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Response of green garlic to plant density and spraying with algae extract

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Abstract

This experiment was carried out to study the impact of plant density 5, 6, 7 and 8 lines/ridge (22, 27, 31, 36 plants/m^2) and foliar application of *Ascophyllum nodosum* and *Ecklonia maxima* extracts at rate of 0, 0.5 and 1 mL/L and their interaction on plant growth, yield and chemical constituents of green garlic bulbs under new reclaimed soil. The obtained results showed that plant density 5 and 7 lines/ridge recorded highest values of plant length, bulb diameter, plant fresh weight, nitrogen and crude protein percentage in dry matter of green garlic bulbs. The plant density of 5 lines/ridge scored the highest values of leaf area, plant dry weight, bulb weight at harvest time and total carbohydrate content. In addition, plants cultivated at rate of 8 lines/ridge gave the highest values of total yield of green garlic and bulbing ratio. The plant densities at rate of 5 and 6 lines/ridge scored the highest values of bulb diameter and bulb dry matter at harvest time. Foliar application of 1 mL/L *A. nodosum* extract led to the highest total yield of green garlic, bulb weight at harvest time, bulb diameter, dry matter percentage, nitrogen and crude protein percentage in dry matter of bulbs. On the other hand, plants sprayed with 0.5 mL/L of *A. nodosum* and *E. maxima* extracts gave higher total carbohydrate content in bulbs than other treatments. Additionally, plants sprayed with 0.5 and 1 mL/L of *A. nodosum* extract gave higher potassium percentage in bulbs than other foliar application treatments.

Key words: Green garlic, plant density, algae, *Ascophyllum nodosum, Ecklonia maxima*, bulb quality

Introduction

Garlic (*Alllium sativum* L.) is considered one of the oldest and important vegetable bulb crops after onion especially in Egypt. Recently, Egyptian green garlic exports raised exponentially. However, the main production practice followed by farmers is cultivation of garlic for bulb production and collection of the green garlics in February leaving the remaining plants for dry bulbs in May without any special practice for green garlic production. This emphasise the importance of studying the factors affecting production of green garlic under Egyptian conditions.

Plant density is one of the most important factors that affects both quality and quantity of garlic bulbs. Optimum plant density give the chance to fair competition among plants on water and light as well as elements and ensure the balanced consumption of previous factors (Geremew *et al*., 2010). Both quality and quantity of total yield of garlic depends on total number of plants per unit area (Mirshekari and Mobasher, 2006). No standard plant density for garlic production under different regions for different soil and climate for the maximum production and nutritive value is avaialble (Singh and Singh, 2007). The increase of intra-row spacing specially 10 cm between plants and 30 cm between the rows reflected on total bulb yield and enhanced bulb size as well as bulb weight (Alam *et al*., 2010).

Many species of seaweeds are used in agriculture as growth promoters for vegetable crops production such as *E. maxima, Kappaphycus alvarezii, A. nodosum, Laminaria digitata, Laminaria hyperborea, Fucus vesiculosus, Durvillea potatorum, Fucus serratus* (Kocira *et al*., 2013). Seaweeds affect agricultural crops by enhancing plant and seedling growth as well as root development (Mukherjee and Patel, 2020). *A. nodosum*, one of the macro algae (brown seaweeds) which is known as rockweed, is available in large scale through the European northwest coast and North America northeastern coast (Moreira *et al*., 2017). The analysis of *A. nodosum* shows that it is rich in phenolic compound phlorotannins and alginic acid (28 %), fucoidans (11.6 %), mannitol (7.5 %) and laminarin (4.5 %), (Holdt and Kraan, 2011; Yuan and Macquarrie, 2015 and Moreira *et al*., 2017). The analysis of dried *A. nodosum* show that it contains carbohydrates (44.7 %), ash (18.6 %), protein (5.2 %), lipids (3.0 %), phenolic compounds (1.4 %) and other compounds (13.6 %) (Moreira *et al*., 2017), inorganic compounds such as nitrogen, phosphorus, potassium, calcium, iron, magnesium, zinc, sodium and sulfur (Rayorath *et al*., 2009). *E. maxima* is another species of brown macro algae, which is produced as a seaweed extract under the trade name of Kelpak. It contains cytokinins, auxins, polyamines, gibberellins, brassinosteroids (brassinolide and castasterone), phlorotannins (eckol and phloroglucinol) and low concentrations of abscisic acid (Papenfus *et al*., 2012; Stirk *et al*., 2014; Rengasamy *et al*., 2015).

Thus, the aim of this work was to evaluate the effect of plant density combined with seaweed extracts on the quantity and quality of green garlic bulbs under Egyptian new reclaimed soil conditions.

Materials and methods

The experiment was carried out during the two successive seasons of 2016/2017 and 2017/2018, at private farm at EL Adlia Region, Sharkia Governorate, Egypt. This experiment was conducted to study the effect of plant densities, some foliar seaweeds application treatments and their interaction on plant growth, yield of green garlic and its components as well as chemical composition of green garlic bulbs.

Soil samples were collected from 30 cm depth, air dried then transferred to the Soil, Water and Environment Research Institute for chemical and physical analysis of soil samples (Table 1).

Bulbs of garlic (*cv.* Sids 40) were obtained from Horticultural Research Institute, Agricultural Research Centre, Dokki, Giza, Egypt. Cloves were soaked in tap water for 24 hours before cultivation at 13th of October in both seasons.

