho-compost 4 t ha^{-1}) with curd lengths of 15.85 cm and 15.63 cm, and curd diameters of 17.55 cm and 16.75 cm, T_5 (FYM 12 t ha^{-1}) with curd lengths of 15.65 cm and 15.27 cm, and curd diameters of 17.26 cm and 16.37 cm, T_1 (Vermicompost 3t ha^{-1}) with curd lengths of 13.55 cm and 13.29cm, and curd diameters of 16.25 cm and 15.43 cm, as well as T_3 (Tricho-compost 3 t ha^{-1}) with curd lengths of 12.45 cm and 12.17cm, and curd diameters of 14.75 cm and 13.81cm in 2020-21 and 2021-22, respectively. Minimum curd length (10.25cm and 9.45cm) and diameter (11.07 cm and 10.51cm) were recorded in the control (2020-21 and 2021-22, respectively).

Marketable curd weight per plant

The perusal of data in Table 1 revealed that marketable maximum curd weight per plant (446.66g and 425.35g) was recorded in the T2 treatment group (Vermicompost 4 t ha^{-1}) followed by T_4 (Tricho-compost 4 t ha^{-1}) with marketable curd weights per plant (395.23 g and 375.53 g), T_5 (FYM 12 t ha^{-1}) with marketable curd weights per plant (349.25g and 343.16 g), T1 (Vermicompost 3t ha^{-1}) with marketable curd weights per plant (325.05g and 311.77g) and T3 (Tricho-compost 3 t ha^{-1}) with marketable curd weights per plant (309.43g and 295.46g) in 2020-21 and 2021-22, respectively. Meanwhile, the control group (T_6) resulted in minimum curd weights (155.16 g and 145.73 g) in the two respective years.

Marketable curd yield

From Table 1, it is evident that maximum marketable curd yield (22.33 t ha^{-1} and 21.27 t ha^{-1}) were recorded in the treatment T_2 (Vermicompost 4 t ha^{-1}) followed by T_4 (Tricho-compost 4 t ha^{-1}) with marketable curd yields of 19.76 t ha^{-1} and 18.78 t ha-1, T_5 (FYM 12 t ha^{-1}) with 17.46 t ha^{-1} and 17.16 t ha^{-1}, T_1 (Vermicompost 3t ha^{-1}) with 16.25 t ha^{-1} and 15.59 t ha^{-1} , and T_3 (Tricho-compost 3 t ha^{-1}) with 15.47 t ha^{-1} and 14.77 t ha^{-1} in 2020-21 and 2021-22, respectively. Minimum marketable curd yields (7.76 and 7.29 t ha^{-1}) were recorded in T_6 (control) in 2020-21 and 2021-22, respectively. It was observed that the marketable curd yield increased in the T_2 treatment group (Vermicompost 4 t ha^{-1}) by 187.76% and 191.77% compared to the control, by 37.42% and 36.43% compared to the T1 treatment, by 44.34% and 44.00% compared to the T3 treatment, by 13.01% and 13.26% compared to the T4 treatment, and by 27.89% and 23.95% compared to the T_5 treatment in 2019-20 and 2020-21, respectively.

Table 1. Effects of organic nutrient sources on yield attributes and yield of broccoli

Treatment	Curd length (cm)		Curd diameter (cm)		Marketable curd weight per plant (g)		Marketable curd yield (t ha^{-1})	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
T_1	13.55ab	13.29bc	16.25ab	15.43ab	325.05b	311.77ab	16.25b	15.59ab
T_2	16.36a	16.75a	19.53a	19.27a	446.66a	425.35a	22.33a	21.27a
T_3	12.45bc	12.17cd	14.75bc	13.81bc	309.43b	295.46b	15.47b	14.77b
T_4	15.85a	15.63ab	17.55ab	16.75ab	395.23ab	375.53ab	19.76ab	18.78ab
T_5	15.65a	15.27abc	17.26ab	16.37ab	349.25ab	343.16ab	17.46ab	17.16ab
T_6	10.25c	9.45d	11.07c	10.51c	155.16c	145.73c	7.76c	7.29c
SEm ±	0.9020	0.9020	1.22	1.22	34.67	34.67	1.73	1.73
LSD(P=0.05)	0.03	0.01	0.07	0.06	0.02	0.02	0.02	0.02

