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Effect of Spraying Some Microelements and Bio-Stimulants on Yield, Quality and Storage Ability of Red Cabbage Heads

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TWO field experiments were conducted, followed by two storage experiments of heads, on the red cabbage, to study the impact of spraying some microelements (iron, zinc, and boron), some plant bio-stimulants (seaweed extract and chitosan) and a combination between them on some chemical constituents, yield, and quality (in a complete randomized block design) as well as the storage ability of heads (in a two-way randomized complete design). Obtained results showed the significant superiority of red cabbage plants sprayed with all studied materials compared to the control treatment in the measured characteristics, i.e., N, P, K, Fe, Zn, B, dry matter, quality attributes, number and weight of outer leaves, head height, head diameter, head weight, and total yield/feddan. Plants treated with seaweed extract + chitosan + element mixture significantly gave the highest values of all studied parameters, except NO_3-N content. Concerning the effect of the storage experiment, the heads wrapped with light polyethylene significantly gave the superiority in crude protein, total carbohydrates, TSS, total sugars, vitamin C content and anthocyanin. Moreover, these wrapped heads were the least in weight loss in both seasons. In this concern, seaweed extract + chitosan + element mixture along with wrapping harvested heads with light polyethylene gave the maximum storage ability. Thus, it could be recommended that spraying red cabbage with seaweed extract + chitosan + element mixture gave the highest values for characteristics of yield, quality, and storage ability when such treatment was combined with wrapping heads with light polyethylene.

Keywords: Red cabbage, Foliar spraying, Iron, Zinc, Boron, Seaweed extract, Chitosan, Polyethylene wrapping, Head yield and quality.

Introduction

Red cabbage is a nutritious and delicious vegetable crop that belongs to the family Brassicaceae. It has become very popular throughout the world because it is very good for the body health; thus its rich in many important nutrients such as phytochemicals, antioxidants, anthocyanins, and vitamins A, C, E, K and B. Moreover, it contains several elements such as Ca, Fe, Mg and K. It is often eaten in salad and soup. It has started to be cultivated and consumed in Egypt in the recent years, but it has not received enough attention in research to increase productivity and improve quality.

The role of micronutrients in the regulation of many processes in plant growth and yield is well established and well defined. Different micronutrients have a specific role in red cabbage production. Although micronutrients are required in trace amounts for better plant growth and development, they play vital role in the completion of the life cycle of crops. Among all micronutrients, boron and molybdenum are more important than others due to their availability

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in soil, mobility in plants and soil, and more dependence on pH in soil (Naqib and Jahan, 2017).

Boron (B) is an essential micronutrient required for the growth and development of plants. In most crops, it shows very poor phloem mobility. Consequently, B in leaf tissue cannot be transported sufficiently into the reproductive organs, *i.e.*, shoot tips, buds, flowers, and seeds. Spraying B element during all stages of plant growth because of this poor mobility, particularly during reproductive growth, is critical for optional plant nutrition (Ahmad et al., 2009). Zinc (Zn) is a plant micronutrient which is involved in many physiological functions in the plant; an inadequate supply of zinc will reduce crop yield. Zinc deficiencies can affect the plants *via* stunting, decreasing number of tillers, chlorosis and smaller leaves, increasing crop maturity period, spikelet sterility and inferior quality of harvested products. Zn activates enzymes responsible for the formation of chlorophyll and carbohydrates, the conversion of starches to sugars and helps plants to resist cold. It is important in the formation of auxins, which improve growth regulation and cell elongation (Rudani et al., 2018). Iron plays an important role in the photosynthesis process in plants and is a constituent of several enzymes including catalase and peroxidase. It is essential for nutrient absorption from the soil and the reduction of nitrate and sulphate formation (Rout and Sahoo, 2015).

Many investigators revealed the effect of microelements, Hou and Shang (2006) indicated that foliar application of Zn and B microelement fertilizers could obviously increase yield and improve the quality of cabbage heads. The effect of the combined application of Zn and B on cabbage was the best. Its production increasing ratio had reached 32.2 % and cleared that the B fertilization had a better effect than the Zn fertilization on yield because the production-increasing ratio of B fertilization was 16.1 % higher than Zn fertilization. The same results were obtained by Merghany (2007), Naher et al. (2014), and Jagtap et al. (2016) on cabbage and Abd El-Hady and Shehata (2019) on potato.

Kanujia et al. (2006) studied the effect of micronutrients (boron, manganese, iron, copper, molybdenum, and zinc) on growth and yield of cabbage and revealed that the maximum values for plant spread, number of non-wrapper leaves, head diameter, head weight, and head yield were attained with foliar application of a mixture of all nutrients at 100 ppm during both seasons. Meanwhile, Sarkar et al. (2007) found that foliar spraying of micronutrients Zn, Fe and Mn, significantly increased the yield of some vegetable crops. Foliar application of boron increased vegetative growth parameters, chemical constituents, yield and quality of cabbage (Devi et al., 2012; Mohamed and Zewail, 2016).

Chitosan is a natural biodegradable compound derived from crustaceous shells such as crabs and shrimps, whose main attribute corresponds to its polycationic nature (Bautista-Banos et al., 2006). It has been used as a natural agro-chemical applied to protect plants against oxidative stress and to improve plant growth (Farouk and Ramadan, 2012), and it also increases photosynthesis, improves plant growth, nutrient uptake, and seed germination (Kim et al., 2005). Many investigators reported that using chitosan as a foliar spray increased growth, yield and quality (Abdel- Mawgoud et al., 2010; Kamal and Ghanem 2011; Fawzy et al., 2012). Furthermore, chitosan application resulted in increased vegetative growth, yield and components of vegetable crops such as strawberry (El-Miniawy et al., 2013); tomato (Abd El-Gawad and Bondok, 2015); cucumber (Shehata et al., 2012; Abd El-Hady and Abd-Elhamied, 2018) and broccoli (Hamaiel et al., 2020).

