International Journal of Sustainable Agricultural Research
2022 Vol. 9, No. 3, pp. 110-128.
ISSN(e): 2312-6477
ISSN(p): 2313-0393
DOI: 10.18488/ijsar.v9i3.3084

PRE-HARVEST FOLIAR APPLICATION EFFECTS OF MINERAL NUTRIENTS ON YIELD, QUALITY AND SHELF LIFE OF BROCCOLI

Sushanta Kumar Tarafder[1+]
Mrityunjoy Biswas[2]
Asit Baran Mondal[3]

[1]*Department of Agro Product Processing Technology, Jashore University of Science and Technology, Jashore, Bangladesh and Department of Agricultural Extension, Bangladesh.*
Email: tarafdersushanta@gmail.com Tel: +8801712195781
[2]*Department of Agro Product Processing Technology,Jashore University of Science and Technology, Jashore, Bangladesh.*
Email: mrityunjoy_appt@just.edu.bd Tel: +8801711240580
[3]*Project Manager, Sustainable Enterprise Project, Rural Reconstruction Foundation, Jashore, Bangladesh.*
Email: mondalasit90@gmail.com Tel +8801712577750

(+ Corresponding author)

Article History
Received: 6 December 2021
Revised: 20 June 2022
Accepted: 8 July 2022
Published: 4 August 2022

Keywords
Broccoli
Mineral nutrients
Pre-harvest
Quality
Shelf life
Yield.

ABSTRACT

This study was conducted at the farmer's field of Jashore Sadar Upazila, Bangladesh during the Rabi seasons of 2020-2021 to evaluate pre-harvest foliar application effects of mineral nutrients on yield, quality and shelf life of broccoli. The experiment was designed in Randomized Complete Block Design (RCBD), including three replications and seven treatments for field study which were: T1=control, T2=Ca@0.30%, T3=B@0.30%), T4= Zn@0.30%, T5=Mo@0.30%, T6=Mn@0.30%, and T7= (Ca+B+Zn+Mo+Mn)@0.30%. In order to determine the shelf life of broccoli, a Completely Randomized Design (CRD) was conducted with three replications considering three factors; (i) pre-harvest foliar application of mineral nutrient sources; (ii) room temperature along with storage materials, and (iii) cold storage along with storage materials that were used accordingly. Findings revealed that the effects of pre-harvest foliar application of mineral nutrients had a significant influence on the yield, post-harvest quality, and shelf life of broccoli. The treatment T7 (Ca+B+Zn+Mo+Mn)@0.30% produced significantly in all respects of yield contributing attributes denoting curd length, diameter, and marketable curd yield of broccoli. The same treatment effectively increased post-harvest quality attributes such as color, compactness, texture, dry matter, fats, carbohydrates, energy, vitamin C, antioxidants, and phenols content in the curd. In addition, the treatment also recorded the highest shelf life of 7.25 days at room temperature (14-24^{0}c with RH 60-65%) and 24.33 days at cold storage (4^{0}c with RH 90-95%) conditions within a High-Density Polyethylene (HDP; 15 micron) Vacuum pack.

Contribution/Originality: This study is one of very few studies which have investigated to evaluate pre-harvest foliar application effects of mineral nutrients on yield, quality and shelf life of broccoli. As a new concept, the study is original.

1. INTRODUCTION

Broccoli is one of the most important high-value and nutrient-rich vegetables of Cole crops belonging to the family *Brassicaceae*, and has a reputation as a supper food, known to be a healthy and delectable vegetable. Broccoli is a nutritional powerhouse full of vitamins, minerals, fibers, and antioxidants that support many elements of human health (Cartea, Velasco, Obregón, Padilla, & De Haro, 2008; Faller & Fialho, 2009; Yvette, 2012), and is also considered low on the Glycemic Index (GI=10) for diabetics (Nagraj, Anita, Swarna, & Amit, 2020). Global production of broccoli was 27 million tons in 2019, 73%

of which was produced in China and India. The rest of production was in USA, Mexico, Spain, Italy, Turkey, Bangladesh, Poland, and France (Food and Agriculture Organization of the United Nations, 2020). Farmers of Bangladesh are very much interested to produce and extent broccoli for its high value.

Application of balanced fertilizers is essential to produce high-quality for achieving maximum returns (Ahirwar & Nath, 2020). Most of the farmers in Bangladesh are not aware of the use of balanced fertilizers and as such produce vegetables without maintaining proper dosages of fertilizers to test the soil. Generally, in an effort to increase yield, the farmers use chemical fertilizers without addition of sufficient quantities of organic manures which are responsible for the improvement of soil health as well as vegetables' high value and shelf life (Mal, Chatterjee, & Nimbalkar, 2014). Chemical fertilizers may accelerate the crops yield initially but it has adverse effects later on Gupta, Swami, and Rai (2019). On the other hand, most of the soils in Bangladesh are deficient in essential mineral nutrients such as calcium, boron, zinc, molybdenum and manganese due to crop intensification. Insufficient supply of these essential nutrients in the soil is having a negative impact on the yield, quality, and shelf life of vegetables. In addition to the application of chemical fertilizers in the soil, foliar application of essential mineral nutrients is understood to be very important to overcoming this problem. Foliar application of essential mineral nutrients is the most effective and simplest way to improving the quality and shelf life of broccoli and other vegetables. Among the essential mineral nutrients, especially calcium, boron, zinc, molybdenum and manganese are appropriate for maintaining the quality and shelf life of broccoli. For these reasons, the researcher has included the issue of foliar application of essential mineral nutrients in this study. Preservation capability of broccoli is comparatively poor than other Cole crops like cabbage and cauliflower and farmers are not aware about the impacts of shelf life of any other vegetables. As well as the indiscriminate use of chemical fertilzers, it is known that farmers even mix two or more chemicals as cocktail formulation to achieve better yield. Consequently, the storage quality of broccoli reduces. There appears to be no education storage aspect after harvesting of broccoli and they do not adopt any steps in this regard. So, they used to sell the broccoli at a reduction price on the day of harvesting from the field. It will take time to increase the number of cold storage in Bangladesh, especially for this type of crop. At the grower as well as entrepreneurs level, such problem leads to serious financial loss, therefore it is essential to improve post-harvest quality and extending the shelf life of the crop. The investigator opined that foliar application of essential mineral nutrients is the most effective and simplest way of keeping the quality of broccoli and other vegetables intact while increasing their shelf life. This study also focuses on low cost technology such as Low-Density Polyethylene (LDP; 35 micron) bags, High-Density Polyethylene (HDP; 15 micron) Vacuum pack, 2% egg shell powder, and 2% ascorbic acid solution to enhance shelf life of broccoli both at room temperature as well as in cold storage conditions. Few investigators has partially studied the matter, but in-depth research on the matter remains particularly scarce. Considering the above, the investigator would like to take an in-depth study on "pre-harvest foliar application effects of mineral nutrients on yield, quality and shelf life of broccoli".

