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Green Seaweed Extract: A Complementary Bio-Fertilizer and Bio-Stimulator for Growth and Yield of Sweet Potato plants.

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ABSTRACT

Seaweed is one of the most essential raw materials for the manufacture of bio-stimulant, which are processed and marketed for use in improving and maximizing agricultural production. Two field experiments were performed at the Agricultural Experimental Station Farm (Abies region), Faculty of Agriculture, Alexandria University during the 2016 and 2017 summer seasons. The study investigate the effect of NPK soil chemical fertilizers at the rates of 25, 50, 75% of recommended dose RD, in addition to 100% as a control treatment combined with application of seaweed extract *Ulva lactuca* (SWC) at the concentration of 0, 5, 10, and 15% as a foliar spray. The gradual increase in NPK chemical fertilizers had significant effects on growth, yield and chemical composition traits of sweet potato plants. The spraying of sweet potato plants with seaweed extract at a concentration of 15 % resulted in a positive response to all the traits tested. The application of NPK mineral fertilizer at the rate of 75% of the RD, combined with seaweed foliar spray at the concentration of 15%, was generally the most efficient treatment gave the best sweet potato growth, yield and tuber root chemical compositions Thus, this treatment can be decrease the NPK-chemical fertilizer by 25 % without sacrificing the output value of the sweet potato plants concerning the yield and quality of the tuber roots.

KEYWORDS: Sweet potato, *Ulva lactuca,* seaweed extract, minimizing NPK mineral fertilizers, bio-stimulant.

1. INTRODUCTION

Sweet potato is one of the most important root vegetable crops widely cultivated in Egypt. Tuber roots have excellent nutritional quality because they are an outstanding source of complex carbohydrates, high antioxidants, vitamins (A & B), starch, and nutrients, particularly in the orange flesh types (Woolfe, 1992). Sweet potato has a high biomass output yield, so it may have a superior effect as a portion of common human food, green foliage, and as a raw material for many industries such as starch and alcohol. (Mahmoud *et.al.* 2018 and Doss *et.al.* 2015). In 2018, the cultivated sweet potato area in Egypt was around 11,544 ha, producing 387,481 tons (FAOSTAT, 2018). Egyptian farmers have paid great attention to improving the production and quality of sweet potatoes over the last decade with the goal of increasing local consumption and export yield (Mansour *et.al.* 2002 and Sadek 2000).

The seaweeds or algae are groups of primitive organisms with no have real roots, stems, and leaves. Green seaweed (*Ulva Lactuca*) is one of the marines living resources of enormous commercial importance for imports. Seaweed products are well known for their quality of auxin and cytokinin, as these endogenous phytohormones are responsible for the division of cells, root, and shoot elongation (Crouch & Van Staden 1993). Due to the proper level of potassium, nitrogen, growth-promoting hormones, micro-nutrients, humic acids, etc.in seaweed, it is considered an excellent fertilizer. (Dhargalkar & Pereira 2005). Over the past 40 years, liquid extracts collected from marine algae have been used on different plants to promote growth and improvement productivity. The use of seaweed as an low-cost source of naturally occurring plant growth regulator is a matter of interest in the agricultural system (Zodape 2001)

Several researchers have been investigating the use of seaweed in modern agriculture in recent years. Hence, Doss *et.al.* (2015) found that the tuber roots marketable yield were substantially increased by seaweed extract sprays and non-marketable yield on sweet potato damage were minimized over control. Sarhan (2011) mentioned that seaweed extracts had a positive impact on potato plant growth and thus significantly improved overall potato yield, both qualitatively and quantitatively. Haider *et.al.* (2012) also concluded that seaweed extracts could increase potato yield. However, the stages in the crop at which the seaweed is treated play an important role. When seaweed extract was sprinkled at intervals between 30 and 60 days after planting, increased tuber production was recorded. The use of seaweed extracts also recorded significant increases in the percentages of nitrogen, total soluble solids and protein content of potato tubers (Sarhan 2011, Haider *et.al.* 2012, and Ahmed *et.al.* 2018), and led to the improvement of most of the cucumber and pepper vegetative growth and fruiting characteristics (Sarhan & Ismail 2014 and Sridhar & Rengasamy 2012). Liquid seaweed fertilizer (LSF) spray (2.5 %) significantly increased the yield and nutritional quality of okra plant (20.47 %), as stated by, Zodape *et.al.* (2008). The addition of seaweed extracts have improved seed yield productivity and protein percentage in bean (Jasim & Obaid 2014).

In plants, the macronutrients nitrogen (N), phosphorus (P) and potassium (K) are very important for crop growth and production, yield formation and improvement of vegetable quality. It can be considered as a constituent of various organic plant molecules such as chlorophyll, amino acids, enzymes, proteins and nucleic acids, etc. (Ukom *et.al.* 2009 and Purcell & Walter 1982). The response of sweet potato plants to macro nutrient fertilization, nitrogen and potassium have been recognized as a vital step in increasing the yield of sweet potato tubers' roots, as stated by Uwah *et.al.* (2013), Abdel-Razzak *et. al.* (2013), Doss *et.al.* (2015), Abdel-Naby *et.al.* (2018) and Sidiky *et.al.* (2019).

Therefore, the present study was suggested to investigate the main effects of foliar spraying of green seaweed extract (*Ulva lactuca*), as a bio-stimulant growth under different levels of mineral NPK fertilizer, as well as their interactions on the growth , yield and quality of the sweet potato plants. A special attention was also directed to study the possibility of reducing rates of the mineral fertilizers NPK by using varying concentrations of seaweed extracts to maximize the yield and quality of sweet potato plants, in order to minimize the cost of production as well as the environmental pollution.

2. MATERIALS AND METHODS

At the Agriculture Experimental Station Farm, Faculty of Agriculture, Alexandria University, two field trials were performed at Abies region during the 2016 and 2017 summer seasons. This study was conducted to evaluate the effect of foliar spraying by several concentrations of green seaweed extracts (*Ulva Lactuca*) under different levels of chemical fertilizer (NPK) on growth, yield and quality of tuber components of sweet potato plants, as well as certain tuber root chemical constituents.

