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Effect of different concentrations of seaweed extract on growth, yield and quality of two carrot (*Daucus carota* L.) cultivars

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ABSTRACT

An open field experiment were conducted in 2012 and 2013 seasons to study the effect of different concentrations of the commercial seaweed extract "Actiwave®" on growth, yield and quality of orange and purple carrots (*Daucus carota* L. cvs Chantenay and Purple Sun), respectively. Plants were grown in sand soil and the experiment was arranged in complete randomized block design in three replicates. Actiwave was applied as foliar applications at 0, 2.5, 5 and 10 g/l, with two weeks interval for two months. Results indicate that both cultivated carrot cultivars responded differentially to the foliar applications of seaweed extract. Results show that Chantenay cultivar was more vigor than Purple Sun cultivar in terms of plant height, number of leaves and shoot fresh weight in the two growing seasons, with some exceptions. In addition, increasing foliar concentrations of "Actiwave®" up to 10 g/l was more efficient to increase carrot vegetative growth characteristics, concentrations of N, P and K in leaves of both cultivars. However, root length and weight of Purple Sun cultivar was significantly higher than Chantenay cultivar. Furthermore, foliar application of seaweed extract at 5 and 10 g/l resulted in higher yield of both Chantenay and Purple Sun cultivars (17.6, 17.9 and 17.3, 18.2 ton/fed), respectively, if compared to control in the second season. On contract, no significant increase was found in term of total yield between the cultivars. Notably, foliar spraying of seaweed extract enhanced nutritional values of the two cultivars in term of TSS, total sugars and dry matter content in both growing seasons. Furthermore, carotene, anthocyanin and total antioxidants content tended to increase with the highest level of "Actiwave®" than lower concentrations. However, all foliar levels showed higher level of the same traits than control. In conclusion, this work shows the importance of seaweed extract to increase growth and quality of carrot plants under Egyptian condition.

Key words: Carrot, seaweed extract, growth, yield, quality.

Introduction

Carrot is a widely vegetable crop that used as salad or in food processing industry because of its high nutritional value (Abo Elkhier, 2013). Roots of carrot are rich in fiber, minerals, calcium, amino acids, vitamin C, minerals, glucose and fructose (Bose *et al.,* 2000 and Chantaro *et al.,* 2008). In addition, carrot is great source for β-carotene, a precursor of vitamin A, which plays a main role in protecting human against cancer and anti-aging (Rao and Rao, 2007).

Using of inorganic fertilizers, mainly nitrogen and potassium, improve soil fertility, increase carrot growth and productivity in many areas (Dawuda *et al.,* 2011). However, excessive application of NPK causes unfavorable changes in physical and chemical properties of soil (Sarma *et al.,* 2015). Thus, in modern agriculture, there is an argent need to use alternative sources for plant nutrition to overcome problems of toxicity and environmental pollution (Zodape *et al.,* 2011) without affecting plant yield or quality (Hong *et al.,* 2007).

In recent years, biostimulants, i.e. algal and plant extracts or secondary plant metabolites, have got a lot of attention in the last decay since it acts as synthetic products that capable to stimulate plant growth, stress resistance and increase yield (Chojnacka *et al.,* 2015), hence being integrated in agricultural production system (Brown and Saa, 2015). Many reports mentioned that alga extracts are ecology-oriented products that increase growth and biological yield of different vegetable species (Sharma *et al.,* 2014) by increasing plant resistance against stresses and diseases. Likewise, multicellular alga "Seaweed" is one of the most marine resources that have been used as a bio-fertilizer since sixteen's of this century (Zodape, 2001 and Craigie, 2011). Also, seaweed has been

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used as manure or soil conditioner (Hong *et al.,* 2007). It contains many bioactive substances and plant growth regulators such as auxins, cytokinins, and betaines (Zhang and Ervin, 2008), as well as considers a cost effective source for minerals and micronutrients (Reitz and Trumble, 1996). In connection, Gajewski *et al.* (2009) showed that seaweed caused a favorable effect on the quantitative and qualitative parameters of carrot, depending on time a dose of application (Alam *et al.,* 2014).