Seaweed extracts are new types of products currently used in plant production. The sources of seaweed are many species of marine algae, which seem to be valuable for plant growth and development. It is also considered a plant bio-stimulant because of the presence of hormones. Foliar spraying of garlic plants with seaweed extract significantly increased carbohydrate content and yield (Shalaby and El-Ramady, 2014). As well, seaweed extracts contain phytohormones including auxins, cytokines, gibberellins, abscisic acid and brassinosteroids (Stirk et al., 2014), micro- and macronutrients (Craigie, 2011). Applying seaweed extract significantly increased vegetative growth characters and yield as reported by Lola-luz et al. (2013) on cabbage, Farouk (2015) and Abd El-Hady et al. (2016) on potato.

The application of chitosan coatings reduced the weight loss percentage during storage as compared with the untreated control on fresh-cut apple cubes (Zhelyazkov et al., 2012). In addition, Silva et al. (2015) studied the effect of

Cucumis anguria fruit packed in polystyrene trays and wrapped with PVC film, containing $KMnO_4$ sachets of 0, 1, 2, 3 or 4 g and stored at 10° C. They found that trays with 4 g of $KMnO_4$ retained a higher content of vitamin C in the stored fruit.

These experiments were carried out as an attempt to increase the productivity of red cabbage and improve the quality of the product, while also prolonging the storage period of the heads under the conditions of Dakhalyia Governorate.

Materials and Methods

Field experiments

Two field experiments were conducted during the winter growing seasons of 2020 and 2021, at the Experimental Farm of the Faculty of Agriculture, Mansoura University, Dakhalyia Governorate, Egypt aiming to study the effect of spraying some microelements (iron, zinc, and boron), some plant biostimulants (seaweed extract and chitosan) and a combination between them on yield and quality as well as the storage ability of red cabbage heads (*Brassica oleracea* L. var. *capitata*. After the preparation of the experimental soil for cultivation, the uniform thirty-day-old red cabbage seedlings with 4-5 true leaves cv. Nadine were transplanted on November 9 and 12, 2020 and 2021 seasons, respectively, on two ridges of 8 m length, 0.7 m width, thus the plot area was 11.2 m^2 and the distances between seedlings were 40 cm on one side of the ridges. Before planting, representative soil samples were randomly taken at a depth of 30-50 cm from the experimental field for physical and chemical analysis (Table 1).

In accordance with the recommendations of the Ministry of Agriculture for crop production, the soil of the experiment was fertilized with 10 m^3/fed. organic manure as chicken manure, in addition the phosphate fertilizer in the form of calcium super phosphate (15.5%) at a rate of 50 kg P_2O_5/fed. during the preparation of the experimental soil. While nitrogen and potassium were added in the form of ammonium nitrate (33.5%) at a rate of 80 kg N/fed and potassium sulphate (48%) at a rate of 50 kg K_2O/fed., their quantities were divided into two equal parts. The first was added three weeks after the transplanting date and the second two weeks later beside the plants. All other agricultural practices, such as irrigation, hoeing, pests, diseases, and weed controls have been done.

Experimental treatments

Foliar application was carried out three times during the growth period starting at 20, 40, and 60 days after the transplanting date as follow:

T1: Tap water (control)

T2: Boron (B) at 50 ppm as boric acid.

T3: Zinc (Zn) at 100 ppm as zinc sulphate.

T4: Iron (Fe) at 300 ppm as iron chelates from EDTA.

T5: Mix elements (B 50 ppm + Zn 100 ppm + Fe 300 ppm).

T6: Chitosan (Deactylation 93%) at 2 g/l,was freshly prepared by dissolving in acetic acid solution.

T7: Chitosan (2 g/l) + Mix elements (B 50 ppm + Zn 100 ppm + Fe 300 ppm).

T8: Seaweed extract at 2 g/l, a commercial product named Alga 600® consist of *Ascophyllum nodosum, Laminaria* spp. and *Sargassum* sp., also contains N (1%), K (18.5%), Ca (0.17%), Mg (0.42%), Fe (0.06%), S (2.2%), alganic acids (10-12%) and plant hormones (600 ppm).

T9: Seaweed extract (2 g/l) + Chitosan (2 g/l).

T10: Seaweed extract (2 g/l) + Mix elements (B 50 ppm + Zn 100 ppm + Fe 300 ppm).

TABLE 1. Some physical and chemical properties of experimental soil during 2020 and 2021 seasons.

Seasons	Mechanical analysis (%)				Texture class	OM (%)	SP	Total $CaCO_3$ g/kg	ECe $dS.m^{-1}$ 1:5	pH (1:2.5)	Available (mg/kg soil)		
	Coarse Sand	Fine Sand	silt	clay							N	P	K
1st	2.8	22.1	40.3	34.8	Loamy	1.93	51.7	2.45	1.27	7.88	49.8	6.72	312
2nd	3.4	24.3	42.1	30.2	Loamy	2.03	53.9	2.64	1.43	7.76	51.1	7.12	319

SP: Saturation percentage OM: Organic matter EC: Electrical conductivity

T11: Seaweed extract (2 g/l) + Chitosan (2 g/l) + Mix elements (B 50 ppm + Zn 100 ppm + Fe 300 ppm).

Data recorded

After 100 days from the transplanting, five plants were randomly chosen from each experimental plot to measure the following:

Chemical Constituents

The percentages of moisture, protein, carbohydrate, fat, ash and fiber were determined according to A.O.A.C. (2012).

- N, P and K contents were estimated in the head of red cabbage using the method described by A.O.A.C. (2012).
- Fe, and Zn contents were estimated in the heads using the method of Khazaei et al. (2017).
- B content was estimated in heads using the method described by Chapman and Pratt (1961).

Quality parameters

- Dry matter percentage.
- TSS% was determined in the heads by using hand refractometer.
- Vitamin C content and crude fibers were estimated in head according to the method reported in A.O.A.C. (2012).
- Total carbohydrates and total sugars were determined in head according to the method described by Hedge and Hofreiter (1962).
- NO_3-N was estimated in the heads according to the procedure described by Singh (1988).
- Total phenols were determined according to Slinkard and Singleton (1977).
- Anthocyanin content was determined according to Giusti et al. (2001).