In preparation for each experiment, soil samples were taken at random from surface layers (0 - 30 cm) of the experimental area and prepared for analysis in accordance with the procedures defined by Page *et al*. (1982). The soil analysis results are shown in table (1).

Table 1. Some soil physical and chemical properties of the experimental sites of the two summer seasons of 2016 and 2017.

Summer season	Soil texture	EC (ds m^{-1})	pH	Organic matter (%)	Available N, P and K (mg g^{-1})		
					N	P	K
2016	Clay	3.6	8.1	1.2	98.23	21	561
2017	Clay	3.2	7.9	1.8	102.0	20	596

-A physical and chemical property analysis was carried out at the Department of Soil and Water Science, Faculty of Agriculture, University of Alexandria.

2.1. Seaweed Extracts Source.

Green Seaweed was collected during the first days of September 2016 from several coastal beaches of El-Shatby, Abu Qir and Al Qalaa in Alexandria. In order to clean the sediment, epiphytes and organic matter on their surface, they were washed. The cleaned seaweed was returned to the laboratory in polythene bags and washed again in the laboratory with tap water to eliminate salt and surface contamination (Sivasankari *et.al.* 2006). After then seaweed was drying with shading for four days, followed by oven drying for 12h at 60°C. Then a fine powder of dried algae was made using a mixer. Fifty gram of the dry powder was taken and 500 ml of distilled water was added to it, which was boiled for one hour and then filtered through the muslin cloth. It was filtered with Whatman filter paper, and then the volume of the extract was completed to reach 500 ml with the addition of distilled water, to prepare an extract at a concentration of 100% (Stock solution).

Different concentrations of the liquid seaweed extract were prepared from the stock solution using distilled water 5%, 10% and 15 %, in addition to 0% concentrate as a control treatment (Bhosle *et al.* 1975.) and Zodape, 2001). The photos assembled in Figure (1) show the steps for preparing green seaweed extract used in this study.

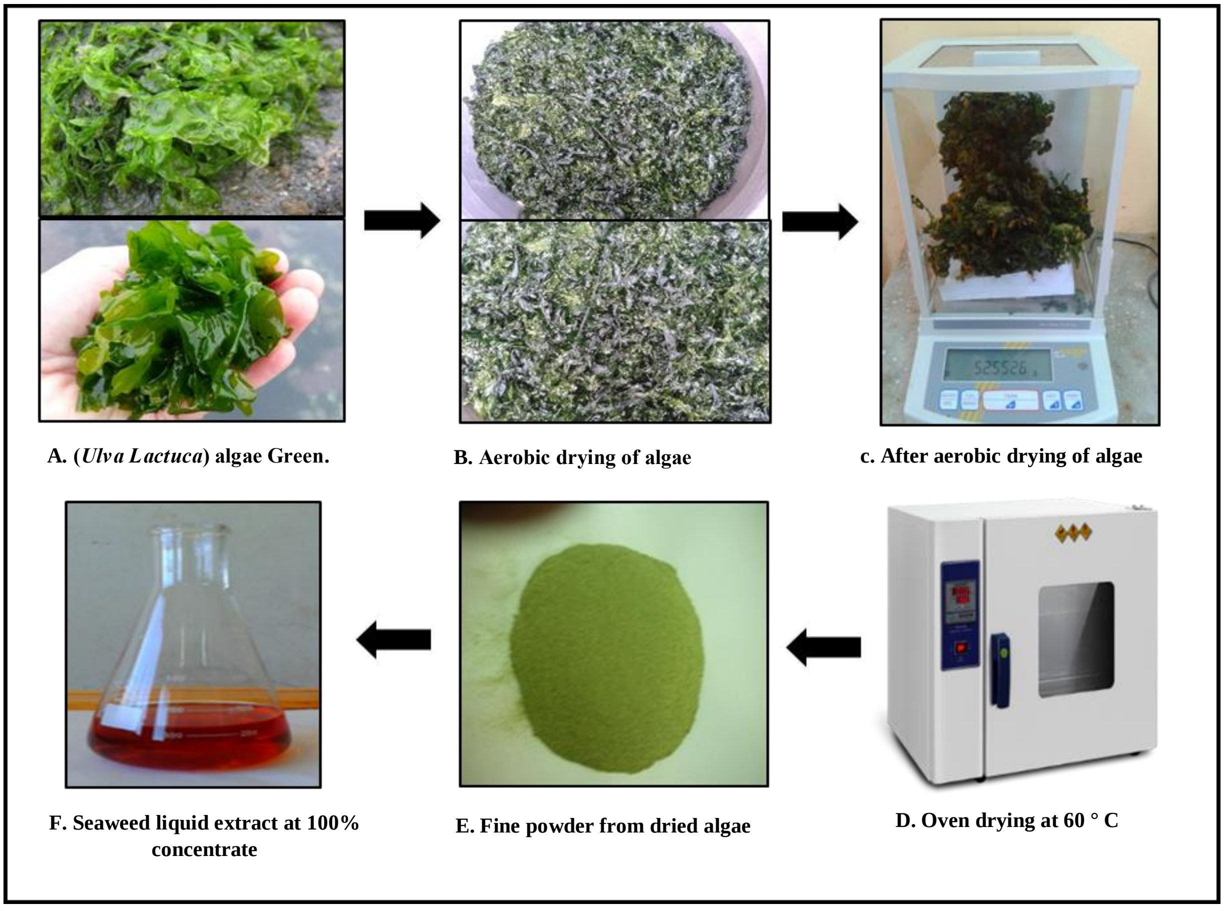

Fig. 1. Preparation Stages of liquid seaweed extract (*Ulva lactuca*).

A. Collection of green seaweed (*Ulva lactuca*) from several coastal beaches in Alexandria.
B. Air-dried algae for 4 days in a shaded area.
C. After aerobic drying of algae.
D. Green algae Oven dry for 12h at 60°C.
E. Fine powder from green algae by using a blender.
F. Stock solution at 100 % concentrates of seaweed liquid fertilizer.

Some chemical properties of the liquid fertilizer from green seaweed (*Ulva lactuca*) were analyzed in the Central Laboratory of the Faculty of Agriculture, Alexandria University, and the obtained results are presented in Table (2).