However, foliar application of seaweed extracts proved to enhance crop yield, nutrient uptake and increase immune system of sprayed plants (Zhang and Ervin, 2008). For instance, the liquefied seaweed products Goëmar BM 86® and Kelpak SL reported to improve yield and quality of two strawberry cultivars (Masny *et al.,* 2004). Raghavendra *et al.* (2007) found that soaking seeds of cotton in *Sargassum wightii* extract increased germinated seedlings resistance against bacterial pathogens. Besides, foliar application of *Sargassum johnstonii* extract resulted in develop shoot and root architecture of sprayed tomato than control (Kumari *et al.,* 2011, Hernández-Herrera *et al.,* 2014).

This work aims to investigate effect of different concentrations of the commercial seaweed extract Actiwave®", as foliar application, on growth, yield and quality of orange and purple carrot (*Daucus carota* L.) grown in sand soil. To achieve these work different growth characteristics, physical and chemical quality parameters were measured.

Materials and Methods

An open field experiment was conducted at private farm at Kilo 62, Alexandria road, through the two successive seasons of 2012 and 2013, to study the effect of seaweed foliar application on growth and quality of two carrot cultivars. Seeds of *Daucus carota* L. cv Chantenay and cv Purple Sun (Territorial Seed Company, USA) were sown in sand soil on 15^{th} and 20^{th} of October at t the first and second seasons, respectively. The experiment was arranged in split-design, in randomized complete block design with three replicates. The experimental unit area was 10.5 m^2 per plot (3.0 m x 3.50 m), included 5 ridges, 50 cm apart. Doses of 40 kg N, 15 kg P_2O_5 and 50 kg K_2O/fed, were applied before planting, as recommended by Ministry of Agriculture, to maintain available nutrient in soil. Seeds were drilled on the two ridge sides and thinned after complete emergence to have 5cm space between plants. Other agricultural practices such as drip irrigation; fertilization, disease and pest management were conducted according to commercial carrot production in the district.

Seaweed liquid application

The commercial seaweed extraction product "Actiwave®" (Valagro s.p.a Italy) were applied as foliar additives to carrot plants at 3-4 true leaves. Actiwave® is a metabolic stimuli derived from *Ascophillum nodosum* and contains betaines, alginates and vitamin K. Foliar application was done by mixing four concentrations (0, 5, 10 and 20 g per litter), two weeks intervals for two months. However, adequate amount of the mixture was applied to each plant to fully cover whole vegetative organs, while tap water was used as mock treatment (control).

Growth parameters and yield

Ten plants were collected randomly from each plot at harvest time to measure plant height, number of leaves and shoot fresh weight of selected plants. In addition, root length and diameter were measured after removing plants from the field. Roots were removed from the soil, cut and weighted to calculate total yield.

Chemical composition

Plant tissues were oven dried for 72 h at 70°C to determine macronutrients content in carrot leaves. The fine powder (1.0 g) of dry sample was digested by using sulphuric acid and perchloric acid according to Piper (1947). Dry samples were mineralized before analysis using the micro-Kjeldahl method as described by Jackson (1973), to estimate nitrogen content. Phosphorus was extracted in acidic medium, in the presence in vanadat and molybdate that makes a yellow color to be measured at 430 nm using spectrometer (Holm, 1954). Potassium was determined using the flame photometer according to Brown and Lilliland (1964). The dry matter content was determined by drying plant tissues at 70°C till constant weight was obtained.

Total soluble solids were measured using digital referectometer, while carotenoids content was measured in root according to Umiel and Gabelmoii (1971). Anthocyanin was measured by soaking root tissues in 600 µl 1% HCl, diluted in methanol (v/v) for acidification, and incubated for 24 h at 4 °C, the anthocyanin contents in were measured at 530 nm and 657 nm and calculated as described by Chory (1992). Total antioxidant capacity (TAC) was assessed by the FRAP assay according to Zloch *et al.* (2004) using spectrophotometer.

Statistical analysis

Data was subjected to the statistical analysis and means were analyzed using the analysis of variance (ANOVA). The differences between the means was determined using the L.S.D. test at significant level $p<0.05$. Statistical package Unistat (Unistat, Inc., USA) was used.

