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Response of snap bean growth and seed yield to seed size, plant density and foliar application with algae extract

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Seed yield

Abstract Two field experiments were conducted during the two growing summer seasons of 2013 and 2014, at the experimental farm of vegetables at Kaha, Qalyubia Governorate, Agriculture Research Center (ARC), Egypt, in order to investigate the effect of seed size, plant density and foliar application with some algae extracts on growth and seed yield of snap bean cv. valentino. A split–split plot design was used with three replications, where three sizes i.e., large, small and control (without grading) were randomly distributed in the main plots, two plant density rates (22 and 33 plants per m^2) arranged in subplots and foliar spray with seaweed extract (algost), fresh water algae (spirulina), mixture of them and control (sprayed with distilled water) allocated in sub–subplots. Results showed a clear positively enhancement of plant vegetative growth parameters, chlorophyll, N, P, and K contents of leaves and seed yield quantity and quality positively by sowing large seeds compared with other seed sizes. Meanwhile, higher plant density (33 plants per m^2) gave the highest values of plant length and seed yield per feddan, while the lower plant density (22 plants per m^2) gave the highest values in other studied parameters except weight of 100 seeds where there were no significant differences between the two plant densities. All foliar applications with algae extracts significantly increased all the studied parameters compared to the control treatment. The superior application was the mixture of seaweeds and fresh water algae extracts together followed by seaweed extract alone in the two seasons, respectively.

Introduction

In Egypt, Snap bean (*Phaseolus vulgaris* L.) is cultivated mainly for green pods and secondary for seeds. Snap bean is a cash crop because most cultivated cultivars are short-term

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production for green pods yield. Also the short period for producing green pods makes the crop suitable for cultivation between main crops in the crop rotation. So, snap bean is an important vegetable crop for local consumption and exportation.

Snap bean cultivation in Egypt suffers from many problems finally led to minimizing either yield of green pods or seeds. There are many reasons for decline in growth and yielding of snap bean: 1- Snap bean propagates only via seeds so that its growth and subsequent yielding are affected with seed properties. 2- Most growers used to produce their own seeds by allowing the tail end of their crops to mature into seeds or by cultivating on a little area or obtaining the seeds from uncertified other farms. 3- Uncertified seeds are cheap, unknown quality attributes and often small sized because of repeating cultivation of less quality seeds and without applying practices of certification for production of high quality seeds.

Seed size is an important physical indicator of seed quality that affects vegetative growth and is frequently related to yield and the use of good quality seed is very essential which increases the yield by 15–20% (Ambika et al., 2014). Seed size can influence germination and subsequent development of plants to produce high yield. Also, El-Sawah (2007) and Nosser and Behnan (2011) found that sowing large (heavy) bean seeds gave the highest values in plant vegetative growth parameters and dry seed yield. In addition, heavy seeds positively affected chemical constituents' concentration of plants such as N, P, and K and seed quality of protein and total soluble carbohydrates. Generally, large seed is related to better agronomic aspects and thus has better field performance than small seed.

Also, plant densities i.e., number of plants per unit area are an important agronomic practice that can affect crop yield. Studies showed that there was a significant difference between different plant densities in terms of their effects on traits such as number of pods per plant, number of grains per plant, number of lateral branches, number of grains per square meter, 100-grain weight, grain yield, biological yield, and harvest index of cowpea (Mojaddam and Nouri, 2014). Tuarira and Moses (2014) found an increase in plant height of snap bean plants and seed yield as the population density is increased to 222,222 plants/ha, while the lower plant population of 125,000 plants/ha had the highest number of branches/plant, seeds/pod, number of pods/plant and high percent of good harvested seeds than other plant population densities. In common bean, recommended seeding density can depend on the growth habit of the plant, the yield–density relationship, percent emergence, seed cost and environment (Shirtliffe and Johnston, 2002). This reflects the differences between cultivars in yield-density relationship and seed cost.

Foliar spray can be of great effective because within short time the plant can transport nutrition from its leaves all the way down to its roots. Some seaweed extracts can be used as foliar spray and it is registered as a biostimulants. It elicits many beneficial responses including improved root and shoot growth, higher yields and greater resistance to abiotic and biotic stresses. Previously, cytokinins, auxins and polyamines were identified in the extract. Recently, other groups of plant growth regulators, abscisic acid, gibberellins and brassinosteroids have been quantified (Stirk et al., 2014). The beneficial effect of seaweed extract spraying on bean was demonstrated in terms of increase in growth characteristics i.e., number of leaves/plant as well as leaves dry weight/plant and seed yield i.e., number and weight of seeds and number of pods compared with the control (Abou El-Yazied et al., 2012 and Kocira et al., 2013).

Based on the previous information the aim of this article was to aid the growers within simple practices for maximizing yield potential of snap bean crop. So we investigated the impact of sizing seeds before cultivation and utilizing the stimulation effect of foliar application of algae extracts for more vigorous plant growth impacted in yielding either green pods or quality of seeds. Regarding the relation between seed size and its cultivation rate, we cultivated the three sizes of seeds in two rates to clarify the optimum plant population per area unit under each seed size. So, this study was conducted with the objectives of determining appropriate sizing of the sowing seed, optimum plant density, algae extract foliar spray and their combination for better growth and seed yield attributes of common beans.

Materials and methods

Two field experiments were conducted during summer seasons of 2013 and 2014 at the experimental farm of vegetables at Kaha, Qalyubia Governorate, Horticulture Research Institute (HRI), Agriculture Research Center (ARC), Egypt. A lot of pure snap bean seed (*Phaseolus vulgaris* L.) cultivar Valantino was obtained from the Vegetable Crops Seed Production and Technology Department, HRI, ARC, Egypt. Sowing date of the experiment were done on 3rd and 4th of March in the two summer seasons 2013 and 2014, respectively. Seeds were sown in a single row on one side of the irrigation line. Each row was 4 m long and 0.6 m width. Each plot contained 3 rows. So the area of each plot was 7.2 m^2.

The experiment included three factors during the two growing seasons as follows:

1. **Seed size**, three different seed sizes were classified as follows:
   a. Large seeds obtained through sieve > 4.76 mm diameter and the weight of 100 seeds was 25 g approximately.
   b. Small seeds obtained through sieve > 4.0 mm diameter and the weight of 100 seeds was 18 g approximately.
   c. Control, seeds without grading and the weight of 100 seeds was 22 g approximately.

2. **Plant density**, included two treatments as follows:
   a. 33 plants/m^2, one plant/hill at 5 cm a part.
   b. 22 plants/m^2, one plant/hill at 7.5 cm a part.

3. **Foliar spray with algae extracts**

Foliar spray with algae extracts was carried out three times during plant growth period. The first time was applied after 21 days from seed sowing date and then two times each was applied after two weeks interval. The source of seaweed extract was from Misr-ElSalam International Company and the fresh water algae extract was from Algal Biotechnology Unit, National Research Centre, Egypt.

The types of algae extract which applied were as follows:

a. Seaweeds algae extract (Algost 3 ml/l) as recommended.

b. Fresh water algae extract (Spirulina 1 ml/l) as recommended.
c. Mixture extract of seaweeds and fresh water algae (3 ml/l of Algost + 1 ml/l of Spirulina).
d. Control treatment (spray with distilled water).