The experimental plot area was 10.5 m^2 included 7 meters in length and 1.5 meters in width per ridge. Garlic cloves were planted in rows on ridges, the planting distance between plants in the line (row) was 15 cm. The clove number was 22, 27, 31 and 36 clove/m^2 (93333, 112000, 130666 and 149333 garlic plants per Feddan (4200 m^2) with plant density 5, 6, 7 and 8 lines/ridge, respectively. This study included 20 treatments arranged in a split plot design with three replicates. Plant densities (five, six, seven and eight lines per ridge) occupied the main plots whereas, the foliar application treatments were assigned to sub plots as following, control (tap water), seaweed extract (*A. nodosum)* at 0.5 and 1 m/L which was produced by Growtech company under the commercial name of Algreen and seaweed extract (*E. maxima*) at 0.5 and 1 mL/L which was produced by Agron company under the commercial name of Kelpak.

Algreen was used as a source of seaweeds extract *A. nodosum,* its chemical composition is presented in Table 2. Kelpak was used as a source of seaweeds extract *E. maxima,* its chemical composition is presented in Table 3. Plants were sprayed with foliar application treatments three times during the growing seasons. The first foliar application was conducted 45 days after planting and every 15 days during the growing season.

All experimental units were fertilized with 120 kg of N as ammonium sulphate, 75 kg of P_2O_5 as calcium superphosphate during soil preparation and 72 kg of K_2O as potassium sulphate per Feddan, respectively. The amounts of mineral fertilizers were divided into equal portions and were added through the drip irrigation system two times per week starting after germination and ended 15 days before the end of harvest season.

Table 2. The chemical composition of commercial seaweed extract (Algreen)

Component	Concentration	Component	Concentration
Soluble dry matter	350 g/L	S	12 %
Organic matter	20 g/L	B	0.001 %
Alginic acid	4 g/L	Mo	0.13 %
N	6 %	Growth regulators	300 ppm
Mg	3 %		

Table 3. The chemical composition of commercial seaweed extract (Kelpak)

Component	Concentration	Component	Concentration
Specific gravity	1.01	Auxin	11 g/L mg/L
pH	4.10	cytokinin	0.03 g/L mg/L
N	0.02 %	K	0.71 %
P	0.08 %		

Vegetative characters: Random samples of three plants from each experimental plot were taken after 105 days from planting date. The vegetative characters recorded were plant length (cm), leaf number per plant, leaf area (cm^2), neck diameter (cm), bulb diameter (cm), bulbing ratio, plant fresh weight (g) and plant dry weight (g).

Total green yield and its components: After garlic bulbs reached the optimum maturity stage on the first of March (135 days after planting). Plants of each experimental plot were harvested, weighted and total green yield of whole plants was determined. After harvesting five bulbs were randomly taken from each experimental sub-plot to determine neck and bulb diameter (cm), bulbing ratio, bulb weight (g) and bulb dry matter percentage.

Chemical constituents: Chlorophyll a, b and total chlorophyll (mg/g fresh weight) in leaves were measured after 105 days from planting date according to Wettestein (1957), total carbohydrates were determined calorimetrically in dry matter of bulbs (James, 1995). Total nitrogen, phosphorus and potassium were determined in dry matter of bulbs according to A.O.A.C. (1990), and crude protein percentage was calculated as nitrogen content x 6.25.

Statistical analysis: Data of the experiment were subjected to Analysis of Variance according to Snedecor and Cochran (1980). Least significant difference (L.S.D.) was used to verify significant difference between means.

Results and discussion

Vegetative growth characters: Data presented in Tables 4 and 5, revealed that plant densities of 5 and 7 lines/ridge gave the tallest plants in both seasons. Plant density of 5 lines/ridge gave the highest leaf area while 7 and 8 lines gave the lowest values in both seasons. Highest value of bulb diameter and plant fresh weight was recorded in plants grown at 5 and 7 lines/ridge in the

Table 1. Chemical and physical analysis of the experimental soil of EL Adlia Region, Sharkia Governorate during 2016/2017 and 2017/2018 seasons

Physical properties	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Texture
2016/2017	18.7	68.3	10.1	2.9	sandy
2017/2018	19.4	67.5	10.7	2.4	sandy

Chemical properties			Soluble anions (meq/L)				Soluble cations (meq/L)			
	PH (1: 2.5)	EC dS/m	CO_3^-	HCO_3^-	Cl^-	SO_4^-	Ca^{++}	Mg^{++}	Na^+	K^+
2016/2017	7.32	4.90	-	1.93	44.54	2.53	12.89	8.91	26.62	0.58
2017/2018	7.28	3.20	-	1.26	39.16	1.65	11.42	5.82	24.38	0.45

Table 4. Effect of plant density, foliar application treatments and their interaction on plant length (cm), leaf number, leaf area (cm^2), neck and bulb diameter (cm), bulbing ratio, fresh and dry weight (g) of green garlic plants in 2016/2017 season