Yield and its component

Weight of outer leaves, number of outer leaves/plant, head height, head diameter, head weight and total yield.

Storage experiment

In the middle of the harvesting season, marketable size heads of red cabbage were harvested at maturity stage from all treatments. The heads were then transferred to the above-mentioned Institute. Afterward, heads were divided into two groups, one wrapped with non-perforated light polyethylene (20 micron thickness) and the other not, and stored for one month under room conditions (temperature 20°C and relative humidity 64%). Heads were weighted every week after the beginning of storage period to assess weight loss percentage. At the end of the storage period, some heads quality parameters were determined in wrapped and unwrapped treatments:

- Moisture
- Crude protein percentage was calculated by multiplying the total N by 6.25 (A.O.A.C., 2000).
- Total fats were determined in head according to the method described in A.O.A.C. (2000).
- Ash.
- Total carbohydrates, TSS, total sugars, vitamin C content and anthocyanin.

Experimental design

The experiment was carried out in a complete randomized block design with three replicates, while the storage experiment was laid in a factorial experiment in randomized complete design with three replicates, since wrapping treatments were the first factor, while the foliar spraying treatments (11 treatments) were the second factor.

Statistical analysis

All obtained data were tabulated and subjected to the statistical analysis of variance (ANOVA) using the computer software package “MSTAT-C” as reported by Gomez and Gomez (1984). The least significant difference (LSD) at 5% levels of probability was employed to compare significant differences among the means of treatments according to the procedures mentioned by Snedcor and Cochran (1980).

Results

Chemical constituents

Concerning the effect of the foliar application used in the field experiment on N, P, and K concentrations, the results shown in Table 2 show that all spraying treatments resulted in an increase of N, P, and K percentages significantly compared with the control treatment. Treatment of seaweed extract + chitosan + mix elements (T11) gave the highest values of N, P and K percentages followed by chitosan + mix elements (T7) treatment except for potassium percentage in the the first season only. The same superiority of T11 treatment occurred with Fe, Zn and B concentrations in the two seasons, followed by the treatments of T10 (seaweed extract + mix elements) and T7 with significant differences among them. In contrast, control treatment occupied the last rank in every case.

Head quality

Results presented in Tables 3 and 4 point out the same trend mentioned previously, where the treatment of T11 (seaweed extract + chitosan + mix elements) surpassed significantly all other treatments in terms of estimated quality parameters of red cabbage heads such as dry matter, TSS, vitamin C content, anthocyanin, total carbohydrates, total sugars and total phenols concentrations followed by T7 (chitosan+ mix elements) or T10 (seaweed extract + mix elements) treatments, while the control treatment gave the minimum values except for crude fibers percentage and nitrate content with significant differences among them.

Yield and its components

Figure 1 shows that T11 treatment significantly exceeded all other treatments in weight, and number of outer leaves, head height, diameter, weight, and total yield. However, the control treatment recorded the lowest values of the aforementioned parameters. Spraying red cabbage plants with chitosan + mix elements (T7) occupied the second rank in the weight of outer leaves, head height and total yield measurements in both seasons of 2020 and 2021.

Storage experiment

As shown from the results in Tables 5, 6 and 7, it can be seen clearly that the storage treatments, wrapped and non-wrapped of red cabbage heads with light polyethylene film during the storage period at room temperature for one month after harvesting significantly affected moisture, crude protein, total fats, ash, total carbohydrates, TSS, total sugars, vitamin C content, anthocyanin and head weight loss during both seasons. Wrapping red cabbage heads during the storage period with light polyethylene film recorded the lowest values of total fats, ash, moisture and weight loss,

TABLE 2. The effects of different foliar spraying treatments on N, P, K, Fe, Zn and B contents in red cabbage leaves during 2020 and 2021 seasons.

Characters / Foliar treatments	N (%)		P (%)		K (%)		Fe (mg/100 g)		Zn (mg/100 g)		B (mg/100 g)	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
T_1	1.020	1.133	0.182	0.197	1.440	1.580	2.967	3.150	1.183	1.030	0.593	1.880
T_2	1.087	1.240	0.193	0.205	1.537	1.690	3.290	3.443	1.453	1.330	1.223	5.960
T_3	1.193	1.313	0.205	0.212	1.627	1.783	3.123	3.313	2.193	2.037	0.663	5.693
T_4	1.327	1.497	0.218	0.236	1.853	1.967	4.047	3.977	1.337	1.157	0.767	4.373
T_5	1.673	1.767	0.242	0.262	2.113	2.267	3.877	4.197	2.060	2.250	1.123	6.427
T_6	1.473	1.603	0.230	0.239	1.923	2.067	3.583	3.640	1.750	1.637	0.950	3.440
T_7	1.850	1.970	0.268	0.287	1.990	2.527	4.217	4.417	2.330	2.473	1.427	4.813
T_8	1.250	1.423	0.214	0.223	1.750	1.883	3.447	3.587	1.617	1.463	0.870	2.493
T_9	1.570	1.690	0.237	0.250	2.013	2.143	3.710	3.783	1.910	1.820	1.040	3.893
T_{10}	1.743	1.867	0.254	0.271	2.230	2.410	3.727	4.657	2.463	2.357	1.330	5.440
T_{11}	1.927	2.087	0.277	0.297	2.423	2.563	4.567	4.833	2.620	2.580	1.460	6.760
LSD at 5%	0.061	0.059	0.007	0.006	0.067	0.059	0.095	0.078	0.050	0.064	0.067	0.085

T_1: Control. **T_2:** B (50 ppm). **T_3:** Zn (100 ppm). **T_4:** Fe (300 ppm). **T_5:** Mix (B+Zn+Fe). **T_6:** Chitosan (2 g/l). **T_7:** Chitosan + Mix (B+Zn+Fe) **T_8:** Seaweed extract (2 g/l). **T_9:** Seaweed + Chitosan. **T_{10}:** Seaweed + Mix (B+Zn+Fe). **T_{11}:** Seaweed + Chitosan + Mix.

