Influence of Foliar Spraying of Gibberellic Acid, Abscicic Acid and Seaweed Extracts on Vegetative Growth, Quality and Storability of Broccoli.

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ABSTRACT

Two field and postharvest experiments were carried out on the broccoli plant during the winter seasons of 2020 and 2021. This study was conducted to a: evaluate the effect of foliar spraying (two levels) with gibberellic acid (GA_3) 50 mg/L,100 mg/L, abscisic acid (ABA) 50 mg/L,100 mg/L, and seaweed extract 1000 mg/L,2000 mg/L on some traits of vegetative growth, heads, total yield, and some quality traits, b: to investigate the impact of past prior to harvesting treatments on broccoli perfect variety during different cold storage periods. The results showed that the treated broccoli plants were significantly superior in vegetative growth, head characteristics and total yield compared to the untreated plants (control). These treatments also had a positive effect on the quality characteristics of broccoli heads postharvest, with high significant differences compared to the control treatment, until the end of the cold storage period in both seasons. The treatment with the higher concentration for each treatment gave higher values for most of the studied traits. The results showed that spray with higher level of seaweed (2000 mg/L), was excelled in all studied traits until the end of the experiment. It was also the best treatment that reduced weight loss and maintained an excellent general appearance for up to 28 days. It preserved the content of broccoli heads of vitamin C, total soluble solids, total phenols content, and total chlorophyll. It also attempted to limit peroxidase enzyme activity during cold storage in both seasons. While the control treatment had the lowest values of all studied characters.

Keywords: Broccoli-GA_3-ABA- Seaweed extract -Cold storage.

INTRODUCTION

Broccoli (*Brassica oleracea L.* var. Italica) is a member of the Brassicaceae family, which also includes cauliflower and cabbage. Broccoli is beneficial to human health because it contains antioxidants that prevent cancer; it also has several nutritional benefits owing to the presence of vitamins (E, A, B1, B2, B5, and B6) and minerals (Fe, Zn, Ca, and Mg) (Al-jaf et al., 2018). According to Yong Chen et al. (2020), the head of broccoli is known as the "king of vegetables" due to its high nutritional, antioxidant, and anti-carcinogenic component content.

Broccoli postharvest is vulnerable to yellowing, quality degradation, hormone and nutritional depletion, and accelerated aging (Perini et al., 2017). Many preservations can help delay senescence and maintain quality. Among the methods of preserving broccoli are pre-harvest treatments with some plant hormones and seaweed to maintain the postharvest quality and storage ability of broccoli.

Gibberellins are plant hormones that are essential in regulating the growth and development of fruits (Huang and Liang 2012). Pooja et al. (2019) found that the foliar application of GA_3 improved broccoli growth characteristics. Manjit et al., (2011) and Thapa et al., (2013) studied the effect of GA_3 on growth and quality of sprouting broccoli. They clarified that the increase in head weight and yield could be attributed to increased carbohydrate accumulation via increased photosynthesis, increased cell division, cell elongation, and cell expansion, all of which could have increased yield. Mamunur et al. (2015) reported that foliar application of different concentrations of GA_3 increased yield. Manjit et al. (2011) found that GA_3 has a strong relationship with broccoli growth and yield. Saleh (1990) showed that the GA_3 plant hormones play an important role in postharvest fruit and vegetable preservation stimulated cell growth and expansion by increasing cell wall plasticity played important roles in delaying horticultural crop ripening and senescence, enhancing the internal and external quality of horticultural crops.

Abscisic acid (ABA) is a significant phytohormone that regulates plant growth and development, stress responses, and a variety of physiological activities (Gupta et al., 2022and Yoshida et al., 2019). According to Kou et al. (2021), abscisic acid is a crucial plant hormone that controls the ripening of fruit, plays a role in the processes of softening, coloring, and the synthesis of aromatic substances. It accomplishes these goals by acting directly or indirectly on substances that control important ripening genes, other plant hormones, transcription factors, sugars, and polyamines (Kou et al., 2021). It supports growth and productivity, as well as maintaining quality postharvest may be attributed to works as a multipurpose mediator of numerous physiological processes (Gupta et al.,2022, Liu et al., 2022 and Shibata and Sugimoto, 2019) cleared that ABA supports shoot growth, plants' root growth and leaf senescence are promoted. Furthermore, Miret et al. (2018) and Zhao et al. (2016) showed that ABA promotes and protects chloroplast functionality. During fruit ripening, ABA export decreases, leading to ABA accumulation in ripening fruit. ABA controls fruit growth, ripening, and senescence, with interactions between ABA and ethylene found in both climacteric and non-climacteric fruits. Although it is known that ABA regulates ethylene production and signaling during fruit ripening, the molecular mechanism governing this connection has yet to be uncovered. (Gupta et al., 2022).

Seaweeds are one of the world's most valuable marine resources, utilized as human food, animal feed, and raw materials in a variety of industries. In 2019, 35.8 million tons of algae were produced in the world (FAO, 2021) with a significant amount of it being utilized as biofertilizers in agriculture. The benefits of Seaweed products on cultured plants have been well documented; these compounds boost, seedling development, plant tolerance to environmental challenges, and plant growth and yield (Kumari et al., 2011). Currently, using Seaweeds as plant bio stimulants is one of their most exciting uses. This impact is explained by the presence of chemicals in the algal extracts that promote plant development, such as auxins, gibberellins, cytokinins, ethylene, polyamines, and betaines (Blunden et al., 2010 and Prasad et al., 2010). The aim of this study was to investigate the effect of the pre-harvest applications of GA_3, ABA, and Seaweed extract on some vegetative growth characteristics**,** yield and some postharvest quality traits of broccoli crop during cold storage.

MATERIALS AND METHODS

Field Experiment

Field experiments were carried out during the winter seasons of 2020 and 2021. The experiment was conducted at a privet farm in Alexandria, to investigate the effect of foliar spray by plant growth regulators GA_3, ABA, and Seaweed extract on the growth and yield of broccoli. Seven treatments were applied as a foliar application using two levels for each growth regulator in addition to control treatment as follows:

1- Control (spray with distilled water).

2- Lower level of Gibberilic acid (GA_3 50 mg/L).

3- Higher level of Gibberilic acid (GA_3 100 mg/L).

4- Lower level of Abscisic acid (ABA 50 mg/L).

5- Higher level of Abscisic acid (ABA 100 mg/L).
6- Lower level of Seaweed extract (1000 mg/L).
7- Higher level of Seaweed extract (2000 mg/L).