Means with the same letter are not significantly different. Here, T_1 = Vermicompost 3 t ha^{-1}, T_2 = Vermicompost 4t ha^{-1}), T_3 =Trichocompost 3 t ha^{-1}, T_4 = Trichocompost 4 t ha^{-1}, T_5 = FYM 12 t ha^{-1}), T_6 = (control)

Shelf life

Shelf life of broccoli using low-density polyethylene (LDP; 35-micron bag)

The perusal of data in Table 2, 3, 4 and 5 revealed that using Low-Density Polyethylene (LDP;35 micron) bag at room temperature (14-22 0C with RH 60-65%) caused the shelf life of broccoli to range from 4.75 to 6.25 days. Maximum shelf life (6.13 and 6.25 days) were observed in the T2 treatment (Vermicompost 4 t ha^{-1}) followed by the T_4 treatment (Tricho-compost 4 t ha^{-1}) with 5.59 and 5.54 days, T_5 (FYM 12 t ha^{-1}) with 5.53 and 5.49 days, and T_1 (Vermicompost 3 t ha^{-1}) with 5.25 and 5.33 days in 2020-2021 and 2021-2022, respectively. Minimum shelf life (4.75 and 4.83 days) were noted in treatment T3 (Tricho-compost 3 t ha^{-1}) in 2020-2021 and 2021-2022, respectively. On the other hand, with Low-Density Polyethylene (LDP; 35-micron) at cold storage (40 C with 90-95% RH), the shelf life ranged from 15.33 to 20.75 days. Maximum shelf life (20.33 and 20.75 days) were observed in treatment T_2 (Vermicompost 4 t ha^{-1}) followed by treatment T_4 (Tricho-compost 4 t ha^{-1}) with 18.75 and 18.87 days, T_5 (FYM 12 t ha^{-1}) with 18.53 and 18.49 days, and treatment T_1 (Vermicompost 3 t ha^{-1}) with 16.45 and 16.33 days in 2020-2021 and 2021-2022, respectively. Minimum shelf life (15.75 and 15.33 days) were noted in treatment T_3 (Tricho-compost 3 t ha^{-1}) in 2020-2021 and

2021-2022, respectively.

Shelf life of broccoli using High-Density Polyethylene (HDP; 15-micron) vacuum pack

The perusal of data in Table 2, 3, 4 and 5 revealed that using High-Density Polyethylene (HDP; 15-micron) vacuum pack at room temperature (14-22 0C with RH 60-65%) caused the shelf life of broccoli to range from 5.33 to 7.55 days. Maximum shelf life (7.33 and 7.55 days) were observed in treatment T_2 (Vermicompost 4 t ha^{-1}) followed by treatment T_4 (Tricho-compost 4 t ha^{-1}) with 6.36 and 6.54 days, T_5 (FYM 12 t ha^{-1}) with 6.25 and 6.15 days, and treatment T1 (Vermicompost 3 t ha^{-1}) with 5.75 and 5.81 days in 2020-2021 and 2021-2022, respectively. Minimum shelf life (5.33 and 5.49 days) were noted in treatment T_3 (Tricho-compost 3 t ha^{-1}) in 2020-2021 and 2021-2022, respectively. On the other hand, High-Density Polyethylene (HDP; 15-micron) vacuum pack at cold storage (4 0C with 90-95% RH) made the shelf life of broccoli range from 16.33 to 25.19 days. Maximum shelf life (24.75 and 25.19 days) were observed in treatment T_2 (Vermicompost 4 t ha^{-1}) followed by treatment T_4 (Tricho-compost 4 t ha^{-1}) with 22.65 and 22.75 days, T_5 (FYM 12 t ha^{-1}) with 20.33 and 20.56 days, and treatment T_1 (Vermicompost 3 t ha^{-1}) with 18.27 and 18.55 days in 2020-2021 and 2021-2022, respectively. Minimum shelf life (17.15 and 16.33 days) were noted in treatment T_3 (Tricho-compost 3 t ha^{-1}) in 2020-2021 and 2021-2022, respectively.