Treatments were arranged in split-split-plot design with three replicates. The main plots contained seed size treatments, while plant density treatments were randomly distributed in the subplots and algae extract foliar spray treatments were randomly distributed in the sub-subplots. All agricultural practices were carried out as recommended for the conventional bean production published via Ministry of Agriculture in the experimental location.

Data recorded

1. **Vegetative growth characters**

The following growth attributes were measured at the onset of flowering stage. Ten plants from each treatment were randomly chosen, uprooted and used for measuring plant length (cm), leaf area per plant and plant dry weight (g). Leaf area was determined using the recently full expanded fourth leaf from the plant top as relation between unit area and leaf fresh weight (Koller, 1972).

$$\text{Leaf area (cm}^2) = \frac{\text{Disk area} \times \text{No. Disks} \times \text{Leaf F. Wt.}}{\text{Disk F. Wt.}}$$

2. **Seed yield and its components**

At harvest stage (after ripening and drying pods), samples of ten random plants from each treatment were collected and used for recording seed yield parameters such as seeds weight per plant (g), weight of 100 seeds (g) and total seed yield per feddan (kg).

3. **Chemical analysis of leaf**

At the onset of flowering stage, top fourth leaf from 10 random plants were picked up and subjected for determining total chlorophyll. A digital chlorophyll meter, Minolta SPAD-502 (Minolta Company, Japan) was used. Reading was transformed to mg/m^2 by (Monje and Bugbee, 1992) according to the equation:

$$\text{Chl} = -80.05 + 10.40\,(\text{SPAD} - 501)\ \text{mg/m}^2$$

The same leaves were dried, grinded and prepared for measuring minerals such as N, P, and K. Total nitrogen was determined according to the method described by Pregl (1945) using micro-Kjeldahl apparatus. Phosphorus was estimated colorimetrically according to the method described by Murphy and Riley (1962) as modified by John (1970). Potassium was determined flame-photometrically as described by Brown and Lilleland (1946).

4. **Seed quality**

Total nitrogen and total carbohydrates were determined in dry seeds. Total protein percentage was calculated by multiplying total nitrogen by a factor of 6.25 to calculate crude protein content as described by Kelly and Bliss (1975). Total carbohydrate percentage was assayed colorimetrically according to the method described by Dubois et al. (1956).

Statistical analysis

All the collected data were tabulated and statistically analyzed by Statistical Analysis of variance using software (costat) according to Snedecor and Cochran (1980) and the treatments means were compared using the Duncan Multiple Range test (Duncan, 1955).

Results and discussion

This experiment involved three factors, seed size (large size, small size and control without grading), planting density (33 and 22 plants per m^2) and foliar application with some biostimulants (seaweed, fresh water algae extract, mixture of them and control) and their interaction on bean plant growth and seed yield.

Vegetative growth

Data tabulated in Table 1 show that sowing the bigger seeds (>4.76 mm size) increased plant length, leaf area per plant and plant dry weight significantly compared with plants sown via small seeds (>4.0 mm size) or seeds without sizing (control treatment) during the two experimental seasons. The mentioned improvement in snap bean vegetative growth parameters might be due to production of vigorous seedling from sowing large seeds. The bigger seeds reserve enough protein, carbohydrate and other nutrients for faster seedling growth and subsequently produce more above-ground biomass. These results are in agreement with findings of Tawaha and Turk (2004) on field pea, Nosser and Behnan (2011) on common bean and Mekkei (2014) on broad bean.

With regard to the effect of plant density on plant vegetative growth, sowing plants at a higher rate of plant density at 33 plants per m^2 gave taller plant. This increase in plant length from higher plant density may due to decrease in reaching light to plant stems resulting in accumulation of auxin which is a major growth hormone stimulating cell division and enlargement, at the same time reducing gibberellins oxidation which leads to increase in nodule spacing and subsequent increase in plant elongation.

These results are in line with those recorded by Kazemi et al. (2012) and Tuarira and Moses (2014) on bean. Meanwhile less plant density at rate of 22 plants per m^2 increased leaf area per plant and plant dry weight significantly. The increment of this vegetative growth parameters at low planting density may be due to the lowest competition between plants on spacing, water, CO_2 and elements. Also plants at lower density receive more solar radiation which increase photosynthetic pigments and increase the photosynthetic assimilation rate consequently positively affecting plant growth. These data are consistent with those of Abd El-Latif et al. (2009) on cowpea, Salem et al. (2014) on faba bean and El-Atabany (2015) on bean.

Concerning the response of bean plants to foliar application with extract of seaweed, fresh water algae and mixture of them, it is clearly that foliar application of the mixture

Table 1 Effect of seed size, plant density and foliar application with algae extract on vegetative growth parameters of bean plants grown during 2013 (S1) and 2014 (S2) seasons.

Treatments		Parameters					
		Plant length (cm)		Leaf area/plant (cm^2)		Plant dry weight (g)	
		S1	S2	S1	S2	S1	S2
Seed size	Large	44.16A	43.04A	1628.5 A	1484.8A	17.18A	15.52A
	Small	37.41C	36.62C	1203.2C	1093.7C	13.77C	11.89C
	Control	40.87B	39.12B	1398.7B	1276.2B	15.10B	13.76B
Plant density	33 plants/m^2	42.02A	40.86A	1338.9B	1225.1B	14.37B	12.91B
	22 plants/m^2	39.61B	38.33B	1481.4A	1344.7A	16.33A	14.54A
Foliar application	Seaweed	41.38B	40.88A	1494.3B	1398.0B	16.29A	14.83A
	Fresh algae	40.66B	39.55B	1352.6C	1244.9C	14.58B	13.34B
	Mix.	43.11A	41.44A	1608.2A	1449.0A	17.61A	15.23A
	Control	38.11C	36.50C	1185.5D	1047.8D	12.91C	11.48C

Mix. (Seaweed + Fresh algae).
Values within the same column followed by the same letters are not significantly different at 5% level (Duncan's multiple range test).

between seaweed and fresh water algae extracts significantly improved plant length in the first season and leaf area in both seasons, while foliar spray with the mixture or seaweed extract alone significantly improved plant length in the second season and dry weight per plant in both seasons compared to either control treatment or spraying with fresh water algae extract. The lowest response was obtained from control treatment (without spraying bio-stimulants). The enhancing effect of seaweeds or fresh algae extract may be referred to its high levels of organic matter, vitamins, amino acids and growth regulators such as gibberellins, cytokinins, betaines, and auxins (IAA and IBA), which have an encourage role in cell division and its enlargement. Also it contains macronutrients i.e., N, P, and K which are essential for growth and development of the plant, and in addition it contains micronutrients i.e., Ca, Cu, Fe, Mg, Mn, P and Zn which have a great role in cell division and enlargement and induce photosynthesis and this in turn reflected on plant growth. These results are in conformity with those reported by Nour et al. (2010) on tomato, Sarhan et al. (2011) on cucumber, Abou El-Yazied et al. (2012), Latique et al. (2013) on bean.

Data in Table 2 explained the effect of bilateral interaction between the experimental factors on bean plant vegetative growth attributes.