2.2. Experimental Design.

A split plot design based on randomized complete blocks design with three replicates was used. Four levels of NPK fertilizers (25%, 50%, 75% and 100% of the recommended dose RD) were assigned to main plots. The sub-plots were devoted to four effective concentration of seaweed extract i.e., 0%, 5%, 10% and 15%. The recommended NPK fertilizer levels for commercial production of sweet potatoes are (45 kg N, 90 kg K_2O and 45 kg P_2O_5 fed^{-1}.). There were four rows in each sub-plots, 4 m long and 0.7 m in width. Each sub plot area was 11.2 m^2. The main plots were given four quantities of NPK fertilizer, while the four concentrations of seaweed extract (SWC) were randomly distributed in the sub-plots. Without planting, a row was left to separate each of the adjacent sub-plots.

Table 2. Mineral composition of green seaweed liquid extract (*Ulva lactuca*) collected from Alexandria coastal beaches during 2017.

Elements	Amount mg g^{-1} dry weight
Nitrogen (N)	321.8
Potassium (K)	182.9
Phosphor (P)	74.75
Magnesium (Mg)	95.4
Calcium (ca)	109.5
Iron (I)	8.74
Manganese (Mn)	5.69
Zinc (Zn)	1.84
Copper (Cu)	1.70

2.3. Experimental Work.

In this research, the most popular local Egyptian sweet potato cultivar 'Abies' was used, characteristic by a purple skin and sweet orange-flesh. The 20 cm long sweet potato vine cuttings were planted, 30 cm in rows, on 1 May, during the first and second seasons (2016 and 2017). The assigned amounts of phosphorus fertilizer in the form of calcium super phosphate (15.5 % P_2O_5) were added for the experimental units prior to planting and those of nitrogen and potassium in the form of ammonium sulfate (20.5 % N) and potassium sulfate (48.5 % K_2O). At three separate times, nitrogen fertilizer was similarly side-dressed with the soil; after 3, 7, and 10 weeks of planting. The potassium fertilizer doses were added in similar quantities after 3 and 7 weeks of planting. On the other hand, 3, 6 and 9 weeks after planting, foliar spraying of various concentrations of seaweed extract was carried out three times. For all the experimental units, all other cultural activities like irrigation and weeding were applied in usual manure.

2.4. Data Recorded:

Vegetative growth characters: Two weeks before harvesting (about 100 days from planting), four plants were randomly picked up from each sub-plot to calculate the following characters: number of branches plant^{-1}, number of leaves plant^{-1} and vine fresh weight plant^{-1} (kg).

Tuber roots yield and its components: All plants, from each sub-plot, at the harvest stage (at 120 days from planting), the following characters; number of tuber roots plant^{-1}, un-marketable tuber roots yield fed^{-1} (ton), marketable tuber roots yield fed^{-1} (ton) and total tuber roots yield fed^{-1} (ton) were recorded for all plants from each sub-plot. Un-marketable yield was determined as the total weight of strings form, thinner tuber roots (less than 3 cm in diameter) and thicker tuber roots (more than 10 cm in diameter), as well as cut or injured tuber roots of all harvested roots per sub-plot (kg / sub-plot), and then convert in to ton per fed.

Chemical composition of tuber roots: A random sample of five uniform roots from each sub-plot was carefully washed with distilled water, then weighted and prepared for some tuber roots chemical analyses. Total carotene (mg 100 g^{-1} fresh weight) was measured, according to Witham *et.al.* (1971). Total sugars %, starch%, carbohydrates % and protein%, were determined, following the standard methods of association of official analytical chemists (AOAC 2000).

Mineral Composition of Tuber Roots percentage: After harvesting, random samples of roots were collected from each sub plot. All samples were washed, dried at 70 ˚C and used to determine mineral contents of roots as follows. Nitrogen, potassium and phosphorus according to the methods described by Evenhuis & Dewaord (1980), Chapman and Pratt (1961), and Toth *et.al.* (1948), respectively.

2.5. Statistical Analyses:

All data collected was statistically analyzed according to the experimental design used, using the computer program Co-Stat Software (2004). Comparisons were made between the means of the different treatments, using Duncan's multiple range tests at a probability level of 0.05 (Steel & Torrie 1980).

3. RESULTS AND DISCUSSION

3.1. Vegetative growth characters.

Regarding the impact of the chemical fertilizer levels (NPK), seaweed extract concentrations (SWC), and their interactions on vegetative growth characters of sweet potato, the data presented in Tables (3 & 4). Significant increment in all studied traits; number of branches plant^{-1}, number of leaves plant^{-1} and vine fresh weight plant^{-1} of sweet potato plants was reflected. The detected increases in all growth characters, in both seasons, were generally corresponding to the increase in NPK levels from 25% to 100% however no significant differ between the two treatment 75% and 100% in most cases. These results could probably be generally explained on the basis that the available NPK content in the experimental soil area was apparently low (Table 1), which reflected the detected high response to the increased supplies of these nutrients. The obtained results are in harmony with those reported by (Abdel-Razzak *et.al.* 2013, Uwah *et.al.* 2013, Doss *et.al.* 2015, Helaly 2016, Abdel-Naby *et.al.* 2018 and Sidiky *et.al.* 2019), who concluded that the best plant growth of sweet potato plants was attained by the plants that received the commercially recommended rates of NPK fertilizers; in addition to the agreement with the outcome of Arisha & Bardisi (1999) and Mukhtar *et.al.*(2010), on potato crop. Sadek, (2000) reported that the application of N-fertilizer increased gradually and significantly all traits of vine growth of sweet potato plants. Moreover, Ukom *et.al.* (2009) stated that N is the major constituent of numerous products of sweet potato plant metabolism.

The findings recorded in Table (3) showed that the values of the vegetative growth characteristics were significantly increased when spraying at different concentrations of seaweed extract. With the rise in seaweed extract concentrations, the values of the studied traits increased. While the highest values were reported by the foliar spray with a concentration of 15 % of seaweed extract, during the two seasons, without a significant difference when spraying with a concentration of 10 % on all the studied vegetative growth characteristics.

Table 3. Vegetative growth characters of sweet potato as affected by NPK levels and seaweed extract concentrations (during the two summer seasons of 2016 and 2017.