Shelf life of broccoli when treated with 2% Egg shell power solution

The perusal of data in Table 2, 3, 4 and 5 revealed that using 2% egg shell powder solution at room temperature (14-22 0C with RH 60-65%) caused the shelf life of broccoli to range from 3.25 to 4.75 days. Maximum shelf life (4.75 and 4.67 days) were observed in treatment T_2 (Vermicompost 4 t ha^{-1}) followed by treatment T_4 (Tricho-compost 4 t ha^{-1}) with 3.93 and 4.05 days, T_5 (FYM 12 t ha^{-1}) with 3.63 and 3.75 days, and treatment T1 (Vermicompost 3 t ha^{-1}) with 3.45 and 3.56 days in 2020-2021 and 2021-2022, respectively. Minimum shelf life (3.25 and 3.33 days) were noted in treatment T_3 (Tricho-compost 3 t ha^{-1}) in 2020-2021 and 2021-2022, respectively. However, using 2% egg shell powder solution at cold storage (4 0C with 90-95% RH) caused the shelf life of broccoli to range from 12.75 to 18.25 days. Maximum shelf life (17.33 and 18.25 days) were observed in treatment T_2 (Vermicompost 4 t ha^{-1}) followed by treatment T_4 (Tricho-compost 4 t ha^{-1}) with 15.75 and 16.36 days, T5 (FYM 12 t ha^{-1}) with 15.57 and 15.49 days, and treatment T_1 (Vermicompost 3 t ha^{-1}) with 14.45 and 15.33 days in 2020-2021 and 2021-2022, respectively. Minimum shelf life (13.56 and 12.75 days) were noted in treatment T_3 (Tricho-compost 3 t ha^{-1}) in 2020-2021 and 2021-2022, respectively.

Shelf life of broccoli when treated with 2% ascorbic acid solution

Data in Table 2, 3, 4 and 5 revealed that using 2% ascorbic acid solution at room temperature (14-22 0C with RH 60-65%) caused the shelf life of broccoli to range between 3.05 and 4.24 days. Maximum shelf life (4.15 and 4.24 days) were observed in treatment T_2 (Vermicompost 4 t ha^{-1}) followed by treatment T_4 (Tricho-compost 4 t ha-1) with 3.74 and 3.49 days, T_5 (FYM 12 t ha^{-1}) with 3.55 and 3.33 days, and treatment T_1 (Vermicompost 3 t ha^{-1}) with 3.40 and 3.19 days in 2020-2021 and 2021-2022, respectively. Minimum shelf life (3.15 and 3.05 days) were noted in treatment T_3 (Tricho-compost 3 t ha^{-1}) in 2020-2021 and 2021-2022, respectively. Meanwhile, treatment with 2% ascorbic acid solution at cold storage (4 0C with 90-95% RH) caused the shelf life of broccoli to range between 12.26 and 16.73 days. Maximum shelf life (15.33 and 16.73 days) were observed in treatment T_2 (Vermicompost 4 t ha^{-1}) followed by treatment T_4 (Tricho-compost 4 t ha^{-1}) with 14.25 and 15.47 days, T_5 (FYM 12 t ha^{-1}) with 14.07 and 14.15 days, and treatment T_1 (Vermicompost 3 t ha^{-1}) with 13.65 and 14.05 days in 2020-2021 and 2021-2022, respectively. Minimum shelf life (12.26 and 12.33 days) were noted in treatment T_3 (Tricho-compost 3 t ha^{-1}) in 2020-2021 and 2021-2022, respectively.