Data demonstrated that combination between higher plant density (33 plants per m^2) and either the higher seed size or spraying with the mixture and seaweed extract alone produced the longest plant. Meanwhile sowing seeds at rate of 22 plants per m^2 combined with either the bigger seed size or spraying with the mixture and seaweed extract alone significantly improved leaf area and dry weight per plant. Sowing large seeds combined with mixture spray or seaweed extract alone gave higher plant length, leaf area and dry weight per plant approximately in the two seasons. Sowing large seeds accompanied with spraying fresh water algae extract had the same effect of interaction between control (without seeds sizing) and spraying plants with the mixture. So the two treatments increased plant length, leaf area and plant dry weight significantly.

Data shown in Table 3 explain the effect of tripartite interaction.

Average plant length recorded the highest value for the plants which were sown with large seeds at rate of 33 plants per m^2 and then sprayed with the mixture or seaweed extract alone. Concerning the response of leaf area and plant dry weight for the experimental treatments, it is clear that the highest leaf area and plant dry weight were obtained from plants produced via sowing large seeds at rate of 22 plants per m^2 and then sprayed with the mixture or seaweed extract alone.

Seed yield

Data represented in Table 4 demonstrate the effect of the main experimental factors on snap bean seed yield and its components, data revealed that sowing large seeds gave the highest seeds weight per plant, 100 seeds weight and seed yield per feddan as compared to sowing small seeds or seeds without sizing, in the two seasons. Sowing seeds without sizing was superior for seed yield and its components compared to small seeds.

Such increments in total seed yield and its components might be attributed to the increase in plant vegetative growth (Tables 1–3), concentrated chlorophyll pigment in leaves (Table 10) and subsequent increase in fruit set percent. The obtained results are in agreement with those reported by Bicer (2009) who stated that chickpea plants, produced from sowing large seeds, produce heavier weight of 100 seeds and yielded 6% more than medium seeds and 10% more than mixed seeds. Similar findings were obtained by Nosser and Behnan (2011) on common bean and Mekkei (2014) on faba bean, and they found the highest seed yield and its components were obtained by plants from large seeds.

Concerning plant density, sowing seeds at rate of 22 plants per m^2 increased seed yield per plant significantly compared to sowing at rate 33 plants per m^2, and such increment may be due to that, cultivation of snap bean at lower population is efficient in utilizing the resources for production than higher plant population. So, at low plant density cultivation, there are large quantities of nutrients, water and sunlight which could be available enough for each plant and this may produce more pods could be reached to maturity stage without fall off. Also high number of branches per plant at low densities cultivation could be translated to more sites for flower development which resulted in a prolific pod production and consequently seed weight per plant. These results agree with

Table 2 Effect of dual interaction between seed size and plant density, plant density and foliar application and foliar application with algae extract and seed size on vegetative growth parameters of bean plants grown during 2013 (S1) and 2014 (S2) seasons.

Treatments		Plant length (cm)		Leaf area/plant (cm^2)		Plant dry weight (g)	
		S1	S2	S1	S2	S1	S2
Seed size × plant density							
Large	33 plants/m^2	45.66a	44.41a	1566.3b	1426.0b	16.25ab	14.66b
	22 plants/m^2	42.66b	41.66b	1690.7a	1543.6a	18.11a	16.38a
Small	33 plants/m^2	38.33 c	38.08d	1127.2e	1035.0f	12.76c	11.13d
	22 plants/m^2	36.50 d	35.16e	1279.3d	1152.4 e	14.78bc	12.65c
Control	33 plants/m^2	42.08b	40.08c	1323.1d	1214.3 d	14.09bc	12.93c
	22 plants/m^2	39.66c	38.16d	1474.3 c	1338.0 c	16.11ab	14.59b
Plant density × foliar application							
33 plants/m^2	Seaweed	43.00ab	42.22 a	1423.5c	1337.0bc	15.15 cd	13.93b
	Fresh algae	41.66b	40.77 b	1276.3d	1184.6d	13.77de	12.63c
	Mix.	44.33a	42.66 a	1540.8 b	1388.4b	16.64a–c	14.31b
	Control	39.11c	37.77 c	1114.9e	990.4 f	11.91e	10.76d
22 plants/m^2	Seaweed	39.77 c	39.55 b	1565.2b	1459.0a	17.43ab	15.74a
	Fresh algae	39.66c	38.33 c	1428.9 c	1305.1c	15.39b–d	14.05b
	Mix.	41.88b	40.22 b	1675.6a	1509.5a	18.59a	16.16a
	Control	37.11d	35.22 d	1256.0d	1105.2e	13.92de	12.21c
Foliar application × seed size							
Seaweed	Large	45.00ab	44.33ab	1720.6b	1580.0a	17.93ab	16.08b
	Small	37.33 h	38.00 fg	1281.0 f	1251.5e	14.80c–e	13.73de
	Control	41.83 cd	40.33 cd	1481.3d	1362.5 cd	16.13b–d	14.70 cd
Fresh algae	Large	44.00 b	43.00 b	1554.4c	1476.9b	16.47b–d	15.35bC
	Small	38.00gh	36.66gh	1171.8 g	986.7 f	12.94ef	10.85 g
	Control	40.00d–f	39.00d–f	1331.6e–f	1271.0e	14.32de	13.83de
Mix.	Large	46.66a	44.83 a	1850.0a	1642.2a	19.72a	17.36a
	Small	39.50e–g	38.50 ef	1368.8e	1288.7de	15.93b–d	13.69de
	Control	43.16bc	41.00 c	1605.8 c	1416.0bc	17.19bc	14.66 cd
Control	Large	41.00de	40.00c–e	1388.9e	1240.2e	14.58c–e	13.31e
	Small	34.83i	33.33 i	991.3 h	847.9 g	11.41f	9.29 h
	Control	38.50f–h	36.16 h	1176.2 g	1055.2f	12.75ef	11.86f

Mix. (Seaweed + Fresh algae).
Values within the same column followed by the same letters are not significantly different at 5% level (Duncan's multiple range test).

those obtained by Jafroudi et al. (2007) and Pawar et al. (2007) on common bean. On the other hand, the rate of sowing seeds did not manifest any effect on 100 seeds weight parameter, and these results agree with those by Shirtliffe and Johnston (2002) and Kazemi et al. (2012) on common bean. On the other hand sowing seeds at rat of 33 plants per m^2 increased seed yield per feddan significantly, in both seasons. The increase in seed yield per feddan resulted from increasing no. of plants per unit area which seems to be more critical than the number of pods per plant for influencing seed yield per feddan. These findings are in line with those recorded by Pawar et al. (2007), Tuarira and Moses (2014) on bean and Mojaddam and Nouri (2014) on cowpea.

With respect to the impact of foliar spray, it is clear that all foliar application treatments significantly increased seeds weight per plant, 100 seeds weight and seed yield per feddan compared to control (distilled water spraying) treatment. Superior enhancement of seed yield was obtained by applying the mixture followed by seaweed alone and then fresh water algae extract respectively. The increment of bean plant seed yield may be due to the increase in plant growth parameters (Tables 1–3), stimulating the production of chlorophyll (Table 10) and efficiency of the photosynthesis process and physiological activities which provide plant by nutrition consequently lead to increase in seed yield per plant, hundred-seed weight and total seed yield per feddan. The results are in agreement with those obtained by Rathore et al. (2009) on soybean, Kocira et al. (2013) on common bean and Nawar and Ibraheim (2014) on pea.