The experiment design was Randomized Complete Block Design with three replications. Each experiment unit consisted of three rows, with 4.0 × 0.7meter row size, spacing of plant was 30 cm, apart occupying an area of 2.8 square meters. A guard raw was left between each plot as a separator. The above areas were planted with broccoli seedlings, cv. perfect in 20/9/2020and 25 / 9/2021 for the first and second season, respectively.

The treatments were applied as a foliar application three times. Thirty days after planting, the first foliar spray was applied in the morning. Following the wetting agent, then the second leaf treatment was applied at 45 days, and the third application was applied at 60 days following planting. With the aid of the knapsack sprayer, the leaves were uniformly sprayed until the entire surface was covered with spray solution. Representative broccoli plants determined the total amount of solution needed to be sprayed on the experimental plants. After ninety days following planting, the harvest is done.

Vegetative growth characters

Representative samples of five plants were taken randomly from each plot after 75 days from transplanting and the vegetative growth parameters were determined as follows. The average plant height was measured in cm from the soil surface to the plant top. Leaves area/plant were calculated according to the formula described by Koller (1972) as follows: leaf area/plant = fresh weight of leaves/plant (g)/fresh weight of 20 disks× 20 × area of one disk. Number of leaves per plant as an average of the previously five plants.

Head characters and total yield:

Five heads samples were collected from each plot to determine the head weight, length(cm), diameter, and the head compactness index, which was computed using the formula: Head compactness index = main head weight/plant (g)/head diameter (cm) (Metwaly, 2016) .Dry matter: head samples were dried in an electrical oven at 70°C until they reached a consistent weight, and the dry weight percentage of the heads was computed as follows: dry weight %= head dry weight/head fresh *100 . Total yield: at harvest time, 90 days after planting, all heads of each plot were collected, then it was calculated in tons per feddan.

Postharvest Experiment

The broccoli crop was transferred to the post-harvest center, Faculty of Agriculture, Alexandria University during the seasons of 2020 and 2021. The goal of this experiment was to investigate the impact of prior-to-harvesting treatments on broccoli perfect variety during different cold storage periods; Representative samples of broccoli yield for each treatment were used. This experiment was factorial experiment included two factors; seven pre harvest treatments and five storage periods. The samples were divided into three replicates in a completely randomized design, each treatment contained15 heads. The heads were wrapped with sealed polypropylene bags (35 µm) and then packed in plastic boxes; all samples were stored at a temperature of 0°C and 95 % RH for 28 days. Three replicates of each treatment were tested at 7days intervals until 28 days for the following qualities characteristics:

Visual characters

The following equation was used to compute the weight loss percentage: Loss in weight% = Initial weight of head - weight of head at sample date / the initial weight of the head x 100. As detailed by Kader et al. (1973), general appearance was rated on a scale of 9 to 1, with (9) excellent, (7) good, (5) fair, (3) bad, and (1) unsalable head grading (5) or lower being unmarketable. The aroma was assessed using a five-point scale: 5 = no off-odors, 3 = light off-odors but noticeable and 1=strong off-odors. The color rating scale was as follows: 5=dark green, 3 = light green, 1 = yellowing/yellow. The following scale was used to assess texture: 5 = very firm, 4=firm, 3=lightly wilted but acceptable, 2 = wilted, 1 = very wilted. (Toivnen and Deell, 2001)

Chemical component

Total chlorophylls (a + b) were calculated using Goodwine's (1965) approach. Carotenoids were determined using the method given by Hartmut (1987). A.O.A.C. (2000) was used to calculate vitamin C levels. The total soluble solid percentage was calculated using an Abbe Leica digital refractometer. The peroxidase enzyme activity is measured according to Ranganna (1991). Gsecka et al. (2015) proposed a technique for determining total phenolic content (TPC).

Statistical Analysis

According to El-Rawy and Khalf-Allah (1980), the recorded data were statistically examined. The differences in the means of the treatments under study were compared using the revised L.S.D. test, as described by Smith (1978).

RESULTS AND DISCUSSIONS

Field Experiment

Vegetative growth characters

The results regarding that the differences due to the studied factors on the vegetative growth characters of broccoli plants which included plant height, leaf area plant^{-1}, and number of leaves plant^{-1}are shown in **Table (1).** The results in **Table (1)** clearly indicated that plant height, leaf area and number of leaves were significantly increased by all applications of different plant growth regulators as compare to control. Comparing among the six growth regulators treatments, The Seaweed2000 mg/L treatment recorded the highest values with significant differences for plant height (89.00, 95.00 cm), leaf area per plant (690.26, 695.00 cm^2) and number of leaves per plant (27.66, 28.66), in both seasons. Whereas, the lowest values for plant height (67.66, 71.66 cm), leaf area per plant (616.77, 622.47) and number of leaves per plant (19.33, 20.66) were reflected by $GA_3$50 mg/L treatment in both seasons, respectively.

Table (1). Effect of Gibberellic Acid, Abscisic Acid and Seaweed extract treatments on vegetative growth characteristics of Broccoli in the 2020 and 2021 seasons.

Treatments	Plant height (cm)		Leaf area (cm)^2		Number of leaves plant^{-1}	
	2020	2021	2020	2021	2020	2021
Control	55.00G	58.00F	542.12G	554.03G	14.00F	15.00F
$GA_3$50 mg/L	67.66F	71.66E	616.77F	622.47F	19.33E	20.66E
$GA_3$100 mg/L	77.33D	80.66C	626.75E	631.67E	22.66D	23.66D
ABA50 mg/L	71.66E	75.33D	633.25D	645.77D	24.33C	25.33C
ABA100 mg/L	78.66C	81.66BC	642.29C	664.17C	25.33B	26.00BC
Seaweed 1000 mg/L	81.00B	83.00B	666.21B	676.81B	25.66B	26.66B
Seaweed 2000 mg/L	89.00A	95.00A	690.26A	695.00A	27.66A	28.66A

The L.S.D. multiple rang test shows that means in the same column with the same letter are not significantly different at the 0.05 level.

Head characters and total yield:

The results in **Table (2)** showed that the all growth regulators treatments were superior to the control treatment during the two seasons. The Seaweed extract 2000mg/L treatment gave the highest weight, length, and diameter of the heads in both seasons, followed by the treatment of Seaweed 1000mg/L, for the two characters head weight and head length. However, the treatment ABA 100mg/L showed superiority in head diameter (cm) characteristics over the treatment Seaweed1000mg/L. On the other hand, the lowest value among the six treatments for each of the weight, length, and diameter of the head was reflected by the $GA_3$50mg/L then ABA50mg/L.