Shelf life of broccoli in the control treatment

According to the data in Table 2, 3, 4 and 5, the shelf life of broccoli ranged between 2.13 and 3.36 days in the control treatment at room temperature (14-22 0C with RH 60-65%). Maximum shelf life (3.33 and 3.36 days) were observed in treatment T_2 (Vermicompost 4 t ha^{-1}) followed by treatment T_4 (Tricho-compost 4 t ha-1) with 3.07 and 2.85 days, T_5 (FYM 12 t ha^{-1}) with 2.75 and 2.57 days, and treatment T_1 (Vermicompost 3 t ha^{-1}) with 2.45 and 2.53 days in 2020-2021 and 2021-2022, respectively. Minimum shelf life (2.13 and 2.19 days) were noted in treatment T_3 (Tricho-compost 3 t ha^{-1}) in 2020-2021 and 2021-2022, respectively. Meanwhile, the shelf life of broccoli in the control treatment ranged between 11.49 and 15.25 days in response to cold storage (4 0C with 90-95% RH). Maximum shelf life (14.33 and 15.25 days) were observed in treatment T_2 (Vermicompost 4 t ha^{-1}) followed by treatment T_4 (Tricho-compost 4 t ha^{-1}) with 13.36 and 13.57 days, T_5 (FYM 12 t ha^{-1}) with 13.25 and 13.47 days, and treatment T_1 (Vermicompost 3 t ha^{-1}) with 12.25 and 12.73 days in 2020-2021 and 2021-2022, respectively. Minimum shelf life (11.49 and 12.03 days) were noted in treatment T_3 (Tricho-compost 3 t ha^{-1}) in 2020-2021 and 2021-2022, respectively.

Table 2. Shelf life (days) and a comparison of storage materials at each level of treatment, under different storage conditions (2020-2021)

Treatment	Shelf life(days) at room temperature (14-22°C) with RH 60-65%)					Shelf life(days) at Cold Storage (4°C with RH 90-95%)				
	Storage Materials					Storage Materials				
	LDP (35 micron) bag	HDP(15micron) Vacuum pack	2% Egg shell power solution	2% Ascorbic acid solution	Control	DP (35 micron) bag	HDP(15micron) Vacuum pack	2% Egg shell power solution	2% Ascorbic acid solution	Control
T_1	5.25d	5.75d	3.45e	3.40e	2.45e	16.45b	18.27a	14.45c	14.18c	13.65c
T_2	6.13ef	7.33e	4.75fg	4.15g	3.33g	20.33b	24.75a	17.33c	17.25c	15.33d
T_3	4.75d	5.33d	3.25e	3.15ef	2.13f	15.25b	17.15a	13.56c	13.37c	12.26c
T_4	5.59e	6.36e	3.93f	3.75f	3.07f	18.75b	22.65a	15.75c	15.33cd	14.12d
T_5	5.53e	6.25e	3.63f	3.55f	2.75f	18.53b	20.33a	15.57c	15.25cd	14.07d
LSD(P=0.05)	0.0000									

Means with the same letter are not significantly different. Here, T_1 = Vermicompost 3 t ha^{-1}, T_2 = Vermicompost 4t ha^{-1}), T_3 = Trichocompost 3 t ha^{-1}, T_4 = Trichocompost 4 t ha^{-1}, T_5 = FYM 12 t ha^{-1}), T_6 = (control)

Table 3. Shelf life (days) and a comparison of treatments at each level of storage materials, under different storage conditions (2020-2021)

Treatment	Shelf life(days) at room temperature (14-22°C) with RH 60-65%)					Shelf life(days) at Cold Storage (4°C with RH 90-95%)				
	Storage Materials					Storage Materials				
	LDP (35 micron) bag	HDP(15micron)V acuum pack	2% Egg shell power solution	2% Ascorbic acid solution	Control	LDP (35 micron) bag	HDP(15micron)V acuum pack	2% Egg shell power solution	2% Ascorbic acid solution	Control
T1	5.25ab	5.75bc	3.45b	3.40ab	2.45ab	16.45c	18.27d	14.45c	14.18c	13.65b
T2	6.13a	7.33a	4.75a	4.15a	3.33a	20.33a	24.75a	17.33a	17.25a	15.33a
T3	4.75b	5.33c	3.25b	3.15b	2.13b	15.25d	17.15e	13.56c	13.37c	12.26c
T4	5.59ab	6.36b	3.93ab	3.75ab	3.07ab	18.75b	22.65b	15.75b	15.33b	14.12b
T5	5.53ab	6.25b	3.63b	3.55ab	2.75ab	18.53b	20.33c	15.57b	15.25b	14.07b
LSD(P=0.05)	0.0000									

Means with the same letter are not significantly different. Here, T_1 = Vermicompost 3 t ha^{-1}, T_2 = Vermicompost 4t ha^{-1}), T_3 =Trichocompost 3 t ha^{-1}, T_4 = Trichocompost 4 t ha^{-1}, T_5 = FYM 12 t ha^{-1}), T_6 = (control)