Treatments	Number of branches plant^{-1}		Number of leaves plant^{-1}		Vine fresh weight plant^{-1} (Kg)	
	2016	2017	2016	2017	2016	2017
(NPK %) levels.						
25%	4.58 b*	4.33 b	165.33 d	178.92 c	1.15 c	1.23 c
50%	4.83 ab	4.75 b	185.17 c	191.75 b	1.23 b	1.33 bc
75%	5.17 a	5.42 a	204.50 b	206.08 a	1.51 a	1.42 b
100%	5.25 a	5.42 a	214.92 a	211.58 a	1.55 a	1.59 a
Seaweed extracts concentrations (SWC).						
0%	4.33 b	4.50 b	179.08 b	188.50 b	1.26 b	1.26 c
5%	4.58 b	4.42 b	182.83 b	195.75 ab	1.30 b	1.34 bc
10%	5.33 a	5.58 a	200.33 a	199.00 ab	1.39 ab	1.43 ab
15%	5.58 a	5.42 a	207.67 a	205.08 a	1.49 a	1.53 a

* Means values followed by similar letter (s)do not differ significantly, using Duncan' s multiple range test at 0.05 level.

These results, generally agreed with the findings of Doss *et.al.* (2015), Helaly 2016 and Mahmoud *et.al.* (2018), who noticed the effect of spraying seaweed extracts on increasing the vegetative growth characteristics of sweet potato plant. Moreover, Kowalski *et.al.* (1999), Sarhan (2011) and Haider *et.al.* (2012); stated the effect of spraying seaweed extracts on increasing the vegetative growth of potato crop. A possible explanation for the increased plant growth, due to using seaweed extracts, is that the extracts contain auxins, gibberellins, and precursors of ethylene, betaine and cytokinins, which are present and potentially involved in enhancing plant growth responses (Crouch & Van Staden; 1993).

The results of the interaction effect between the two factors analyzed are shown in the table (4). Generally, some positive significant interaction effects on mean values of number of branches plant^{-1}, number of leaves plant^{-1} and vine fresh weight plant $^{-1}$ (kg) were noticed in both growing seasons. It is indicated, generally, that the addition of NPK fertilizers at the rates of 75% or 100% with the foliar spray with 10 % or 15 % concentrations of seaweed extract led to marked increases on the mean values of all above-mentioned characters. The favorable influences of seaweed extract application on the studied vegetative growth characters, appeared to be in a general agreement with the results obtained by Doss *et.al.*

Table 4. Mean of vegetative growth characters of 'Abies' cv. sweet potato, as affected by interactions between NPK levels and seaweed extract concentrations (SWC), during the two summer seasons of 2016 and 2017.

Treatments		Number of branches plant^{-1}				Number of leaves plant^{-1}				Vine fresh weight plant^{-1} (Kg)			
		2016		2017		2016		2017		2016		2017	
(NPK %) levels interacted with (SWC).													
NPK 25%	0%	3.67	c	3.33	c	151.33	h	169.33	g	1.00	i	1.00	f
	5%	4.00	c	4.00	c	154.33	h	182.00	d-g	1.11	hi	1.13	ef
	10%	5.00	ab	5.00	b	170.67	f-h	176.00	e-g	1.18	f-h	1.28	c-e
	15%	5.67	a	5.00	b	185.00	d-f	188.33	c-g	1.32	e-g	1.51	ab
NPK 50%	0%	4.33	bc	4.00	c	161.67	gh	174.67	fg	1.17	gh	1.27	c-e
	5%	4.00	c	3.67	c	181.00	e-g	200.00	b-d	1.09	hi	1.22	de
	10%	5.67	a	5.67	ab	194.33	c-e	183.67	d-g	1.32	ef	1.35	b-d
	15%	5.33	a	5.67	ab	203.67	b-d	208.67	a-c	1.35	de	1.47	a-c
NPK 75%	0%	4.33	bc	5.00	b	185.67	d-f	209.67	a-c	1.39	c-e	1.33	b-e
	5%	5.00	ab	5.00	b	192.00	de	197.00	b-f	1.45	c-e	1.38	b-d
	10%	5.67	a	6.00	a	213.67	a-c	219.00	ab	1.53	a-c	1.47	a-c
	15%	5.67	a	5.67	ab	226.67	a	198.67	b-e	1.66	a	1.52	ab
NPK 100%	0%	5.00	ab	5.67	ab	217.67	ab	200.33	b-d	1.50	b-d	1.45	a-c
	5%	5.33	a	5.00	b	204.00	b-d	204.00	a-d	1.53	a-c	1.64	a
	10%	5.00	ab	5.67	ab	222.67	ab	217.33	ab	1.53	a-c	1.63	a
	15%	5.67	a	5.33	ab	215.33	ab	224.67	a	1.63	ab	1.62	a

* Values followed by similar letter (s), within a comparable group of means, do not significantly differ, using Duncan' s multiple range test, at 0.05 level.

(2015), Helaly (2016) and Abdel-Naby *et.al.*(2018), indicated that the growth characteristics; like plant height, number of branches, number of leaves and foliage fresh weight; of sweet potato plant were enhanced due to the seaweed liquid fertilizers (SLFs) treatments individually as well as along with chemical fertilizers.

3.2. Tuber roots yield and its components.

The results listed in Table (5) describe the mean values of the characteristics; number of tuber roots plant^{-1}, marketable yield fed^{-1} (ton) and total yield fed^{-1} (ton); which affected by NPK fertilizer levels and seaweed extract concentrations (SWC) . Generally, increased by raising the NPK level from 25% up to 100%, during the two study seasons. The highest values for the three traits were reflected by 100% NPK level without significant differences with 75% for a number of tuber roots plant^{-1} at both seasons, and for marketable and total yield at the second season. However, with decreasing NPK levels from 100% to 25%, the value of the un-marketable yield fed-1 (ton) was increased (desirable effect). This result is in agreement with both Doss *et.al.,* (2015) and Helaly (2016) when studying the same aforementioned traits on sweet potato plants. This could be explained by the fact that the nutrients contained in mineral fertilizers are available and readily absorbable by crops as demonstrated by the work of Arisha & Bardisi (1999) on potato plants.