Table (2). Effect of Gibberellic Acid, Abscisic Acid and Seaweed extract treatments on head characters of Broccoli in 2020 and 2021 seasons.

Treatments	Head weight (g)		Head length (cm)		Head diameter(cm)	
	2020	2021	2020	2021	2020	2021
Control	458.00G	465.13G	10.13G	10.63G	13.80G	14.16F
$GA_3$50 mg/L	677.00F	685.66F	12.03F	12.63F	15.30F	15.86E
$GA_3$100 mg/L	742.00D	773.30D	15.70D	16.46D	17.13C	17.63C
ABA50 mg/L	722.00E	744.00E	14.26E	15.60E	15.86E	16.33D
ABA100 mg/L	833.00C	843.33C	16.30C	17.60C	17.70B	18.16B
Seaweed1000 mg/L	888.00B	891.66B	17.30B	18.33B	16.56D	16.70D
Seaweed2000 mg/L	986.00A	988.30A	18.30A	19.70A	18.06A	18.70A

The L.S.D. multiple rang test shows that means in the same column with the same letter are not significantly different at the 0.05 level.

Results in **Table (3)** investigated that the effect of foliar application treatments on head compactness (g/cm), dry matter% and total yield (ton/fed) were superior to the control treatment during both seasons. The results clarified that the plants which treated with seaweed extract 2000 mg/L reflected the highest value for the three characters head compactness, dry matter% and total yield followed by the treatment of seaweed 1000 mg/L. While the differences between the two Seaweed treatments regarding the compactness of heads did not reach the level of significance in both seasons.

Table (3). Effect of Gibberellic Acid, Abscisic Acid and Seaweed extract Treatments on head compactness, dry matter and total yield characteristics of Broccoli in the 2020 and 2021 seasons.

Treatments	Head compactness(g/cm)		Dry matter%		Total yield(ton/fed)	
	2020	2021	2020	2021	2020	2021
Control	33.16D	32.86D	7.81E	8.81E	3.43 F	3.64 F
GA350 mg/L	44.23C	43.21C	8.60D	9.82D	6.22E	6.27 E
GA3100 mg/L	43.30C	43.84C	8.81D	9.15DE	6.32 D	6.37 D
ABA50 mg/L	45.50C	45.55B	9.64C	9.80D	6.25 E	6.28 E
ABA100 mg/L	50.05B	46.42B	10.52B	10.71C	6.42 C	6.53 C
Seaweed1000 mg/L	53.61A	53.39A	10.72B	11.45B	6.72 B	6.82 B
Seaweed2000 mg/L	54.57A	53.85A	11.52A	12.51A	7.20 A	7.34 A

The L.S.D. multiple rang test shows that means in the same column with the same letter are not significantly different at the 0.05 level.

Visual characters of postharvest experiment

Weight loss percentage

Table (4) showed that pre-harvest treatments affect the post-harvest weight loss percentage of broccoli, weight loss % decreasing with storage duration over two years. All treatments minimized head weight loss rates compared to the control, and pre-harvest treatments significantly impacted weight loss percentages during storage. In both seasons, the broccoli head treated with Seaweed 2000 mg/L had a lower weight loss percent in broccoli heads (cm), whereas the GA_3 50mg/L treatment had the highest weight loss percentage. In two seasons, the relationship between pre-harvest treatments and storage durations was substantial. Broccoli plants sprayed with seaweed 2000mg/L showed the lowest percentage of weight loss in heads after 28 days of cold storage in two seasons compared with control at the same time.

General appearance:

Table (5) showed that the effect of pre-harvest treatments on the general appearance (GA) of broccoli heads postharvest, it was decreased with the prolongation of the storage period in both seasons. All pre-harvest treatments had the highest significant score of appearance compared to the untreated control. In both seasons, the relationship between pre-harvest treatments and postharvest storage durations was significant. The results revealed that broccoli heads sprayed with seaweed 2000mg/L did not exhibit any change in GA and had an excellent appearance at the end of the storage period (28 days of storage), while the untreated heads (control) had a poor overall appearance at the same time.

Table (4). Effect of gibberellic acid, abscisic acid and seaweed extract treatments on weight loss (%) of Broccoli during different cold storage periods in the 2020 and 2021 seasons.

Pre harvest Treatments	Cold Storage Period (day)					
	0	7	14	21	28	Mean
	First Season 2020					
Control	0.00y	9.62k	22.34d	41.70b	67.98a	28.33A
GA_3 50 mg/L	0.00y	1.7u	5.5o	13.57h	26.37c	9.43B
GA_3 100 mg/L	0.00y	1.13v	3.58qr	9.96j	18.50e	6.63C
ABA 50 mg/L	0.00y	1.03v	3.36r	8.91l	17.21 f	6.10CD
ABA 100 mg/L	0.00y	0.9vw	2.68s	7.62n	14.90g	5.22D
Seawead 1000 mg/L	0.00y	0.7wx	2.09t	4.87p	10.53i	3.64E
Seawead 2000 mg/L	0.00y	0.5x	1.62u	3.88q	8.53m	2.90E
Mean	0.00E	2.22D	5.88C	12.93B	23.43A	
	Second Season 2021					
Control	0.00u	8.24l	21.35d	38.34b	60.67a	25.72A
GA_3 50 mg/L	0.00u	1.45r	4.35no	11.63h	23.39c	8.16B
GA_3 100 mg/L	0.00u	1.17s	3.13p	9.13j	17.23e	6.13C
ABA 50 mg/L	0.00u	0.92t	2.94p	8.2l	15.47f	5.50D
ABA 100 mg/L	0.00u	0.76t	2.25q	6.38m	12.89g	4.46E
Seawead 1000 mg/L	0.00u	0.76t	2.21q	4.55n	9.48i	3.42F
Seawead 2000 mg/L	0.00u	0.84t	1.68r	4.13o	8.6k	3.03G
Mean	0.00E	2.02D	5.42C	11.76B	21.10A	

The L.S.D multiple rang test shows that means in the same column with the same letter are not significantly different at the 0.05 level

Table (5). Effect of gibberellic acid, abscisic acid and seaweed extract treatments on general appearance (score) of Broccoli during different cold storage periods in the 2020 and 2021 seasons.