Treatments		2016/2017 season							
Density (Lines / ridge)	Foliar application (mL/L)	Plant length (cm)	Leaf number/ plant	Leaf area (cm^2)	Neck diameter (cm)	Bulb diameter (cm)	Bulbing ratio	Plant F.W (g)	Plant D.W (g)
5 Lines		65.15	8.70	254.90	1.51	2.84	0.54	65.40	15.47
6 Lines		64.25	8.60	252.50	1.46	2.82	0.52	62.87	14.29
7 Lines		64.42	8.87	226.92	1.55	2.83	0.55	62.93	13.08
8 Lines		61.57	8.40	249.10	1.40	2.66	0.53	62.60	13.52
L.S.D. (*P*=0.05)		2.48	N.S	18.67	N.S	N.S	N.S	N.S	1.16
	Control	60.79	8.25	227.48	1.33	2.51	0.54	52.33	11.51
	A. nodosum (0.5)	64.69	8.96	247.21	1.53	2.85	0.54	64.92	14.30
	A. nodosum (1)	66.50	8.88	264.30	1.64	2.91	0.56	69.92	15.39
	E. maxima (0.5)	63.05	8.54	243.67	1.46	2.77	0.53	67.83	15.15
	E. maxima (1)	64.21	8.58	246.60	1.44	2.90	0.50	62.25	14.10
L.S.D. (*P*=0.05)		1.74	N.S.	14.34	0.13	0.16	0.04	3.78	1.33
	Control	58.67	8.33	253.33	1.34	2.61	0.51	51.00	11.10
	A. nodosum (0.5)	65.83	8.67	253.26	1.57	2.67	0.59	63.67	16.16
5 Lines	*A. nodosum* (1)	67.17	8.50	266.78	1.52	2.91	0.52	67.33	15.77
	E. maxima (0.5)	65.27	8.83	250.13	1.58	2.74	0.58	76.33	18.51
	E. maxima (1)	68.83	9.17	250.99	1.54	3.25	0.48	68.67	15.80
	Control	61.00	8.00	229.46	1.16	2.67	0.44	50.33	12.19
	A. nodosum (0.5)	61.75	9.33	256.84	1.62	3.12	0.52	63.00	13.85
6 Lines	*A. nodosum* (1)	67.50	8.67	267.98	1.71	3.05	0.56	69.67	15.98
	E. maxima (0.5)	64.33	9.00	267.93	1.56	2.83	0.55	69.67	15.42
	E. maxima (1)	66.67	8.00	240.27	1.23	2.43	0.51	61.67	14.02
	Control	63.50	8.67	198.15	1.57	2.56	0.61	62.33	13.07
	A. nodosum (0.5)	65.33	9.50	242.61	1.56	2.92	0.53	68.00	13.59
7 Lines	*A. nodosum* (1)	66.83	9.67	260.88	1.66	2.80	0.59	63.00	13.04
	E. maxima (0.5)	60.75	8.00	197.90	1.44	2.81	0.51	57.33	12.83
	E. maxima (1)	65.67	8.50	235.05	1.52	3.05	0.50	64.00	12.89
	Control	60.00	8.00	228.96	1.25	2.18	0.57	45.67	9.70
	A. nodosum (0.5)	65.83	8.33	236.15	1.36	2.67	0.51	65.00	13.60
8 Lines	*A. nodosum* (1)	64.50	8.67	261.55	1.67	2.88	0.58	79.67	16.76
	E. maxima (0.5)	61.83	8.33	258.73	1.24	2.68	0.46	68.00	13.84
	E. maxima (1)	55.67	8.67	260.09	1.47	2.87	0.51	54.67	13.68
L.S.D. (*P*=0.05)		3.49	N.S.	28.68	0.26	0.31	0.07	7.56	2.66

second season, while 8 lines/ridge gave the lowest value of bulb diameter and plant fresh weight in the second season. Plant dry weight was highest in 5 lines/ridge in both seasons. While, plant densities 7 and 8 lines/ridge gave the lowest plant dry weight. Similar findings were reported by Alam *et al*. (2010), Hussen *et al*. (2014), Badawy and Mohamed (2018), Gaikwad *et al*. (2018) on garlic and Hasan *et al.* (2017) on green garlic and found that the highest plant densities gave higher yield than lower plant densities., Our result disagrees on leaf number per plant with that obtained by Alam *et al.* (2010), Badawy and Mohamed (2018) and Gaikwad *et al.* (2018) on garlic and Hasan *et al.* (2017) on green garlic who reported that the high plant densities scored higher leaf number per plant than lower plant densities. However, our results on bulb diameter are similar to Ahmed *et al*. (2017) and Hasan *et al*. (2017).

These results indicate that low plant density helped garlic plants to efficiently utilize soil water, absorption of nutrients and light resulting better growth than higher plant density (Dhakulkar *et al*., 2009).

Additionally, results presented in Tables 4 and 5 indicate that all foliar applications did not affect number of leaves per plant in both seasons. Plant length, leaf area, neck and bulb diameter, bulbing ratio, plant fresh and dry weight were significantly affected by spraying garlic plants with both extracts of *A. nodosum* and *E. maxima* at the rate of 0.5 and 1 mL/L compared with untreated plants. Garlic plants sprayed with 1 mL/L of *A. nodosum* extract gave highest values of plant length, leaf area, bulb diameter, plant fresh and dry weight than other treatments in both seasons and neck diameter and bulbing ratio increased in the first season only. Untreated plants gave the lowest values of plant length, leaf area, bulb diameter, plant fresh and dry weight in both seasons. Similarly, Mansour (2012) found that garlic plants sprayed with algae extract scored higher leaf area than untreated plants. Also, El-Miniawy *et al*. (2014) reported that the highest concentration of algreen extract scored the tallest strawberry plants and the highest leaf area, plant fresh and dry weight. Osman (2015) indicated that the highest concentration of seaweed extract (750 ppm) scored the tallest garlic plants. Moreover, Hidangmayum and Sharma (2017) found that the foliar application of onion with *A. nodosum* improved its vegetative characters. The stimulating effect of seaweed extract on plants might be referred to its content of macro nutrients *i.e.,* N, P, K which play an important role in growth and development and micronutrients *i.e.*, Cu, Fe, Mn and Zn and the presence of organic matter, vitamins, amino acids and growth promoters like cytokinins, betaines and auxins which play an important role in cell division and enlargement (Stirk *et al*., 2014 and Elansary *et al*., 2016).