Positive responses of sweet potato plants to foliar application of seaweed extract concentrations (SWC) were observed for tuber roots yield and its component characteristics. Among the foliar spray of the seaweed extract treatments, the highest average values were recorded for the number of tuber roots plant-1, marketable tuber roots yield fed-1 (ton) and total tuber roots yield fed-1 (ton) for a level of 15% foliar spray, during the two consecutive seasons. On the other hand, by decreasing foliar spray concentrations of seaweed extract from 15 % to 0 % during the two seasons of cultivation, the percentage of non-marketable yield increased from 8% to 14%. These results reflected similar trends to those reported by Kowalski et.al. (1999); Sarhan (2011); Haider et.al. (2012); Doss et.al., (2015) and Helaly, (2016), reflected the effect of spraying seaweed extracts on

Table 5. Mean of tuber roots yield and its components characters of 'Abies' cv. sweet potato , as affected by NPK levels and seaweed extract concentrations (SWC), during the two summer seasons of 2016 and 2017.

Treatments	Number of tuber plant^{-1}		Unmarketable yield fad^{-1} (ton)		Marketable yield fad^{-1} (ton)		Tuber root Yield fed^{-1} (ton)	
	2016	2017	2016	2017	2016	2017	2016	2017
(NPK %) levels.								
25%	2.58 c*	2.75 c	1.14 a	1.17 a	3.76 d	3.77 c	4.91 d	4.94 c
50%	4.33 b	4.17 b	1.05 ab	1.12 ab	7.20 c	6.89 b	8.23 c	8.01 b
75%	5.33 a	5.00 a	1.03 b	0.86 bc	9.78 b	9.95 a	10.84 b	10.84 a
100%	5.25 a	5.08 a	0.84 c	0.89 c	11.06 a	10.35 a	11.90 a	11.32 a
Seaweed extracts concentrations (SWC).								
0%	4.00 b	4.08 a	1.20 a	1.09 a	6.86 c	6.98 b	8.05 c	8.06 b
5%	4.25 b	4.25 a	1.05 ab	1.07 a	6.94 c	6.71 b	8.00 c	7.81 b
10%	4.42 ab	4.33 a	0.97 ab	0.99 a	8.26 b	8.53 a	9.23 b	9.51 a
15%	4.83 a	4.33 a	0.85 b	0.98 a	9.74 a	8.74 a	10.59 a	9.73 a

* Values followed by similar letter (s), within a comparable group of means, do not significantly differ, using Duncan's multiple range test, at 0.05 level.

increasing the productivity of potato crop. The efficacy of the extracts is probably based upon plant hormones (mainly cytokinins) and trace nutrients present in the extracts and soil (Verkleij 1992).

The results of the interaction effect between the two factors are shown in the table (6). The interaction had a positive and significant effect on mean values of number of tuber roots plant-1, un-marketable tuber roots yield fed-1 (ton), marketable tuber roots yield fed-1 (ton) and total tuber roots yield fed-1 (ton), in both growing seasons.

Table 6. Mean of tuber roots yield and its components characters of 'Abies' cv. sweet potato, as affected by interactions between NPK levels and seaweed extract concentrations (SWC), during the two summer seasons of 2016 and 2017.

Treatments		Number of tuber plant^{-1}		Un-marketable yield fad^{-1} (ton)		Marketable yield fad^{-1} (ton)		Yield fed^{-1} (ton)	
		2016	2017	2016	2017	2016	2017	2016	2017
(NPK %) levels interacted with (SWC).									
	0%	2.33 de	2.33 d	1.44 a	1.20 a-c	1.93 k	2.25 g	3.37 k	3.45 h
NPK	**5%**	3.00 c-e	3.00 cd	1.24 ab	1.20 a-c	3.74 j	3.42 fg	4.98 j	4.62 gh
25 %	**10%**	2.00 e	2.67 d	1.08 b-d	1.12 a-d	4.29 ij	4.56 ef	5.38 j	5.68 fg
	15%	3.00 c-e	3.00 cd	0.81 e	1.16 a-d	5.08 hi	4.86 ef	5.89 ij	6.01 e-g
	0%	3.00 c-e	4.00 bc	1.15 bc	1.35 a	5.84 h	5.45 e	6.99 hi	6.80 ef
NPK	**5%**	4.00 b-d	4.67 ab	1.11 b-d	1.32 ab	6.23 gh	5.95 e	7.34 gh	7.28 de
50 %	**10%**	4.33 a-c	4.00 bc	1.02 c-e	1.00 a-d	7.55 fg	7.68 d	8.57 fg	8.69 cd
	15%	6.00 a	4.00 bc	0.84 e	0.79 d	9.18 de	8.48 cd	10.03 de	9.26 c
	0%	5.33 ab	5.00 ab	1.24 ab	0.79 d	8.26 ef	9.40 bc	9.50 ef	10.18 bc
NPK	**5%**	5.00 ab	4.33 ab	0.91 de	1.06 a-d	8.86 d-f	8.50 cd	9.77 d-f	9.56 c
75 %	**10%**	5.67 ab	5.33 a	0.91 de	0.87 cd	10.06 cd	11.05 a	10.98 cd	11.92 a
	15%	5.33 ab	5.33 a	1.16 bc	0.83 cd	11.95 ab	10.87 ab	13.10 ab	11.70 ab
	0%	5.33 ab	5.00 ab	0.97 c-e	0.96 b-d	11.39 bc	10.84 ab	12.36 ab	11.79 a
NPK	**5%**	5.00 ab	5.00 ab	0.95 c-e	0.78 d	8.93 de	8.98 cd	9.88 de	09.76 c
100 %	**10%**	5.67 ab	5.33 a	0.86 e	0.94 cd	11.14 bc	10.81 ab	12.00 bc	11.75 ab
	15%	5.00 ab	5.00 ab	0.58 f	0.77 d	12.76 a	10.76 ab	13.33 a	11.96 a

* Values followed by similar letter (s), within a comparable group of means, do not significantly differ, using Duncan's multiple range test, at 0.05 level.