Pre harvest Treatments	Cold Storage Period (day)					
	0	7	14	21	28	Mean
	First Season 2020					
Control	9.00a	8.80ab	7.30c	5.60d	3.60e	6.80C
GA_3 50 mg/L	9.00a	9.00a	9.00a	8.30ab	6.30d	8.30B
GA_3 100 mg/L	9.00a	9.00a	9.00a	8.60a	7.60bc	8.60AB
ABA 50 mg/L	9.00a	9.00a	9.00a	8.30ab	7.60bc	8.60AB
ABA 100 mg/L	9.00a	9.00a	9.00a	8.60a	7.60bc	8.60AB
Seawead 1000 mg/L	9.00a	9.00a	9.00a	9.00a	7.60bc	8.70A
Seawead 2000 mg/L	9.00a	9.00a	9.00a	9.00a	8.30ab	8.80A
Mean	9.00A	8.90A	8.70B	8.20C	7.00D	
	Second Season 2021					
Control	9.00a	8.60ab	7.60d	6.30f	4.30g	7.20C
GA_3 50 mg/L	9.00a	9.00a	9.00a	8.60ab	7.00e	8.50B
GA_3 100 mg/L	9.00a	9.00a	9.00a	8.60ab	7.60d	8.60AB
ABA 50 mg/L	9.00a	9.00a	9.00a	8.60ab	8.00cd	8.70AB
ABA 100 mg/L	9.00a	9.00a	9.00a	8.60ab	8.30bc	8.80AB
Seawead 1000 mg/L	9.00a	9.00a	9.00a	9.00a	8.60ab	8.90A
Seawead 2000 mg/L	9.00a	9.00a	9.00a	9.00a	8.60ab	8.90A
Mean	9.00A	8.90A	8.80A	8.40B	7.50C	

The L.S.D. multiple rang test shows that means in the same column with the same letter are not significantly different at the 0.05 level.

Aroma, Color and Texture

Results in **Figures (1-6)** clearly demonstrated the impact of pre-harvest interventions on postharvest aroma, color and texture of broccoli heads compared with the untreated plants in two years, respectively. Despite of, the results obtained that these traits decreased with the storage period. But also, showed that the pre-harvest treatments maintained significantly the excellent value of aroma, color and texture until 14 day, and good quality at the end of the experiment compared with the control treatment. Concerning the interaction among treatments, the differences were not significant except for the GA_3 50mg/L. plants sprayed with seaweed treatment showed highest values for aroma, color and texture until the end of the experiment for both seasons.

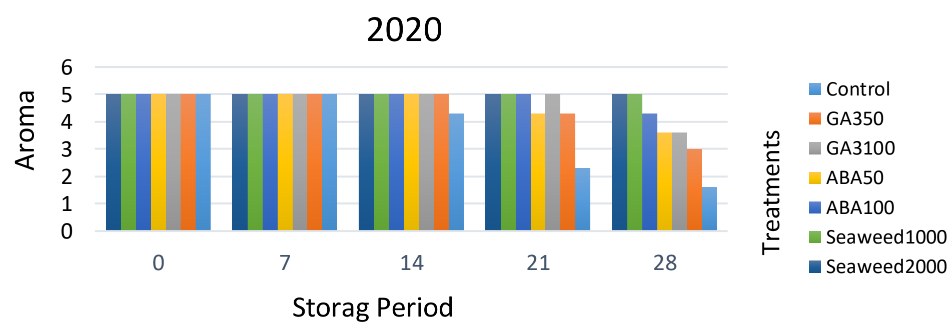

Fig. 1. Effect of Gibberellic Acid, Abscisic Acid and Seaweed Extract treatments on…

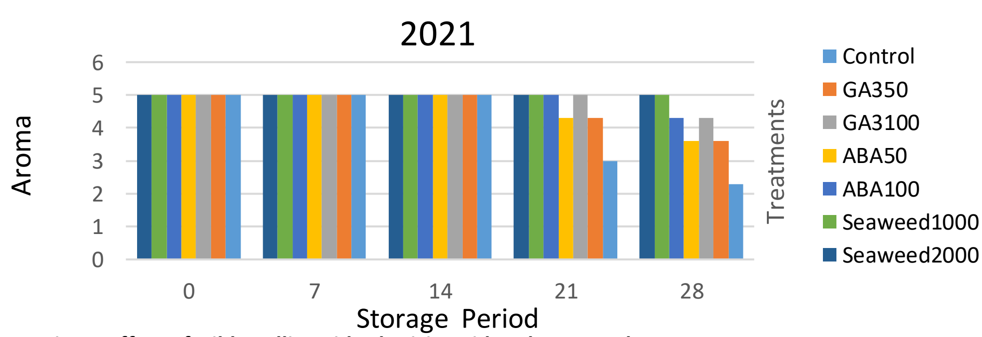

Fig. 2. Effect of Gibberellic Acid, Abscisic Acid and Seaweed Extract treatments on Aroma of Broccoli

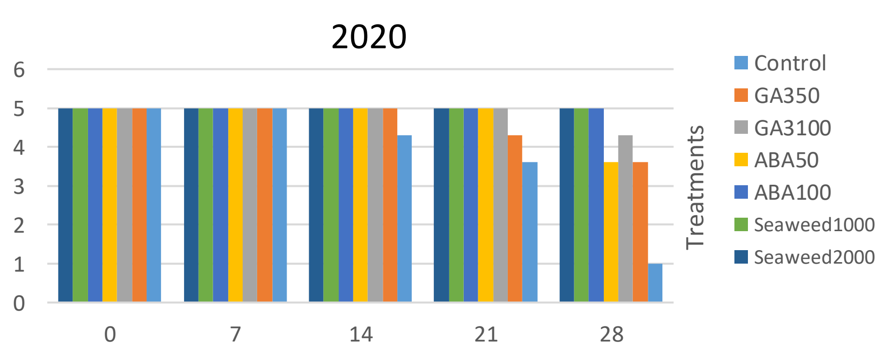

Fig.3. Effect of Gibberellic Acid, Abscisic Acid and Seaweed Extract treatments on Color of Broccoli

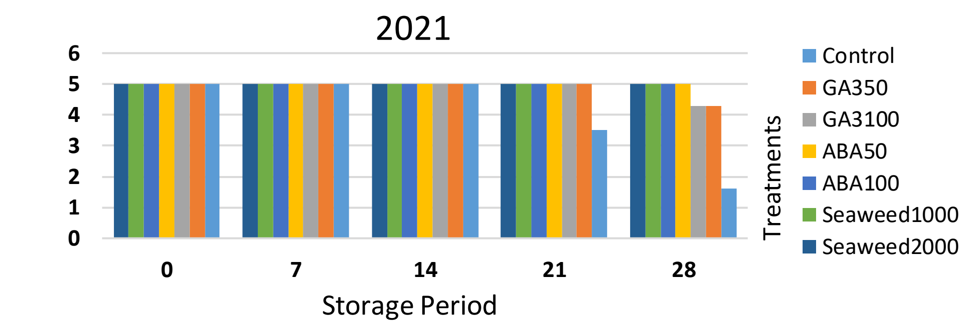

Fig. 4. Effect of Gibberellic Acid, Abscisic Acid and Seaweed Extract treatments on Color of Broccoli