Data in Table 5 show the interaction between seed size and plant density, and it is clearly that incorporation of large seeds and lower plant density cultivation (22 plants/m^2) produced high seeds weight per plant. Large seeds with any plant density improved average weight of 100 seeds, while seed yield per feddan increased by combining treatment between large seeds and higher plant density (33 plants/m^2). Concerning the effect of interaction between seed size and foliar application, treatment of combining large seeds and spraying the mixture improved seeds weight per plant and seed yield per feddan, while the surpassing in average weight of 100 seeds was noticed in treatment of combining large seed and spraying the mixture or seaweed extract.

Table 3 Effect of triple interaction between seed size, plant density and foliar application with algae extract on vegetative growth parameters of bean plants grown during 2013 (S1) and 2014 (S2) seasons.

Treatments			Plant length (cm)		Leaf area/plant (cm²)		Plant dry weight (g)	
			S1	S2	S1	S2	S1	S2
Large	33 plants/m²	Seaweed	47.33ab	45.66ab	1657.4cd	1513.0cd	17.00b–e	14.78d–g
		Fresh algae	45.33bc	44.33a–c	1502.3e–h	1429.2d–f	15.75b–f	14.67d–g
		Mix.	48.33a	46.00a	1775.4b	1579.7bc	18.61ab	16.70a–c
		Control	41.66d–h	41.66d–f	1329.9j–l	1182.2ij	13.64d–h	12.50jk
	22 plants/m²	Seaweed	42.66c–f	43.00cd	1783.8b	1647.1ab	18.87ab	17.38ab
		Fresh algae	42.66c–f	41.66d–f	1606.4c–e	1524.6cd	17.20a–d	16.03b–d
		Mix.	45.00bc	43.66b–d	1924.6a	1704.7a	20.83a	18.01a
		Control	40.33f–i	38.33g–i	1447.9f–i	1298.2f–i	15.53b–f	14.12e–i
Small	33 plants/m²	Seaweed	38.33i–l	39.66c–g	1202.2m	1193.0ij	13.07e–h	13.02h–j
		Fresh algae	40.66f–j	38.00 g–i	1080.2 n	917.5mn	12.00f–h	10.20lm
		Mix.	38.66i–l	40.00c–g	1306.4 k–m	1229.5 g–j	15.12b–g	12.50jk
		Control	36.00lm	34.66j	920.0o	800.1n	10.85h	8.78n
	22 plants/m²	Seaweed	36.33kl	36.33ij	1359.9i–l	1310.0f–i	16.54b–e	14.44e–h
		Fresh algae	37.33j–l	35.33j	1263.4l–m	1056.0kl	13.88d–h	11.50kl
		Mix.	38.66i–l	37.00h–j	1431.2g–j	1348.0 fg	16.73b–e	14.88d–g
		Control	33.66m	32.00k	1062.5n	895.7mn	11.96f–h	9.80mn
Control	33 plants/m²	Seaweed	43.33c–e	41.33d–f	1410.8h–k	1305.0f–i	15.39b–f	14.00f–j
		Fresh algae	41.00e–I	40.00e–g	1246.2l–m	1207.3h–j	13.56d–h	13.03h–j
		Mix.	44.33cd	42.00de	1540.6e–g	1356.1e–g	16.19b–e	13.72g–j
		Control	39.66g–j	37.00h–j	1094.9n	988.8lm	11.23gh	11.00lm
	22 plants/m²	Seaweed	40.33f–i	39.33f–h	1551.8d–f	1420.0d–f	16.87b–e	15.40c–f
		Fresh algae	39.00h–k	38.00g–i	1417.0h–k	1334.6f–h	15.09b–g	14.63d–g
		Mix.	42.00d–g	40.00c–g	1671.0c	1475.9c–e	18.20a–c	15.60c–e
		Control	37.33j–l	35.33j	1257.6l–m	1121.6jk	14.28c–h	12.73i–k

Mix. (Seaweed + Fresh algae).
Values within the same column followed by the same letters are not significantly different at 5% level (Duncan's multiple range test).

Table 4 Effect of seed size, plant density and foliar application with algae extract on seed yield and its components of bean plants grown during 2013 (S1) and 2014 (S2) seasons.

Treatments		Parameters					
		Seed weight/plant (g)		100 Seeds weight (g)		Total seed yield/fed (kg)	
		S1	S2	S1	S2	S1	S2
Seed size	Large	23.23A	20.64A	23.24A	22.87A	1164.8A	1012.0A
	Small	17.80C	14.74C	20.03C	19.59C	713.7C	637.0C
	Control	20.41B	17.41B	21.24B	21.07B	919.1B	800.8B
Plant density	33 plants/m²	19.25B	16.29B	21.33A	20.97A	991.3A	864.2A
	22 plants/m²	21.72A	18.90A	21.68A	21.39A	873.8B	769.0B
Foliar application	Seaweed	21.83B	18.78B	21.97AB	21.61AB	990.4B	874.0B
	Fresh algae	19.49C	16.82C	21.45B	20.87B	881.2C	769.7C
	Mix.	23.90A	20.41A	22.54A	22.41A	1082.7A	955.6A
	Control	16.71D	14.38D	20.05C	19.82C	775.8D	667.2D

Mix. (Seaweed + Fresh algae).
Values within the same column followed by the same letters are not significantly different at 5% level (Duncan's multiple range test).

The highest seeds weight per plant was produced from plant density of 22 plants per m^2 and foliar application with the mixture, while weight of 100 seeds was improved when cultivation all plant densities then sprayed with the mixture or seaweed extract. Meanwhile the highest seed yield per feddan was produced from plant density of 33 plants per m^2 and foliar application with the mixture.

Data tabulated in Table 6 demonstrate the effect of triple interaction. Seed yield per plant was produced from the treatment of sowing large seeds at rate of 22 plants per m^2 and then sprayed with the mixture.

Heaviest weight of 100 seeds was produced from sowing large seeds at rate of 22 or 33 plants per m^2 and then sprayed with the mixture or seaweed extract. On the other hand the

Table 5 Effect of dual interaction between seed size and plant density, plant density and foliar application and foliar application with algae extract and seed size on seed yield and its components of bean plants grown during 2013 (S1) and 2014 (S2) seasons.