2. MATERIALS AND METHODS

The field study was conducted in the Rabi seasons at Jashore Sadar Upazila of Bangladesh during the year 2020-2021. Randomized Complete Block Design (RCBD) has been followed including seven treatments and three replications for the field study which were; T_1=control, T_2=Ca@0.30%, T_3=B@0.30%), T_4=Zn@0.30%, T_5=Mo@0.30%, T_6=Mn@0.30%, and T_7=(Ca+B+Zn+Mo+Mn)@0.30%. The soil test-based chemical fertilizers $N_{115}P_{3}0K_{75}Zn_{3}B_{1}Kgha^{-1}$ was applied in all treatments including control plot. The 'Green Crown' variety of broccoli was used for conducting the field experiment. Before sowing on the nursery bed, seeds were treated with Thiram @ 2.5g per kg of seeds. Seedlings at a healthy and appropriate age (21 days) had been transplanted to the experimental plots of size 3m by 2m at spacing of 50cm by 40cm as per the layout on the 16th November 2020. All TSP, Gypsum, Zinc sulphate (mono), and Boric acid had been used as basal in the respective plots. Urea and MOP fertilizers were used as equal three splits at 15, 30 and 45 days after transplanting. Fresh solution of minerals Calcium sulphate($CaSO_4$), Boric acid(H_3BO_3), Zinc sulphate(Z_nSO_4), Ammonium hepta molybdate tetra hydrate($(NH_4)_6Mo_7O_2.4H_2O$), and Manganese sulphate ($MnSO_4$) was applied as foliar spray. Spraying was done at 15 days after transplanting and then at 30, 45 and 60 days after transplanting. Improved intercultural operations were pursued in all the research plots. The crop was irrigated and pests were managed through biological methods. Broccoli curds were harvested before the buds opened between 19 and 28 January 2021. The observation associated with yield and its contributing characteristics; curd length and diameter, gross weight of plant (g), gross yield per plot (kg), gross yield ton per hectare, marketable curd weight (g), marketable yield per plot (kg), marketable yield ton per hectare. The results were recorded after taking five plants randomly from each experimental plot in each replication. Quality indices of broccoli were as follows: colour, compactness and texture detected in fresh and stored condition. The numerical ratings for broccoli quality indices were quantified on a scale from 1 to 5 (Ranganna, 1986). In order to determine different nutrient contents in fresh and stored broccoli curd, samples of each treatment were analyzed in the laboratory of Nutrition and Food Technology, Jashore University of Science and Technology, Jashore, Bangladesh. The methods and procedures which had been used to ascertain the respective nutrient at each level of treatment are as follows:

Dry matter (%): The sample of broccoli curd for each treatment was taken and fresh weight was recorded. The samples were then oven dried at 60ºC for 72 hours and weighed again.

Dry matter was expressed in percentage using the following formula:

$$\text{Dry matter (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

Vitamin C(mg/100g): vitamin C content in the curd was determined by diluting the known volume with 3% metaphosphoric acid(HPO_3) and titrating with 2, 6-dichlorophenol-indo-phenol solution, until the faint pink colour persisted. The vitamin C (mg/100g) was calculated by the following formula: $a = \frac{bcdx \times 100}{ef}$

Where, a = Vitamin-C content as mg/100g.

b= Titration value for sample.

c=Dye factor =0.125.

d=Volume made up 100ml.

e=aliquot extract.

f= weight of sample.

Protein(g): Protein was determined by using the Kjeldahl method. At first, 0.5-2g samples were taken in a Kjeldahl Digestion unit flask and 6.0g K_2SO_4,0.4g $CuSO_4$ and added to 20 ml 98% H_2SO_4. Then, digestion at 420⁰C for 1 h 30 min. After cooling, 10 ml distilled water was added to hydro-lysates before neutralization and titration with 0.1 N.HCl. The blank solution was made in the same way. The amount of total nitrogen in the curd multiplied with conversion factor of 6.25 in order to determines total protein content. Protein Calculated by the following formula:

$$\text{Protein(g)} = \frac{(S - B) \times 0.1 \times 0.014 \times DF \times 100}{W} \times 6.25$$

Anti-oxidants (mg/100g): Anti-oxidants were determined according to the method of DPPH free radical scavenging activity reported by Brand-Williams, Cuvelier, and Berset (1995). The stock solution of the radical was prepared by dissolving 24 mg DPPH in 100 ml methanol and was kept in a refrigerator until further use. The working solution of the radical was prepared by diluting the DPPH stock solution with methanol to obtain an absorbance of about 0.98 (±0.02) at 517 nm. In a test tube, 3 ml DPPH working solution was mixed with 100 µl curd extract (1 mg/ml) or the standard solution. The absorbance was measured at 517 nm for a period of 30 min. The percent antioxidant or radical scavenging activity was calculated using the following formula:

$$\text{\%Antioxidant activity} = \frac{(Ac - As)}{Ac} \times 100$$

Where Ac and As are the absorbance of control and sample, respectively. The control contained 100 µl methanol in place of the curd sample.

Phenols (mg/100g): phenols content in curd was estimated according to the method of Slinkard and Singleton (1977). Each curd sample was prepared by dissolving 4.3 mg in 10 ml methanol. The mixture was sonicated for 5 minutes to obtain a homogenized solution. Then, 300 µl of this solution taken in a test tube with 1 ml methanol, 3.16 ml distilled water and 200 µl Folin-Ciocalteu reagent added. After 8 minutes incubation at room temperature, 600 µl sodium carbonate solution (10%) was added and the test tube was covered with aluminum foil and incubated in a hot water bath at 40 °C for 30 minutes. A blank was prepared using the same procedure but replacing the curd extract with an equal volume of methanol. The absorbance of the sample was determined using a UV visible spectrophotometer at 765 nm. The standard curve of Gallic acid was obtained using the same procedure. Phenol content was expressed as µg of Gallic acid equivalents (GAE) per ml, which was calculated using the formula, $y = m x + c$ where, y is the absorbance at 765 nm and x is the amount of Gallic acid equivalent (µg/ml).

To ascertain the shelf life for the said crop the following methodology was followed:

Statistical design: Completely Randomized Design (CRD).

Number of replication: 3

Flow chart of the details of the experimental design:

Treatments

Treatment level: -1	Treatment level: -2	Treatment level: -3
Pre-harvest foliar application of mineral nutrient sources	Room temperature along with storage materials: i. Low-Density Polyethylene (LDP; 35 micron) bag ii. High-Density Polyethylene (HDP; 15 micron) Vacuum pack, iii. 2% Egg shell powder solution, iv. 2% Ascorbic acid solution v. Control (At open place)	Cold storage: along with storage materials: i. Low-Density Polyethylene (LDP; 35 micron) bag ii. High-Density Polyethylene (HDP; 15 micron) Vacuum pack, iii. 2% Egg shell powder solution, iv. 2% Ascorbic acid solution v. Control (At open place)

Visual and sensory quality, physiological weight loss (PLW), and marketability were observed on a daily basis at room temperature conditions and on a 5-days basis at cold storage condition and cumulative results were recorded. The change of curd color was observed by eye estimation and to ascertain the shelf life of curd both at room temperature and cold storage condition. The recorded data of various characters were analyzed with the help the of Statistical Tool for Agricultural Research (STAR) Program and the mean values of all the treatments had been adjudged by Tukeye's test at 5% level of probability for interpretation. Benefit-Cost Ratio (BCR) for each treatment was calculated based on the present market prices of inputs and outputs in order to find out the maximum profitable treatment.

3. RESULTS AND DISCUSSION

3.1. Yield and Yield Attributing Characteristics

3.1.1. Curd Length and Diameter

Table 1 revealed that a maximum curd length 19.45 cm and diameter 21.25 cm were observed in the treatment T_7(Ca+B+Zn+Mo+Mn)@0.30% as compared to other treatments. Whereas, minimum curd length 14.33 cm and curd diameter 15.69cm were noted in the control sample. As a result of increased the rate of photosynthesis and carbohydrates accumulation in the curd, length and diameter accelerated due to the synergistic action of different mineral nutrient sources mentioned above. These findings corroborate with the findings of Choudhury and Sikder (2017) in broccoli; Chaudhari, Patel, Tandel, and Vibhuti (2017) in cauliflower.

3.2. Marketable Curd Weight

Table 1 revealed a marketable maximum curd weight 570.20 g recorded in the treatment T_7(Ca+B+Zn+Mo+Mn)@0.30%) as compared to other treatments. Whereas, a marketable minimum curd weight 455.07g was noted from T_1(control). These findings are in concordance with Singh, Sarvanan, Jalam, and Bhanwar (2016), Choudhury and Sikder (2017) in broccoli; Chaudhari et al. (2017) in cauliflower.

