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Enhancing the productivity of potato crop by using sea weeds extract

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ABSTRACT

Two field experiments were carried out during the two successive growth seasons of 2012/2013 and 2013/2014 in a sandy soil at Sadat City, Taba Farm, EL-Menofyia Governorate to study the effect of seaweed rates on potato productivity. These experiment included three levels of seaweed extract (0, 2.5 and 5 cm^3/L). The obtained results indicated that the vigorous potato plants, i.e. plant height, number of leaves and shoots as well as fresh and dry weight of whole plant and its leaves and shoots were recorded with plants which were sprayed by seaweed extract at 5.0 cm^3/ L. The highest values of chlorophyll a, chlorophyll b, chlorophylls a + b as well as carotenoids were detected when potato plants were sprayed as foliar by seaweed extract at the highest rate, i.e. 5.0 cm^3/L. The highest percent of small tubers were recorded without foliar spraying by seaweed, but when the highest rates of seaweed (5 cm^3/L.) was sprayed the highest percentage of medium tuber was noticed in both seasons. The large tuber percentages were found with plants that were treated with seaweed at rate of 2.5 cm^3/L. In general, the foliar spraying of seaweed caused an enhancement in all physical properties of potato tubers (diameter, length, volume and specific gravity) if compared with that plants sprayed with tap-water (0 seaweed). With increasing the seaweed rate up to 5.0 cm^3/L., resulted more improvement in physical properties were observed. The best values were estimated with that plants which were treated by seaweed extract as foliar spraying at 5.0 cm^3/L., rate. The lowest nutritional values were detected with that tuber which its plants were sprayed by tap-water (checked plants).

Key words: Potato, seaweed, physical properties and yield

Introduction

Potato (*Solanum tuberosum* L.) is recognized as one of the most important vegetable crops for local consumption and exportation and it is known as the fourth most important world crop, after rice, wheat, and maize. Potato is a major source of inexpensive energy; it contains high levels of carbohydrates, the predominant form of this carbohydrate is starch and amounts of vitamins B, C and minerals as well as an assortment of phytochemicals, such as carotenoids and natural phenols. (Muthoni and Nyamongo, 2009). In Egypt, Potato occupies about 405.840 thousand feddans produced about 4.8 million tons with an average of 11.8 tons/fed., according to FAOSTAT (2013). As Globally, Egypt is ranked as number twelfth among potato producers.

Seaweed extracts contain various micro elements (Cu, Zn, Mo, B, Co) in addition to macro elements and contain auxins, gibberellins, and cytokinins, when seaweed was sprayed on plants it led to significant increase in root growth ability and stem thickness and growth (Jensen, 2004 ; Thirumaran *et al*., 2009). Numerous studies have revealed a wide range of beneficial effects of seaweed extract applications on plants, such as early seed germination and establishment, improved crop performance and yield, elevated resistance to biotic and abiotic stress, and enhanced postharvest shelf-life of perishable products (Norrie and Keathley, 2006; Khan *et al*., 2009).

Therefore, the present investigation is, undertaken to find out maximizing the beneficial using of seaweed on the productivity of potato plants.

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Materials and Methods

Two field experiments were carried out in sandy soil at Sadaat city, Taba farm, EL-Menofyia Governorate during the two successive growth seasons of 2012/2013 and 2013/2014. The physical and chemical characteristics of experimental soils are presented in Table (1).These experiments were conducted to investigate the effect of 3 levels as foliar application of seaweed extract (0, 2.5 and 5 cm^3/L). Certified of seed potato tubers of cultivar diamante (locally produced and cold stored), obtained from General Authority for Producers and Exporters of Horticulture Crops, Cairo, Egypt, were used in two seasons. The tubers were planted on the 1st week of October month during the two seasons on one side of ridge at distance of 25 cm between tubers and 75 cm within rows. Seaweed extract (Kalpak) is a natural liquid extract of seaweed, and it is a global commercial product of seaweed. All rates of seaweed extract were sprayed 3 times, starting 40 days after planting with 10 – day intervals. The properties of seaweed extracts are shown in Table (2).