Table 4. Shelf life (days) and a comparison of storage materials at each level of treatment, under different storage conditions (2021-2022)

Treatment	Shelf life (days) at room temperature (14-22°C) with RH 60-65%)					Shelf life (days) at Cold Storage (4°C with RH 90-95%)				
	Storage Materials					Storage Materials				
	LDP (35 micron) bag	HDP(15micron)Vacuum pack	2% Egg shell power solution	2% Ascorbic acid solution	Control	LDPE Polyethylene bag	HDP(15micron)Vacuum pack	2% Egg shell power solution	2% Ascorbic acid solution	Control
T_1	5.33e	5.81e	3.56f	3.49f	2.53f	16.33b	18.55a	15.33bc	14.25cd	13.25d
T_2	6.25e	7.55e	4.67f	4.24f	3.36f	20.75b	25.19a	18.25c	16.73d	16.33d
T_3	4.83c	5.49c	3.33d	3.05d	2.19d	15.33a	16.33a	12.75b	12.33b	12.17b
T_4	5.54e	6.54e	4.05f	3.33f	2.75f	18.87b	22.75a	16.36c	15.27cd	14.26d
T_5	5.49e	6.15e	3.75f	3.15f	2.57f	18.49b	20.56a	15.49c	15.07cd	14.03d
LSD(P=0.05)	0.0000									

Means with the same letter are not significantly different. Here, T_1 = Vermicompost 3 t ha^{-1}, T_2 = Vermicompost 4 t ha^{-1}), T_3 =Trichocompost 3 t ha^{-1} , T_4 = Trichocompost 4 t ha^{-1} ,T_5 = FYM 12 t ha^{-1}), T_6 = (control)

Table 5. Shelf life (days) and a comparison of treatments at each level of storage materials, under different storage conditions (2021-2022)

Treatment	Shelf life (days) at room temperature (14-22°C) with RH 60-65%)					Shelf life (days) at Cold Storage (4°C with RH 90-95%)				
	Storage Materials					Storage Materials				
	LDP (35 micron) bag	HDP(15micron)Vacuum pack	2% Egg shell power solution	2% Ascorbic acid solution	Control	LDPE Polyethylene bag	HDP(15micron)Vacuum pack	2% Egg shell power solution	2% Ascorbic acid solution	Control
T_1	5.33b	5.81bc	3.56b	3.49ab	2.53ab	16.33c	18.55d	15.33c	14.25c	13.25c
T_2	6.25a	7.55a	4.67a	4.24a	3.36a	20.75a	25.19a	18.25a	16.73a	16.33a
T_3	4.83b	5.49c	3.33b	3.05b	2.19b	15.33d	16.33e	12.75d	12.33d	12.17d
T_4	5.54ab	6.54b	4.05ab	3.33b	2.75ab	18.87b	22.75b	16.36b	15.27b	14.26b
T_5	5.49ab	6.15bc	3.75b	3.15b	2.57ab	18.49b	20.56c	15.49c	15.07bc	14.03bc
LSD(P=0.05)	0.0000									

Means with the same letter are not significantly different. Here, T_1 = Vermicompost 3 t ha^{-1}, T_2 = Vermicompost 4t ha^{-1}), T_3 = Trichocompost 3 t ha^{-1}, T_4 = Trichocompost 4 t ha^{-1}, T_5 = FYM 12 t ha^{-1}), T_6 = (control)

Economic consideration

Data in Table 6 and 7 indicated maximum gross returns (BDT 334950.00 ha^{-1} and BDT 319050.00 ha^{-1}), maximum net returns (BDT 207042.00 ha^{-1} and BDT 190642.00 ha^{-1}), along with benefit cost ratios (BCR) of 2.62 and 2.48 in the treatment T_2 (Vermicompost 4 t ha^{-1}) in 2020-21 and 2021-22, respectively. In contrast, minimum gross returns (BDT 116400.00 ha^{-1} and BDT 109350.00 ha^{-1}), minimum net returns (BDT 23604.00 ha^{-1} and BDT 16554.00 ha^{-1}) along with BCR (1.25 and 1.18) were noted in T_6 (control) in 2020-21 and 2021-22, respectively. The results of the present research were in line with previous findings by Panta et al. (2018) and Rabbee et al. (2020) in broccoli.