3.3. Marketable Yield

Table 1 revealed a maximum marketable curd yield 28.51 t ha^{-1} recorded in the treatment T_7 (Ca+B+Zn+Mo+Mn)@0.30% followed by 26.63 t ha^{-1} in T_3 (B@0.30%) and 26.17 t ha^{-1}in T_4(Zn@0.30%), whereas, a minimum marketable curd yield 22.75t ha^{-1} noted in T_1 (control).. This might be due to the combined foliar application of Ca, B, Zn, Mo, and Mn in accelerating the advanced physiological functions in plants such as cell division and elongation, amino acid formation, chlorophyll and protein synthesis, carbohydrate metabolism, sugar translocation, and various enzymatic reactions which led to more carbohydrate accumulation in curds resulting in an increased yield. These findings corroborate with the findings of Singh et al. (2016); Shatis et al. (2018) in broccoli; Chaudhari et al. (2017) in cauliflower.

3.4. Quality Attributes

3.4.1. Physioco-Chemical Analysis of Fresh Broccoli

3.4.1.1. Sensory Evaluation of colour, Compactness and Texture

Table 3 revealed that pre-harvest foliar application effects of mineral nutrient sources significantly influenced the quality attributes (colour, compactness, and texture) of broccoli. Ranganna's (1986), one to five point hedonic scale was produced as follows: maximum colour rating 4.85, compactness rating 4.69, and texture rating 4.81 in the treatment T_7 (Ca+B+Zn+Mo+Mn)@0.30% followed by T_3 (B@0.30%) with colour rating 4.49, compactness rating 4.54, and texture rating 4.67, and T_4 (Zn@0.30%) with colour rating 4.45, compactness rating 4.51, and texture rating 4.58 respectively. Treatment T_1 (control), however, produced a minimum colour rating of 3.69, compactness rating of 3.25, and a texture rating of 3.29..This finding corroborates with Li and Gao (2000); Chingtham and Banik (2019).

Table 1. Pre-harvest foliar application effects of mineral nutrients on yield and yield contributing attributes of broccoli.

Yield attributes								
Treatment	**Curd length (cm)**	**Curd diameter (cm)**	**Gross plant weight(g)**	**Gross yield polt^{-1} (kg)**	**Gross yield (t ha^{-1}**	**Marketable curd weight (g)**	**Marketable yield plot^{-1} (kg)**	**Marketable yield(t ha^{-1})**
T_1	14.33d	15.69c	945.13c	28.35c	47.26c	455.07e	13.65d	22.75e
T_2	16.29bcd	16.14c	975.87abc	29.28abc	48.79abc	474.35cde	14.23cd	23.72cde
T_3	18.55ab	19.04ab	1025.25ab	30.76ab	51.26ab	532.53ab	15.98ab	26.63ab
T_4	17.33abc	18.10bc	1015.45abc	30.46abc	50.77abc	523.36abc	15.70abc	26.17abc
T_5	16.47bcd	16.44bc	990.47abc	29.71abc	49.52abc	510.25bcd	15.31bc	25.51bcd
T_6	15.58cd	15.85c	965.16bc	28.95bc	48.26bc	469.29de	14.08cd	23.46de
T_7	19.45a	21.25a	1045.33a	31.36a	52.27a	570.20a	17.10a	28.51a
SEm ±	0.6930	0.8271	20.32	0.6094	1.02	15.41	0.4632	0.7705
HSD(P=0.05)	1.01	1.01	1.38	1.38	1.38	1.11	1.11	1.11

Note: Here, these letters a, b, c, d, e indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control,T_2=Ca@o.30%,T_3=B@o.30%),T_4=Zn@o.30%,T_5=Mo@o.30%,T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

Table 2. Description of numerical ratings for broccoli quality (According to 1 to 5 point hedonic scale (Ranganna, 1986)*

Scale	Ranges of Scores	Rating for Quality attributes of broccoli		
		Color	Compactness	Texture
1	4.50-5.00	Dark green	Very compact	Highly crispy
2	3.50-4.49	Green	Compact	Crispy
3	2.50-3.49	Light green	Medium compact	moderately crispy
4	1.50-2.49	Light yellow	Slightly loose	Soft
5	1.00-1.49	Very yellow	Loose	Very soft

Note: *Refer to Table 2 for rating and indicating quality of broccoli

Table 3. Quality indices of fresh broccoli as influenced by pre-harvest foliar application effects of mineral nutrient sources.

Treatment	Quality indices of fresh broccoli					
	Color		Compactness		Texture	
	Rating Score	Level of Color	Rating Score	Level of Compactness	Rating Score	Level of Texture
T_1	3.69b	Green	3.25c	Medium compact	3.29c	Moderately crispy
T_2	3.95b	Green	3.67c	Compact	3.75bc	Crispy
T_3	4.49ab	Green	4.54ab	Very compact	4.67ab	Highly crispy
T_4	4.45ab	Green	4.51ab	Very compact	4.58ab	Highly crispy
T_5	4.17ab	Green	3.85bc	Compact	4.49ab	Crispy
T_6	3.83b	Green	3.52c	Compact	3.34c	Moderately crispy
T_7	4.85a	Dark Green	4.69a	Very compact	4.81a	Highly crispy
HSD (P=0.05)	0.35		0.02		0.03	

Note: Here, these letters a, b, c indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control,T_2=Ca@o.30%,T_3=B@o.30%),T_4=Zn@o.30%,T_5=Mo@o.30%,T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

3.4.2. Chemical Analysis of Fresh Broccoli Curds

3.4.2.1. Dry Matter

Table 4 revealed a maximum dry matter of 15.27% recorded in the treatment T_7 (Ca+B+Zn+Mo+Mn)@o.30% followed by T_3(B@o.30%) with 14.73% and T_4 (Zn@o.30%) with 14.45%, whereas a minimum dry matter of 10.47% was noted in treatment T_1(control). Maximum dry matter content in the above treatments might be due to optimum uptake in the vegetative growth related nutrients from the different mineral nutrient sources. The findings of the study related to dry matter content in broccoli curd corroborates with Shatis et al. (2018) in broccoli.

3.4.2.2. Protein

Protein content related data in the Table 4 revealed a maximum protein content of 3.53g recorded in the treatment T_5(Mo@o.30%). Minimum protein of 2.49 g was observed from T_1(control). This might have been due to the involvement of absorption of nitrogen and nitrogen metabolism which led to higher protein content. This finding of present investigation in respect of protein content in broccoli curd corroborates with the findings of Singh, Singh, Singh, Kumar, and Mohrana (2018) and Sharma (2012) in broccoli.

3.4.2.3. Fats

Table 4 revealed a maximum fats content of 0.4385g was recorded in the treatment T_7 (Ca+B+Zn+Mo+Mn)@o.30% followed by T_4 (Zn@o.30%) with 0.4357 g and T_3 (B@o.30%) with 0.4325g. Minimum fats content of 0.3825g was noted in treatment T_1 (control).

3.4.2.4. Carbohydrates

Table 4 revealed a maximum carbohydrates content of 5.25g recorded in the treatment T_7 (Ca+B+Zn+Mo+Mn)@o.30% followed by T_4(Zn@o.30% with 4.45g and T_3(**B**@o.30%) with 4.13g. Minimum carbohydrates content of 2.89g was noted from treatment T_1 (control), possibly due to the better performance on potential vegetative growth and higher metabolic activities which influenced in the deposition of more carbohydrate accumulation in curd due to adequate supply of different mineral nutrients from the said sources. These findings are supported by Sharma (2012) and Singh et al. (2018).

3.4.2.5. Energy

Table 4 revealed a maximum energy of 37.91kcal recorded in the treatment T_7 (Ca+B+Zn+Mo+Mn)@o.30% followed byT_4(Zn@o.30%) with 35.28 kcal and T_3 (B @o.30%) with32.19kcal. Maximum energy in the said treatment might be due to accumulated fats in the curd from sources of mineral nutrients broken down into energy molecule Adenosine Triphosphate (ATP), resulting in maximum energy produced in the broccoli curds. Minimum energy of 24.96 kcal was recorded in treatment T_1 (control).