Table 1: Physical properties and chemical analysis of the experimental soil.

Properties	Values
Physical	
Sand %	90
Silt %	5
Clay %	5
Texture Sandy	sandy
Available nutrient	
N %	Traces
P %	0.443
K %	0.575
Chemical properties (meq/L)	
pH	8.20
EC ds/m	1.50
$CaCO_3$ %	5.50
Ca^{++}	2.65
Mg^{++}	2.40
Na^{+}	4.34
CO_3^{-}	Zero
HCO_3^{-}	3.85
Cl^{-}	53.00
SO_4^{-}	55.65

Table 2: The chemical composition of seaweed compound*

Nutritional elements %		Plant hormones		Amino acids	
		hormones	Value		
N	1	Auxin	11 mg/L	Alganic acids	10-12%
K	18.5	Cytocinin	0.03 mg/L	Glycine	20 %
Ca	0.17	Other hormones	600 ppm	Aspartic	
Mg	0.42			Glutamic	
Fe	0.06			Alanine	
S	2.2				

* *(Crouch and van Staden, 1993)*

Experimental design:

A complete randomized design with four replicates was used during the two seasons. The normal cultural practices were used for the potato production, i.e. fertilization irrigation, weed control as well as diseases and pest control were followed according to the recommendation of the Egyptian Ministry of Agriculture.

Recorded data:

A: Vegetative growth.

A random samples of 3 plants was taken at 70, 80 and 90 days after planting for the determination of the following characters:

- Plant height (cm), number of leaves / plant, number of shoots / plant, fresh and dry weight of whole plant and its leaves and shoots.
- Leaf area (m^2/plant), net assimilation rate (g/m^2/day), relative growth rate (mg/g/day) and leaf area index were measured according the method described by Gardner *et al.* (1985).

B- Tubers yield and its categories:

1- Tubers yield:

Weight of tubers g/plant, Number of tubers / plant, Average weight of tubers g/ tuber, Average weight of tubers tons/fed., Marketable tubers yield (yield of good shapes and healthy) and Unmarketable tubers yield (off shape, blemished, green and diseased). The total tubers yield of each experimental plot divided into three categories i. e. large (weight more than 200 g/tuber), small (weight less than 100 g/tuber) and medium (weight within 100-200 g/tuber) and the percentages of each category was calculated.

2- Physical properties of tubers yield:

Samples of tubers yield were taken randomized for determination of physical properties as following: diameter of tuber as cm. - length of tuber as cm. - volume of tuber as cm3/tuber- and specific gravity as g/cm^3. Where the average specific gravity of the tuber was determined by dividing the tuber weight by its volume.

C- Nutritional values:

Dry matter percentage, Total carbohydrates (it was determined according to Dobbis *et al*. (1956), Starch content (it was determined using the method of Somogi (1952), Total sugars (it determined according to the method described by Dobbis *et al*. (1956). Total nitrogen was determined according to the procedures described by Cottenie *et al*. (1982). Phosphorus content was determined according to the procedures described by Cottenie *et al.* (1982). Potassium and Calcium content was measured as described by), Chapman and Pratt 1982) Fe, Zn, Mn and Cu (were determined as described by Chapman and Pratt (1982) and Sulphur was determined using the modified colorimetric method using spectrophotometer (SPECTRONIC 200, Milton Roy Co., Ltd, USA).

Statistical analysis:

Obtained data were subjected to the analysis of variance procedure and means were compared to the L.S.D. test according to Gomez and Gomez (1984) and the least significant differences (L.S.D) test at 5% level was used to verify differences between treatments.

Results and Discussion

A- Effect of seaweed extract rates on Plant growth characteristics:

1- Height of plant, leaves and shoots number as well as fresh and dry weight of plant

The presented data in table (3) showed the foliar application of seaweed with potato plant gained superiority in plant height, number of leaves and shoots per plant at different stages, i.e. 70, 80 and 90 days after planting date. Whereas, the highest plants which carried the biggest leaf and shoot number were recorded with that plants which sprayed with seaweed extract at rate of 5 cm^3. /L. The

Table 3: Effect of seaweed extract rates on some vegetative growth characters at different growth stages of potato plant during 2012/2013 and 2013/2014 seasons.