Results and Discussion

Plant growth performance

Data in Table (1) show significant differences between both cultivated carrot cultivars in term of plant height, number of leaves and shoot fresh weight in the first growing season. No differences were observed in number of leaves and shoot fresh weight between the two cultivars in the second season. Notably, cultivar Chantenay was more vigor than Purple Sun through the two seasons. In this respect, it could be concluded that differences between the two cultivars is related mainly to the genotype variations. Chantenay cultivar is used to grow under arid and semi-arid conditions, while Purple Sun is originally form European climate that require different growth conditions (FAO, 2003). In addition, earlier studies indicated that individual cultivar of the same species may behave differently to seaweed extracts, McHugh and Lawrence (2003) working on potato. According to the effect of different foliar levels of seaweed on growth of carrot plants, data in Table (1) reveal that seaweed foliar applications increased growth of the two cultivars if compared to control treatment. Obviously, the highest foliar level of Actiwave (10 g/l) caused significant increases in the above growth traits than (2.5 g/l), similar impact was obtained when carrots were treated with (5 or 10 g/l). Moreover, interaction between different foliar concentrations and cultivars showed better plant height, number of leaves and shoot fresh weight with Chantenay than Purple Sun when sprayed with 10 g/l of seaweed extract, if compared to lower concentrations. In connection, similar results showed that foliar applications of seaweed extract increased growth of canola (Ferreira and Lourens, 2002), carrot (Sekoli *et al.,* 2011), sweet pepper (Arthur *et al.,* 2003) and tomato (Mikiciuk *et al.,* 2014). Many reports mentioned that biostimulants improve growth and development of sprayed plants by increasing carbon and nitrogen metabolism (Gonzalez *et al.,* 2013), photosynthesis (Parrado *et al.,* 2008) as will as enhancing nutrients uptake from the soil (Halpern *et al.,* 2015).

Yield and its components

As shown in Table (2), yield of Purple Sun (16.4 and 17.1 ton/fed.) was not significantly higher than Chantenay (15.7 and 16.9 ton/fed.) in the two growing seasons, respectively.
In addition, increasing foliar concentrations of seaweed extract gradually improved yield of both cultivars, especially at 10 g/l than control. Concerning root length and weight, significant differences were obtained between both carrot cultivars. Meanwhile, increasing levels of foliar seaweed extract up to 10 g/l found to increase both root length and weight in the two growing seasons. However, interaction between cultivars and the different levels of foliar seaweed application did affect significantly root length. On contrast, root weight showed the highest increase (99.6, 84.3 cm) with Purple Sun and Chantenay cultivars, respectively, when treated with 10 g/l in the second season. These favorable effects of Actiwave on carrot root maybe attributed to the capability of seaweed extract to develop a vigorous root system; root formation; and growth characters of roots of treated

plants by strengthening cell wall and enhance plant immunity against biotic and abiotic stresses (Hernandez-Herrera *et al.,* 2014 and Omar *et al.,* 2015). Also, ths enhancement in carrot total yield because that seaweed extract contains numerous of growth regulators that enhances plant yield as reported by Rathore *et al.* (2009) on soybean, Vijayanand *et al.* (2013) on bean, Zodape *et al.* (2011) on tomato.

Table 1: Effect of different concentrations of seaweed extract on plant height, number of leaves and shoot fresh weight of Chantenay and Purple Sun cultivars

Treatments	**Plant height (cm)**					
	Chantenay	**Purple Sun**	Mean	**Chantenay**	**Purple Sun**	Mean
	Season 1		(B)	Season 2		(B)
Control	50.1	43.2	46.7	45.6	40.4	43.0
2.5 g/l	54.6	50.4	52.5	51.2	37.3	44.3
5 g/l	58.6	52.5	55.6	53.7	54.6	54.2
10 g/l	57.3	55.5	56.4	55.9	56.8	56.4
Mean (A)	55.2	50.4		51.6	47.3	
LSD. 0.05						
A	2.1			1.4		
B	2.6			1.9		
AxB	3.3			2.7		

Treatments	**Number of leaves**					
	Chantenay	**Purple Sun**	Mean	**Chantenay**	**Purple Sun**	Mean
	Season 1		(B)	Season 2		(B)
Control	9	8	8.5	9	7	8.0
2.5 g/l	10	9	9.5	9	8	8.5
5 g/l	13	9	11.0	10	9	9.5
10 g/l	15	11	13.0	11	10	10.5
Mean (A)	11.8	9.3		9.8	8.5	
LSD. 0.05						
A	1.1			NS		
B	1.3			2.2		
AxB	2.1			NS		