3.4.2.6. Vitamin C

Table 4 revealed a maximum vitamin C content of 88.45 mg/100g recorded in the treatment T_7 (Ca+B+Zn+Mo+Mn)@o.30% followed by T_4 (Zn@o.30%) with86.37 mg/100g and T_3 (B@o.30%) with_85.43 mg/100g. A minimum vitamin C content 71.26mg/100g was noted from treatment T_1 (control). This could be due to synergistic effects of Ca,B,Zn,Mo and Mn with inorganic nutrient sources that helped to absorbed need-based nutrients to plants and enhanced the rate of photosynthesis during growth and development of the broccoli bunches, leading to a mobilizing of the biosynthesis of ascorbic acid and consequently increased vitamin C in broccoli curd. The findings of the present investigation in respect of vitamin C content in broccoli curd corroborates with the findings of Singh et al. (2016); Choudhury and Sikder (2017); Pankaj, Kujur, and Saravanan (2018) in broccoli.

3.4.2.7. Antioxidants

Table 4 revealed a maximum antioxidant content of 73.43mg/100g recorded in the treatment T_7 (Ca+B+Zn+Mo+Mn)@o.30% followed by T_4 (Zn@o.30%) with_70.56 mg/100g and T_3(B@o.30%) with_68.34 mg/100g, while a minimum antioxidant content 56.23 mg/100g was recorded in treatment T_1 (control). This might be due to stimulating effects of mineral sources of nutrients which enhanced biosynthesis of phenol in the curd resulting possessed high-potential activity of antioxidants as compared to other treatments. The findings of present investigation in respect of antioxidant content in broccoli curd corroborates with the findings of Rice-Evans, Miller, and Paganga (1997).

3.4.2.8. Phenols

Table 4 revealed a maximum phenol content of 40.95mg/100g in broccoli curd recorded in the treatment T_7 (Ca+B+Zn+Mo+Mn)@o.30% followed by T_4 (Zn@o.30%) with_40.15mg/100g and T_3 (B@o.30%) with_38.38 mg/100g. Minimum phenol content of 27.39mg/100g was recorded in treatment T_1 (control). This finding defends with Zaki, Abdelhafez, El-dewiny, and Camilia (2009) in broccoli florets.

Table 4. Pre-harvest foliar application effects of mineral nutrient sources on nutrient content in fresh broccoli curd.

Treatment	Nutrients content in fresh broccoli curd.							
	Dry Matter (%)	Protein (g)	Fat (g)	Carbohy-drates(g)	Energy (kcal)	Vitamin c (mg/100g)	Antioxidants (mg/100g)	Phenol (mg/100 g)
T_1	10.47c	2.49c	0.3825c	2.89d	24.96d	71.26d	56.23d	27.39d
T_2	13.36abc	2.65bc	0.4237ab	3.67bcd	29.09bcd	75.53cd	60.19cd	31.23cd
T_3	14.73ab	2.87abc	0.4325ab	4.13bc	32.19abc	85.43ab	68.34ab	38.38ab
T_4	14.45ab	3.39ab	0.4357a	4.45ab	35.28ab	86.37ab	70.56ab	40.15ab
T_5	12.25bc	3.53a	0.4175ab	3.46bcd	31.72abc	82.25abc	65.17bc	35.17abc
T_6	11.82bc	2.55c	0.4033bc	3.24cd	26.78cd	78.36bcd	63.25bcd	33.56bcd
T_7	15.27a	3.24abc	0.4385a	5.25a	37.91a	88.45a	73.43a	40.95a
SEm±	0.8493	0.225	0.0084	0.3147	1.87	2.48	2.14	1.98
HSD (P=0.05)	0.09	0.21	0.02	0.01	0.02	0.01	0.00	0.02

Note: Here, these letters a, b, c, d indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control, T_2=Ca@o.30%, T_3=B@o.30%), T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

3.5. Physioco-Chemical Analysis of Stored Broccoli

3.5.1. Sensory Evaluation of Colour, Compactness and Texture

Table 5 revealed that pre-harvest foliar application of mineral nutrient sources along with storage materials significantly influenced the quality of the colour, compactness, and texture of broccoli, both at room temperature (14-24^{0}c with RH 60-65%) and cold storage (4^{0}c with RH 90-95%) conditions. Ranganna's one to five point hedonic scale produced the following: maximum colour rating of 3.75, compactness rating of 3.87, and texture rating of 3.73 in relation to the treatment T_7 (Ca+B+Zn+Mo+Mn)@o.30% in the High-Density Polyethylene (HDPE) Vacuum pack after 20 days in cold storage (4^{0}c with RH 90-95%) followed by a Low-Density Polyethylene (LDPE) bag with a colour rating of 3.69, compactness rating of 3.75, and texture rating of 3.65 in the same treatment after 15 days in cold storage (4^{0}c with RH 90-95%). The minimum colour rating was 1.95, compactness rating 2.05, and texture rating 1.93 for treatment T_1 (control) after11 days at open place condition within cold storage.

Similarly, when broccoli curds were stored at room temperature (14-24^{0}c with RH 60-65%), the maximum colour had a rating of 3.63, compactness rating was 3.75, and the texture rating was 3.65 in the same treatment T_7 (Ca+B+Zn+Mo+Mn)@o.30% within High-Density Polyethylene (HDP; 15 micron) Vacuum packs after 5 days followed by Low-Density Polyethylene (LDP; 35 micron) bag with a colour rating of 3.07, compactness rating of 3.15, and texture rating of 2.95 in the same treatment after 5 days at room temperature (14-24^{0}c with RH 60-65%). Minimum colour rating of 1.69, compactness rating of 2.15, and texture rating of 1.39 were noted in treatment T_1 (control) after 3 days at room temperature (14-24^{0}c with RH 60-65%). This finding corroborates with Chingtham and Banik (2019).

3.5.2. Chemical Analysis of Post-Storage Broccoli Curds

Table 6 revealed that High-Density Polyethylene (HDPE) Vacuum packs in combination with cold storage condition (4^{0}c with RH 90-95%) were significantly effective in maintaining the quality of broccoli in keeping its nutrients at maximum shelf life stage. Maximum appreciable amount of nutrients of fats at 0.4375g, carbohydrates at 5.19g, vitamin C at 80.57mg/100g, antioxidants at 71.26mg/100g, and phenols 39.49mg/100g were found to be retained in the treatment T_7(Ca+B+Zn+Mo+Mn)@ 0.30% along with High-Density Polyethylene (HDPE) Vacuum packs in cold storage (4^{0}c with RH 90-95%) up to a maximum of 24.33 days which is less than the nutrients in fresh brocolli by 0.23%,1.14%, 8.91%, 2.96%, and 3.57% as mentioned in Table 4. Similarly, when broccoli curds were stored at room temperature (14-24^{0}c with RH 60-65%), the various nutrients of fats at 0.4317g, carbohydrates at 4.73g, vitamin C at 77.16mg/100g, antioxidants at 66.03mg/100g, and phenols at 37.31mg/100g remained intact even after the broccoli curds were kept within High-Density Polyethylene (HDPE) Vacuum packs for a maximum of 7.25 days in the same treatment which is less than the nutrients in fresh brocolli by 1.55%, 9.90%, 12.76%, 10.08%, and 8.89% as mentioned in Table 4. This finding corroborates with Li and Gao (2000); Chingtham and Banik (2019) and Manisha and Rajkumari (2020).

Table 5. Effects of pre-harvest foliar application of mineral nutrient sources and storage condition along with each level of storage materials on quality attributes in stored broccoli curd at maximum shelf life stage.
A) Within Low- Density Polyethylene (LDP) bag.