Data presented in Tables 4 and 5 showed that highest values of plant length were obtained by plants grown at plant density of

Table 5. Effect of plant density, foliar application treatments and their interaction on plant length (cm), leaf number, leaf area (cm^2), neck and bulb diameter (cm), bulbing ratio, fresh and dry weight (g) of green garlic plants in 2017/2018 season

Treatments		2017/2018 season							
Density (Lines/ridge)	Foliar application (mL/L)	Plant length (cm)	Leaf number/ plant	Leaf area (cm^2)	Neck diameter (cm)	Bulb diameter (cm)	Bulbing ratio	Plant F.W (g)	Plant D.W (g)
5 Lines		68.28	10.03	239.81	1.50	3.85	0.39	98.13	21.18
6 Lines		63.03	9.91	194.96	1.32	3.56	0.37	77.53	16.22
7 Lines		66.43	10.48	215.84	1.46	3.82	0.38	91.80	19.58
8 Lines		62.97	10.47	189.68	1.25	3.39	0.37	72.67	15.96
L.S.D. (P=0.05)		2.60	N.S.	15.54	N.S.	0.26	N.S.	5.27	1.41
	Control	62.88	10.25	200.60	1.40	3.44	0.41	78.50	17.06
	A. nodosum (0.5)	65.40	10.15	202.90	1.28	3.68	0.35	81.83	18.92
	A. nodosum (1)	68.54	10.23	219.58	1.34	3.76	0.36	89.33	18.99
	E. maxima (0.5)	65.08	10.30	209.51	1.44	3.67	0.39	86.67	17.96
	E. maxima (1)	64.00	10.17	217.78	1.44	3.73	0.38	88.83	18.23
L.S.D. (P=0.05)		2.43	N.S.	14.97	0.12	0.12	0.03	4.05	0.96
	Control	64.17	10.27	228.99	1.35	3.69	0.37	91.00	19.02
	A. nodosum (0.5)	69.75	9.87	245.26	1.35	3.89	0.35	94.67	24.97
5 Lines	*A. nodosum* (1)	69.67	10.00	239.59	1.55	3.85	0.40	105.67	22.84
	E. maxima (0.5)	71.50	9.87	235.62	1.68	4.01	0.42	100.00	20.00
	E. maxima (1)	66.33	10.13	249.61	1.55	3.80	0.41	99.33	19.05
	Control	60.67	10.00	167.39	1.28	3.35	0.39	65.33	13.72
	A. nodosum (0.5)	60.33	10.00	191.63	1.15	3.41	0.34	67.67	13.37
6 Lines	*A. nodosum* (1)	64.50	10.00	215.83	1.27	3.75	0.34	80.67	16.93
	E. maxima (0.5)	63.67	9.73	192.41	1.37	3.51	0.39	80.67	16.85
	E. maxima (1)	66.00	9.80	207.53	1.52	3.79	0.40	93.33	20.24
	Control	64.83	10.27	226.46	1.68	3.81	0.44	90.67	20.43
	A. nodosum (0.5)	67.67	10.33	209.53	1.35	4.05	0.33	92.00	21.14
7 Lines	*A. nodosum* (1)	73.00	10.33	213.51	1.38	3.86	0.36	95.67	20.22
	E. maxima (0.5)	65.00	10.67	216.14	1.38	3.59	0.39	90.33	17.71
	E. maxima (1)	61.67	10.80	213.55	1.48	3.77	0.40	90.33	18.38
	Control	61.83	10.47	179.57	1.28	2.92	0.44	67.00	15.06
	A. nodosum (0.5)	63.83	10.40	165.19	1.27	3.38	0.38	73.00	16.22
8 Lines	*A. nodosum* (1)	67.00	10.60	209.40	1.17	3.56	0.33	75.33	15.98
	E. maxima (0.5)	60.17	10.93	193.86	1.33	3.56	0.37	75.67	17.29
	E. maxima (1)	62.00	9.93	200.41	1.20	3.56	0.34	72.33	15.27
L.S.D. (P=0.05)		4.87	N.S.	N.S.	N.S.	0.25	N.S.	8.11	1.93

5 lines/ridge and sprayed with 1 mL/L of *E. maxima* extract in the first season, while the highest value was obtained by plants grown under 7 lines/ridge and sprayed with 1 mL/L of *A. nodosum* extract in the second season. Data revealed that there was no significant difference between plant density and seaweeds extract on leaf number per plant in both seasons. The highest values of leaf area and neck diameter were obtained from plants grown at 6 lines/ridge and sprayed with 1 mL/L of *A. nodosum* extract in the first season. Highest values of bulb diameter were obtained by plants grown at 5 lines/ridge and sprayed with 1 mL/L of *E. maxima* extract in the first season and plants grown at 7 lines/ridge and sprayed with 0.5 mL/L of *A. nodosum* extract in the second one. The obtained results showed that untreated plants grown under 7 lines/ridge in the first season only scored the highest bulbing ratio. Plants grown at 8 lines/ridge and sprayed with 1 mL/L of *A. nodosum* extract in the first season and under 5 lines/ridge and sprayed with 1 mL/L of *A. nodosum* extract in the second season gave higher plants fresh weight than other treatments. Data show that plants grown at 5 lines/ridge and sprayed with 1 mL/L of *E. maxima* extract in the first season and plants grown at 5 lines/ridge and sprayed with 0.5 mL/L of *A. nodosum* extract in the second season scored the highest plant dry weight.