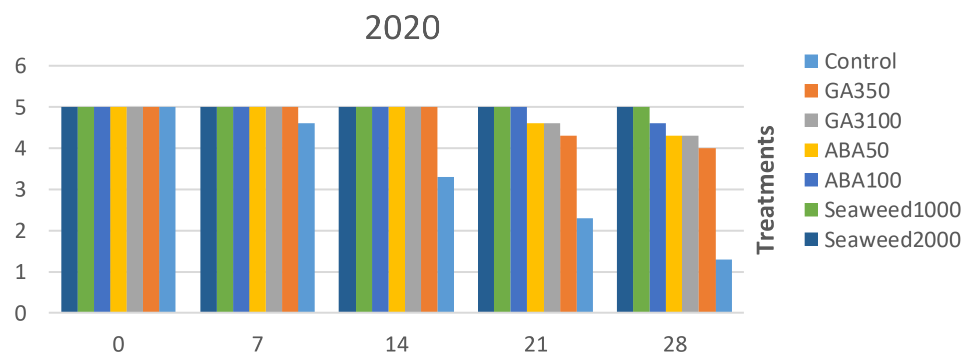

Fig.5. Effect of Gibberellic Acid, Abscisic Acid and Seaweed Extract treatments on Texture of Broccoli

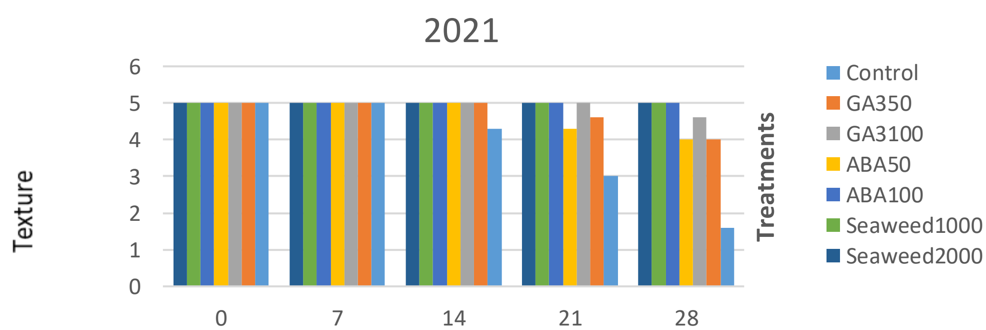

Fig.6. Effect of Gibberellic Acid, Abscisic Acid and Seaweed Extract treatments on Texture of Broccoli

Chemical component

Total chlorophyll content

Data in **Table (6)** illustrated the effect of pre- harvest treatments on the total chlorophyll of broccoli heads during cold storage periods in both years. Results cleared that all pre- harvest treatments gave significantly higher total chlorophyll than the control treatment in both seasons. The total chlorophyll decreased significantly by the increasing storage period in both seasons. Sprayed plants with Seaweed extracts had the highest total chlorophyll value in both seasons compared with other treatments. Concerning the interaction among treatments, it was observed that the Broccoli heads that were treated with pre-harvest treatments had double the quantity of total chlorophyll almost at 28 days of storage period (87.3) (89.3) compared to the control treatments (48.3) (55.3) in both seasons, respectively. It was also noted from the results that plants treated with the higher concentration of GA_3, ABA and Seaweed applications contained higher chlorophyll than plants treated with the lower concentration.

Table (6). Effect of Gibberellic Acid, Abscisic Acid and Seaweed extract treatments on total chlorophyll (mg/100 g f.w.) of Broccoli during different cold storage periods in the 2020 and 2021 seasons.

Pre harvest Treatments	Cold Storage Period (day)					
	0	7	14	21	28	Mean
First Season 2020						
Control	87.90v	79.90x	74.20y	65.0z	48.30a	71.10G
GA_3 50 mg/L	95.80mn	92.70q	89.40u	87.5v	85.40w	90.20F
GA_3 100 mg/L	97.60l	95.30no	91.40s	90.2t	89.00u	92.70E
ABA 50 mg/L	100.20h	98.20k	96.10m	94.6p	92.10r	96.30D
ABA 100 mg/L	102.10f	100.70h	99.10j	97.1l	95.20o	98.80C
Seaweed 1000 mg/L	104.60d	103.30e	101.30g	99.7i	97.60l	101.31B
Seaweed 2000 mg/L	110.40a	108.50b	107.10c	105.0d	103.30e	106.80A
Mean	99.80A	96.90B	94.10C	91.30D	87.30E	
Second Season 2021						
Control	91.00p	87.50q	79.10r	70.20s	55.30t	76.60G
GA_3 50 mg/L	97.40ij	95.80k-m	93.90no	90.70p	87.10q	93.00F
GA_3 100 mg/L	99.40g	97.10ij	95.60lm	93.80o	91.20p	95.40E
ABA 50 mg/L	99.50g	98.20hl	97.00i-k	95.20m	93.90no	96.80D
ABA 100 mg/L	102.10e	99.80fg	98.80gh	96.80j-l	95.00mn	98.50C
Seaweed 1000 mg/L	104.20d	102.30e	100.70f	98.80fg	97.10ij	100.60B
Seaweed 2000 mg/L	111.4a	108.40b	107.50bc	106.90C	105.40d	107.90A
Mean	100.70A	98.30B	96.20C	93.20D	89.30E	

The L.S.D. multiple rang test shows that means in the same column with the same letter are not significantly different at the 0.05 level.

Carotene Content

Table (7) showed the influence of pre-harvest interventions on the carotene content of broccoli heads under different cold storage periods, in both seasons. The findings revealed that the carotene content of head broccoli increased with storage time. In terms of how pre-harvest treatments affect the quantity of carotene in broccoli heads after harvest, the results showed gradual decreasing carotene content for preharvest treatments compared to the control treatment at different storage period in both years. The significant differences among the treatments were not high, but the Seaweed 2000mg/L treatment had the least amount of carotene (7.59) (7.23) and GA_3 50 mg/L treatment was the highest amount (7.99) (7.52) in both seasons respectively.