Characters	0			2.5 cm^3/L			5 cm^3/L			L.S.D. at 5 % level		
	Days after planting											
	70	80	90	70	80	90	70	80	90	70	80	90
	First season											
Plant height (cm)	71.11	72.00	72.72	75.44	76.89	77.50	78.78	79.78	80.78	2.55	2.63	2.87
Number of leaves / plant	65.89	66.22	66.56	75.44	76.89	77.50	76.22	76.67	77.33	3.58	3.66	3.40
Number of shoots / plant	5.11	5.11	5.67	6.00	6.11	6.44	6.78	7.00	7.33	0.83	0.75	0.82
Fresh wt. of leaves g/plant	335.90	344.33	358.83	399.61	407.36	415.54	433.36	440.03	462.22	37.17	40.20	41.34
Fresh wt. of shoots g/plant	191.71	197.55	203.28	229.94	236.80	246.31	245.37	252.26	263.64	15.52	18.69	21.19
Total fresh weight	527.61	541.88	562.11	629.54	644.16	661.85	678.73	692.29	725.86	14.71	17.51	21.17
Dry wt. of leaves g/plant	46.08	50.53	54.19	54.75	59.64	63.42	57.24	61.90	65.90	2.91	6.01	5.30
Dry wt. of shoots g/plant	19.75	20.97	22.75	23.34	25.00	26.89	24.47	25.80	27.58	0.76	0.64	1.47
Total dry weight g/plant	65.83	71.49	76.94	78.09	84.64	90.31	81.71	87.71	93.48	3.26	4.00	3.91
	Second season											
Plant height (cm)	69.78	71.33	73.22	73.44	75.33	78.11	76.67	77.94	80.33	1.14	1.75	1.98
Number of leaves / plant	63.56	65.56	67.56	69.00	72.00	74.56	74.00	77.22	79.89	3.42	2.70	2.31
Number of shoots / plant	5.22	5.22	5.22	6.00	6.11	6.44	6.89	7.11	7.33	0.77	0.66	0.69
Fresh wt. of leaves g/plant	356.84	362.28	368.62	409.79	415.94	423.38	434.87	441.54	449.77	21.46	17.00	39.55
Fresh wt. of shoots g/plant	197.03	200.37	203.26	218.38	222.60	225.71	235.25	239.58	242.69	5.45	5.54	8.55
Total fresh weight	553.87	562.65	571.87	235.25	239.58	242.69	670.12	681.12	692.47	54.17	55.15	55.98
Dry wt. of leaves g/plant	41.16	45.22	53.09	47.86	52.68	60.80	52.75	56.53	66.91	1.02	5.56	2.32
Dry wt. of shoots g/plant	17.89	20.19	28.35	21.50	24.49	34.79	23.52	27.62	41.50	0.76	2.17	2.86
Total dry weight g/plant	59.05	65.42	81.43	69.36	77.17	95.59	76.27	84.15	108.41	1.62	N.S.	4.99

differences within the various treatments were significant for the 3 stages of plant growth during the two seasons. The data of El-Aidy *et al.* (2002) on pepper, Shehata *et al*. (2011) on celeriac plants is in good accordance with that obtained herein.

The application of seaweed extract had an enhancement in fresh weight of whole potato plant and its leaves and shoots if compared with control treatment. Increasing the rate of seaweed up to 5 cm^3. /L., resulted in the heaviest significant fresh weight, but the poorest vigor of plant was recorded with plants that was not supplied by seaweed. This increment amount by 21.2, 19.5 and 21.0 respectively for the average fresh weight of leaves, shoots and total plant in 1st season, but amounted by 28.5, 28.4 and 28.51% for the same character respectively in the second season. Generally, it could be summarized that, the application of seaweed extract for potato plant was beneficial, where it caused more plant growth than no treatment. The results obtained herein confirmed those obtained by others regarding the response of fresh weight of potato plant to the spraying of seaweed (Gajewski *et al*., 2008 on Chinese cabbage; Shehata *et al*., (2011) on celeriac plants; Ghurbat, (2013) on pepper plant).