Treatments		Seed weight/plant (g)		100 Seeds weight (g)		Total seed yield/fed (kg)	
		S1	S2	S1	S2	S1	S2
Seed size × plant density							
Large	33 plants/m^2	22.20b	19.33b	23.14a	22.66a	1223.2a	1068.4a
	22 plants/m^2	24.25a	21.95a	23.33a	23.09a	1106.5b	955.5b
Small	33 plants/m^2	16.50d	13.59d	19.85c	19.01c	770.0e	673.9e
	22 plants/m^2	19.11c	15.90c	20.21c	20.17b	657.4f	600.2f
Control	33 plants/m^2	19.05c	15.97c	20.00bc	21.24b	980.7c	850.3c
	22 plants/m^2	21.78b	18.85b	21.49b	20.90b	857.5d	751.3d
Plant density × foliar application							
33 plants/m^2	Seaweed	20.60c	17.44d	21.78ab	21.41a–c	1048.7b	923.3b
	Fresh algae	18.24d	15.68e	21.28bc	20.77b–d	941.8d	815.1c
	Mix.	22.70b	18.86bc	22.35ab	22.03ab	1140.8a	1004.3a
	Control	15.46e	13.20f	19.91d	19.66d	833.9e	714.2d
22 plants/m^2	Seaweed	23.06b	20.12b	22.16ab	21.80ab	932.1d	824.7c
	Fresh algae	20.74c	17.96cd	21.63ab	20.97b–d	820.7e	724.4d
	Mix.	25.10a	21.95a	22.73a	22.80a	1024.6c	907.0b
	Control	17.96d	15.56e	20.20cd	19.98cd	717.8f	620.1e
Foliar application × seed size							
Seaweed	Large	24.65b	20.86b	23.71ab	23.06ab	1219.7b	1076.2b
	Small	18.68ef	16.65e	20.38ef	20.28d–f	772.8h	686.6 f
	Control	22.16cd	18.83cd	21.83c–e	21.48b–e	978.7f	859.2d
Fresh algae	Large	22.38cd	20.30bc	23.13a–c	22.47bc	1117.2c	963.3c
	Small	17.30fg	13.53f	20.31ef	19.45fg	662.3i	585.3h
	Control	18.80e	16.65e	20.91d–f	20.70c–f	864.3g	760.6e
Mix.	Large	26.70a	23.71a	24.60a	24.55a	1315.5a	1152.1a
	Small	21.40d	17.50de	20.83d–f	20.60c–f	858.2g	776.4e
	Control	23.60bc	20.01bc	22.19b–d	22.10b–d	1074.6d	938.3c
Control	Large	19.20e	17.70de	21.51c–f	21.42b–e	1007.0e	856.4d
	Small	13.85h	11.30g	18.60g	18.05g	561.7j	499.9i
	Control	17.10g	14.15f	20.05fg	20.00ef	758.9h	645.3g

Mix. (Seaweed + Fresh algae).
Values within the same column followed by the same letters are not significantly different at 5% level (Duncan's multiple range test).

highest seed yield per feddan was obtained from sowing large seeds at rate of 33 plants per m^2 and then sprayed with the mixture.

Leaf chemical components

Data in Table 7 reveal that sowing large seeds increased N, P and K percent in leaves significantly compared with non-sized or small seeds. Phosphorus and potassium content did not manifest significant difference when sowing non-sized or small seeds, while potassium content in the first season not manifest significant difference when sowing the three seed sizes. The increase in minerals might be attributed to the fact that large seeds produce bigger seedling and have better access to nutrient sources. These results confirmed with those of Perin et al. (2002) and El-Sawah (2007) on common bean.

Regarding the impact of planting density, the data clarified that sowing seeds at rate of 22 plants per m^2 recorded highest value of measured nutrients than sowing seeds at rate of 33 plants per m^2, except phosphorus content in the second season which did not manifest significant difference with the two plant densities. Such positive effect of lowering plant density may be due to that it reduces the competition between plants on water and nutrient elements absorption and increases the uptake of such macro elements by plants. These findings are in line with those reported by Arisha and Bradisi (1999) and Khairy (2013) on common bean.

Referring to the data of foliar application, the data indicate significant increment of plant content of the three nutrients (NPK) as spraying plants with bio-stimulants than spraying with distilled water (control). Furthermore, the highest values were recorded with spraying plants with extract of seaweed alone or the mixture. Such increments may be due to the enrichment of algae extracts with growth regulators especially cytokines and IAA which encourage the roots growth and uptake such elements. These results are in harmony with those reported by Abou El-Yazied et al. (2012) on snap bean.

Data in Table 8 show the effect of dual interaction on plant content of N, P and K. Data clarified that sowing large snap bean seeds at rate 22 plants per m^2 or sprayed with seaweed

Table 6 Effect of triple interaction among seed size, plant density and foliar application with algae extract on seed yield and its components of bean plants grown during 2013 (S1)and 2014 (S2) seasons.

Treatments			Seed weight/plant (g)		100 Seeds weight (g)		Total seed yield /fed (kg)	
			S1	S2	S1	S2	S1	S2
Large	33 plants/m^2	Seaweed	23.40de	19.73c–e	24.32ab	22.31a–e	1286.4b	1123.2b
		Fresh algae	21.43e–g	18.80de	22.73b–f	23.03a–d	1180.4c	1021.8c
		Mix.	25.70a–c	22.60b	23.60a–c	24.30ab	1358.2a	1217.6a
		Control	18.30i–l	16.20f–h	21.93b–h	21.00d–g	1067.8e	911.3d
	22 plants/m^2	Seaweed	25.90ab	22.00bc	23.10b–e	23.82a–c	1153cd	1029.2c
		Fresh algae	23.33de	21.80bc	23.53a–d	21.92b–f	1054.1e	904.9d
		Mix.	27.70a	24.83a	25.60a	24.80a	1272.7b	1086.7b
		Control	20.10g–i	19.20de	21.10d–i	21.84b–f	946.2g	801.5e
Small	33 plants/m^2	Seaweed	17.70i–k	15.30g–j	20.00h–j	19.97e–h	841.6h	743.7f
		Fresh algae	15.70km	12.86jk	20.53f–j	18.70gh	714.4j	621.8g
		Mix.	19.90g–j	15.80f–h	20.66e–j	20.00e–h	922.2g	807.6e
		Control	12.70n	10.40l	18.20j	17.40h	602.0k	522.5ij
	22 plants/m^2	Seaweed	19.67g–k	18.00d–f	20.76e–i	20.60d–g	704.0j	629.6g
		Fresh algae	18.90h–k	14.20h–k	20.10g–j	20.20d–g	610.2k	548.8hi
		Mix.	22.90de	19.20de	21.01e–i	21.20c–g	794.3i	745.3f
		Control	15.00m	12.20kl	19.00ij	18.70gh	521.4l	477.4j
Control	33 plants/m^2	Seaweed	20.70f–h	17.30e–g	21.04e–i	21.96b–f	1018.1f	903.0d
		Fresh algae	17.60j–l	15.50g–i	20.57e–j	20.60d–g	930.6g	801.8e
		Mix.	22.50d–f	18.20d–f	22.80b–f	21.80b–f	1142.2d	987.7c
		Control	15.40m	13.00i–k	19.60h–j	20.60d–g	832.0h	709.0f
	22 plants/m^2	Seaweed	23.63c–e	20.36b–d	22.62b–g	21.00d–g	939.4g	815.4e
		Fresh algae	20.00g–i	17.90d–f	21.26c–i	20.80d–g	798.0i	719.5f
		Mix.	24.70b–d	21.83bc	21.58c–h	22.41a–e	1007.0f	889.0d
		Control	18.80h–k	15.30g–j	20.50f–j	19.40f–h	685.9j	581.6gh

Mix. (Seaweed + Fresh algae).
Values within the same column followed by the same letters are not significantly different at 5% level (Duncan's multiple range test).