Ascorbic acid content

Data in **Table (8)** revealed the effect of pre-harvest treatments on vitamin C content (V.C) of broccoli heads during cold storage in both seasons. The results showed that vitamin C decreased as the storage period increased in both seasons. All treatments maintained the vitamin C content of broccoli until the end of the experiment, where the vitamin C content in the treated heads reached approximately three times (91.64) from Seaweed 2000 mg/L treatment at 28 days than vitamin C content in the control (28.97) in the first season, and more than double (92.11) from Seaweed 2000mg/L treatment at 28 days compared to the control (32.56) in the second season during cold storage.

Table (7). Effect of gibberellic acid, abscisic acid and seaweed extract treatments on carotene content (mg/ 100 g f.w.) of Broccoli during different cold storage periods in the 2020 and 2021 seasons.

Pre harvest Treatments	Cold Storage Period (day)					
	0	7	14	21	28	Mean
			First Season 2020			
Control	6.56p	10.77d	14.74c	22.24b	23.11a	15.49A
GA_3 50 mg/L	6.56p	6.93m-o	7.94ij	8.89f	9.64e	7.99B
GA_3 100 mg/L	6.58p	6.91m-o	7.77jk	8.60fg	9.51e	7.88B-D
ABA 50 mg/L	6.55p	6.95mn	7.76jk	8.88f	9.53e	7.93BC
ABA 100 mg/L	6.54p	6.72n-p	7.55kl	8.62fg	9.44e	7.78CD
Seaweed 1000 mg/L	6.55p	6.82n-p	7.46kl	8.45gh	9.43e	7.74DE
Seaweed 2000 mg/L	6.51p	6.68n-p	7.25lm	8.22hi	9.31e	7.59E
Mean	6.55E	7.40D	8.64C	10.56B	11.42A	
			Second Season 2021			
Control	6.49ij	11.53d	18.25c	22.75b	25.21a	16.85A
GA_3 50 mg/L	6.48ij	6.78h-j	7.60f	7.88f	8.88e	7.52B
GA_3 100 mg/L	6.45j	6.66h-j	7.57f	7.66f	8.78e	7.42BC
ABA 50 mg/L	6.44j	6.77h-j	7.64f	7.85f	8.89e	7.55B
ABA 100 mg/L	6.45j	6.65h-j	7.48fg	7.67f	8.87e	7.45BC
Seaweed 1000 mg/L	6.40j	6.56h-j	7.02gh	7.59f	8.84e	7.38BC
Seaweed 2000 mg/L	6.41j	6.54h-j	6.98g-i	7.48fg	8.74e	7.23C
Mean	6.44E	7.36 D	8.93C	9.84B	11.17A	

The L.S.D. multiple rang test shows that means in the same column with the same letter are not significantly different at the 0.05 level.

Table (8): Effect of gibberellic acid, abscisic acid and seaweed extract treatments on V.C (mg/100g f.w.) of Broccoli during different cold storage periods in the 2020 and 2021 seasons.

Pre harvest Treatments	Cold Storage Period (day)					
	0	7	14	21	28	Mean
		First Season 2020				
Control	97.79a	91.87k	84.87p	62.12q	28.97r	73.12F
GA_3 50 mg/L	97.76a	96.57b	95.13f	92.76j	90.11o	94.47E
GA_3 100 mg/L	97.73a	96.56b	95.16ef	92.98hi	90.21o	94.53E
ABA 50 mg/L	97.83a	96.45b	95.29d-f	92.87ij	90.65n	94.62D
ABA 100 mg/L	97.77a	96.55b	95.33de	92.99hi	91.31m	94.79C
Seaweed 1000 mg/L	97.88a	96.59b	95.34d	93.12h	91.53l	94.89B
Seaweed 2000 mg/L	97.89a	96.56b	95.52c	93.34g	91.64l	94.99A
Mean	97.81A	95.88B	93.81C	88.60D	82.06E	
			Second Season 2021			
Control	97.96ab	92.67r	86.45x	65.23y	32.56z	74.97F
GA_3 50 mg/L	97.94bc	96.70i	95.60m	93.21q	91.36w	94.96E
GA_3 100 mg/L	97.85ef	96.72hi	95.63lm	93.23q	91.45v	94.98E
ABA 50 mg/L	97.82f	96.76gh	95.64lm	93.40p	91.54u	95.03D
ABA 100 mg/L	97.88de	96.78g	95.66l	93.52o	91.55u	95.08C
Seaweed 1000 mg/L	97.92cd	96.77g	95.76k	93.54o	91.62t	95.12B
Seaweed 2000 mg/L	97.99a	96.98g	95.99j	94.22n	92.11s	95.24A
Mean	97.91A	96.17B	94.37C	89.42D	83.12E	

The L.S.D. multiple rang test shows that means in the same column with the same letter are not significantly different at the 0.05 level.

T.S.S content

Data in **Table (9)** demonstrated the influence of pre-harvest interventions on T.S.S of broccoli heads during cold storage in two years. Results showed that T.S.S significantly decreased as the storage period increased in both years. All sprayed plants with pre-harvest applications contain significantly higher T.S.S than untreated plants (control) treatment in both years. Results showed that the Seaweed treatment gave the highest T.S.S content followed by ABA and then GA_3 mg/L, the higher concentration was better at preserving total soluble solids than the lower one from the pre-harvest applications. Regarding the interaction treatment the Seaweed 2000mg/L at 28 days of experiments gave the highest significant T.S.S (%) value during the storage period in the two years followed by Seaweed 1000 mg/L, while the differences between the two gibberellin treatments were not significant.

Table (9): Effect of Gibberellic Acid, Abscisic Acid and Seaweed extract treatments on T.S.S (%) of Broccoli during different cold storage periods in the 2020 and 2021 seasons.

Pre harvest Treatments	Cold Storage Period (day)					
	0	7	14	21	28	Mean
	First Season 2020					
Control	8.36l	8.13m	6.20r	5.10s	2.5t	6.06F
GA_3 50 mg/L	9.30efg	9.20gh	8.56k	8.00mn	7.20q	8.45E
GA_3 100 mg/L	9.40ef	9.26fg	8.66jk	7.86no	7.30q	8.50E
ABA 50 mg/L	9.60d	9.43e	8.83i	8.13m	7.56p	8.71D
ABA 100 mg/L	9.76bc	9.63cd	8.86i	8.13m	7.76o	8.83C
Seaweed 1000 mg/L	9.86b	9.73b-d	9.30e-g	8.76ij	7.86no	9.11B
Seaweed 2000 mg/L	10.16a	10.06a	9.63cd	9.06h	8.11m	9.40A
Mean	9.49A	9.35B	8.58C	7.86D	6.9E	
	Second Season 2021					
Control	8.50j	8.13lm	6.30q	5.40r	2.93s	6.25G
GA_3 50 mg/L	9.56fg	9.26h	8.80i	8.20lm	7.50p	8.66F
GA_3 100 mg/L	9.66ef	9.43g	8.83i	8.26kl	7.70o	8.78E
ABA 50 mg/L	9.80c-e	9.66ef	8.86i	8.36ik	7.60op	8.86D
ABA 100 mg/L	9.90c	9.76c-e	9.16h	8.80i	7.96n	9.12C
Seaweed 1000 mg/L	10.23ab	10.10b	9.73de	8.86i	8.06mn	9.38B
Seaweed 2000 mg/L	10.33a	10.20ab	9.83cd	9.13h	8.13lm	9.52A
Mean	9.71A	9.51B	8.79C	8.15D	7.13E	

The L.S.D. multiple rang test shows that means in the same column with the same letter are not significantly different at the 0.05 level.