Treatment	Quality indices of stored broccoli after 5 days at room temperature						Quality indices of stored broccoli after 20 days at cold storage condition					
	Color		Compactness		Texture		Color		Compactness		Texture	
	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level
T_1	2.29c	Light yellow	2.41c	Slightly loose	2.45c	Soft	2.25d	Light yellow	2.36c	Slightly loose	2.29c	Soft
T_2	2.85abc	Light green	3.13abc	Medium compact	3.03abc	Moderately crispy	2.56bcd	Light green	2.91bc	Medium compact	2.73bc	Moderately crispy
T_3	3.41ab	Light green	3.67a	Compact	3.33ab	Moderately crispy	3.27ab	Light green	3.65ab	Compact	3.17ab	Moderately crispy
T_4	3.25ab	Light green	3.45ab	Medium compact	3.17abc	Moderately crispy	3.13abc	Light green	3.49ab	Medium compact	3.25ab	Moderately crispy
T_5	3.07ab	Light green	3.15abc	Medium compact	2.95abc	Moderately crispy	3.19ab	Light green	3.33ab	Medium compact	2.93abc	Moderately crispy
T_6	2.71bc	Light green	2.73bc	Medium compact	2.69bc	Moderately crispy	2.43cd	Light yellow	2.51c	Medium compact	2.59bc	Moderately crispy
T_7	3.55a	Green	3.73a	Compact	3.55a	Crispy	3.69a	Green	3.75a	Compact	3.65a	Crispy
HSD (P=0.05)	0.10		0.04		0.38		0.02		0.01		0.07	

Note: Here, these letters a, b, c, d indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control, T_2=Ca@o.30%, T_3=B@o.30%), T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

B) Within High -Density Polyethylene (HDP) Vacuum pack.

Treatment	Quality indices of stored broccoli after 5 days at room temperature						Quality indices of stored broccoli after 15 days at cold storage condition					
	Color		Compactness		Texture		Color		Compactness		Texture	
	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level
T_1	2.37c	Light yellow	2.45c	Slightly loose	2.47c	Soft	2.45c	Light yellow	2.39c	Slightly loose	2.36c	Soft
T_2	2.96abc	Light green	3.16abc	Medium compact	3.13abc	Moderately crispy	2.69bc	Light green	3.15ab	Medium compact	2.85bc	Moderately crispy
T_3	3.53a	Green	3.71a	Compact	3.41ab	Moderately crispy	3.33ab	Light green	3.81a	Compact	3.21ab	Moderately crispy
T_4	3.33ab	Light green	3.55ab	Compact	3.25ab	Moderately crispy	3.17abc	Light green	3.61a	Compact	3.36ab	Moderately crispy
T_5	3.17ab	Light green	3.33ab	Medium compact	3.13abc	Moderately crispy	3.35ab	Light green	3.49ab	Medium compact	3.17ab	Moderately crispy
T_6	2.77bc	Light green	2.87bc	Medium compact	2.75bc	Moderately crispy	2.49c	Light yellow	2.75bc	Medium compact	2.81bc	Moderately crispy
T_7	3.63a	Green	3.75a	Compact	3.65a	Crispy	3.75a	Green	3.87a	Compact	3.73a	Crispy
HSD (P=0.05)	0.09		0.05		0.24		0.03		0.01		0.09	

Note: Here, these letters a, b, c indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control, T_2= Ca@o.30%, T_3=B@o.30%), T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

C) Treatment with 2%egg shell powder solution

Treatment	Quality indices of stored broccoli after 3 days at room temperature						Quality indices of stored broccoli after 15 days at cold storage condition					
	Color		Compactness		Texture		Color		Compactness		Texture	
	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level
T_1	2.05d	Light yellow	2.39c	Slightly loose	2.33c	Soft	2.07c	Light yellow	2.15d	Slightly loose	2.25c	Soft
T_2	2.75bcd	Light green	3.05abc	Medium compact	2.95abc	Moderately crispy	2.35bc	Light yellow	2.73bcd	Medium compact	2.66bc	Moderately crispy
T_3	3.31ab	Light green	3.44a	Medium compact	3.20ab	Moderately crispy	3.17a	Light green	3.41ab	Medium compact	3.04ab	Moderately crispy
T_4	3.04abc	Light green	3.23ab	Medium compact	3.05abc	Moderately crispy	3.03ab	Light green	3.19ab	Medium compact	2.95abc	Moderately crispy
T_5	2.91abc	Light green	2.93abc	Medium compact	2.75abc	Moderately crispy	3.05ab	Light green	3.07abc	Medium compact	2.57bc	Moderately crispy
T_6	2.43cd	Light yellow	2.56bc	Medium compact	2.49bc	Soft	2.16c	Light yellow	2.33cd	Slightly loose	2.45bc	Soft
T_7	3.51a	Green	3.49a	Medium compact	3.43a	Moderately crispy	3.57a	Green	3.69a	Compact	3.56a	Crispy
HSD (P=0.05)	0.03		0.14		0.27		0.01		0.01		0.10	

Note: Here, these letters a, b, c, d indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control,T_2=Ca@o.30%, T_3=B@o.30%), T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

D) Treatment with 2% Ascorbic acid solution

Treatment	Quality indices of stored broccoli after 3 days at room temperature						Quality indices of stored broccoli after 15 days at cold storage condition					
	Color		Compactness		Texture		Color		Compactness		Texture	
	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level
T_1	1.97d	Light yellow	2.33c	Slightly loose	2.25c	Soft	1.95d	Light yellow	2.05d	Slightly loose	1.93c	Soft
T_2	2.69bcd	Light green	2.95abc	Medium compact	2.73abc	Moderately crispy	2.27bcd	Light yellow	2.67bcd	Medium compact	2.53bc	Moderately crispy
T_3	3.27ab	Light green	3.41a	Medium compact	3.13ab	Moderately crispy	3.01ab	Light green	3.33ab	Medium compact	2.93ab	Moderately crispy
T_4	2.96abc	Light green	3.15ab	Medium compact	2.96abc	Moderately crispy	2.75abc	Light green	3.05ab	Medium compact	2.87ab	Moderately crispy
T_5	2.83abc	Light green	2.86abc	Medium compact	2.69abc	Moderately crispy	2.89ab	Light green	2.87bc	Medium compact	2.56bc	Moderately crispy
T_6	2.36cd	Light yellow	2.49bc	Slightly loose	2.41bc	Soft	2.13cd	Light yellow	2.25cd	Slightly loose	2.39bc	Soft
T_7	3.46a	Light green	3.41a	Medium compact	3.33a	Moderately crispy	3.45a	Light green	3.63a	Compact	3.47a	Moderately crispy
HSD (P=0.05)	0.02		0.14		0.30		0.01		0.01		0.04	

Note: Here, these letters a, b, c, d indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control, T_2=Ca@o.30%, T_3=B@o.30%), T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

E) Control (at open place)

Treatment	Quality indicesr of stored broccoli after 3 days at room temperature						Quality indices of stored broccoli after 11 days at cold storage condition					
	Color		Compactness		Texture		Color		Compactness		Texture	
	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level
T_1	1.69c	Light yellow	2.15c	Slightly loose	1.39c	Very soft	1.95d	Light yellow	2.05d	Slightly loose	1.93c	Soft
T_2	2.07abc	Light yellow	2.73abc	Medium compact	2.49ab	Soft	2.27bcd	Light yellow	2.67bcd	Medium compact	2.53bc	Moderately crispy
T_3	2.57ab	Light green	3.33a	Medium compact	2.83ab	Moderately crispy	3.01ab	Light green	3.33ab	Medium compact	2.93ab	Moderately crispy
T_4	2.35abc	Light yellow	3.07ab	Medium compact	2.69ab	Moderately crispy	2.75abc	Light green	3.05ab	Medium compact	2.87ab	Moderately crispy
T_5	2.17abc	Light yellow	2.69abc	Medium compact	2.56ab	Moderately crispy	2.89ab	Light green	2.87bc	Medium compact	2.56bc	Moderately crispy
T_6	1.95bc	Light yellow	2.33bc	Slightly loose	2.25b	Soft	2.13cd	Light yellow	2.25cd	Slightly loose	2.39bc	Soft
T_7	2.76a	Light green	3.33a	Medium compact	3.21a	Moderately crispy	3.45a	Light green	3.63a	Compact	3.47a	Moderately crispy
HSD (P=0.05)	0.44		0.06		0.01		0.01		0.01		0.04	

Note: Here, these letters a, b, c, d indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control, T_2=Ca@o.30%, T_3=B@o.30%), T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

Table-6. Pre-harvest foliar application effects of mineral nutrients and storage condition along with each level of packaging materials on nutrients content in stored broccoli curd at maximum shelf life stage