TABLE 3. The effects of different foliar spraying treatments on the percentages of dry matter (DM), total soluble solids (TSS), vitamin C content and anthocyanin content of red cabbage heads during 2020 and 2021 seasons.

Characters / Foliar treatments	DM (%)		TSS (%)		Vitamin C (mg/100 g)		Anthocyanin (mg/100 g)	
	2020	2021	2020	2021	2020	2021	2020	2021
T_1	10.80	11.09	6.40	6.81	51.93	53.73	297.3	315.6
T_2	10.92	11.19	6.44	6.86	52.63	54.23	304.6	326.3
T_3	11.05	11.31	6.54	6.94	53.06	54.83	313.6	321.6
T_4	11.36	11.55	6.68	7.12	54.33	56.16	322.0	349.3
T_5	11.71	11.90	6.88	7.35	56.23	57.80	341.3	343.6
T_6	11.42	11.66	6.73	7.22	55.20	56.70	325.0	336.0
T_7	11.98	12.19	7.02	7.53	57.20	58.80	347.6	353.6
T_8	11.15	11.43	6.59	7.04	53.70	55.23	316.6	331.0
T_9	11.59	11.80	6.81	7.28	55.80	57.26	331.6	344.6
T_{10}	11.86	12.03	6.92	7.43	56.86	58.16	343.6	358.3
T_{11}	12.07	12.32	7.09	7.58	58.53	59.63	352.3	362.6
LSD at 5%	0.10	0.08	0.06	0.06	0.90	0.89	6.4	5.6

T_1: Control. **T_2:** B (50 ppm). **T_3:** Zn (100 ppm). **T_4:** Fe (300 ppm). **T_5:** Mix (B+Zn+Fe). **T_6:** Chitosan (2 g/l).

T_7: Chitosan + Mix (B+Zn+Fe) **T_8:** Seaweed extract (2 g/l). **T_9:** Seaweed + Chitosan. **T_{10}:** Seaweed + Mix (B+Zn+Fe). **T_{11}:** Seaweed + Chitosan + Mix.

TABLE 4. The effects of different foliar spraying treatments on total carbohydrates, total sugars, crude fibers, nitrate and total phenols contents of red cabbage heads during 2020 and 2021 seasons.

Characters / Foliar treatments	Total carbohydrates (%)		Total sugars (%)		Crude fibers (%)		NO_3-N (ppm)		Total phenols (mg/100 g)	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
T_1	15.83	16.44	6.04	6.45	5.27	5.72	29.20	30.73	202.0	180.66
T_2	15.98	16.60	6.16	6.57	5.31	5.55	25.93	26.63	221.6	206.66
T_3	16.09	16.74	6.23	6.69	4.69	5.36	27.33	28.36	213.0	194.33
T_4	16.42	17.04	6.46	6.91	4.25	5.04	18.26	19.16	287.0	263.00
T_5	16.87	17.48	6.76	7.25	5.14	4.58	19.73	20.83	270.3	252.00
T_6	16.55	17.18	6.57	7.14	4.58	4.87	22.53	23.80	244.0	231.66
T_7	17.08	17.80	6.98	7.49	4.84	4.23	16.86	18.00	295.3	277.33
T_8	16.21	16.88	6.34	6.80	4.37	5.21	24.23	25.10	233.3	221.00
T_9	16.73	17.35	6.65	7.13	4.08	4.71	21.16	22.23	255.0	238.33
T_{10}	16.96	17.66	6.86	7.36	3.93	4.41	15.33	16.30	310.0	295.00
T_{11}	17.27	17.92	7.10	7.63	3.76	4.09	14.03	15.86	319.6	308.66
LSD at 5%	0.15	0.12	0.13	0.15	0.13	0.08	0.94	0.08	6.1	6.0

T_1: Control. **T_2:** B (50 ppm). **T_3:** Zn (100 ppm). **T_4:** Fe (300 ppm). **T_5:** Mix (B+Zn+Fe). **T_6:** Chitosan (2 g/l).

T_7: Chitosan + Mix (B+Zn+Fe) **T_8:** Seaweed extract (2 g/l). **T_9:** Seaweed + Chitosan. **T_{10}:** Seaweed + Mix (B+Zn+Fe). **T_{11}:** Seaweed + Chitosan + Mix.

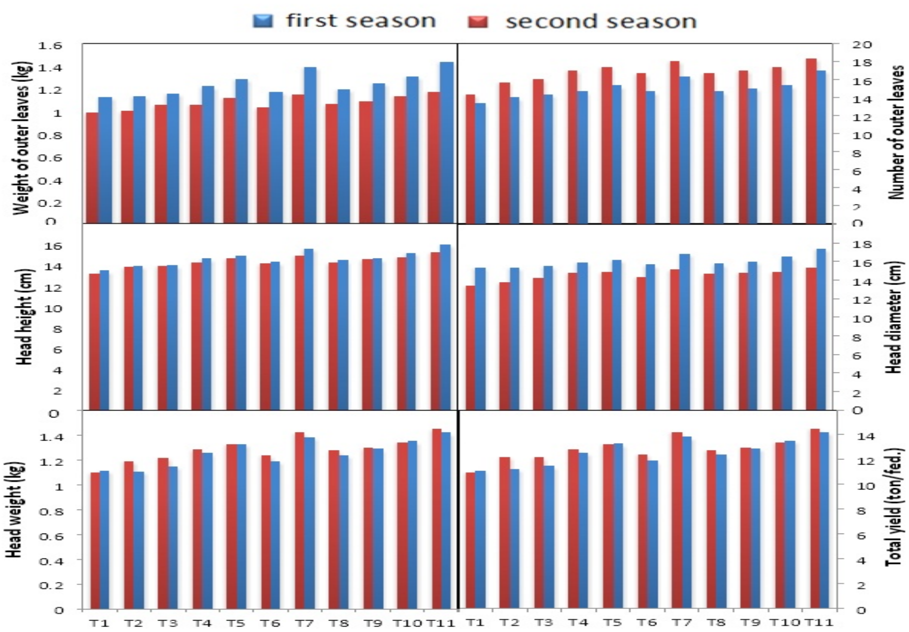

Fig. 1. The effects of different foliar spraying treatments on weight, number of outer leaves, head height, diameter, weight of head and total yield/fed. of red cabbage plants as during 2020 and 2021 seasons.