The peroxidase activity

Results in **Table (10)** showed the impact of the pre-harvest interventions on the peroxidase activity of broccoli heads during cold storage in the two experiment years. Data showed that the peroxidase activity increased with increasing storage period in both seasons. All pre-harvest Treatment resulted in a considerable reduction of peroxidase activity when compared to the control in both seasons, it was also noted from the results that peroxidase decreased with increasing treatment concentration in both seasons. Concerning the interaction treatment effect, noted that the Seaweed2000mg/L at the end of the experiment gave the least peroxidase value in both seasons, and the $GA_3$50mg/L contained the highest peroxidase in both seasons.

Total Phenol content

The results in **Table (11)** indicated the impact of pre-harvest interventions on the total phenol content of broccoli heads postharvest during cold storage in the two experiment years. It was observed that total phenol increased significantly up to 14 days of the experiment and then began to decrease gradually until the end of the experiment. The results showed that broccoli heads treated with pre-harvest treatments contained significantly higher total phenols than the non-treated (control) during cold storage in both years. Regarding the interaction treatment results cleared that there was a direct relationship between the concentration of pre-harvest treatments and the amount of total phenols in broccoli heads postharvest, the Seaweed2000mg/L treatment at 28 days gave significantly more total phenol than the other treatments in broccoli postharvest in both seasons.

Table (10). Effect of Gibberellic Acid, Abscisic Acid and Seaweed extract treatments on Peroxidase (mg/ 100 g f.w.) of Broccoli during different cold storage periods in the 2020 and 2021 seasons.

Pre harvest Treatments	Cold Storage Period (day)					
	0	7	14	21	28	Mean
	First Season 2020					
Control	5.08p-r	5.36k	6.88c	7.88b	9.81a	7.00A
GA_3 50 mg/L	5.06r	5.09p-r	5.48j	5.88g	6.65d	5.63B
GA_3 100 mg/L	5.04r	5.07p-r	5.27lm	5.73h	6.28e	5.48C
ABA 50 mg/L	5.05r	5.08p-r	5.22m-o	5.61i	6.16f	5.42D
ABA 100 mg/L	5.03r	5.05qr	5.19no	5.45j	5.89g	5.32E
Seaweed 1000 mg/L	5.04	5.07qr	5.17n-p	5.32ki	5.76h	5.27F
Seaweed 2000 mg/L	5.02r	5.06r	5.15o-q	5.24mn	5.58i	5.21G
Mean	5.04E	5.12D	5.48C	5.87B	6.59A	
	Second Season 2021					
Control	5.09lm	5.26ij	6.60c	7.43b	9.33a	6.74A
GA_3 50 mg/L	5.07lm	5.08lm	5.29i	5.79f	6.56c	5.55B
GA_3 100 mg/L	5.06lm	5.08lm	5.26ij	5.63g	6.22d	5.45C
ABA 50 mg/L	5.05lm	5.10l	5.18k	5.23j	6.13e	5.33D
ABA 100 mg/L	5.04m	5.07lm	5.17k	5.26ij	5.80f	5.26E
Seaweed 1000 mg/L	5.03m	5.07lm	5.16k	5.24ij	5.67g	5.23F
Seaweed 2000 mg/L	5.02m	5.06lm	5.15k	5.23j	5.56h	5.20G
Mean	5.05E	5.10D	5.40C	5.68B	6.46A	

The L.S.D. multiple rang test shows that means in the same column with the same letter are not significantly different at the 0.05 level.

Table (11). Effect of Gibberellic Acid, Abscisic Acid and Seaweed extract treatments on Total phenol content (mg/ 100 g f.w.) of Broccoli during different cold storage periods in the 2020 and 2021 seasons.

Pre harvest Treatments	Cold Storage Period (day)					
	0	7	14	21	28	Mean
	First Season 2020					
Control	2.72D	6.29y	9.84rs	3.07C	2.02E	4.79G
GA_3 50 mg/L	4.88A	8.73u	12.22m	10.33q	8.52w	8.94F
GA_3 100 mg/L	4.91zA	9.77s	13.56i	10.46p	8.75u	9.49E
ABA 50 mg/L	4.40B	11.30o	15.53f	12.65k	9.27t	10.63D
ABA 100 mg/L	4.98z	11.88n	15.97e	12.85j	9.87r	11.11C
Seaweed 1000 mg/L	6.82x	12.35l	18.24b	16.45d	13.56i	13.48B
Seaweed 2000 mg/L	8.63v	14.32h	20.23a	17.26c	14.77g	15.04A
Mean	5.33E	10.66C	15.09A	11.87B	9.54D	
	Second Season 2021					
Control	3.58D	7.65B	10.33V	6.32C	2.88E	6.15G
GA_3 50 mg/L	6.34C	11.53t	15.23k	12.09r	9.12y	10.86F
GA_3 100 mg/L	7.55B	11.85s	16.48g	12.28q	9.84x	11.60E
ABA 50 mg/L	7.77A	13.65p	18.43e	14.51n	10.29v	12.93D
ABA 100 mg/L	8.22z	14.77m	18.77d	14.91l	11.51t	13.64C
Seaweed 1000 mg/L	10.16w	15.88i	20.55b	17.76f	14.22o	15.72B
Seaweed 2000 mg/L	10.45u	16.33h	21.35a	18.96c	15.74j	16.57A
Mean	7.73E	13.09C	17.31A	13.83B	10.52D	

The L.S.D. multiple rang test shows that means in the same column with the same letter are not significantly different at the 0.05 level.