Chlorophyll a, b and total chlorophyll in leaves: Data presented in Table 6 show that, plant density had no significant effect on chlorophyll a, b and total chlorophyll in both seasons. This result is not in agreement with that of Hasan *et al*. (2017) who found that plant spacing had a significant effect on total chlorophyll.

Data showed a significant difference between foliar applications on chlorophyll a, b and total chlorophyll. Garlic plants sprayed with 1 mL/L of *E. maxima* extract or *A. nodosum* extract gave higher concentrations of chlorophyll a, b and total chlorophyll in leaves of garlic plants in both seasons than other treatments. The lowest values of chlorophyll a, b and total chlorophyll were resulted from untreated plants in both seasons. Similar result was obtained by Kumari *et al*. (2011) who found that tomato plants treated with seaweeds extract scored high content of photosynthetic pigment. The stimulant effect of seaweed extract on chlorophyll content might be referred to their high content of macronutrients such as nitrogen and magnesium which participate in the structure of chlorophyll molecule, also their content of cytokines and betaines which play an important role in decreasing chlorophyll reduction which reflect on photosynthetic pigment (Lola-Luz *et al*., 2014 and Elansary *et al*., 2016).

Chlorophyll a, b and total chlorophyll were significantly affected by spraying with both extracts of *A. nodosum* and *E. maxima* at the rate of 0.5 and 1 mL/L compared with untreated plants under different plant densities in both seasons.

Yield and its components: Plants cultivated at the rate of 8 lines/ridge gave higher total yield than other plant densities in

Table 6. Effect of plant density, foliar application treatments and their interaction on chlorophyll A, B, and total chlorophyll in leaves of green garlic plants (mg/g Fresh weight) in 2016/2017 and 2017/2018 seasons

Treatments		2016/2017			2017/2018		
Density (Lines/ ridge)	Foliar application (mL/L)	Chlorophyll a	Chlorophyll b	Total chlorophyll	Chlorophyll a	Chlorophyll b	Total chlorophyll
5 Lines		1.05	0.72	1.77	1.10	0.72	1.82
6 Lines		1.05	0.67	1.72	1.08	0.70	1.78
7 Lines		1.08	0.68	1.76	1.10	0.70	1.79
8 Lines		1.06	0.67	1.73	1.08	0.71	1.79
L.S.D. (*P*=0.05)		NS	NS	NS	NS	NS	NS
	Control	0.97	0.53	1.50	0.97	0.61	1.58
	A. nodosum (0.5)	1.10	0.67	1.77	1.12	0.70	1.82
	A. nodosum (1)	1.08	0.76	1.84	1.12	0.73	1.85
	E. maxima (0.5)	1.09	0.68	1.77	1.10	0.73	1.83
	E. maxima (1)	1.06	0.79	1.85	1.15	0.76	1.91
L.S.D. (*P*=0.05)		0.06	0.07	0.09	0.07	0.04	0.09
5 Lines	Control	0.96	0.58	1.54	0.98	0.62	1.60
	A. nodosum (0.5)	1.13	0.66	1.79	1.14	0.69	1.83
	A. nodosum (1)	1.04	0.79	1.83	1.13	0.76	1.89
	E. maxima (0.5)	1.06	0.76	1.82	1.08	0.77	1.85
	E. maxima (1)	1.02	0.81	1.84	1.17	0.78	1.95
6 Lines	Control	0.93	0.49	1.42	0.96	0.59	1.55
	A. nodosum (0.5)	1.08	0.66	1.75	1.16	0.65	1.81
	A. nodosum (1)	1.07	0.77	1.84	1.09	0.78	1.87
	E. maxima (0.5)	1.11	0.67	1.78	1.10	0.69	1.79
	E. maxima (1)	1.06	0.78	1.83	1.12	0.79	1.91
7 Lines	Control	0.98	0.48	1.46	0.99	0.58	1.57
	A. nodosum (0.5)	1.15	0.70	1.84	1.10	0.76	1.86
	A. nodosum (1)	1.06	0.81	1.87	1.08	0.67	1.75
	E. maxima (0.5)	1.10	0.64	1.74	1.13	0.76	1.89
	E. maxima (1)	1.10	0.79	1.89	1.17	0.73	1.90
8 Lines	Control	0.99	0.58	1.57	0.95	0.66	1.61
	A. nodosum (0.5)	1.05	0.67	1.73	1.08	0.71	1.79
	A. nodosum (1)	1.15	0.68	1.83	1.15	0.72	1.87
	E. maxima (0.5)	1.07	0.64	1.71	1.08	0.70	1.78
	E. maxima (1)	1.05	0.78	1.83	1.14	0.73	1.87
L.S.D. (*P*=0.05)		0.13	0.15	0.18	0.14	0.08	0.17

both seasons (Table 7). Similar results were obtained by Abdalla *et al*. (2011), Asgharipour and Arshadi (2012), Ahmed *et al*. (2017), Hasan *et al*. (2017) and Badawy and Mohamed (2018) who found that the increase of plant densities increases total yield of garlic plants.