Regarding the effect of foliar spraying by seaweed extract data in Table (3) reveals that there were significant enhancement in plant growth measures (dry weight of whole plant and its leaves and shoots) during the two seasons. Moreover, the recorded data reveals that no significant differences at 5% level were found between spraying by the two applied rates of seaweed, i.e., 2.5 with 5.0 cm3. /L. Shortly it could be concluded that the useful rate of seaweed extract for spraying potato plant was within 2.5-5.0 cm3/fed. These tendencies of results are very much similar with El-Aidy *et al*. (2002) on pepper plant, Shehata *et al*. (2011) on celeriac plants and Shalaby and El-Ramady (2014) on garlic.

2- Leaf area, leaf area index, relative growth rate and net assimilation rate:

Foliar spraying of seaweed extracts at rates of 2.5 and 5.0 cm^3/L. significantly increased the leaf area and leaf area index of potato plant at various growth stages in both seasons compared the untreated control as showed in Table (4). On the contrary, the relative growth rate and net assimilation rate values had no significant response to the seaweed treatments. Moreover, with increasing the level of seaweed to 5.0 cm^3/L., the vigorous plant growth expressed as leaf area, LAI, RGR and NAR was gained.

Table 4: Effect of seaweed extract rates on leaf area, leaf area index, relative growth rate and net assimilation rate at different growth stages of potato plant during 2012/2013 and 2013/2014 seasons.

Seaweed rates	Leaf area (m^2 / plant)			Relative growth rate mg /g / day)		Net assimilation rate (mg /m2/ day)	
	Days after planting			Days after planting			
	70	80	90	70-80	80-90	70-80	80-90
First season							
0	1.43	1.61	1.81	4.61	6.58	0.19	0.28
2.5 cm^3/L	1.55	1.72	1.89	4.76	6.85	0.21	0.32
5cm^3/L	1.64	1.86	2.11	4.74	7.18	0.21	0.34
L.S.D. at 5 %	0.20	0.12	0.13	N.S.	N.S.	N.S.	0.06
Second season							
0	1.47	1.61	1.81	4.56	6.79	0.18	0.29
2.5 cm^3/L	1.61	1.72	1.89	4.74	6.91	0.21	0.33
5cm^3/L	1.71	1.86	2.11	5.05	7.57	0.23	0.37
L.S.D. at 5 %	0.11	0.12	0.13	N.S.	1.44	N.S.	0.06

The results obtained herein confirmed with these obtained by El-Aidy *et al.* (2002) on pepper and Sasikumar *et al*. (2011) on okra. Regarding, the effect of seaweed extracts (Kalpak) on the plant growth characteristics, the obtained data reveal that application of Kalpak at rate within 2.5 – 5.0 cm^3. /L gave the vigorous potato plant if compared with control treatment. These superiority might be attributed to Kalpak contained high levels of organic matter, microelements, vitamins, amino acids, fatty acids and also rich in growth regulators such as auxins, cytokinin, gibberellins and abscisic acid (Stirk *et al*., 2004; Jensen, 2004; Ordog *et al.,* 2004).

The beneficial effect of seaweed extract application is as a result of many components that may work synergistically at different concentrations, although the mode of action still remains unknown (Khan *et al,* 2009; Zamani *et al*., 2013). The obtained results are in agreement with the previous investigation which pointed out the same direct correlation between foliar spraying of seaweed extract and vegetative plant growth of potato (Sarhan *et al*., 2011 Wasim *et al*., 2012 on potato).