Table 6. Economic analysis of broccoli production as influenced by different organic sources of nutrients (2020-21)

Treatment	Marketable Yield (t ha^{-1})	Total cost of production (BDT ha^{-1})	Gross returns (BDT ha^{-1})	Net returns (BDT ha^{-1})	Benefit Cost ratio (BCR)
T_1	16.25	119130.00	243750.00	124620.00	2.05
T_2	22.33	127908.00	334950.00	207042.00	2.62
T_3	15.47	125714.00	232050.00	106336.00	1.85
T_4	19.76	136686.00	296400.00	159714.00	2.17
T_5	17.46	112547.00	261900.00	149353.00	2.33
T_6	7.76	92796.00	116400.00	23604.00	1.25

Sale rate of broccoli (BDT 15 /kg). Here, T_1 = Vermicompost 3 t ha^{-1}, T_2 = Vermicompost 4 t ha^{-1}), T_3 =Tricho-compost 3 t ha^{-1}, T_4 = Tricho-compost 4 t ha^{-1}), T_5 = FYM 12 t ha^{-1}), T_6 = (control)

Table 7. Economic analysis of broccoli production as influenced by different organic sources of nutrients (2021-22)

Treatment	Marketable Yield(t ha^{-1})	Total cost of production (BDT ha^{-1})	Gross returns (BDT ha^{-1})	Net returns (BDT ha^{-1})	Benefit Cost ratio (BCR)
T_1	15.59	119630.00	233850.00	114220.00	1.95
T_2	21.27	128408.00	319050.00	190642.00	2.48
T_3	14.77	126214.00	221550.00	95336.00	1.76
T_4	18.78	137186.00	281700.00	144514.00	2.05
T_5	17.16	113047.00	257400.00	144353.00	2.28
T_6	7.29	92796.00	109350.00	16554.00	1.18

Sale rate of broccoli (BDT 15/kg). Here, T_1 = Vermicompost 3 t ha^{-1}, T_2 = Vermicompost 4 t ha^{-1}), T_3 =Tricho-compost 3 t ha^{-1}, T_4 = Tricho-compost 4 t ha^{-1}), T_5 = FYM 12 t ha^{-1}), T_6 = (control)

Discussion

The results of the present study revealed that organic nutrient sources had significant effects on yield and shelf life of broccoli. The treatment T_2 (vermicompost 4 t ha^{-1}) produced significantly high amounts of yield and high values of yield-related attributes, i.e. curd length, diameter and marketable curd yield. It was evident from Table 1 that maximum curd length (16.36 cm and 16.75cm), curd diameter (19.53 cm and 19.27cm), maximum curd weight per plant (446.66g and 425.35g), and maximum marketable curd yield (22.33 and 21.27 t ha^{-1}) were recorded in treatment T_2 (Vermicompost 4 t ha^{-1}) followed by the effect of T_4 (Tricho-compost 4 t ha^{-1}) which caused significant values in curd length (15.85 cm and 15.63cm), curd diameter (17.55 cm and 16.75cm), curd weight per plant (395.23 g and 375.53 g), and marketable curd yield (19.76 and 18.78 t ha^{-1}). Meanwhile, T_5 (FYM 12 t ha^{-1}) caused notable values in curd length (15.65 cm and 15.27 cm), curd diameter (17.26 cm and 16.37 cm), curd weight per plant (349.25g and 343.16 g) and marketable curd yield (17.46 and 17.16 t ha^{-1}). The effect of T_1 (Vermicompost 3t ha^{-1}) was significant on curd length (13.55 cm and 13.29cm), curd diameter (16.25 cm and 15.43 cm), marketable curd weight per plant (325.05g and 311.77g), and marketable curd yield (16.25 t ha-1 and 15.59 t ha^{-1}). Also, the effect of T_3 (Tricho-compost 3 t ha^{-1}) was significant on curd length (12.45 cm and 12.17cm), curd diameter (14.75 cm and 13.81cm), marketable curd weight per plant (309.43g and 295.46g) and marketable curd yield (15.47 t ha^{-1} and 14.77 t ha^{-1}) in 2020-21 and 2021-22, respectively. In contrast, minimum values of curd length (10.25cm and 9.45cm), diameter (11.07 cm and 10.51cm), curd weight per plant (155.16 g and 145.73 g) and marketable curd yield (7.76 t ha^{-1} and 7.29 t ha^{-1}) were noted in T_6 (control) in 2020-21 and 2021-22, respectively. The increase in yield and yield-related attributes might have been due to a better performance on potential vegetative growth which contributed to an accumulation of more amounts of carbohydrates in the curds, especially as a result of more adequate supplies of different essential nutrients, as well as a successive increase in vermicompost levels. The findings of the present study are supported by those previously reported in cases of research by Panta et al. (2018) and Rabbee et al. (2020) on broccoli. It is worthwhile to note that plants of the control treatment remained stunted because of deficiencies in essential nutrients, micronutrients, etc., resulting from minimum curd weight and marketable yield.