The addition of NPK fertilizer at a level of 75 % NPK with 15 % of seaweed extract (SWC) showed a significant increase in the mean values of the four listed traits that did not differ significantly from the highest interaction treatment (100 % NPK with 15 % SWC). The favorable influences of seaweed extracts application on tuber roots yield and its components could be linked to the vital role of seaweed extracts as plant growth stimulants on the increase of the availability of nutrient supply, improving the efficiency of macro-elements as well as its ability to meet some microelements requirements of the crop. Our results are in agreement with Doss *et.al.* (2015), Helaly (2016) and Abdel-Naby *et.al.* (2018), mentioned the possibility of spraying seaweed extracts to reduce the required amounts of NPK as mineral fertilization for sweet potato plants (Abies cv.).

3.3. Tuber roots chemical composition.

With regard to the results listed in the table (7); the effects of NPK fertilizer levels and seaweed extract concentrations, on the performance of sweet potato tuber roots chemical composition, the results showed that the use of different NPK mineral fertilizer levels at the commercially recommended rate showed a significant increase in mean values of total sugars (%), starch (%), carbohydrates (%), carotene (mg100 g-1 fresh weight) and protein (%); over the two seasons. The two levels 100% and 75% of NPK recorded significantly higher mean values for all of the above-mentioned characters among the different levels of NPK fertilizers without significant differences between each other. The results of Abdel-Razzak et al. (2013), Uwah *et.al.* (2013), Doss et.al. (2015), Helaly (2016), Abdel-Naby et.al. (2018), and Sidiky et.al. (2019), generally, revealed similar trends to those obtained in the present study. They observed that the sweet potato plant significantly responds to fertilization, in general; and to N and, K in particular, which were recognized as a vital step in stepping up the tuber roots quality of sweet potato.

With regard to the main impact of seaweed extract concentrations, the findings showed that increasing seaweed extract concentrations led to significant increases in mean values of total sugars (%), starch (%), carbohydrates (%), carotene (mg 100 g^{-1} fresh weight) and protein (%). In the two growth seasons, the foliar spray with a concentration of 15% reflected the greatest significant value for the aforementioned characters. These results could be attributed to the effect of seaweed extract concentrations on increasing the absorption of nutrients and on the photosynthesis process, which led to more accumulation of metabolites in reproductive organs; which, in turn, enhanced the potato tuber quality (Gawish *et.al.* 1994 and Haider 2012). Moreover, the results obtained are consistent with the findings of Doss *et.al.* (2015) and Helaly, (2016) on sweet potato plants.

The differences between the mean values of total sugar, starch, carbohydrate, carotene, and protein content tended to be significantly affected over the two seasons by the interaction effects between the different (NPK) fertilizer levels and the different concentrations of seaweed extract (SWC) described in table (8).

The combinations between the each of two concentrations of the seaweed extract; 10 %, or 15%; with NPK mineral fertilization of 100% or 75%, did not reflect any significant differences for the mean values of the five studied characters, during the two seasons. The results, generally, illustrated that the addition of NPK fertilizer, as 75% of recommended rate, combined with spraying seaweed extract, at 15% resulted in the highest mean values in all the above mentioned treats. These results reflected the general trends of the finding of Doss *et.al.* (2015), Helaly (2016) and Abdel-Naby *et.al.* (2018) of chemical composition characteristics of sweet potato tuber roots.

3.4. Mineral Composition percentage of Tuber Roots:

The results of the main effects of NPK (%) fertilizer rates and seaweed extract concentrations (SWC %) on the mean values of N (%) , P (%) and K (%) contents of sweet potato tuber roots , in the two growing seasons of 2016 and 2017, are showed in Table. (9).

The effect of different levels of chemical fertilizer NPK were significant on macronutrient contents N, P and K of sweet potato tuber roots in both growing seasons. The highest mean values of mineral contents (N, P and K) of leaves were accompanied by the highest rate of NPK fertilizer (100%) comparing with all other rates were used of mineral fertilization. Generally, mineral concentrations (N, P and K) of sweet potato tuber roots were significantly increased with increase the rate of NPK from 0% up to 100%. this could be due to higher availability of the nutrients with increase in the fertilizer application (NPK) which ultimately resulted in better root nutrient and increased physiological activity of roots to absorb the nutrients and thereby, nutrient, uptake was found closely linked

Table 7. Mean of tuber roots chemical constituents of 'Abies' cv. sweet potato, as affected by NPK levels and seaweed extract concentrations (SWC), during the two summer seasons of 2016 and 2017.

Treatments	Total sugar (%)				Starch (%)				Carbohydrates (%)				Carotene (mg 100 g^{-1} fresh weight)				Protein (%)			
	2016		2017		2016		2017		2016		2017		2016		2017		2016		2017	
(NPK %) levels.																				
25%	7.44	b*	6.85	c	11.04	c	11.25	c	18.47	c	18.10	c	4.76	a	4.83	a	8.31	d	8.52	c
50%	7.21	b	8.36	a	13.52	b	0.59	b	20.73	b	19.89	b	4.74	a	4.95	a	11.43	c	12.20	b
75%	7.89	a	7.29	b	15.95	a	15.78	a	23.83	a	24.14	a	4.99	a	4.99	a	13.73	b	14.70	a
100%	8.15	a	8.29	a	15.72	a	15.57	a	23.87	a	23.86	a	5.16	a	4.74	a	15.25	a	15.82	a
Seaweed extracts concentrations (SWC).																				
0%	6.86	d	7.18	b	12.56	c	12.57	c	19.42	d	19.76	c	4.35	b	4.54	b	10.91	b	11.74	c
5%	7.49	c	7.71	a	13.46	b	13.53	b	20.96	c	21.24	b	4.79	ab	4.80	b	10.89	b	12.46	bc
10%	7.84	b	7.89	a	14.74	a	14.44	a	22.58	b	22.33	a	5.23	a	4.70	b	12.87	a	13.19	ab
15%	8.50	a	8.01	a	15.45	a	14.66	a	23.95	a	22.67	a	5.27	a	5.48	a	14.07	a	13.84	a

* Values followed by similar letter (s), within a comparable group of means, do not significantly differ, using Duncan' s multiple range test at 0.05 lev

Table 8. Mean of tuber roots chemical constituents of 'Abies' cv. sweet potato, as affected by interactions between NPK levels and seaweed extract concentrations (SWC), during the two summer seasons of 2016 and 2017.