A) Within Low- Density Polyethylene (LDP) bag

Treatment	Nutrients content At room temp.(14-24°c with RH 60-65%)							Nutrients content At cold storage (4°c with RH 90-95%)						
	Dry Matter (%)	Protein (g)	Fat (g)	CHO (g)	Vitamin c (mg/100g)	Antioxidants (mg/100g	Phenol (mg/100g	Dry Matter (%)	Protein (g)	Fat (g)	CHO (g)	Vitamin c (mg/100g)	Antioxidant (mg/100g	Phenol (mg/100 g
T_1	9.25c	2.21c	0.3735c	2.49d	54.54d	44.25c	20.47d	10.37d	2.36d	0.385c	2.75d	60.23e	52.17d	24.16c
T_2	11.93abc	2.36abc	0.4147ab	3.08bcd	60.75cd	50.76bc	24.75bcd	13.18abcd	2.53bcd	0.4193ab	3.49bcd	64.53de	55.63cd	28.33bc
T_3	13.05ab	2.53abc	0.4259a	3.63abc	71.23abc	57.33ab	31.36ab	14.53ab	2.77abcd	0.4307a	4.01bc	74.17abc	64.36abc	35.17ab
T_4	12.62ab	3.01ab	0.4253a	3.95ab	73.44ab	59.45ab	33.17a	14.15abc	3.28ab	0.4315a	4.29ab	76.14ab	67.19ab	37.48a
T_5	10.83abc	3.13a	0.4056ab	2.96bcd	66.48abc	52.26bc	29.46abc	11.96bcd	3.46a	0.4135ab	3.33bcd	70.16bcd	60.45abcd	31.23ab
T_6	10.33bc	2.27bc	0.3942bc	2.75cd	63.26bcd	49.53bc	24.23cd	11.54cd	2.43cd	0.3996bc	3.11cd	66.33cde	58.36bcd	29.19bc
T_7	13.56a	2.86abc	0.4305a	4.36a	75.33a	64.27a	35.16a	15.09a	3.15abc	0.4369a	5.14a	79.26a	70.17a	38/15a
HSD (P=0.05)	0.24	0.61	0.02	0.06	0.05	0.04	0.01	0.10	0.15	0.02	0.01	0.01	0.06	0.01

Note: Here, these letters a, b, c, d, e indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control, T_2=Ca@o.30%, T_3=B@o.30%),T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

B) High- Density Polyethylene (HDP) Vacuum pack

Treatment	Nutrients content At room temp. (14-24°c with RH 60-65%)							Nutrients content At cold storage(4°c with RH 90-95%)						
	Dry Matter (%)	Protein (g)	Fat (g)	CHO (g)	Vitamin c (mg/100g)	Antioxidants (mg/100g	Phenol (mg/100g)	Dry Matter (%)	Protein (g)	Fat (g)	CHO (g)	Vitamin c (mg/100g)	Antioxidant (mg/100g	Phenol (mg/100 g
T_1	9.37c	2.35b	0.3756c	2.61d	57.23c	47.56c	23.35c	10.43c	2.41c	0.3813c	2.81d	61.37d	54.13d	25.17c
T_2	12.02abc	2.39b	0.4165ab	3.33bcd	63.91bc	53.17bc	27.01bc	13.25abc	2.59bc	0.4215ab	3.57bcd	65.76cd	57.75cd	29.46bc
T_3	13.26ab	2.58ab	0.4276a	3.74abc	74.36ab	59.25ab	33.49ab	14.57ab	2.82abc	0.4309a	4.07bc	75.47ab	65.49abc	36.13ab
T_4	12.71ab	3.06ab	0.4273a	4.05ab	76.45a	61.69ab	35.33a	14.23ab	3.33ab	04333a	4.35ab	77.25a	68.37ab	38.55a
T_5	11.03abc	3.18a	0.4073ab	3.11bcd	69.56ab	55.47bc	31.59ab	12.07bc	3.49a	0.4156ab	3.37bcd	72.19abc	62.16abcd	33.16ab
T_6	10.64bc	2.30b	0.3975bc	2.92cd	66.37abc	52.65bc	27.46bc	11.63bc	2.51c	0.4012bc	3.17cd	68.46bcd	60.43bcd	30.63bc
T_7	13.75a	2.92ab	0.4317a	4.73a	77.16a	66.03a	37.31a	15.17a	3.18abc	0.4375a	5.19a	80.57a	71.26a	39.49a
HSD (P=0.05)	0.26	0.72	0.02	0.03	0.06	0.08	0.01					0.01	0.11	0.01

Note: Here, these letters a, b, c, d indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control, T_2=Ca@o.30%, T_3=B@o.30%), T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

C) Treatment with 2%egg shell powder solution

Treatment	Nutrients content At room temp. (14-24°c with RH 60-65%)							Nutrients content At cold storage (4°c with RH 90-95%)						
	Dry Matter (%)	Protein (g)	Fat (g)	CHO (g)	Vitamin c (mg/100g)	Antioxidants (mg/100g)	Phenol (mg/10 0g	Dry Matter (%)	Protein (g)	Fat (g)	CHO (g)	Vitaminc (mg/100 g)	Antioxidant (mg/100g	Phenol (mg/100g)
T_1	8.37c	2.16c	0.3716c	2.42d	51.82d	41.78d	18.23c	10.25abc	2.29c	0.3743c	2.69d	57.31d	50.13d	23.17d
T_2	11.75ab	2.33abc	0.4138ab	3.03bcd	59.16cd	49.21bcd	22.86bc	12.87a	2.48bc	0.4177ab	3.45bcd	61.25cd	53.75cd	26.15cd
T_3	12.83ab	2.50abc	0.4251a	3.58abc	69.24abc	55.97abc	29.25ab	14.09ab	2.71abc	0.4281a	3.96abc	70.67abc	62.27abc	34.23ab
T_4	12.02ab	2.98ab	0.4241a	3.87ab	71.95ab	58.04ab	31.45a	13.95ab	3.25ab	0.4288a	4.23ab	74.33ab	65.13ab	36.19a
T_5	10.46abc	3.09a	0.4030ab	2.93bcd	64.34abc	50.87bcd	27.33ab	11.05bc	3.41a	0.4113ab	3.17bcd	67.45abcd	59.16abcd	30.25sbc
T_6	10.05bc	2.24bc	.0.3923bc	2.71cd	61.18bcd	47.42cd	22.36bc	10.83c	2.39c	0.3967bc	2.96cd	62.75bcd	56.43bcd	27.46bcd
T_7	13.17a	2.84abc	0.4297a	4.30a	73.95a	62.92a	33.37a	14.87a	3.03abc	0.4356a	5.03a	77.37a	68.15a	37.13a
HSD (P=0.05)	0.12	0.57	0.02	0.05	0.05	0.02	0.01	0.06	0.15	0.01	0.01	0.11	0.06	0.01

Note: Here, these letters a, b, c, d indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control, T_2=Ca@o.30%, T_3=B@o.30%), T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

D) Treatment with 2% ascorbic acid solution

Treatment	Nutrients content At room temp. (14-24°c with RH 60-65%)							Nutrients content At cold storage (4°c with RH 90-95%)						
	Dry Matter (%)	Protein (g)	Fat (g)	CHO (g)	Vitamin c (mg/100g)	Antioxidants (mg/100g	Phenol (mg/100g	Dry Matter (%)	Protein (g)	Fat (g)	CHO (g)	Vitamin c(mg/100g)	Antioxidant (mg/100g	Phenol (mg/100g)
T_1	8.25c	2.12c	0.3708c	2.38d	49.64c	40.45d	16.25c	9.73c	2.13c	0.3705c	2.61d	55.44c	47.25d	21.35d
T_2	11.69ab	2.27abc	0.4129ab	2.97bcd	56.98bc	47.93bcd	20.99bc	12.05abc	2.36bc	0.4156ab	3.39bcd	59.39bc	50.43cd	24.47cd
T_3	12.75ab	2.44abc	0.4233a	3.50abc	67.29ab	54.94abc	27.33ab	13.86a	2.63abc	0.4235a	3.83abc	67.25abc	60.25abc	32.66ab
T_4	11.89ab	2.93ab	0.4237a	3.81ab	70.04a	56.88ab	29.46a	13.64ab	3.19a	0.4259a	4.05ab	71.46ab	63.37ab	34.29a
T_5	10.39abc	3.03a	0.4018ab	2.81bcd	61.82abc	48.96bcd	25.16ab	10.75bc	2.91abc	0.4095ab	3.07bcd	63.25abc	56.13abcd	29.13abc
T_6	9.93bc	2.19bc	0.3913bc	2.61cd	59.17abc	45.23cd	20.43bc	10.33c	2.25bc	0.3916bc	2.85cd	60.13bc	53.47bcd	26.14bcd
T_7	13.03a	2.79abc	0.4293a	4.19a	71.06a	62.13a	31.45a	14.56a	2.97ab	0.4343a	4.91a	74.36a	66.33a	35.16a
HSD (P=0.05)	0.12	0.60	0.02	0.05	0.05	0.02	0.01	0.04	0.32	0.01	0.01	0.19	0.03	0.01