Treatments	**Shoot fresh weight (g)**					
	Chantenay	**Purple Sun**	Mean	**Chantenay**	**Purple Sun**	Mean
	Season 1		(B)	Season 2		(B)
Control	55.3	52.4	53.9	50.2	49.5	49.9
2.5 g/l	56.1	52.0	54.1	53.1	50.7	51.9
5 g/l	59.2	55.7	57.5	56.6	56.2	56.4
10 g/l	62.3	58.5	60.4	58.4	56.7	57.6
Mean (A)	58.2	54.7		54.6	53.3	
LSD. 0.05						
A	3.2			NS		
B	4.3			3.8		
AxB	6.7			8.1		

Table 2: Effect of different concentrations of seaweed extract on root length, weight and total yield of Chantenay and Purple Sun cultivars

Treatments	Root length (cm)					
	Chantenay	**Purple Sun**	Mean	**Chantenay**	**Purple Sun**	Mean
	Season 1		(B)	Season 2		(B)
Control	15.3	26.4	20.9	14.1	26.3	20.2
2.5 g/l	16.1	27.2	21.7	15.2	26.6	20.9
5 g/l	16.5	28.2	22.4	16.4	27.9	22.2
10 g/l	18.2	28.3	23.3	17.7	28.2	23.0
Mean (A)	16.5	27.5		15.9	27.3	
LSD. 0.05						
A	2.3			1.1		
B	4.9			5.7		
AxB	9.4			8.2		

Treatments	Root weight (g)					
	Chantenay	**Purple Sun**	Mean	**Chantenay**	**Purple Sun**	Mean
	Season 1		(B)	Season 2		(B)
Control	62.4	86.3	74.4	58.6	83.2	70.9
2.5 g/l	77.1	95.5	86.3	65.2	91.3	78.3
5 g/l	80.2	96.1	88.2	77.7	97.5	87.6
10 g/l	81.5	83.7	82.6	84.3	99.6	92.0
Mean (A)	75.3	90.4		71.5	92.9	
LSD. 0.05						
A	7.5			5.1		
B	10.7			9.1		
AxB	15.3			12.2		

Treatments	Yield (ton/fed.)					
	Chantenay	**Purple Sun**	Mean	**Chantenay**	**Purple Sun**	Mean
	Season 1		(B)	Season 2		(B)
Control	13.6	14.3	14.0	14.0	15.9	15.0
2.5 g/l	15.2	16.7	16.0	15.9	17.1	16.5
5 g/l	16.4	17.2	16.8	17.6	17.0	17.3
10 g/l	17.4	19.3	18.4	17.9	18.5	18.2
Mean (A)	15.7	16.9		16.4	17.1	
LSD. 0.05						
A	NS			NS		
B	1.9			1.4		
AxB	2.4			3.0		

Concentrations of nitrogen, phosphorus and potassium

Results in Table (3) indicate that concentrations of nitrogen, phosphorus and potassium were significantly higher in leaves of Purple Sun cultivar than Chantenay cultivar, with some exceptions. Furthermore, concentration on the three major nutrients were gradually increased with increasing levels of foliar seaweed application up to 10 g/l if compared to control or lower concentrations. In addition, the interaction between treatments show significant increase in contents of N, P and K in leaves of Purple Sun cultivar than Chantenay, mainly with 10 g/l than control. In this respect, it could be suggested that seaweed extracts has different mechanisms to increase concentrations of N, P and K in leaves of sprayed carrots cultivar like improve nutrient uptake from soil, stimulate nitrogen uptake and fixation, solubilize insoluble minerals through the production of organic acids as well as activate hormonal apparatus of the plant (Bashan, 1998; Linser *et al.,* 2006; Abbas, 2013 and Colla *et al.,* 2015)

Table 3: Effect of different concentrations of seaweed extract on N, P and K in leaves of Chantenay and Purple Sun cultivars

Treatments	N (mg/g d.w)					
	Chantenay	**Purple Sun**	Mean	**Chantenay**	**Purple Sun**	Mean
	Season 1		(B)	Season 2		(B)
Control	26.1	28.7	27.4	27.4	28.5	28.0
2.5 g/l	27.4	30.2	28.8	29.3	29.1	29.2
5 g/l	28.2	30.9	29.6	29.5	31.3	30.4
10 g/l	28.6	31.6	30.1	30.1	33.2	31.7
Mean (A)	27.6	30.4		29.1	30.5	
LSD. 0.05						
A	1.2			NS		
B	2.0			1.7		
AxB	2.86			2.2		