(T_1: Control, T_2: B (50 ppm), T_3: Zn (100 ppm), T_4: Fe (300 ppm), T_5: Mix (B+Zn+Fe), T_6: Chitosan (2 g/L), T_7: Chitosan + Mix (B+Zn+Fe) T_8: Seaweed extract (2 g/L), T_9: Seaweed + Chitosan, T_{10}: Seaweed + Mix (B+Zn+Fe) and T_{11}: Seaweed + Chitosan + Mix)

while it gave the highest values of crude protein, total carbohydrates, TSS, total sugars, vitamin C content and anthocyanin in both seasons compared to non-wrapped heads.

The relevant results in Tables 5, 6 and 7 clearly indicated the impact of foliar spraying treatments of red cabbage plants in the field on the storage behavior of red cabbage head traits. Significant differences were noticed on all storage parameters of heads between foliar spraying treatments and unsprayed ones in both seasons. The treatment of T11 (seaweed extract + chitosan + mix elements) gave the highest values of crude protein, TSS, vitamin C content, and anthocyanin in both seasons of the study, and total carbohydrates, and total sugars in the second season only compared to control treatment (T1). On the other hand, the control treatment T1 (tap water) gave the highest values of moisture, total fats, and ash in both seasons.

The interaction between storage treatments and foliar spraying treatments had significant effects on moisture, ash, total carbohydrates, TSS, total sugars and vitamin C content in the second season, and on crude protein and total fats in the first season (Tables 5, 6 and 7). Furthermore, significant effects were detected on anthocyanin concentration and weight loss after 1, 2, 3 and 4 weeks at the room temperature in both seasons. The superiority of the storage treatments, treatment of T11(plants sprayed in the field with seaweed extract + chitosan + mix elements and wrapped with light polyethylene film) was superior in crude protein, TSS, vitamin C and anthocyanin in both seasons, as well as total carbohydrates in the second season, in addition total sugars in the first season, followed by treatments of T7 (plants sprayed in the field with chitosan + mix elements and wrapped with light polyethylene film) and T10 (plants sprayed in the field with chitosan + mix elements and wrapped with light polyethylene film). However, treatment of T1 (plants sprayed with tap water in the field and wrapped with light polyethylene film) gave the maximum contents of moisture, total fats, ash and weight loss after 1, 2, 3 and 4 weeks of storage at the room temperature.

Discussion

The positive effect of microelement foliar spraying may be due to the fact that B is a component of plant cell walls and reproductive

TABLE 5. The effects of different foliar spraying treatments and wrapping with light polyethylene film as well as their interaction on moisture, crude protein, total fats, ash and total carbohydrates percentages of red cabbage heads stored at room conditions for one month during 2020 and 2021 seasons.

Characters		Moisture (%)		Crude protein (%)		Total fats (%)		Ash (%)		Total carbohydrates (%)	
Treatments		2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
A. Wrapping effect:											
Unwrapped		77.02	75.34	6.95	6.31	2.61	2.55	1.87	2.22	11.54	13.55
Wrapped		73.00	73.82	7.33	6.59	2.33	2.29	1.53	1.79	15.80	15.49
F. test		*	*	*	*	*	*	*	*	*	*
B. Foliar treatments effects:											
T_1		77.39	75.81	5.74	5.00	2.87	2.99	2.24	2.65	11.74	13.53
T_2		77.00	75.57	6.01	5.28	2.80	3.00	2.12	2.46	12.04	13.67
T_3		76.69	75.29	6.32	5.58	2.74	2.85	2.01	2.25	12.21	14.01
T_4		76.15	74.79	6.86	6.17	2.54	2.60	1.80	2.10	12.62	14.33
T_5		75.36	74.12	7.72	7.05	2.28	2.14	1.43	1.78	13.19	14.89
T_6		75.91	74.57	7.15	6.47	2.47	2.47	1.70	2.02	12.75	14.45
T_7		69.82	73.61	8.19	7.60	2.14	1.86	1.29	1.56	18.53	15.35
T_8		76.42	75.03	6.61	5.86	2.65	2.74	1.91	2.27	12.39	14.08
T_9		75.65	74.38	7.43	6.77	2.38	2.29	1.60	1.91	12.93	14.63
T_{10}		70.09	73.85	7.97	7.36	2.21	2.00	1.37	1.66	18.34	15.11
T_{11}		74.60	73.38	8.52	7.82	2.05	1.69	1.19	1.42	13.61	15.67
LSD at 5%		1.07	0.80	0.09	0.07	0.05	0.09	0.06	0.06	0.39	0.20
C. Interaction effects:											
Un-wrapped	T_1	78.42	76.52	5.65	4.87	3.05	3.28	2.45	2.89	10.42	12.42
	T_2	78.05	76.25	5.92	5.15	2.96	3.12	2.33	2.67	10.72	12.78
	T_3	77.73	75.98	6.22	5.45	2.88	2.98	2.18	2.36	10.98	13.21
	T_4	77.23	75.46	6.74	6.05	2.72	2.71	1.98	2.28	11.31	13.49
	T_5	76.51	74.96	7.51	6.92	2.41	2.25	1.55	2.01	12.01	13.84
	T_6	76.98	75.31	6.98	6.36	2.62	2.61	1.88	2.25	11.53	13.46
	T_7	76.01	74.45	7.85	7.41	2.24	1.98	1.46	1.79	12.42	14.35
	T_8	77.47	75.73	6.47	5.75	2.84	2.87	2.09	2.52	11.11	13.12
	T_9	76.76	75.21	7.24	6.68	2.53	2.41	1.77	2.13	11.68	13.56
	T_{10}	76.22	74.70	7.72	7.22	2.33	2.09	1.52	1.89	12.20	14.08
	T_{11}	75.85	74.18	8.14	7.62	2.15	1.81	1.34	1.64	12.51	14.72
Wrapped	T_1	76.36	75.10	5.83	5.14	2.70	2.70	2.02	2.41	13.06	14.64
	T_2	75.95	74.88	6.10	5.41	2.65	2.89	1.92	2.24	13.36	14.56
	T_3	75.66	74.61	6.43	5.71	2.61	2.73	1.85	2.13	13.44	14.81
	T_4	75.07	74.11	6.97	6.30	2.37	2.49	1.63	1.91	13.94	15.17
	T_5	74.21	73.28	7.93	7.17	2.16	2.04	1.32	1.56	14.36	15.94
	T_6	74.84	73.84	7.32	6.58	2.32	2.33	1.53	1.79	13.97	15.44
	T_7	63.63	72.78	8.53	7.79	2.05	1.73	1.13	1.32	24.64	16.35
	T_8	75.38	74.33	6.74	5.97	2.46	2.62	1.73	2.03	13.67	15.03
	T_9	74.54	73.55	7.62	6.87	2.23	2.16	1.42	1.69	14.17	15.71
	T_{10}	63.96	72.99	8.22	7.51	2.10	1.90	1.23	1.43	24.47	16.15
	T_{11}	73.35	72.57	8.91	8.02	1.96	1.57	1.04	1.20	14.72	16.62
LSD at 5%		NS	1.11	0.13	NS	0.08	NS	NS	0.08	NS	0.28