Table 7 Effect of seed size, plant density and foliar application with algae extract on (N, P and K) content of leaf bean plants grown during 2013 (S1) and 2014 (S2) seasons.

Treatments		Parameters					
		N (%)		P (%)		K (%)	
		S1	S2	S1	S2	S1	S2
Seed size	Large	2.75A	2.68A	0.54A	0.48A	1.76A	1.67A
	Small	2.47C	2.43C	0.43B	0.36B	1.68A	1.42B
	Control	2.62B	2.54B	0.46B	0.40B	1.72A	1.48B
Plant density	33 plants/m^2	2.57B	2.50B	0.46B	0.42A	1.69B	1.48B
	22 plants/m^2	2.66A	2.59A	0.49A	0.41A	1.75A	1.57A
Foliar application	Seaweed	2.70A	2.61A	0.52A	0.44B	1.78AB	1.58B
	Fresh algae	2.58B	2.52B	0.45BC	0.39C	1.70B	1.49C
	Mix.	2.72A	2.65A	0.49AB	0.50A	1.85A	1.65A
	Control	2.46C	2.41C	0.43C	0.33D	1.55C	1.39D

Mix. (Seaweed + Fresh algae).
Values within the same column followed by the same letters are not significantly different at 5% level (Duncan's multiple range test).

extract alone or mixed with fresh water algae gave the highest values of bean leaves nutrient content.

For the interaction effect of planting density and foliar application, the data mentioned superiority of foliar application of seaweed alone or mixed with fresh water algae with either planting rates of 22 or 33 plants per m^2 approximately.

Regarding the trilateral effect, data in Table 9 reveal that sowing large seeds at rates 22 or 33 plants per m^2 and then sprayed plants with the mixture recorded the highest values of plant nutrient content followed by sowing non-sized seeds at rate 22 plants per m^2 and then sprayed plants with the mixture. The lowest values of plants nutrients content were

Table 8 Effect of dual interaction between seed size and plant density, plant density and foliar application and foliar application with algae extract and seed size on macro elements (N, P and K) content of leaf bean plants grown during 2013 (S1) and 2014 (S2) seasons.

Treatments		N (%)		P (%)		K (%)	
		S1	S2	S1	S2	S1	S2
Seed size × plant density							
Large	33 plants/m^2	2.71b	2.63b	0.53b	0.46a	1.71bc	1.64a
	22 plants/m^2	2.79a	2.72a	0.55a	0.50a	1.80a	1.71a
Small	33 plants/m^2	2.42d	2.39d	0.41e	0.36a	1.66c	1.37d
	22 plants/m^2	2.52c	2.46cd	0.45cd	0.37a	1.71bc	1.47bc
Control	33 plants/m^2	2.59bc	2.49c	0.45de	0.43a	1.70bc	1.43cd
	22 plants/m^2	2.66b	2.59b	0.47c	0.38a	1.75ab	1.54b
Plant density × foliar application							
33 plants/m^2	Seaweed	2.66a–c	2.56b	0.50bc	0.45ab	1.76a–c	1.53c
	Fresh algae	2.56c–e	2.47c	0.45cd	0.39bc	1.67cd	1.45d
	Mix.	2.67a–c	2.61ab	0.47b–d	0.49a	1.82ab	1.60bc
	Control	2.41e	2.36d	0.43d	0.34cd	1.52e	1.34e
22 plants/m^2	Seaweed	2.74ab	2.65a	0.55a	0.44ab	1.81ab	1.62ab
	Fresh algae	2.60b–d	2.56b	0.46b–d	0.39bc	1.73b–d	1.54c
	Mix.	2.77a	2.69a	0.52ab	0.50a	1.88a	1.69a
	Control	2.51de	2.46c	0.44d	0.32d	1.59de	1.44d
Foliar application × seed size							
Seaweed	Large	2.86a	2.73ab	0.59a	0.50ab	1.86ab	1.74a
	Small	2.54bc	2.49d–f	0.48c–e	0.39cd	1.70a–c	1.47cd
	Control	2.70ab	2.60cd	0.51bc	0.43bc	1.79ab	1.52c
Fresh algae	Large	2.70ab	2.65a–c	0.52bc	0.45bc	1.71a–c	1.65b
	Small	2.45cd	2.40f	0.41ef	0.34de	1.67bc	1.40de
	Control	2.60bc	2.50d–f	0.43d–f	0.39cd	1.71a–c	1.44c–e
Mix.	Large	2.86a	2.77a	0.56ab	0.56a	1.90a	1.80a
	Small	2.57bc	2.54c–f	0.45c–f	0.45bc	1.79ab	1.52c
	Control	2.73ab	2.64bc	0.48c–e	0.48b	1.87ab	1.62b
Control	Large	2.60bc	2.55c–e	0.49b–d	0.39cd	1.56c	1.51c
	Small	2.32d	2.28g	0.38f	0.28e	1.57c	1.30f
	Control	2.47cd	2.42ef	0.42ef	0.32de	1.53c	1.36ef

Mix. (Seaweed + Fresh algae).
Values within the same column followed by the same letters are not significantly different at 5% level (Duncan's multiple range test).

recorded when sowing small seeds at any planting density and then spraying plants by distilled water.

Leaf chlorophyll content

Data in Table 10 prove that sowing large seeds revealed an increase in leaf chlorophyll content in both experimental seasons comparing with sowing small seeds and control. The encourage effect of large seed size on chlorophyll content might be the result of the stimulation in vegetative growth as shown in Tables 1–3. These results are in harmony with those obtained by El-Sawah (2007) who found that the highest values of chlorophyll a, b and total chlorophyll were recorded in plants produced from heavy seeds compared with light seeds or control in common bean cultivation.

Data in Table 10 reveal that leaf chlorophyll content increased at snap bean plants sown at low density of 22 plants per m^2 as compared with those sown at high density of 33 plants per m^2, in the two seasons. The enhancing effect of low plant density on leaves chlorophyll content may be due to that increase spacing between plants make it receive more sunlight which plays the main role in chlorophyll molecule formation and subsequently increases chlorophyll pigment accumulation. Similar results were obtained by Helal (2000) on cowpea, El-Atabany (2000) on pea and El-Atabany (2015) on common bean.

Concerning the impact of foliar application, the data show that leaves chlorophyll content significantly increased as a result of spraying plants with the two types of algae extracts as compared with the control treatment during the two tested seasons. The highest chlorophyll content was recorded with application of the mixture followed by seaweed application. These results may be attributed to the presence of some nutrient materials in seaweed extracts such as nitrogen and magnesium which enter in the structure of chlorophyll molecule. Also they contain cytokinins and betaines which act a role in reduction of not in chlorophyll degradation (Whapham et al., 1993). The obtained results agree with those of Sarhan et al. (2011) on cucumber, Abou El-Yazied et al. (2012) on snap bean and Nawar and Ibraheim (2014) on pea.

For the effect of interaction of the different tested factors, data in Table 11 show that the highest values of chlorophyll

Table 9 Effect of triple interaction between seed size, plant density and foliar application with algae extract on macro elements (N, P and K) content of leaf bean plants grown during 2013 (S1) and 2014 (S2) seasons.