Treatments		Total sugar (%)		Starch (%)		Carbohydrates (%)		Carotene (mg 100 g^{-1} fresh weight)		Protein (%)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
(NPK%) levels interacted with (SWC).											
NPK 25 %	**0%**	86.05 g	6.43 f	10.09 h	10.46 i	16.14 f	16.88 g	3.59 e	4.74 b-f	6.40 i	6.67 i`
	5%	7.36 de	7.26 d-f	9.97 h	10.61 hi	17.33 f	17.88 fg	4.56 c-e	5.01 a-d	7.42 hi	8.46 jk
	10%	7.89 b-d	6.87 ef	11.92 g	11.59 gh	19.81 de	18.45 fg	5.19 a-d	3.88 ef	9.31 g-i	8.81 i-k
	15%	8.45 ab	6.84 ef	12.17 fg	12.34 fg	20.62 d	19.17 ef	5.68 ab	5.70 ab	10.13 e-h	10.15 h-j
NPK 50 %	**0%**	6.79 e-g	6.80 ef	11.86 g	10.66 hi	18.65 e	17.46 g	4.73 b-d	4.29 d-f	9.58 f-h	10.81 g-i
	5%	7.09 ef	7.05 d-f	13.24 ef	12.44 fg	20.33 d	19.49 ef	4.78 b-d	4.82 a-e	10.27 d-h	12.06 f-h
	10%	6.85 ef	7.42 c-e	13.90 e	13.06 f	20.75 d	20.49 de	5.17 a-d	5.28 a-c	12.35 c-f	12.73 e-g
	15%	8.10 b-d	7.90 b-d	15.07 cd	14.21 e	23.18 c	22.12 cd	4.27 de	5.58 ab	13.52 a-c	13.19 d-f
NPK 75 %	**0%**	6.41 fg	7.32 c-e	14.16 de	14.85 c-e	20.57 d	22.16 c	4.78 b-d	3.84 f	11.50 c-g	12.13 f-h
	5%	7.39 c-e	8.59 ab	15.50 bc	15.66 bc	22.89 c	24.25 ab	4.82 b-d	4.80 b-f	12.75 b-e	14.13 c-f
	10%	8.54 ab	8.61 ab	16.66 a	16.93 a	25.20 b	25.54 a	5.14 a-d	5.35 a-c	14.27 a-c	16.46 ab
	15%	9.20 a	8.91 a	17.46 a	15.69 bc	26.67 a	24.60 ab	5.22 a-d	5.80 a	16.42 a	16.10 a-c
NPK 100 %	**0%**	8.18 b	8.19 a-c	14.12 de	14.33 de	22.30 c	22.51 c	4.31 de	5.29 a-c	16.15 a	17.35 a
	5%	8.13 bc	7.93 b-d	15.15 cd	15.41 b-d	23.28 c	23.34 bc	5.00 a-d	4.56 c-f	13.10 b-d	15.21 a-d
	10%	8.08 b-d	8.65 ab	16.50 ab	16.17 ab	24.58 b	24.83 ab	5.41 a-c	4.28 d-f	15.54 ab	14.77 b-e
	15%	8.23 b	8.40 ab	17.10 a	16.38 ab	25.33 b	24.78 ab	5.91 a	4.83 a-e	16.21 a	15.94 a-c

* Values followed by similar letter (s), within a comparable group of means, do not significantly differ, using Duncan' s multiple range test at 0.05 lev

Table 9. Mean of tuber roots chemical constituents of 'Abies' cv. sweet potato, as affected by NPK levels and seaweed extract concentrations (SWC), during the two summer seasons of 2016 and 2017.

Treatments	N (%) of tuber roots		P (%) of tuber roots		K (%) of tuber roots	
	2016	2017	2016	2017	2016	2017
(NPK %) levels.						
25%	1.33 d*	1.36 c	0.31 b	0.32 c	1.61 d	1.51 c
50%	1.83 c	1.95 b	0.39 a	0.39 bc	1.83 c	1.90 b
75%	2.20 b	2.35 a	0.42 a	0.44 ab	2.27 b	2.43 a
100%	2.44 a	2.53 a	0.45 a	0.48 a	2.56 a	2.47 a
Seaweed extracts concentrations (SWC).						
0%	1.75 b	1.88 c	0.35 a	0.37 b	1.86 c	1.90 b
5%	1.74 b	1.99 bc	0.39 a	0.40 ab	2.03 b	1.94 b
10%	2.06 a	2.11 ab	0.39 a	0.42 ab	2.10 b	2.14 ab
15%	2.25 a	2.22 a	0.43 a	0.45 a	2.29 a	2.33 a

* Values followed by similar letter (s), within a comparable group of means, do not significantly differ, using Duncan's multiple range test at 0.05 level.

with productivity Marschner (1995). Similar results were reported by Arisha & Bradisi, (1999) on potato plant and Helaly (2016) on sweet potato tuber roots.

Concerning the effect of spraying with different concentrations of seaweed extract of macronutrient N, P and K contents of sweet potato tuber roots in both growth seasons, the results showed that foliar spray with concentrate 15 % SWC scored the highest mean value of the percentage of nitrogen, phosphorus and potassium in tuber roots, during the two seasons, without a significant difference with a concentrate of 10%. Also, the impact of the foliar spray on the potassium content of tuber roots ; in significant differences was observed among all concentrations during the first season. This trend is similar to that of Helaly, (2016) when they found that seaweed extracts significantly increased N ,P and K% content compared with control treatment of sweet potato plants. The obtained increase of these elements could be attributed to mineral elements constituents of seaweed extracts as reported in Table (2).

The results concerning the interaction between the two studied factors are presented in Table (10). The interaction had positive significant effect on mean values of mineral contents (N, P and K) of sweet potato roots , in both growing seasons. However, the addition of NPK fertilizer at the rates of 75% NPK interacted with 15% of seaweed extracts led to marked increases in mean values of the mineral contents (N and P) of tuber roots during the two seasons. While the interacted treatment of 100% NPK with 15% SWC gave the highest significant value for the percentage of potassium in the roots without significant difference between the interventions treatment of 75% NPK with 15% SWC, during the two study seasons. Helaly, (2016), reported similar results on sweet potato plant tuber roots.