T_1: Control . **T_2:** B (50 ppm). **T_3:** Zn (100 ppm). **T_4:** Fe (300 ppm). **T_5:** Mix (B+Zn+Fe). **T_6:** Chitosan (2 g/l).

T_7: Chitosan + Mix (B+Zn+Fe) **T_8:** Seaweed extract (2 g/l). **T_9:** Seaweed + Chitosan. **T_{10}:** Seaweed + Mix (B+Zn+Fe). **T_{11}:** Seaweed + Chitosan + Mix.

TABLE 6. The effects of different foliar spraying treatments and wrapping with light polyethylene film as well as their interaction on total soluble solids (TSS), total sugars percentages, vitamin C and anthocyanin contents of red cabbage heads stored at room conditions for one month during 2020 and 2021 seasons.

Characters	TSS (%)		Total sugars (%)		Vitamin C (mg/100 g)		Anthocyanin (mg/100 g)	
Treatments	2020	2021	2020	2021	2020	2021	2020	2021
A. Wrapping effect:								
Unwrapped	6.13	6.29	5.35	5.65	29.37	29.56	177.4	162.0
Wrapped	6.49	6.74	5.61	5.88	31.10	30.52	208.1	189.2
F. test	*	*	*	*	*	*	*	*
B. Foliar treatments effects:								
T_1	5.77	5.94	5.07	5.25	29.28	29.08	171.6	155.6
T_2	5.91	6.06	5.15	5.34	29.42	29.28	175.1	160.3
T_3	6.01	6.19	5.24	5.42	29.62	29.50	180.1	163.6
T_4	6.23	6.44	5.39	5.62	30.05	29.89	188.5	171.1
T_5	6.51	6.74	5.64	6.56	30.64	30.50	200.8	184.1
T_6	6.34	6.53	5.48	5.72	30.22	30.06	193.0	171.6
T_7	6.67	6.94	5.80	6.07	31.02	30.67	210.1	193.1
T_8	6.16	6.31	5.33	5.52	29.85	29.65	184.5	167.0
T_9	6.45	6.65	5.55	5.78	30.43	30.28	196.6	179.0
T_{10}	6.63	6.83	5.72	5.98	30.81	30.66	205.6	188.3
T_{11}	6.75	7.04	5.89	6.18	31.25	30.91	214.1	198.0
LSD at 5%	0.04	0.04	0.05	0.09	0.08	0.09	2.1	2.8
C. Interaction effects:								
Un-wrapped T_1	5.62	5.77	4.97	5.10	28.47	28.68	158.3	142.6
T_2	5.73	5.88	5.04	5.18	28.59	28.87	161.0	147.3
T_3	5.79	5.97	5.14	5.25	28.78	29.04	166.3	151.0
T_4	6.07	6.21	5.26	5.43	29.18	29.43	172.6	158.6
T_5	6.33	6.48	5.49	7.04	29.75	29.99	185.0	171.6
T_6	6.19	6.30	5.35	5.55	29.36	29.62	175.6	154.6
T_7	6.51	6.70	5.65	5.88	30.12	30.03	194.3	179.6
T_8	6.00	6.08	5.21	5.34	28.97	29.24	168.6	154.3
T_9	6.26	6.42	5.42	5.60	29.59	29.81	181.0	164.3
T_{10}	6.44	6.59	5.56	5.80	29.92	30.17	190.0	175.3
T_{11}	6.56	6.77	5.75	5.98	30.34	30.34	198.6	182.6
Wrapped T_1	5.93	6.11	5.18	5.41	30.09	29.49	185.0	168.6
T_2	6.10	6.25	5.26	5.51	30.25	29.69	189.3	173.3
T_3	6.23	6.42	5.33	5.59	30.47	29.97	194.0	176.3
T_4	6.39	6.68	5.53	5.80	30.91	30.35	204.3	183.6
T_5	6.70	7.00	5.78	6.08	31.53	31.01	216.6	196.6
T_6	6.49	6.77	5.62	5.90	31.07	30.50	210.3	188.6
T_7	6.82	7.18	5.96	6.26	31.93	31.31	226.0	206.6
T_8	6.32	6.54	5.44	5.70	30.73	30.07	200.3	179.6
T_9	6.64	6.87	5.68	5.97	31.28	30.75	212.3	193.6
T_{10}	6.82	7.08	5.87	6.15	31.71	31.16	221.3	201.3
T_{11}	6.93	7.30	6.03	6.38	32.16	31.48	229.6	213.3
LSD at 5%	NS	0.06	NS	0.14	NS	0.13	3.1	3.9

T_1: Control . **T_2:** B (50 ppm). **T_3:** Zn (100 ppm). **T_4:** Fe (300 ppm). **T_5:** Mix (B+Zn+Fe). **T_6:** Chitosan (2 g/l).
T_7: Chitosan + Mix (B+Zn+Fe) **T_8:** Seaweed extract (2 g/l). **T_9:** Seaweed + Chitosan. **T_{10}:** Seaweed + Mix (B+Zn+Fe). **T_{11}:** Seaweed + Chitosan + Mix.