Note: Here, these letters a, b, c, d indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control, T_2=Ca@o.30%, T_3=B@o.30%), T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

E) Control (at open place)

Treatment	Nutrients content At room temp. (14-24^{0}c with RH 60-65%)							Nutrients content At room temp(4^{0}c with RH 90-95%)						
	Dry Matter (%)	**Protein (g)**	**Fat (g)**	**CHO (g)**	**Vitamin c (mg/100g)**	**Antioxidants (mg/100g**	**Phenol (mg/100g**	**Dry Matter (%)**	**Protein (g)**	**Fat (g)**	**CHO (g)**	**Vitamin c (mg/100g)**	**Antioxidant (mg/100g**	**Phenol (mg/100g)**
T_1	7.75c	2.08a	0.3686c	2.24c	47.56d	37.85d	15.49e	8.75b	1.85c	0.3673	2.49d	53.25b	45.33d	20.33d
T_2	9.53abc	2.21ab	0.4099ab	2.79bc	55.06cd	46.24bcd	19.76cde	10.46ab	2.26abc	0.4075	3.17bcd	57.27b	48.26cd	23.27cd
T_3	11.36ab	2.40ab	0.4197a	3.28abc	65.35abc	52.91abc	25.46abc	11.67ab	2.49abc	0.4141	3.65abc	65.33ab	57.75abc	31.56ab
T_4	10.16abc	2.87ab	0.4221a	3.69ab	67.95ab	54.98ab	27.20ab	11.33ab	2.97a	0.4210	3.93ab	70.17a	61.43ab	33.37a
T_5	9.25abc	2.98a	0.3996ab	2.73bc	58.42abcd	47.03bcd	23.17bcd	9.45b	2.76ab	0.4017	2.87bcd	61.36ab	54.25abcd	28.17abc
T_6	8.63bc	2.14b	0.3817 bc	2.45c	56.27bcd	43.20cd	17.37de	9.17b	2.05bc	0.3824	2.77cd	59.21ab	51.26bcd	25.23bcd
T_7	12.05a	2.76ab	0.4260a	4.07a	69.16a	59.92a	30.35a	13.25a	2.83ab	0.4315	4.56a	71.35a	63.45a	34.36a
HSD (P=0.05)	0.35	0.61	0.01	0.05	0.05	0.01	0.01	0.20	0.22	0.01	0.03	0.23	0.04	0.01

Note: Here, these letters a, b, c, d indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control, T_2=Ca@o.30%, T_3=B@o.30%, T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

3.6. Shelf life

Table 7 and 8 revealed that pre-harvest foliar application effects of mineral nutrient sources and storage condition, along with each level of storage materials, had significantly influenced the shelf life of broccoli. The shelf life of broccoli at room condition (14-24^{0c} with RH 60-65%) ranged from 1.75 days to 7.25 days. A maximum shelf life of 7.25 days was observed in the treatment T_7 (Ca+B+Zn+Mo+Mn)@o.30% followed by T_3 (B@o.30%) with 6.13 days, and T_4 (Zn@o.30%) with 5.75 days where the brocolli was kept in High-Density Polyethylene (HDP;15 micron) Vacuum packs. A minimum shelf life 1.75 days was noted in the treatment T_1 (control) at open place conditions. On the other hand, the shelf life of broccoli in cold storage (4^{0C} with 90-95% RH) ranged from 11.33 days to 24.33 days. The maximum shelf life at cold storage 24.33 days was observed in the treatment T_7 (Ca+B+Zn+Mo+Mn)@o.30% followed by T_3 (B@o.30%) with 23.45 days, T_4 (Zn@o.30%) with 22.67 days and it was kept in a High-Density Polyethylene (HDP; 15 micron) Vacuum pack. This might be due to synergistic effects of pre-harvest foliar application of mineral nutrients and inorganic nutrient sources influenced broccoli longevity through increased nutrients uptake by the plants and enhanced greater development of water conducting tissue which enhanced the shelf life of broccoli. A minimum shelf life of 11.33 days was noted in treatment T_1 (control) in open place condition within cold storage. A maximum shelf life in both the storage conditions in a High-Density Polyethylene (HDP; 15 micron) Vacuum pack might be due to its sophisticated techniques which delayed and protected the physiological deterioration of broccoli curd. With High-Density Polyethylene (HDP; 15 micron) Vacuum pack having more control over the gas exchange with the surrounding air, the levels of CO_2 and O_2 around the produce might have further slowed down conversion of starch to sugars. Curds stored in the cold conditions had maintained a greener color and at the same time no chilling injury symptoms, no decay incidence, and no rot were observed. In addition, storage at low temperature reduced the rate of respiration, and delayed senescence during storage of curds. Pre-harvest foliar application of mineral nutrients in broccoli production and better storage conditions including appropriate use of scientific storage materials like the High-Density Polyethylene (HDP; 15 micron) Vacuum pack might protect the chlorophyll degradation and ethylene production. The synchronized effects of the said treatment might also protect available moisture and minimize the rate of respiration along with strengthening the cell wall in the vegetative parts of broccoli which restricted the yellowing color and reduced weight loss. This might have maintained the shelf life and quality of broccoli. The findings of present investigation in respect of shelf life corroborate with the findings of Jadhav (2018) in broccoli.

Table 7. Shelf life (days) comparison of storage materials at each level of treatment under different storage condition.

Treatment	Shelf life(days) At room temperature (14-24°C) with RH 60-65%					Shelf life(days) At Cold Storage (4°C with RH 90-95%)				
	storage materials					storage materials				
	LDP Polyethylene bag	HDP Vacuum pack	2% Egg shell power solution	2% Ascorbic acid solution	Control	LDP Polyethylene bag	HDP Vacuum pack	2% Egg shell power solution	2% Ascorbic acid solution	Control
T_1	3.29de	3.85d	2.33ef	2.25ef	1.75f	15.33b	17.25a	12.33c	11.33c	12.25c
T_2	4.25e	5.07e	2.67f	2.56f	2.33f	18.45b	20.36a	13.37c	11.66d	13.25c
T_3	5.33e	6.13e	3.45f	3.33f	3.05f	21.39b	23.45a	14.47c	12.47d	13.75cd
T_4	4.85e	5.75e	3.25f	3.13f	2.55f	20.56b	22.67a	14.16c	12.16d	13.63c
T_5	4.37e	5.23e	2.75f	2.45f	1.93f	18.60b	21.54a	13.55c	11.75d	13.25c
T_6	3.77de	4.16d	2.49ef	2.33ef	1.85f	16.51b	18.75a	12.79c	11.53c	12.36c
T_7	5.53f	7.25e	3.73g	3.69g	3.25g	22.47b	24.33a	15.25c	13.25d	15.17c
LSD(P=0.05)	0.0000									

Note: Here, these letters a, b, c, d, e, f, g indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control, T_2=Ca@o.30%, T_3=B@o.30%, T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

Table 8. Shelf life (days) comparison of treatment at each level of storage materials under different storage condition.