Plants sprayed with 1 mL/L of *A. nodosum* extract had highest total yield while the lowest values were recorded in plants with 0.5 mL/L of *E. maxima* extract and untreated plants in both the seasons. Mansour (2012) and Osman (2015) reported that the highest concentration of seaweeds extract increased total yield of garlic. Hidangmayum and Sharma (2017) reported that spraying onion plants with *A. nodosum* extract led to an increase in bulb yield. The effect of seaweed extract on increasing bulb yield might be referred to its role in improved rate of net photosynthesis and the nutritional status of plants, which reflect on a perfect minerals translocation, development of a vigorous root system, and enhancement in chlorophyll content.

As for the interaction between plant densities and foliar application, it was found that the application of 1 mL/L of *A. nodosum* extract combined with 8 lines/ridge gave the highest total yield in both seasons.

Bulb quality: Data presented in Table 7 indicate that there were significant differences between plant densities on bulb diameter and bulb weight during the two successive seasons, bulbing ratio and bulb dry matter in the first season, while there were no significant differences among different plant densities on neck diameter in both seasons. Results show that plant densities 5, 6 and 7 lines/ridge gave the highest bulb diameter in both seasons. Similar result was obtained by Hasan *et al*. (2017) who found that the high spacing between rows increase bulb diameter of green garlic bulbs. The highest value of bulbing ratio was resulted from plant density 8 lines/ridge in the first season. Plants cultivated at the rate of 5 lines/ridge gave the highest bulb weight in both seasons.

Data illustrated that plants grown under lower plant densities (5 and 6 lines/ridge) gave the highest bulb dry matter percentage. In accordance with the obtained results, Ahmed *et al*. (2017) and Hasan *et al*. (2017) indicated that the increment of intra-row spacing led to an increase in bulb weight of garlic and green garlic plants. Also, Badawy and Mohamed (2018) who found that planting garlic in two rows/ ridge gave the intermediate values of bulb quality between planting in one or three rows/ ridge. Garlic plants grown under low plant density were subjected to lower degree of competition for space and fertilizers as well as all environmental conditions than other plants grown under high plant density, which affect plant growth and led plants to strengthen vegetative growth which reflect on increasing yield and enhancing quality (Dhakulkar *et al*., 2009).

Table 7. Effect of plant density, foliar application treatments and their interaction on total green yield at harvest (ton/fed.), neck and bulb diameter (cm), bulbing ratio, bulb weight (g) and bulb dry matter percentage of green garlic plants in 2016/2017 and 2017/2018 seasons

Treatments		2016/2017 season						2017/2018 season					
Density (Lines/ ridge)	Foliar application (mL/L)	Total green yield (ton/fed.)	Neck diameter (cm)	Bulb diameter (cm)	Bulbing ratio	Bulb weight (g)	Bulb dry matter	Total green yield (ton/fed.)	Neck diameter (cm)	Bulb diameter (cm)	Bulbing ratio	Bulb weight (g)	Bulb dry matter
5 Lines		6.483	1.43	5.23	0.27	60.21	27.13	9.264	1.32	5.31	0.25	70.05	24.67
6 Lines		7.015	1.57	5.05	0.31	60.07	27.13	9.273	1.13	5.02	0.22	57.26	24.96
7 Lines		7.725	1.59	5.22	0.30	55.81	25.65	9.848	1.19	5.15	0.23	63.01	24.99
8 Lines		8.697	1.59	4.43	0.36	56.16	25.27	10.368	1.07	4.65	0.24	52.47	25.21
L.S.D. (P=0.05)		0.552	N.S.	0.31	0.05	3.23	1.42	0.685	N.S.	0.30	N.S.	2.18	N.S.
	Control	7.249	1.62	5.08	0.32	54.49	26.71	7.762	1.06	4.95	0.21	54.06	25.17
	A. nodosum (0.5)	7.729	1.61	5.14	0.32	61.80	26.74	10.532	1.12	5.19	0.22	61.44	26.14
	A. nodosum (1)	7.738	1.61	5.08	0.32	62.16	26.59	10.885	1.22	5.17	0.24	64.73	25.84
	E. maxima (0.5)	7.114	1.42	4.86	0.30	56.44	25.85	9.950	1.21	4.94	0.25	64.33	23.93
	E. maxima (1)	7.569	1.46	4.73	0.31	55.43	25.59	9.311	1.28	4.91	0.26	58.93	23.71
L.S.D. (P=0.05)		0.452	0.15	N.S.	0.03	4.43	N.S.	0.546	N.S.	N.S.	N.S.	2.48	N.S.
5 Lines	Control	5.878	1.38	5.37	0.26	55.67	27.68	6.717	1.05	4.93	0.21	55.68	25.32
	A. nodosum (0.5)	6.331	1.51	5.35	0.28	65.56	26.67	10.911	1.19	5.38	0.22	68.33	25.85
	A. nodosum (1)	6.656	1.59	5.15	0.31	63.92	27.44	11.567	1.55	5.12	0.31	70.99	25.13
	E. maxima (0.5)	6.220	1.31	5.22	0.25	57.92	27.62	9.180	1.33	5.59	0.24	78.26	23.82
	E. maxima (1)	7.330	1.35	5.07	0.27	57.97	26.25	7.944	1.49	5.52	0.27	76.97	23.25
6 Lines	Control	6.507	1.69	5.07	0.33	55.02	26.00	8.896	1.09	5.17	0.21	59.18	24.97
	A. nodosum (0.5)	7.146	1.57	5.23	0.30	62.38	27.35	9.049	1.13	5.03	0.23	56.97	25.03
	A. nodosum (1)	6.708	1.65	5.19	0.32	64.44	27.37	9.454	1.01	4.95	0.20	52.21	25.51
	E. maxima (0.5)	6.317	1.62	5.38	0.30	64.02	27.51	10.146	1.32	5.15	0.26	65.83	24.24
	E. maxima (1)	8.397	1.32	4.37	0.29	54.50	27.44	8.822	1.09	4.81	0.23	52.13	25.02
7 Lines	Control	8.429	1.75	5.50	0.32	54.01	28.21	7.845	1.07	4.75	0.23	49.91	25.45
	A. nodosum (0.5)	8.145	1.69	5.35	0.32	59.63	26.56	11.053	1.15	5.29	0.21	65.11	26.58
	A. nodosum (1)	6.774	1.60	5.35	0.30	60.63	25.53	10.750	1.21	5.44	0.22	71.21	26.06
	E. maxima (0.5)	7.268	1.33	4.84	0.27	49.18	24.18	10.142	1.21	5.20	0.23	67.38	23.53
	E. maxima (1)	8.008	1.58	5.03	0.32	55.62	23.74	9.448	1.31	5.06	0.26	61.43	23.33
8 Lines	Control	8.182	1.67	4.39	0.38	53.27	24.95	7.588	1.03	4.97	0.21	51.48	24.91
	A. nodosum (0.5)	9.295	1.68	4.63	0.36	59.61	26.36	11.117	1.02	5.06	0.20	55.33	27.10
	A. nodosum (1)	10.816	1.59	4.64	0.35	59.66	26.01	11.769	1.11	5.17	0.22	64.50	26.65
	E. maxima (0.5)	8.652	1.42	4.02	0.36	54.63	24.08	10.333	0.96	3.83	0.26	45.84	24.13
	E. maxima (1)	6.539	1.59	4.45	0.36	53.64	24.93	11.031	1.22	4.23	0.30	45.19	23.24
L.S.D. (P=0.05)		0.903	N.S.	N.S.	0.06	N.S.	N.S.	1.092	N.S.	0.67	N.S.	4.96	N.S.