Treatments	P (mg/g d.w)					
	Chantenay	**Purple Sun**	Mean	**Chantenay**	**Purple Sun**	Mean
	Season 1		(B)	Season 2		(B)
Control	2.4	3.1	2.8	2.8	3.7	3.3
2.5 g/l	2.5	4.3	3.4	3.4	4.7	4.1
5 g/l	3.1	4.7	3.9	3.6	5.5	4.6
10 g/l	3.6	5.2	4.4	4.6	5.4	5.0
Mean (A)	2.9	4.3		3.6	4.8	
LSD. 0.05						
A	1.1			0.88		
B	1.4			1.1		
AxB	2.7			1.9		

Treatments	K (mg/g d.w)					
	Chantenay	**Purple Sun**	Mean	**Chantenay**	**Purple Sun**	Mean
	Season 1		(B)	Season 2		(B)
Control	25.6	27.3	26.5	23.2	25.4	24.3
2.5 g/l	25.2	28.5	26.9	24.9	25.1	25.0
5 g/l	26.5	30.6	28.6	27.8	29.8	28.8
10 g/l	28.8	31.1	30.0	30.3	32.6	31.5
Mean (A)	26.5	29.4		26.6	28.2	
LSD. 0.05						
A	1.4			NS		
B	2.6			3.8		
AxB	3.1			7.2		

Root nutritional quality

Presented data in Table (4) show that roots of Purple Sun cultivar were more rich in TSS, total sugars and dry matter content than Chantenay, in the two seasons. Also, foliar application of seaweed extract at 10 g/l was more effective than lower concentrations in increasing the above parameters. This enhancement was clearly observed in Purple Sun cultivar than Chantenay. As shown in Fig (1), antioxidants in root tissue found to be higher in Purple Sun Cultivar than Chantenay cultivar. On the other hand, carotene recorded higher values with Chantenay cultivar than Purple Sun. Notably, concentrations of sprayed seaweed extract led to gradual carotene increases in Chantenay cultivar and anthocyanin in Purple Sun cultivar at 10 g/l if compared to control. These results indicate that Actiwave improved root nutritional quality for humane health, especially with using the higher concentrations. This may be based on the mode of action of Actiwave, in the involvement of metabolic stimuli derived from *Ascophillum* nodosum and contains betaines, alginates and vitamin K increase, In addition, seaweed extract helps treated plants to accumulate more photosynthetic pigments (Kusnetsov *et al.,* 1994) that building up more carotene, anthocyanin and total antioxidants in root tissues (Biswall *et al.,* 1995).

Table 4: Effect of different concentrations of seaweed extract on total soluble solid (TSS), total sugars and dry matter (DM) in roots of Chantenay and Purple Sun cultivars

Treatments	TSS					
	Chantenay	**Purple Sun**	Mean (B)	**Chantenay**	**Purple Sun**	Mean (B)
	Season 1			Season 2		
Control	5.2	8.3	6.8	6.2	7.5	6.9
2.5 g/l	6.1	9.3	7.7	6.7	8.9	7.8
5 g/l	7.4	11.5	9.5	7.9	10.1	9.0
10 g/l	7.3	11.1	9.2	8.2	11.5	9.9
Mean (A)	6.5	10.1		7.3	9.5	
LSD. 0.05						
A	1.5			1.2		
B	2.6			1.9		
AxB	6.4			3.8		

Treatments	Total sugars (%)					
	Chantenay	**Purple Sun**	Mean (B)	**Chantenay**	**Purple Sun**	Mean (B)
	Season 1			Season 2		
Control	3.2	5.3	4.3	2.9	3.8	3.4
2.5 g/l	4.6	6.2	5.4	3.1	5.5	4.3
5 g/l	5.1	6.6	5.9	4.2	5.9	5.1
10 g/l	5.0	6.5	5.8	4.5	6.9	5.7
Mean (A)	4.5	6.2		3.7	5.5	
LSD. 0.05						
A	1.0			0.75		
B	1.4			1.1		
AxB	2.5			3.3		