TABLE 7. The effects of different foliar spraying treatments and wrapping with light polyethylene film as well as their interaction on the percentage of weight loss of red cabbage heads after 1, 2, 3 and 4 weeks of storage at room conditions during 2020 and 2021 seasons.

Characters		Weight loss (%)							
		1 week		2 weeks		3 weeks		4 weeks	
Treatments		2020	2021	2020	2021	2020	2021	2020	2021
A. Wrapping effect:									
Unwrapped		7.65	5.19	11.82	8.28	17.05	14.53	19.98	19.89
Wrapped		2.26	1.95	3.71	2.80	6.37	5.22	7.62	7.65
F. test		*	*	*	*	*	*	*	*
B. Foliar treatments effects:									
T_1		6.70	5.98	9.63	7.97	15.62	14.00	17.66	16.81
T_2		5.82	4.72	8.77	7.30	12.95	11.26	15.09	15.88
T_3		5.49	4.46	8.50	6.74	12.42	10.50	14.61	15.29
T_4		5.06	3.69	7.89	5.32	11.85	9.75	14.10	14.18
T_5		4.50	2.86	7.17	4.75	10.97	8.96	13.18	12.78
T_6		4.90	3.44	7.84	5.26	11.40	9.37	13.54	13.55
T_7		3.99	2.38	6.52	4.31	10.19	8.57	12.15	11.61
T_8		5.21	3.85	8.29	6.11	12.13	10.30	14.31	14.60
T_9		4.78	3.19	7.71	4.96	11.26	9.28	13.34	13.25
T_{10}		4.29	2.63	6.98	4.62	10.70	8.50	12.75	12.58
T_{11}		3.79	2.09	6.15	3.63	9.36	8.12	11.08	10.91
LSD at 5%		0.47	0.39	0.40	0.41	0.38	0.50	0.42	0.63
C. Interaction effects:									
Un-wrapped	T_1	9.92	8.59	14.42	11.41	21.76	19.43	25.13	24.00
	T_2	8.83	6.64	13.28	10.48	18.76	16.53	21.94	22.95
	T_3	8.52	6.34	12.93	10.07	18.33	15.39	21.23	22.27
	T_4	7.93	5.21	12.09	7.93	17.54	14.46	20.54	20.32
	T_5	6.98	4.35	10.84	7.28	16.09	13.35	19.26	18.44
	T_6	7.70	4.95	12.06	7.92	16.74	13.82	19.59	19.36
	T_7	6.20	3.77	9.98	6.81	14.73	12.88	17.50	16.92
	T_8	8.12	5.38	12.73	8.89	17.89	15.35	20.79	21.07
	T_9	7.49	4.66	11.84	7.61	16.55	13.77	19.44	18.93
	T_{10}	6.64	4.03	10.58	7.07	15.72	12.50	18.50	18.40
	T_{11}	5.82	3.25	9.27	5.62	13.51	12.35	15.82	16.13
Wrapped	T_1	3.48	3.37	4.83	4.53	9.48	8.57	10.18	9.62
	T_2	2.81	2.81	4.26	4.13	7.14	6.00	8.23	8.81
	T_3	2.46	2.59	4.08	3.41	6.50	5.62	7.99	8.30
	T_4	2.20	2.17	3.68	2.71	6.16	5.04	7.66	8.04
	T_5	2.02	1.38	3.49	2.22	5.85	4.56	7.10	7.12
	T_6	2.09	1.94	3.62	2.59	6.07	4.92	7.50	7.75
	T_7	1.79	1.00	3.06	1.82	5.65	4.27	6.81	6.29
	T_8	2.29	2.33	3.84	3.33	6.37	5.25	7.83	8.14
	T_9	2.07	1.72	3.59	2.31	5.98	4.80	7.24	7.57
	T_{10}	1.95	1.23	3.39	2.16	5.68	4.49	7.00	6.77
	T_{11}	1.75	0.93	3.03	1.63	5.21	3.89	6.35	5.70
LSD at 5%		0.67	0.55	0.57	0.58	0.53	0.71	0.60	0.90

T_1: Control . **T_2:** B (50 ppm). **T_3:** Zn (100 ppm). **T_4:** Fe (300 ppm). **T_5:** Mix (B+Zn+Fe). **T_6:** Chitosan (2 g/l).

T_7: Chitosan + Mix (B+Zn+Fe) **T_8:** Seaweed extract (2 g/l). **T_9:** Seaweed + Chitosan. **T_{10}:** Seaweed + Mix (B+Zn+Fe). **T_{11}:** Seaweed + Chitosan + Mix.

structures. It is important for translocation of sugar or energy into the growing parts of plants. Moreover, spraying B element during all stages of plant growth improves root phosphorus and potassium uptake and the structure of root cell membranes. However, Zn is an important constituent of several enzymes and proteins in the plant cell. It is crucial for plant growth and development and plays a significant part in a wide range of physiological processes. It is essential in the synthesis of auxins, which help growth regulation and cell elongation (Marschener, 2012). Meanwhile, Fe is an essential micronutrient for almost all living organisms and it plays a critical role in plant metabolism such as DNA synthesis, respiration and photosynthesis processes. Iron is also involved in the synthesis of chlorophyll and it is essential for the maintenance of chloroplast structure. The obtained results are in agreement with those obtained by Mohamed and Zewail (2016), Ashruba (2017) on cabbage, Fouda and Abd-Elhamied (2017) on cowpea, Verma et al. (2017) on chickpea, Singh et al. (2018) and Abd El-Hady and Shehata (2019) on potato.