There were significant differences among different foliar application treatments on neck diameter and bulbing ratio in the first season and bulb weight in both seasons (Table 7). There was no significant effect of different seaweed extracts on bulb diameter and bulb dry matter in both seasons. Untreated plants and both *A. nodosum* extract concentrations (0.5 and 1 mL/L) gave highest value of neck diameter in the first season, while there was no significant difference among different foliar application in the second season. Spraying plants with 1 mL/L *A. nodosum* extract led to the highest bulb weight in both seasons. This result was in harmony with that obtained by Mansour (2012) and Osman (2015) who found that foliar application with seaweeds extract of garlic plants scored higher bulb weight than untreated plants.

The interaction between plant densities and different foliar applications on bulb quality show that, all foliar applications combined with plant densities 5 and 7 lines/ridge and all foliar application except spraying plants with 1 mL/L of *E. maxima* extract under plant density of 6 lines/ridge gave the highest bulb diameter in the second season. Also, the obtained results show that, plants sprayed with 0.5 and 1 mL/L of *E. maxima* extract under plant density of 5 lines/ridge gave the highest bulb weight in the second season.

Chemical constituents of green garlic bulbs: Results presented in Table 8 show that plant density 5 lines/ridge gave the highest total carbohydrates concentration in both seasons. Highest value of nitrogen and crude protein percentage in bulbs was resulted from plant densities 7 and 5 lines/ridge in the first season. Plant density had no significant effect on phosphorus and potassium percentage in both seasons. These results agree with that of El-Shal *et al.* (2011) who found that garlic planted on one line/ ridge (low density) gave the highest values of nitrogen and protein percentage of garlic cloves.

Data in Table 8 revealed that plants sprayed with 0.5 mL/L of *A. nodosum* and *E. maxima* gave higher total carbohydrates concentration than other treatments in both seasons. Data revealed that plants sprayed with 1 mL/L of *A. nodosum* extract gave higher nitrogen and crude protein percentage in bulbs than other treatments. On the other side, results show that foliar application had no significant effect on phosphorus percentage during the two successive seasons. The obtained results showed that spraying plants with 0.5 and 1 mL/L of *A. nodosum* extract gave the highest potassium percentage in both seasons. Similar result was obtained by Dobromilska *et al*. (2008) who found that spraying cherry tomato plants with *E. maxima* extract led to an increase in potassium content. Furthermore, Osman (2015) on garlic stated that the foliar application with seaweed extract significantly increased carbohydrates, nitrogen and crude protein in garlic bulbs while, there was no significant effect on

Table 8. Effect of plant density, foliar application treatments and their interaction on carbohydrates concentration (g/100 g dry weight), nitrogen (%), phosphorus (%), potassium (%) and crude protein (%) of green garlic bulbs in 2016/2017 and 2017/2018 seasons