The data in Table 2, 3, 4 and 5 revealed that the effects of organic sources of nutrient and storage condition were significant on the shelf life of broccoli, while each level of storage materials significantly influenced the shelf life as well. Among the groups, the treatment T_2 (Vermicompost 4t ha^{-1}) had the highest shelf life (7.33 and 7.55 days) at room temperature (14-22 0C with RH 60-65%). As a result of using High-Density Polyethylene (HDP; 15-micron) vacuum pack, the shelf life became 24.75 and 25.19 days in cold storage (4 0C with RH 90-95%) during 2020-2021 and 2021-2022, respectively. This might be due to the application of vermicompost, which influenced broccoli shelf life through increased levels of nutrient uptake by the plants, as well as enhanced values of water-conducting tissues which led to longer shelf life in broccoli. This finding was consistent with a previous report by Hidayati (2017) on broccoli. Maximum shelf life in both storage conditions using High-Density Polyethylene (HDP; 15-micron) vacuum pack might have resulted from the nature of sophisticated techniques which delayed the physiological deterioration of broccoli curds. When using High-Density Polyethylene (HDP; 15-micron) vacuum pack, there was more control over the gas exchange with the surrounding environment, while the unique levels of CO_2 and O_2 around the product might have further slowed down the conversion of starch into simple sugars. Curds that were stored in cold conditions maintained a greener color and, at the same time, had no symptoms of chilling injury, no incidence of decay and no rotten areas. In addition, storage at low temperature reduced the rate of respiration and delayed senescence during storage. The pre-harvest application of organic nutrients in broccoli production can be managed to be accompanied by optimal storage conditions, including appropriate use of scientific storage materials like High-Density Polyethylene (HDP; 15-micron) vacuum pack. Such a combination can protect against chlorophyll degradation and ethylene production. The enzymatic activities of vermicompost, also, protected the available moisture, minimized the rate of respiration and strengthened the cell wall in the vegetative parts of broccoli, thereby restricting the yellowing color and reducing weight loss. This might have caused a longer extension of shelf life and an increase in the quality of broccoli. In this respect, the current findings on shelf life are in agreement with previous findings by Jadhav et al. (2018) on broccoli.

Conclusion

This study revealed that the application of vermicompost (4t ha^{-1}) performed most optimally in terms of marketable curd yield, gross returns and net returns with maximum Benefit Cost Ratio (BCR). Simultaneously, broccoli was produced optimally by applying the said organic nutrient sources which extended the shelf life of broccoli. In addition, the High-Density Polyethylene (HDP; 15 micron) vacuum pack was considered as an effective method for maintaining the shelf life of broccoli at room temperature (14-22 0C with RH 60-65%) and at cold storage (4 0C with RH 90-95%) condition.

Funding

This study received no specific financial support.

Competing Interests

The authors declare that they have no competing interests.

Acknowledgement

The author acknowledges deep gratitude to the Department of Agricultural Extension (DAE) under the Ministry of Agriculture, Bangladesh, for giving permission to the present study.

References

Ahirwar, Nath. 2020. Organic broccoli farming: A step towards doubling farmer`s income. Research Today 2(4), 47-50.