Treatments			N (%)		P (%)		K (%)	
			S1	S2	S1	S2	S1	S2
Large	33 plants/m^2	Seaweed	2.83a–c	2.69a–d	0.57ab	0.48a–c	1.80a–d	1.70bc
		Fresh algae	2.70a–g	2.61c–f	0.51b–e	0.43b–g	1.68a–d	1.62c–f
		Mix.	2.80a–d	2.73a–c	0.54a–c	0.54ab	1.86ab	1.76ab
		Control	2.54d–k	2.50e–i	0.49b–g	0.38d–j	1.52cd	1.48f–j
	22 plants/m^2	Seaweed	2.90ab	2.78ab	0.61a	0.53a–c	1.92a	1.79ab
		Fresh algae	2.70a–g	2.70a–d	0.53a–d	0.47a–f	1.75a–d	1.68b–d
		Mix.	2.93a	2.82a	0.57ab	0.59a	1.95a	1.84a
		Control	2.66b–i	2.60c–g	0.50b–f	0.40d–i	1.60b–d	1.54e–i
Small	33 plants/m^2	Seaweed	2.48g–k	2.45f–j	0.44d–i	0.41c–i	1.69a–d	1.42i–k
		Fresh algae	2.40i–k	2.37i–k	0.40g–i	0.32g–j	1.65a–d	1.36j–l
		Mix.	2.52e–k	2.50e–i	0.41f–i	0.44b–g	1.76a–d	1.48f–j
		Control	2.28k	2.23k	0.38i	0.29ij	1.54cd	1.24l
	22 plants/m^2	Seaweed	2.60c–j	2.53c–h	0.51b–e	0.38d–j	1.72a–d	1.53f–i
		Fresh algae	2.50f–k	2.44h–j	0.43e–i	0.36e–j	1.69a–d	1.45g–j
		Mix.	2.62c–j	2.58c–h	0.48b–h	0.47b–f	1.83a–c	1.57c–h
		Control	2.36jk	2.32jk	0.39hi	0.27j	1.60b–d	1.36j–l
Control	33 plants/m^2	Seaweed	2.67a–h	2.55d–h	0.48b–h	0.46b–f	1.79a–d	1.49f–j
		Fresh algae	2.60c–j	2.45g–j	0.43e–i	0.42b–h	1.68a–d	1.38jk
		Mix.	2.70a–g	2.60c–g	0.46c–i	0.51a–d	1.86ab	1.58c–g
		Control	2.42h–k	2.36i–k	0.41f–i	0.35f–j	1.49d	1.30kl
	22 plants/m^2	Seaweed	2.74a–f	2.65b–e	0.53a–d	0.40d–i	1.80a–d	1.56d–i
		Fresh algae	2.60c–j	2.56d–h	0.44d–i	0.36e–j	1.75a–d	1.50f–j
		Mix.	2.76a–e	2.69a–d	0.49b–g	0.45b–f	1.88ab	1.67b–e
		Control	2.53e–k	2.48f–j	0.42e–i	0.30h–j	1.57b–d	1.43h–k

Mix. (Seaweed + Fresh algae).
Values within the same column followed by the same letters are not significantly different at 5% level (Duncan's multiple range test).

Table 10 Effect of seed size, plant density and foliar application with algae extract on leaf chlorophyll content and seed quality parameters of bean plants during 2013 (S1) and 2014 (S2) seasons.

Treatments		Parameters					
		Leaf chlorophyll (mg/m^2)		Total protein (%)		Total carbohydrates (g/100 g D.Wt.)	
		S1	S2	S1	S2	S1	S2
Seed size	Large	366.0A	363.9A	23.12A	21.02A	54.09A	51.16A
	Small	345.9B	327.0C	19.33C	16.94C	48.65C	46.67C
	Control	351.7B	340.7B	21.29B	18.37B	51.00B	48.74B
Plant density	33 plants/m^2	346.8B	336.2B	20.69B	18.14B	50.03B	47.48B
	22plants/m^2	362.3A	351.5A	21.80A	19.42A	52.47A	50.24A
Foliar application	Seaweed	363.8B	347.0B	21.89A	19.40A	53.10B	50.22B
	Fresh algae	346.3C	342.8B	20.87B	18.40B	50.22C	47.83C
	Mix.	382.6A	361.5A	22.33A	20.02A	54.93A	52.52A
	Control	325.4D	324.1C	19.89C	17.29C	46.76D	44.86D

Mix. (Seaweed + Fresh algae).
Values within the same column followed by the same letters are not significantly different at 5% level (Duncan's multiple range test).

content were observed in the treatments of combining sowing large seeds at rate of 22 plants per m^2 or combined with spraying with the mixture, also the lower plant density 22 plants/m^2 combined with spraying with the mixture gave the highest leaf chlorophyll content.

Regarding the three ways interaction, Table 12 shows that sowing large seeds at plant density of 22 plants per m^2 with spraying algal mixture gave the highest chlorophyll content during the two experimental seasons.

Seed quality

Snap bean seed quality attributes, content of protein and carbohydrate are shown in Table 10. Data proved that seed content of protein and carbohydrate recorded the highest values in seeds produced from plants grown through large seeds. Seeds without sizing came up after large seed treatment for the same seed parameters. On the other hand, the lowest values of protein and carbohydrate percentage were obtained when sowing small seeds. These results are in agreement with those obtained on common bean by El-Sawah (2007) and Nosser and Behnan (2011) and on faba bean by Mekkei (2014) and they reported that large seed gave the highest values of protein and carbohydrates percentage.

The parameters of content of protein and carbohydrate were affected significantly by planting density. Seeds produced from planting rate 22 plants per m^2 were superior to planting rate 33 plants per m^2. This can be explained on the basis of efficient photosynthetic activity, increasing the chlorophyll content in leaves, uptake of nutrient and better translocation of photosynthesis from source to sink (seed). These data agree with those of Prashanth et al. (2006) who reported that the higher seed protein percent of French bean was obtained at wider spacing while the minimum value was obtained at closer spacing.

Spraying snap bean plants with seaweed extract or fresh water algae extract individually or mixed increased seed nutritive value significantly compared to spraying with distilled water (control treatment). Concerning foliar application data, it revealed that spraying the mixture or seaweed increased content of protein significantly, while carbohydrate content was the highest for seeds produced through spraying with the mixture. Such increments may be due to the content of algae extracts from growth regulators especially cytokines and IAA which encourage the roots growth and uptake and accumulation of such elements in seeds. These results agree with those reported by Jagannath et al. (2002) on chick pea, Zodape et al. (2010) on green gram and Latique et al. (2013) on bean plants.

Data in Table 11 exhibit bilateral effect, and proved that incorporation sowing large seeds at rate of 22 plants per m^2 increased seed content of carbohydrate significantly.

Table 11 Effect of dual interaction between seed size and plant density, plant density and foliar application and foliar application with algae extract and seed size on leaf chlorophyll content and seed quality parameters of bean plants during 2013 (S1) and 2014 (S2) seasons.