4. CONCLUSIONS

From the mentioned results, it could be concluded that the growth, yield and its components of sweet potato were significantly enhanced in response to the application of NPK fertilizer, as 75% of the commercially recommended rate, in combination with spraying seaweed extract, at the concentration of 15%. Accordingly, the negative impact of using NPK mineral fertilizer could be reduced by 25%, as a result of using a seaweed extract natural alternatives to replace one-fourth of the mineral fertilization amount, without any prejudice to the value of the quantity and quality of sweet potato crop. In addition to the possibility of exploiting marine wastes represented of green seaweed (Ulva lactuca) in the manufacture of organic fertilizers of high economic and marketing value, contributing to raising the production efficiency of all horticultural crops.

Table 10. Mean of tuber roots chemical constituents of 'Abies' cv. sweet potato, as affected by interactions between NPK levels and seaweed extract concentrations (SWC), during the two summer seasons of 2016 and 2017.

Treatments		N (%) of tuber roots				P (%) of tuber roots				K (%) of tuber roots			
		2016		2017		2016		2017		2016		2017	
(NPK %) levels interacted with (SWC).													
NPK 25 %	**0%**	1.02	i	1.07	k	0.29	c	0.31	cd	1.54	g	1.44	h
	5%	1.19	hi	1.35	jk	0.33	bc	0.32	cd	1.53	g	1.36	h
	10%	1.49	g-i	1.41	i-k	0.29	c	0.33	b-d	1.70	e-g	1.67	f-h
	15%	1.62	e-h	1.62	h-j	0.32	bc	0.34	b-d	1.68	e-g	1.58	gh
NPK 50 %	**0%**	1.53	f-h	1.73	g-i	0.33	bc	0.30	d	1.63	fg	1.59	gh
	5%	1.64	d-h	1.93	f-h	0.38	a-c	0.39	a-d	1.75	d-g	1.81	e-h
	10%	1.98	c-f	2.04	f-h	0.41	a-c	0.41	a-d	1.97	c-f	1.96	d-g
	15%	2.16	a-c	2.11	e-g	0.45	ab	0.46	a-c	1.98	c-f	2.23	b-e
NPK 75 %	**0%**	1.84	c-g	1.94	d-f	0.37	a-c	0.33	b-d	2.10	c-e	2.38	a-d
	5%	2.04	b-e	2.26	c-f	0.41	a-c	0.42	a-d	2.26	bc	2.12	c-f
	10%	2.28	a-c	2.63	b-e	0.43	a-c	0.51	a	2.14	cd	2.53	a-c
	15%	2.63	a	2.58	a-d	0.45	ab	0.52	a	2.57	ab	2.67	ab
NPK 100 %	**0%**	2.58	a	2.78	a-c	0.43	a-c	0.52	a	2.17	b-d	2.17	c-e
	5%	2.10	bcd	2.43	a-c	0.45	ab	0.50	a	2.57	ab	2.48	a-c
	10%	2.49	ab	2.36	ab	0.43	a-c	0.44	a-d	2.57	ab	2.41	a-d
	15%	2.59	a	2.55	a	0.48	a	0.48	ab	2.91	a	2.82	a

*Values followed by similar letter (s), within a comparable group of means, do not significantly differ, using Duncan' s multiple range test at 0.05 level.

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الملخـص العربــى

مستخلص الأعشاب البحرية الخضراء : سماد حيوي تكميلي ومحفز حيوي لنمو وإنتاج نباتات البطاطا .

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أجريت تجربتين حقليتين على نباتات البطاطا ، خلال موسمى صيف عام ٢٠١٦ و ٢٠١٧ بمحطة البحوث الزراعية بمنطقة أبيس ، والتابعة لكلية الزراعة – جامعة الإسكندرية . وقد هدفت الدراسة إلى تقييم مدي استجابة نباتات البطاطا (صنف أبيس) للرش بتركيزات مختلفة من مستخلص الاعشاب البحرية لطحلب خس البحر بمعدلات مختلفة (٥ % , ١٠% و ١٥%) ، بالإضافة إلى معاملة المقارنة (صفر % الرش بالماء المقطر) و ذلك مع مستويات مختلفة من السماد المعدنى (ن – فو – بو) ، وذلك بإستخدام نسب مختلفة (٢٥% , ٥٠% و ٧٥%) من المعدل الموصى به فى الإنتاج التجارى للمحصول ، بالإضافة إلى معدل التسميد الموصى به على المستوى التجارى كمعاملة كنترول (١٠٠% من ن – فو – بو) ، وكذلك تقييم تأثير التداخل بينهم على صفات النمو الخضرى ، المحصول ومكوناته و كذا بعض الصفات الكيميائية لجذور البطاطا المتدرنه.

وقد اظهرت النتائج بصورة عامة أن الزيادات التدريجية لمستويات السماد المعدنى (ن – فو– بو) قد أدت إلى زيادات معنوية على نمو نباتات البطاطا وكذلك على المحصول ومكوناته. كما أظهرت النتائج أن رش نباتات البطاطا بمستخلص الأعشاب البحرية لطحلب خس البحر بتركيز ١٥% قد أدى إلى زيادة معنوية إيجابية على جميع الصفات موضع الدراسة خلال موسمى النمو . وعموما، فإن التوافق بين تأثيرات المستويات المختلفة من العاملين المدروسين قد أظهرت أن المعاملة العاملية التى أعطت أفضل نمو خضرى للنباتات وأعلى محصول كلى من الجذور الدرنية – و كذلك مكونات المحصول – و أعلى قيم لمحتويات الجذور من التراكيب الكيماوية المدروسة ، أتضح أنها المعاملة العاملية التى تشمل إضافة الأسمدة المعدنية (ن – فو – بو) بمعدل ٧٥% من الكميات الموصى بها فى الإنتاج التجارى للمحصول ، وذلك مع الرش الورقى للنباتات بمستخلص الأعشاب البحرية بتركيز ١٥ % .

ومن ذلك يتضح أن الرش الورقى بمستخلص الأعشاب البحرية لطحلب خس البحر بتركيز ١٥ % ، يؤدى إلى تقليل إستخدام التسميد المعدنى (ن – فو – بو) بمعدل ٢٥ % عن الكميات التى تستخدم فى الإنتاج التجارى مع المحافظة على النمو الخضرى الجيد ، وكذلك الإنتاج للجذور الدرنية ، كما ونوعا..