The promotive effect of chitosan may be due to its promoting the enzyme activities for nitrogen metabolism (Islam et al., 2016) which led to an increase in vegetative growth and development in addition to improving yield and quality (Abd El-Hady and Abd-Elhamied, 2018). Enhancing P content (as shown in Table 2) which plays a main role in biosynthesis and translocation of carbohydrates (as shown in Table 4) which is necessary for increasing plant cell division and forming DNA and RNA molecules (Farouk and Ramadan, 2012). It is stimulating physiological processes and activating photosynthetic mechanisms that enhance plant growth and hence increase yield. These findings are confirmed with Yang and Xu (2003) on chinese cabbage, Mondal et al. (2012) on okra and Hamaiel et al. (2020) on broccoli.

The enhancement of seaweed extract may be due to its effect as a plant biostimulant that provides plants with some macro-, micro-elements and auxins that increase photosynthetic process, and hence promote plant growth. It also contains cytokinins and alganic acids that promote the growth of root cells which enhance nutrient uptake and increase its contents (as shown in Tables 2 and 3). Therefore, plant performance could be enhanced as reflected in yield and quality. These results are in harmony with those obtained by Farouk (2015) on potato, Lola-luz et al. (2013) on cabbage, Dawa et al. (2014) on pea and Abd El-Hady et al. (2016) on potato.

The superiority of wrapping red cabbage head during storage at room temperature may be attributed to prevent or reduce head water loss, deterioration and damage. The desirable effect of spraying red cabbage plants with seaweed extract + chitosan + mix elements on storage traits of heads might have been attributed to its effective role in improving vegetative growth characters, increasing the chemical formation, activating hormone synthesis and consequently raising enzymatic activities, which reflected on the increment of head storage ability and kept head quality parameters during storage. These results are in the same line with those obtained by No et al. (2007) and Silva et al. (2015)

Conclusions

It could be recommended that yield, quality and storage ability of red cabbage heads could be enhanced by foliar spraying plants in the field with seaweed extract + chitosan + mix elements and wrapping harvested heads with light polyethylene film before storing for one month at the room conditions.

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The authors declare no conflicts of interest.

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تأثير الرش ببعض العناصر الصغرى والمنشطات الحيوية على المحصول وجـودته والقدرة التخزينية لرؤوس الكرنب الأحمر

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أجريت تجربتان حقليتان على نباتات الكرنب الأحمر لدراسة تأثير الرش ببعض العناصر الصغرى (حديد وزنك وبورون) والمنشطات الحيوية (مستخلص الطحالب البحرية و الشيتوزان) وخليط بينهم على التركيب الكيماوى والمحصول وجودته وقد صممت التجربة في تصميم فى تصميم قطاعات كاملة العشوائية من ٣ مكرارات كما تم عمل تجربتين معمليتين بمعامل كلية الزراعة لدراسة القدرة التخزينية لرؤوس الكرنب الأحمر الناتجة من المعاملات السابقة حيث تم تقسيم الرؤوس التى تم إختيارها عشوائياً من كل معاملة إلى مجموعتين وتم تغليف المجموعة الاولى بفيلم البولى إيثيلين وتركت المجموعة الثانية بدون تغليف ثم خزنت تحت ظروف الغرفة (٢٠ °م ورطوبة نسبية٦٤٪) لمدة شهر وتم تقدير الفقد فى الوزن كل أسبوع أثناء مدة التخزين كما تم تقدير نسبة الرطوبة، البروتين، الدهون الكلية، الرماد، الكربوهيدرات والسكريات الكلية، المواد الصلبة الذائبة الكلية، فيتامين سى، الأنثوسيانين. وقد صممت التجربة فى تصميم تجربة عاملية من عاملين فى تصميم تام العشوائية من ٣ مكرارات.

أوضحت النتائج المتحصل عليها تفوق كل المعاملات مقارنة بمعاملة الكنترول فى كل الصفات المدروسة (نتروجين، فوسفور، بوتاسيوم، حديد، زنك، بورون، المادة الجافة، المواد الصلبة الذائبة الكلية، فيتامين سى، الكربوهيدرات والسكريات الكلية، الالياف، الفينولات الكلية، الأنثوسيانين، وعدد الأوراق الخارجية ووزنها، وطول الرأس وقطرها ووزنها وكذلك محصول الفدان) وكانت أفضل المعاملات هى معاملة الرش بخليط من مستخلص الطحالب والشيتوزان والعناصر الصغرى حيث سجلت أعلى القيم معنوياً لمعظم الصفات التى تم قياسها فى حين سجلت معاملة الكنترول أعلى القيم معنوياً بالنسبة لمحتوى الرؤوس من النترات خلال الموسمين.

وبالنسبة لتجربة القدرة التخزينية فقد وجد أن الرؤوس الناتجة من النباتات المعاملة فى الحقل بمستخلص الطحالب والشيتوزان وخليط العناصر الصغرى مع التغليف بفيلم البولى إيثيلين أعطت تفوق معنوى فى المحتوى من البروتين والكربوهيدرات والسكريات الكلية والمواد الصلبة الذائبة الكلية وفيتامين سى والأنثوسيانين وكذلك كانت الأقل فى الفقد فى الوزن وذلك خلال الموسمين.

وبذلك يمكن التوصية برش نباتات الكرنب الاحمر فى الحقل أثناء موسم النمو بخليط من مستخلص الطحالب البحرية والشيتوزان والعناصر الصغرى حيث تم الحصول على أفضل النتائج بالنسبة للمحصول و جودته وكذلك القدرة التخزينية عند تغليف الرؤوس بفيلم البولى إيثيلين.