Treatments		Leaf chlorophyll mg/m^2		Total protein (%)		Total carbohydrates (g/100 g DW)	
		S1	S2	S1	S2	S1	S2
Seed size × plant density							
Large	33 plants/m^2	359.4b	355.5b	22.62ab	20.45a	52.93b	49.57b
	22 plants/m^2	372.6a	372.2a	23.62a	21.59a	55.26a	52.75a
Small	33 plants/m^2	338.0c	319.5c	18.72d	16.29d	47.80d	45.55d
	22 plants/m^2	353.8b	334.5 cd	19.95c	17.59c	49.50c	47.80c
Control	33 plants/m^2	343.0c	333.6de	20.75c	17.69c	49.35c	47.31c
	22 plants/m^2	360.4b	347.9bc	21.83b	19.06b	52.65b	50.17b
Plant density × foliar application							
33 plants/m^2	Seaweed	355.0c	338.9cd	21.39cd	18.58bd	51.93c	48.34c
	Fresh algae	340.3d	335.2d	20.29e	17.76de	48.63d	47.02cd
	Mix.	372.8b	353.0b	21.87a–c	19.59ab	53.63b	51.04b
	Control	319.1f	317.6e	19.23f	16.65e	45.93e	43.51e
22 plants/m^2	Seaweed	372.7b	355.1b	22.39ab	20.23a	54.26b	52.11ab
	Fresh algae	352.3c	350.5bc	21.46b–d	19.04bc	51.81c	48.64c
	Mix.	392.5a	370.0a	22.79a	20.45a	56.22a	54.01a
	Control	331.6e	330.6d	20.56de	17.94cd	47.58d	46.21d
Foliar application × seed size							
Seaweed	Large	378.5b	367.1ab	23.59a	21.35ab	56.90ab	52.30b
	Small	354.3c	329.8fg	20.19d	17.87ef	50.20cd	46.98c
	Control	358.6c	344.1c–f	21.90bc	19.00de	52.20c	51.40b
Fresh algae	Large	355.3c	363.3bc	22.90ab	20.87a–c	52.30c	50.10b
	Small	338.3de	325.9fg	18.87e	16.70f	47.75ef	46.58c
	Control	345.3d	339.4ef	20.84cd	17.62ef	50.61cd	46.81c
Mix.	Large	396.6a	381.1a	23.90a	22.25a	58.39a	56.05a
	Small	373.7b	345.1b–c	20.69d	17.91ef	51.40c	49.66b
	Control	377.7b	358.3b–d	22.40b	19.90b–d	55.00b	51.86b
Control	Large	333.5e	343.9d–f	22.09b	19.62cd	48.79de	46.20c
	Small	317.4g	307.3h	17.59f	15.29g	45.26g	43.48d
	Control	325.3f	321.2gh	20.00d	16.97f	46.21fg	44.90cd

Mix. (Seaweed + Fresh algae).
Values within the same column followed by the same letters are not significantly different at 5% level (Duncan's multiple range test).

Table 12 Effect of triple interaction between seed size, plant density and foliar application with algae extract on leaf chlorophyll content and seed quality parameters of bean plants during 2013 (S1) and 2014 (S2) seasons.

Treatments			Leaf chlorophyll (mg/m^2)		Total protein (%)		Total carbohydrates (g/100 g DW)	
			S1	S2	S1	S2	S1	S2
Large	33 plants/m^2	Seaweed	369.9c	358.4b–e	23.00a–d	20.62a–c	55.80b–e	50.50c–f
		Fresh algae	350.8ef	355.0b–f	22.44b–d	20.43b–e	51.00f–i	48.00e–i
		Mix.	388.9b	372.3a–c	23.50a–c	21.75a–c	57.10a–c	54.70ab
		Control	327.9i–k	336.2e–i	21.56d–f	19.00c–i	47.83i–m	45.10i–k
	22 plants/m^2	Seaweed	387.2b	375.8ab	24.19ab	22.08ab	58.00ab	54.10a–c
		Fresh algae	359.8de	371.6a–c	23.37a–c	21.31a–d	53.60d–f	52.20b–d
		Mix.	404.2a	390.0a	24.31a	22.75a	59.68a	57.40a
		Control	339.0gh	351.5b–g	22.62a–d	20.25b–f	49.76h–k	47.30c–j
Small	33 plants/m^2	Seaweed	344.6fg	322.0h–j	19.87f–i	16.75i–k	50.00g–j	45.23h–k
		Fresh algae	332.4h–j	317.9ij	18.12jk	16.22kl	46.70k–n	46.93f–j
		Mix.	363.3cd	337.3e–i	20.13f–i	17.70g–k	50.00g–j	48.10e–i
		Control	311.6l	300.9j	16.75k	14.50l	44.53n	41.93k
	22 plants/m^2	Seaweed	364.0cd	337.6e–i	20.50e–h	19.00c–i	50.40g–i	48.73d–i
		Fresh algae	344.2fg	333.8e–i	19.62g–j	17.18h–k	48.80i–l	46.23h–j
		Mix.	384.1b	352.9b–f	21.25d–g	18.12f–k	52.80e–h	51.23b–e
		Control	323.1jk	313.7ij	18.44ij	16.08kl	46.00l–n	45.03i–k
Control	33 plants/m^2	Seaweed	350.5ef	336.2e–i	21.31d–g	18.37e–k	50.00g–j	49.30d–h
		Fresh algae	337.6g–i	332.8f–i	20.31e–h	16.62j–l	48.20i–m	46.13h–j
		Mix.	366.1cd	349.4c–g	22.00c–e	19.31d–h	53.80d–f	50.33c–g
		Control	317.9kl	315.8ij	19.37h–j	16.45j–l	45.43mn	43.50jk
	22 plants/m^2	Seaweed	366.8cd	351.8b–f	22.50a–d	19.62c–g	54.40c–e	53.50bc
		Fresh algae	352.9ef	346.0d–h	21.38d–g	18.62e–j	53.03e–g	47.50e–j
		Mix.	389.3b	367.1a–d	22.81a–d	20.50b–e	56.20b–d	53.40bc
		Control	332.8h–j	326.5g–i	20.62e–h	17.50g–k	47.00j–n	46.30g–j

Mix. (Seaweed + Fresh algae).
Values within the same column followed by the same letters are not significantly different at 5% level (Duncan's multiple range test).

Meanwhile sowing large seeds at the two plant densities increased content of protein in both seasons.

Sowing large seeds of snap bean and then spraying the plants with the mixture led to higher values of seed carbohydrate content. Protein percent of seeds recorded the highest values in treatments of sowing large seeds and spraying plants with any of the three extracts.

Regarding the impact of interaction between plant density and foliar application, data demonstrated that spraying plants with either the mixture or the seaweed extract alone combined with planting rate 22 plants per m^2 and combined with any plant density resulted in the highest values of seed protein and carbohydrate content, respectively.

According to Table 12, data explained the impact of trilateral interaction. The data demonstrated that sowing large seeds at rate 22 plants per m^2 and then spraying plants by the mixture resulted in higher values of carbohydrate content. Data clarified that sowing large seeds at rate of 22 or 33 plants per m^2 and then spraying plants with either seaweed or fresh water algae extract or mix of them increased seed protein content significantly than other treatments. Less seed nutritive value was noticed in the combination treatment of sowing small seeds at rate of 33 plants per m^2 and spraying with distilled water.

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