Treatments		2016/2017 season					2017/2018 season				
Density (Lines/ ridge)	Foliar application (mL/L)	Carbohydrates (g/100 g d.w.)	N (%)	P (%)	K (%)	Crude protein (%)	Carbohydrates (g/100 g d.w.)	N (%)	P (%)	K (%)	Crude protein (%)
5 Lines		16.59	2.64	0.04	1.27	16.50	16.96	2.84	0.05	1.40	17.77
6 Lines		12.57	2.53	0.05	1.07	15.84	14.39	2.72	0.05	1.55	17.00
7 Lines		14.24	2.66	0.04	1.32	16.63	15.76	2.69	0.05	1.38	16.78
8 Lines		15.60	2.61	0.04	1.21	16.34	15.70	2.80	0.04	1.32	17.48
L.S.D. (*P*=0.05)		0.34	0.06	N.S.	N.S.	0.38	0.24	N.S.	N.S.	N.S.	N.S.
	Control	14.52	2.50	0.04	1.09	15.63	15.15	2.63	0.05	1.34	16.43
	A. nodosum (0.5)	15.72	2.61	0.05	1.39	16.30	16.64	2.75	0.05	1.39	17.20
	A. nodosum (1)	14.71	2.73	0.04	1.26	17.03	15.53	2.85	0.05	1.56	17.81
	E. maxima (0.5)	14.79	2.64	0.05	1.11	16.51	16.85	2.79	0.05	1.44	17.42
	E. maxima (1)	14.01	2.58	0.04	1.25	16.15	14.34	2.79	0.05	1.33	17.42
L.S.D. (*P*=0.05)		0.36	0.09	N.S.	0.08	0.56	0.24	0.11	N.S.	0.14	0.68
5 Lines	Control	14.61	2.57	0.04	1.17	16.04	14.27	2.87	0.05	1.16	17.92
	A. nodosum (0.5)	17.17	2.63	0.05	1.66	16.46	16.96	2.80	0.05	1.35	17.50
	A. nodosum (1)	18.79	2.90	0.04	1.18	18.13	19.80	2.90	0.05	1.52	18.13
	E. maxima (0.5)	17.51	2.70	0.05	1.01	16.88	18.58	2.80	0.05	1.69	17.50
	E. maxima (1)	14.86	2.40	0.05	1.35	15.00	15.19	2.85	0.05	1.29	17.81
6 Lines	Control	12.49	2.37	0.04	0.98	14.79	12.09	2.70	0.04	1.49	16.88
	A. nodosum (0.5)	12.51	2.50	0.05	1.35	15.63	12.08	2.65	0.05	1.51	16.56
	A. nodosum (1)	12.64	2.70	0.04	1.01	16.88	17.16	2.90	0.04	1.69	18.13
	E. maxima (0.5)	12.35	2.50	0.05	1.08	15.63	17.41	2.70	0.05	1.52	16.88
	E. maxima (1)	12.87	2.60	0.04	0.94	16.25	13.20	2.65	0.05	1.52	16.56
7 Lines	Control	15.39	2.50	0.04	1.22	15.63	18.31	2.35	0.04	1.52	14.69
	A. nodosum (0.5)	14.90	2.60	0.04	1.35	16.25	18.75	2.63	0.05	1.35	16.41
	A. nodosum (1)	12.62	2.70	0.04	1.17	16.88	11.34	2.65	0.04	1.69	16.56
	E. maxima (0.5)	13.97	2.80	0.05	1.18	17.50	15.77	2.85	0.05	1.35	17.81
	E. maxima (1)	14.32	2.70	0.04	1.69	16.88	14.65	2.95	0.05	1.01	18.44
8 Lines	Control	15.60	2.57	0.04	1.01	16.04	15.94	2.60	0.05	1.18	16.25
	A. nodosum (0.5)	18.29	2.70	0.04	1.18	16.88	18.78	2.93	0.05	1.35	18.34
	A. nodosum (1)	14.79	2.60	0.05	1.69	16.25	13.80	2.95	0.05	1.35	18.44
	E. maxima (0.5)	15.32	2.57	0.04	1.18	16.04	15.65	2.80	0.04	1.18	17.50
	E. maxima (1)	13.98	2.63	0.04	1.01	16.46	14.32	2.70	0.04	1.52	16.88
L.S.D. (*P*=0.05)		0.72	0.18	N.S.	0.15	1.13	0.49	0.22	N.S.	0.28	1.35

phosphorus percentage. These results might be referred to the high amount of cytokines and auxins which enhance the growth of root system and increase minerals uptake which reflect on chemical constituents of green bulbs.

Data tabulated in Table 8 show significant effects of the interaction on total carbohydrates concentration, nitrogen, potassium and crude protein percentage in bulbs, while the interaction had no significant effect on phosphorus percentage. Plants sprayed with 1 mL/L of *A. nodosum* extract under plant density 5 lines/ridge gave the highest total carbohydrates concentration in both seasons. The highest level of nitrogen and crude protein percentage in bulbs were resulted from plant density 5 lines/ridge combined with the foliar application with 1 mL/L of *A. nodosum* extract and plant density 8 lines/ridge with foliar application 1 mL/L of *A. nodosum* extract in both seasons. Spraying plants with 0.5 and 1 mL/L of *A. nodosum* extract under 5 lines/ridge and with 1 mL/L of *E. maxima* extract under 7 lines/ridge gave higher potassium percentage in the first season than other treatments. While spraying plants with 0.5 and 1 mL/L of *A. nodosum* extract under plant densities 6 and 7 lines/ridge and foliar application with 0.5 mL/L of *E. maxima* extract under 5 lines/ridge gave the highest percentage of potassium in the second season.

In conclusion, higher plant density (8 lines per ridge) combined with spraying plants with 1 mL/L of *A. nodosum* extract (Algreen) gave the best results for vegetative growth and yield of green garlic under new Egyptian reclaimed sandy soil.

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