Treatment	Shelf life(days) At room temperature (14-24°C) with RH 60-65%)					Shelf life(days) At Cold Storage (4°C with RH 90-95%)				
	Storage materials					Storage materials				
	LDP Polyethylene bag	HDP Vacuum pack	2% Egg shell power solution	2% Ascorbic acid solution	Control	LDP Polyethylene bag	HDP Vacuum pack	2% Egg shell power solution	2% Ascorbic acid solution	Control
T_1	3.29c	3.85d	2.33b	2.25b	1.75b	15.33d	17.25f	12.33c	12.25d	11.33b
T_2	4.25abc	5.07bcd	2.67ab	2.56ab	2.33ab	18.45c	20.36d	13.37bc	13.15bcd	11.66b
T_3	5.33a	6.13ab	3.45ab	3.33ab	3.05ab	21.39ab	23.45ab	14.47ab	13.75b	12.47ab
T_4	4.85ab	5.75b	3.25ab	3.13ab	2.55ab	20.56b	22.67bc	14.16ab	13.63bc	12.16ab
T_5	4.37abc	5.23bc	2.75ab	2.45ab	1.93ab	18.60c	21.54cd	13.55bc	13.25bcd	11.75b
T_6	3.77bc	4.16cd	2.49ab	2.33b	1.85b	16.15d	18.75e	12.79c	12.36cd	11.53b
T_7	5.53a	7.25a	3.73a	3.69a	3.25a	22.47a	24.33a	15.25a	15.17a	13.25a
LSD(P =0.05)	0.0000									

Note: Here, these letters a, b, c, d, e, f indicate the significant treatment among all the treatments. Means with the same letter are not significantly different, T_1=control, T_2=Ca@o.30%, T_3=B@o.30%), T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.

3.7. Economic Consideration

Table 9 revealed that maximum gross returns of BDT 427650 ha^{-1} and maximum net returns of BDT 307854 ha^{-1} were observed in the treatment T_7 (Ca+B+Zn+Mo+Mn)@ 0.30% followed by T_3 (B @ 0.30%) with maximum gross returns of BDT 399450ha-^{1} and maximum net returns of BDT290580 ha-^{1}, and T_4 (Zn@o.30%) with maximum gross returns of BDT 392550ha-^{1} and maximum net returns of BDT283230 ha-^{1}respectively. Minimum gross returns of BDT 341250 ha^{-1} and minimum net returns of BDT 233880 ha^{-1}noted were observed in treatmentT_1 (control). A maximum Benefit-Cost ratio (BCR) of 3.66 was recorded in the treatment T_3 (B@o.30%), followed by T_4 (Zn@o.30%) with BCR 3.58, and T_7 (Ca+B+Zn+Mo+Mn)@o.30% with BCR 3.57 respectively. This investigation corroborates with Sharma (2012), Singh et al. (2018) and Shatis et al. (2018); in broccoli.

Table 9. Economic of broccoli production by pre-harvest foliar application effects of mineral nutrients.

Treatment	Marketable yield(t ha^{-1})	Cost of production (Tk. ha^{-1})	Gross returns (Tk. ha^{-1})	Net returns (Tk. ha^{-1})	Benefit Cost ratio.(BCR)
T_1	22.75	107370	341250	233880	3.18
T_2	23.72	109427	355800	246555	3.25
T_3	26.63	109015	399450	290580	3.66
T_4	26.17	109510	392550	283230	3.58
T_5	25.51	111484	382650	271530	3.43
T_6	23.46	109839	351900	242280	3.20
T_7	28.51	119796	427650	307854	3.57

Note: Here, T_1=control, T_2=Ca@o.30%, T_3=B@o.30%), T_4=Zn@o.30%, T_5=Mo@o.30%, T_6=Mn@o.30% and T_7=(Ca+B+Zn+Mo+Mn)@o.30%.
Sale rate of broccoli @ 15Tk/kg.

4. CONCLUSION

The inference of the present investigation that pre-harvest foliar application of combined mineral nutrients of Ca, B,Zn,Mo and Mn with 0.30% of each concentration performed the best regarding higher yield, gross, and net returns at the grower level. Broccoli also produced through foliar application of the said mineral nutrients is the best for consumption and getting quality attributes and shelf life of broccoli. In addition, use of the High-Density Polyethylene (HDP; 15 micron) Vacuum pack has been considered an effective technology for maintaining the shelf life of broccoli both at room temperature (14-24^{0}c with RH 60-65%) and in cold storage (4^{0}c with RH 90-95%).

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study.

REFERENCES

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

Brand-Williams, W., Cuvelier, M. E., & Berset, C. L. W. T. (1995). Use of a free radical method to evaluate antioxidant activity. *LWT-Food science and Technology, 28*(1), 25-30.

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.

Chaudhari, V. J., Patel, N. K., Tandel, B. M., & Vibhuti, C. (2017). Effect of foliar spray of micronutrients on growth and yield of cauliflower (Brassica oleracea L. var. Botrytis). *International Journal of Chemical Studies, 5*(6), 1133-1135.

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.

Choudhury, R. S., & Sikder, S. (2017). Study the manifestation of growth and yield attributes of broccoli through application of Boron, Molybdenum, Zinc and their combination treatments in Teraiagro-Ecological Region of West Bengal. *Current Agriculture Research Journal, 5*(3), 366- 370.

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*, 1714-1718.

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.

Li, Z., & Gao, X. (2000). The effects of storage temperatures on the qualities of broccoli. *China Vegetables, 4*, 6-9.

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.

Manisha, C., & Rajkumari, A. D. (2020). Influence of packaging material and storage temperature on the shelflife and quality of broccoli: A review. *Journal of Pharmacognosy and Phytochemistry, 9*(6), 233-237.

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

Pankaj, P., Kujur, P. K., & Saravanan, S. (2018). Effect of different micronutrient on plant quality of broccoli (Brassica oleracea var. italica) CV Green Magic. *Journal of Pharmacognosy and Phytochemistry, 2*(1), 2825-2828.

Ranganna, S. (1986). Handbook of analysis and quality control for fruits and vegetables products (2nd ed., pp. 497-529). New Delhi, India: Tata McGraw Hill Publication Co. Ltd.

Rice-Evans, C., Miller, N., & Paganga, G. (1997). Antioxidant properties of phenolic compounds. *Trends in Plant Science, 2*(4), 152-159.

Sharma, P. (2012). *Effect of foliar spray of micronutrients on growth, yield and quality of broccoli (Brassica oleracea var. italica) cv. Pusa KTS-1*. (Doctoral Dissertation, Institution of Agricultural Sciences, Banaras Hindu University), India.

Shatis, X., Praveen, C., Radhelal, D., Preeti, T., Mithlesh, G., & Sunny, A. T. (2018). Effect of different micronutrients on plant growth and yield of broccoli (Brassica oleracea var. Italica). *International Journal of Chemical Studies, 6*(4), 979-982.

Singh, V., Singh, A. K., Singh, S., Kumar, A., & Mohrana, D. P. (2018). Impact of foliar spray of micronutrients on growth, yield and quality of broccoli (Brassica oleracea var. italica) cv. Pusa KTS-1. *The Pharma Innovation Journal*, *7*(8), 99-101.

Singh, G. S., Sarvanan, K. S. R., Jalam, S. R., & Bhanwar, L. (2016). Effect of different micronutrients on plant growth, yield and flower bud quality of broccoli (Brassica oleracea var. Italica) cv. *Green Bud. International Journal Adv. Res*, *4*(9), 2018-2043.

Slinkard, K., & Singleton, V. L. (1977). Total phenol analysis: Automation and comparison with manual methods. *American Journal of Enology and Viticulture*, *28*(1), 49-55.

Yvette, P. (2012). Vacuum pack for maintaining the shelf life of broccoli.Bioscience Horizons. *The International Journal of Student Research*, *5*(4), 23-34.

Zaki, M. F., Abdelhafez, A. A. M., El-dewiny, Y., & Camilia. (2009). Influence of bio-fertilization and nitrogen sources on growth, yield and quality of broccoli (Brassica olercea Var. Italica). *Egyptian Journal of Applied Science*, *24*(3), 86-111.