Discussion

Due to the increasing popularity of the broccoli crop, as a result of increased awareness of its nutritional importance, there is a tendency toward more farmer production as well as consumer consumption. But the main problems were low production, and short shelf life (Mamunur et al., 2015). There is a fairly large increase in broccoli production under Egyptian conditions, spit of it is considered one of the promising export crops. Regarding the Seaweed, the usage of Seaweed extracts has grown in popularity owing to their potential applications in organic and sustainable agriculture. Also, Seaweed extracts are an inexpensive source of naturally occurring plant growth regulators which have greater potential as biostimulants in agriculture. The endogenous plant growth regulators present in the seaweed extracts and concentrates are thought to be involved in the promoting plant growth and yield. Different plant phytohormones and growth regulators present in seaweed extracts are known to enhance the yield and yield attributes o of crops, when applied exogenously. The results confirmed that the seaweed2000 mg/L was superior of the vegetative growth and productivity of broccoli crop. Seaweed fertilizers are beneficial for achieving higher agricultural production, stimulating the growth and productivity of plants, developing the ability to withstand environmental stress, increasing the absorption of nutrients from the soil and enhancing antioxidant properties because the extract contains growth promoting hormones such as auxins, gibberellins, cytokinins, gibberellins, abscisic acid, ethylene, betaine and other polyamines, trace elements, vitamins, amino acids, antibiotics and micronutrients (AL-Ezzil and AL-Alawy,2022, Lola et al. 2014, Panda et al., 2012 and Turan and Kos, 2004). Baldaniya et al. (2023), Manea et al. (2018) and Al Bermani (2017) agreed that the Seaweed increased significantly the plant height, number of leaves, and leaf area. In agreement with Abo El Maged (2019) found that the highest concentration of Seaweed gave the highest values of vegetative growth and yield.

Trejo et al. (2023) discussed that the post-harvest behavior of fruit crops depends on pre-harvest factors. Explaining that vegetative and reproductive activities may be affected by plant growth regulators and that field treatments affect storage behavior and post-harvest physiology. The results in this study indicated that the seaweed 2000 mg/L was the best treatment on postharvest, it reduced weight loss and maintained an excellent general appearance for up to 28 days, it also Protected the aroma, color and texture an excellent quality until the end of the experiment. It preserved the content of the broccoli heads of vitamin C, total soluble solids, total phenol content and total chlorophyll. It also, tried to limit the activity of the peroxidase enzyme during cold storage in both seasons. Miceli et al. (2021) obtained that the scores for overall quality assessed by an informal panel dropped during storage, but the samples treated with seaweed extract had a significantly better visual quality than the control during the first two weeks of storage, and maintained the crop quality. According to Baldania (2023) cleared that the treatment of seaweed provides the highest value of Vitamin C and attributed this increase in ascorbic acid might be due to presence of microelements and plant growth regulators especially cytokinin present in seaweed extract. It helps to increase the enzymatic activity of plants due to the application of seaweed extract. Lola et al. (2014) suggested that increased phenolic content may be related to osmatic stress or increased plant hormone activity.

Also, our result, generally, agreement with that repotted by Kaluzewich. et al. (2017). They found that GA_3 treatment increased phenolic over the control, maintain fruit storage quality by considerably maintaining flesh hardness, decreasing respiration intensity, inhibiting endogenous ethylene release, and inhibiting fruit softening and ripening. It can also maintain the intrinsic and extrinsic quality of fruit storage by enhancing fruit shape, regulating color, delaying soluble solids reduction, promoting sugar accumulation, and delaying vitamin loss, and increasing their resistance to stress and disease, GA_3 capacity to delay fruit senescence is closely connected to their ability to delay fruit senescence. Reduces the generation and buildup of superoxide anion, boosts the antioxidant capacity of fruits, and keeps cell membranes intact during low-temperature storage. Furthermore, GA_3 have the potential to successfully manage various postharvest fruit diseases.

Conclusion

The use of foliar application of Seaweed 2000mg/L significantly enhanced vegetative growth, head attributes, and total yield, it was the best treatment that reduced weight loss and maintained an excellent general appearance, the aroma, color and texture for up to 28 days. It preserved the content of the broccoli heads of vitamin C, total soluble solids, total phenol content and total chlorophyll. It also tried to limit the activity of the peroxidase enzyme during cold storage in both seasons.

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الملخص العربي

تأثير الرش الورقي بحمض الجبريلين وحمض الأبسيسيك ومستخلص الطحالب البحريه علي النمو الخضري و الجودة والقدرة التخزينية للبروكولي.

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نفذت تجربتان حقلية وما بعد الحصاد على نبات البروكلي خلال الموسمين الشتويين 2020 و2021. أجريت هذه الدراسة بهدف: تقييم تأثير الرش الورقي(مستويين) بحامض الجبريليك (GA_3) 50 ملجم/لتر، 100 ملجم /لتر، حامض الأبسيسيك (ABA)50 ملجم /لتر، 100 ملجم /لتر، ومستخلص الطحالب البحرية(Seaweed extract) 1000 ملجم /لتر، 2000 ملجم /لتر علي بعض صفات النمو الخضري والرؤوس والمحصول الكلي وبعض صفات الجودة، ب: لمعرفة تأثير المعاملات السابقة على البروكلي صنف برفكت خلال فترات التخزين المبرد المختلفة. أظهرت النتائج تفوق نباتات البروكلي المعاملة معنويا في كل من النمو الخضري وصفات الرؤوس والمحصول الكلي مقارنة بالنباتات غير المعاملة (الكنترول). كما كان لهذه المعاملات تأثير إيجابي في صفات الجودة لرؤوس البروكلي بعد الحصاد، مع وجود فروق معنوية عالية مقارنة بمعاملة الكنترول، حتى نهاية فترة التخزين المبرد في كلا الموسمين. أعطي التركيز الأعلى لكل معاملة قيما أعلى لمعظم الصفات المدروسة. أظهرت النتائج أن معاملة الرش بالتركيز الأعلى من مستخلص الطحالب البحرية (2000 ملجم /لتر). تفوقت في جميع الصفات المدروسة حتى نهاية التجربة. وكانت أيضًا أفضل معاملة قللت من فقدان الوزن وحافظت على مظهر عام ممتاز لمدة تصل إلى 28 يومًا. وحافظت على محتوى رؤوس البروكلي من فيتامين C، والمواد الصلبة الذائبة الكلية، والفينولات الكلية، والكلوروفيل الكلي. كما حاولت الحد من نشاط إنزيم البيروكسيديز أثناء التخزين المبرد في كلا الموسمين. بينما اعطت معاملة الكنترول أقل القيم بين جميع الصفات المدروسة.