Treatments	DM (%)					
	Chantenay	**Purple Sun**	Mean (B)	**Chantenay**	**Purple Sun**	Mean (B)
	Season 1			Season 2		
Control	13.2	15.3	14.3	12.9	13.8	13.4
2.5 g/l	14.6	16.2	15.4	13.1	15.5	14.3
5 g/l	15.1	16.6	15.9	14.2	15.9	15.1
10 g/l	15.0	16.5	15.8	14.5	16.9	15.7
Mean (A)	14.5	16.2		13.7	15.5	
LSD. 0.05						
A	1.0			0.75		
B	1.4			1.1		
AxB	2.2			3.3		

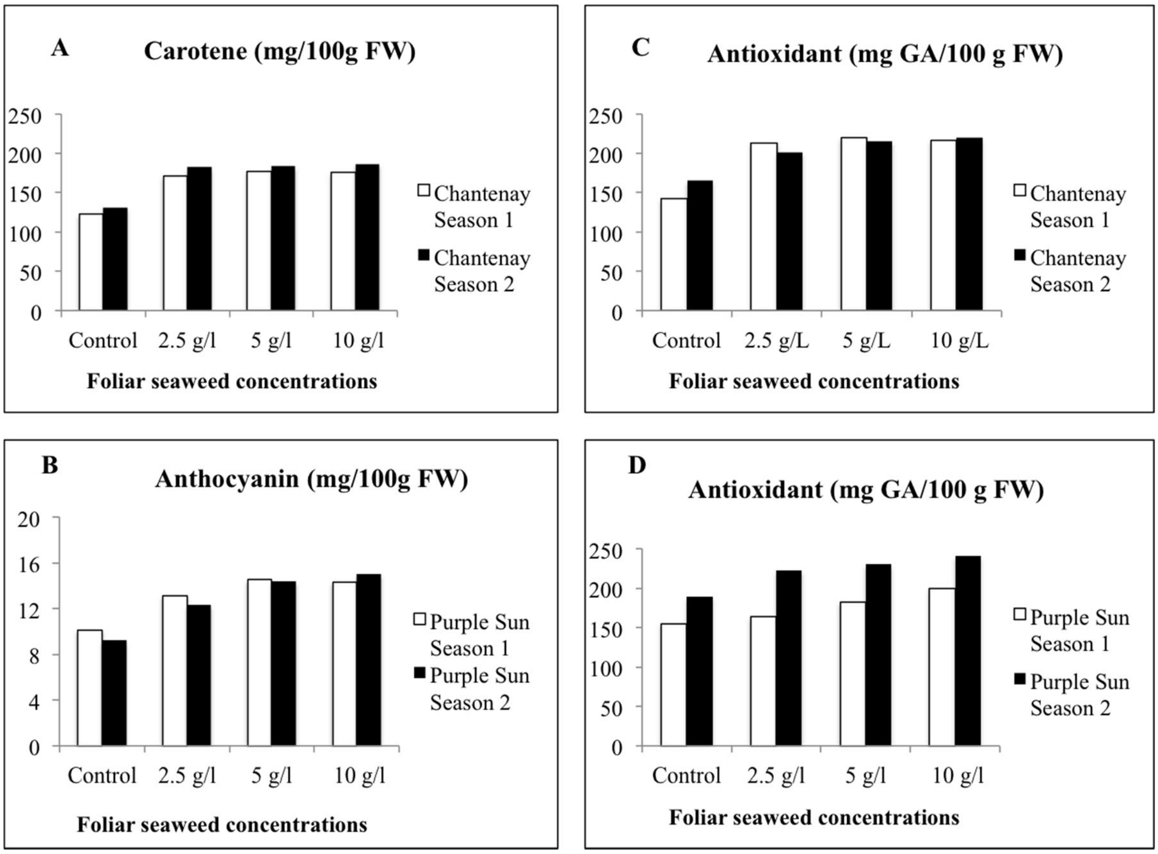

Fig. 1: Effect of different concentrations of seaweed extract on carotene content in Chantenay cultivar, anthocyanin content in Purple Sun cultivar and total antioxidants content in roots of both carrot cultivars

Conclusion

This work shows the importance of seaweed extract to increase growth and quality of carrot under Egyptian condition. Also, it recommends application of foliar commercial seaweed extract in combinations with Purple Sun cultivar to increase its contains of favorable consumption human food for local market.

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