Alam S. M, Ullah M. A, Haider S. I, Nawab N. N, Aamir S. S, Mahmood I. A. 2019. Effect of Farm Yard Manure and Planting Densities on Growth, Yield and Quality of Okra under Natural Farming. International Journal of Research in Agriculture and Forestry 6(4), 21-25.

Cartea M. E, Velasco P, Obregón S, Padilla G, De Haro A. 2008. Seasonal variation in glucosinolate content in Brassica oleracea crops grown in northwestern Spain. Phytochemistry 69(2), 403-410.

Chanu L.J, Hazarika S, Choudhury B.U, RameshT, Balusamy A, Moirangthem P,Yumnam A, Sinha P. K. 2018. A Guide to vermicomposting-production process and socio economic aspects. Extension Bulletin No. 81 ICAR Research Complex for NEH Region, Umiam-793 103, Meghalaya.

Chingtham C, Banik A. 2019. Studies on effectiveness of packaging on storability of broccoli cv. *Aishwarya* International Journal of Chemical Studies 7(2), 5112-5118.

Faller A. L. K, Fialho E. 2009. The antioxidant capacity and polyphenol content of organic and conventional retail vegetables after domestic cooking. Food Research International 42(1), 210-215. Available at: https://doi.org/10.1016/j.foodres.2008.10.009.

Food and Agriculture Organization of the United Nations.2020. Statistics Division, Corporate Statistical Database (FAOSTAT). Retrieved 10 February 2021.

Gupta R, Swami S, Rai A. P. 2019. Impact of integrated application of vermicompost, farmyard manure and chemical fertilizers on okra (*Abelmoschus esculentus* L.) performance and soil biochemical properties. International Journal of Chemical Studies 7(2), 1714-1718.

Hidayati N. 2017. Combined Effect of Vermicompost and Earthworm Pontoscolex Corethrurus Inoculation on the Yield and Quality Of Broccoli (*Brassica Oleracea* L.) Using Organic Growing Media. Journal of Basic and Applied Research International 22, 148-156.

Jadhav P. B. 2018. Extending the storage and Post-Storage life of dragon fruit using a cold room (Ecofrost). International Journal of Agriculture, Environment and Biotechnology 11(3), 573-577.

Mal D, Chatterjee R, Nimbalkar K. H. 2014. Effect of vermi-compost and inorganic fertilizers on growth, yield and quality of sprouting broccoli (Brassica oleracea L. var. italica Plenck). International Journal of Bio-resource and Stress Management 5(4), 507-512.

Nagraj G. S, Anita C, Swarna J, Amit K. J. 2020. Nutritional composition and antioxident properties of fruits and vegetables. Academic Press, School of Food Science and Environmental Health, College of Sciences and Health, Technological University, Dublin - City Campus, Dublin, Ireland. pp. 5-17.

Panta S, Subedi P, Ojha R. B, Shriwastav C. P, Bhattarai I. 2018. Effects of different fertilizer sources on growth and yield of broccoli in Chitwan, Nepal. Azarian Journal of Agriculture, 5(1): 1-6.

Rabbee H. E, Methela N. J, Hossain B, Suhel M. R. I. 2020. Growth and yield response of Broccoli to vermicompost and farmyard manure. Journal of Bioscience and Agriculture Research 25(02), 2107-2113.

Rao D.V.S, Shivashankara K.S. 2015. Individual shrink-wrapping extends the storage life and maintains the antioxidants of mangoes (cvs 'Alphonso' and 'Baganapalli') stored at 80C. Journal of Food Science and Technology 52(7), 4351-4359.

Raseetha S, Nadirah S.2018. Effect of different packaging materials on quality of fresh-cut broccoli and cauliflower at chilled temperature. International Food Research Journal 25(4), 1559-1565.

Shamsunnahar M. 2016. A Project Completion Report on Validation and upscaling of Tricho-products for soil borne disease management in vegetable Crops (TF 09 NR). p-7.

SRDI (Soil Research Development Institute). 2019. Soil Testing Laboratory, SRDI, Jashore, Bangladesh.

Yvette P. 2012. Antioxidant properties of green broccoli and purple-sprouting broccoli under different cooking conditions. Bioscience Horizons: The International Journal of Student Research 5(4),23-24.