B- Effect of seaweed extract rates on Tubers yield and its components:

1- Tubers yield:

Presented data in Table (5) are shown the response of total tubers yield and its components to seaweed extracts at various rates, the given results showed that, all tuber yield components except un-marketable yield were significantly affected by seaweed extracts. Moreover, with increasing the rate of seaweed extract up to 5.0 cm3/L., more increases in tuber yield and its components were obtained. Whereas, the collected data showed that there was no significant difference within using the two seaweed rates, i.e. 2.5 and 5.0 cm3/L., These results were true in both seasons. It could be summarized that seaweed extracts had a favorable effect on total tuber yield of potatoes when applied as foliar spraying at rate within 2.5 up to 5.0 cm3/L., where the heaviest tuber yield were recorded. The higher total tuber yield and its components obtained from using seaweed extract as foliar spraying at rates within 2.5 to 5.0 cm3/L., may be due to the increase in one or more of the estimated attributes either in leaves or shoots. Also, this superiority may be due to seaweed extracts contained macro-and micro-elements, vitamins, growth regulators and amino acids (Jensen, 2004; Ordog *et al*., 2004). The beneficial effect of seaweed extract application is as a result of many components that may work synergistically at different concentrations, although the mode of action still remains unknown (Khan *et al.* 2009 ; Zamani *et al*., 2013).

The previous studies concerning the yield and its components as affected by the application of seaweed extracts (Kelpak) such as those of Wasim *et al*. (2012), Lola-Luz *et al*. (2014) on potato and Selvaraj *et al.* (2004) on tomato and Eris *et al.* (2008) and Ghurbat (2013) on pepper, all of the above investigators reported that the seaweed extracts increased total yield and its components as well as its quality and their results had good accordance with that obtained herein.

Table 5: Effect of seaweed extract rates on tubers yield parameters of potato plant during 2012/2013 and 2013/2014 seasons.

Seaweed rates	Tubers/ plant		Average tuber Wt. (g)	Average tuber Wt. (ton/fed.)	Tuber yield ton/fed.	
	Wt. (g)	No.			Marketable	Un marketable
First season						
0	668.59	6.78	92.86	9.27	7.807	1.48
2.5 cm3/L	826.11	7.22	115.88	13.86	12.679	1.35
5cm3/L	916.84	7.56	121.68	15.46	14.154	1.12
L.S.D. at 5 %	94.94	0.59	5.37	1.52	1.503	0.26
Second season						
0	712.18	7.00	98.13	9.78	8.325	1.12
2.5 cm3/L	858.14	7.67	117.73	15.38	14.487	1.17
5cm3/L	960.22	8.03	114.86	15.33	14.292	1.10
L.S.D. at 5 %	53.95	0.58	4.89	0.86	0.56	N.S.

2- Physical properties:

The effect of foliar spraying by seaweed the data represented in Table (6) showed that diameter, length, size and specific gravity were significantly responded to spraying with seaweed extract during the two experimental seasons. In general the foliar spraying of seaweed caused an enhancement in all physical properties if compared with plants sprayed with tap-water (0 seaweed). Moreover, with increasing the seaweed rate up to 5.0 cm3/L., resulted in more improvement in physical properties.

The results obtained herein, are confirmed that obtained by others regarding the effect of seaweed extracts on physical quality of yield (Crouch and Van Staden, 1993; Sarhan *et al.,* 2011; Sasikumar *et al.,* 2011; Wasim *et al*., 2012 ; Ghurbat, 2013).

Concerning the foliar by seaweed extracts the results of Table (6) showed clearly, that the grades of tuber yield were significantly affected by the various seaweed extract rates. These results were true for different tubers grades in both seasons except the small size in 1st season. Generally, the highest small size percentage of tuber were recorded with no foliar spraying by seaweed, but with using the highest rates of seaweed (5 cm^3/L.) the highest percentage of medium tuber were estimated in both experiments. The large tuber percentage were found with that plants treated with seaweed at rate of 2.5 cm^3/L. In most cases, there were no significant variation within using 2.5 and 5 cm^3/L. is means, that using seaweed at rate within 2.5 - 5.0 cm^3/L., was the most effect on size of tubers yield. The obtained results are in accordance with those of Kowalski *et al*. (1999), Sarhan (2011) and Wasim *et al*. (2012) on potato.

Table 6: Effect of seaweed extract rates on physical tubers quality of potato plant during 2012/2013 and 2013/2014 seasons.

Seaweed rates	Physical tubers quality				The percentages of various grades of tuber		
	diameter (cm)	length (cm)	Volume (cm3 / tuber)	Specific Gravity (g / cm3)	Small g. 100 <	Medium 100 -200 g.	Large g. 200>
First season							
0	6.33	7.70	196.67	0.93	61.38	38.62	0.00
2.5 cm3/L	7.33	8.94	211.67	0.99	36.11	48.02	15.87
5cm3/L	8.00	9.81	224.89	1.02	32.67	49.18	18.14
L.S.D. at 5 %	0.37	0.46	0.21	0.06	3.90	7.38	3.92
Second season							
0	5.94	7.59	203.33	0.56	57.94	42.06	0.00
2.5 cm3/L	6.94	8.72	215.00	0.71	30.27	54.87	14.86
5cm3/L	7.61	9.56	220.00	0.78	28.40	53.09	18.52
L.S.D. at 5 %	0.49	0.20	8.74	0.01	3.04	4.01	2.50

C- Effect of seaweed extract rates on nutrition values of potato tubers:

The response of the chemical values of potato tubers to the foliar spray by seaweed extracts at various rates, i.e., 0, 2.5 and 5.0 cm3/L., are presented in Table (7) for the two seasons. All chemical values of potato tubers, i.e., percentage of dry matter, starch, carbohydrates, sugars, N, P, K, Ca, S, Fe, Mn, Zn and Cu were statistically significant affected by the foliar spraying of seaweed extracts. Plants which treated with seaweed extracts had higher chemical values compared with that no treated plants. Moreover, with increasing the seaweed extract rate the plants gained more increase of nutritional values.

Table 7: Effect of seaweed extract rates on nutritional values content of potato tubers during 2012/2013 and 2013/2014 seasons.

Seaweed rates	%									ppm			
	Dry matter	Starch	Carbohy-drate	Total sugars	N	P	K	Ca	S	Fe	Mn	Zn	Cu
First season													
0	15.63	54.10	55.22	0.605	1.60	1.0	3.53	1.03	0.23	233.11	28.56	30.72	24.12
2.5 cm3/L	16.42	58.77	61.06	0.659	1.74	1.35	4.66	1.37	0.27	279.78	31.76	32.12	30.33
5cm3/L	16.89	61.89	62.83	0.702	1.87	1.43	4.99	1.49	0.30	333.89	33.17	33.72	32.11
L.S.D. at 5 %	0.44	5.76	0.91	N.S.	0.10	0.04	0.46	0.08	0.02	36.65	4.24	0.74	6.09
Second season													
0	15.89	52.88	55.44	0.615	1.61	1.22	3.27	1.09	0.23	224.22	27.30	31.24	19.09
2.5 cm3/L	16.43	57.99	62.35	0.670	1.76	1.35	4.49	1.38	0.26	292.44	32.57	32.96	26.89
5cm3/L	16.87	61.20	64.42	0.694	1.87	1.51	4.81	1.52	0.29	334.67	33.29	33.83	29.67
L.S.D. at 5 %	0.80	5.32	1.13	N.S.	0.09	0.05	0.57	0.05	0.02	30.75	1.73	0.67	4.82

It could be detected that the best nutritional values of potato tubers were estimated with that plants which treated by seaweed extract as foliar spraying at 5.0 cm3/L., rate, followed in decreasing order by that plants received seaweed at the lower rate, i.e., 2.5 cm3/L. The obtained results are in harmony with those detected before by Wasim *et al*, (2012) on potatoes, El-Aidy *et al*. (2002), Eris *et al*. (2008) on pepper ,Shalaby and El-Ramady, (2014) on garlic and Shehata *et al*. (2011) on celeriac. However, Sarhan *et al.* (2011) mentioned that spray of seaweed extracts on potato led to positive significant in mineral contents of N, P and K.

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