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Effect of some active stimulants on plant growth, tubers yield and nutritional values of potato plants grown in newly reclaimed soil.

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ABSTRACT

Two field experiments were carried out during the two successive growing seasons of 2012/2013 and 2013/2014 under newly sandy soil conditions at a private farm (Taba farm), Sadat city, EL-Menofyia Governorate, Egypt to study the effect of some bio-stimulants on growth and productivity of potato plants. The experiment included 4 treatments which were spraying with three bio-stimulant substances, i.e. amino acid (2.5 cm^3/l), Chitosan (5 cm^3/l) and Potassium silicate (2 cm^3/l) in addition to tap water served as a control treatment. The obtained results indicated that the foliar spraying by amino acids mixture or chitosan at rate of 2.5 and 5.0 cm^3/l, respectively, gained the significant vigorous plant growth expressed as plant height, number of leaves/plant, number of shoots/plant, fresh weight and dry weight of potato plant and its leaves and shoots, leaf area, leaf area index, relative growth rate and Net assimilation rate. These were true in all sampling dates, 70, 80 and 90 days after planting date. Also, foliar spraying of potato plant by amino acids mixture or chitosan resulted in the heaviest total and marketable tuber yield as well as the lowest value of un-marketable yield. The contents of starch, total carbohydrates, total sugar, dry matter, N, P, K, Ca, Fe, Mn, Zn and Cu, all of them recorded a superior with potato plants sprayed by the bio-stimulant substances compared with those of control plants.

Keywords: Potato plant, Stimulant substances, Vegetative growth, Relative growth rate, Net assimilation rate, Yield physical properties, Nutritional values.

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INTRODUCTION

Potato (Solanum tuberosum L.) is known as the fourth most important world crop, after rice, wheat and maize with 368 million tons produced from 20 million hectares according to FAOSTAT [1]. It represents a cheap source of carbohydrates in human diets. Whereas, it contains high levels of carbohydrates [2]. It is considered as one of the national income resources. Globally, Egypt is ranked as number twelfth among potato producers. The exported potato from Egypt was remarkably increased in 2015, the total quantity exported were 632 thousand tons compared to the 289 thousand tons in 2012 according to agriculture statistics; the exported Egyptian potato tuber is mainly produced from winter cultivation.

Amino acids and chitosan are considered as precursors and constituents of proteins, which are important for stimulation of cell growth. They contain both acid and basic groups and act as buffers, which help to maintain favorable pH value within the plant cell and stimulation of plant defense against microorganisms to protect plants [3 and 4]. Amino acids can directly or indirectly influence the physiological activities of the plant [5].

Chitosan and chitin are those of the most abundant polysaccharide compounds found in the nature and they were reported to affect on improving the growth of several crops [6]. Chitosan has been used in seed, leaf, fruit and vegetable coating, as fertilizer and in controlled agrochemical release [7].

Nowadays, potassium silicate is considered as an agronomically essential element because of its beneficial effects of Si, including enhancement of growth and quality, photosynthesis stimulation, transpiration reduction and increasing plant resistance to biotic and abiotic stresses, are well-established in several agricultural crops [8]. Also the previous studies reported that, the foliar application of amino acids mixture caused an enhancement in plant growth and yield in a number of vegetable crops, potato [9]; onion [10] and beans [11]. Moreover, other investigators reported that chitosan was mainly used for stimulation of plant defense mechanisms against microorganisms to protect plants [12, 13, 14 and 15].

The aim of current study was to evaluate the response of potato plants to foliar application of some active stimulants (amino acids mixture, chitosan and potassium silicate) and their effect on vegetative growth, tubers yield and nutritional value.

MATERIALS AND METHODS

Two field experiments were carried out in newly sandy soil at Taba farm, Sadat city, EL-Menofyia Governorate, Egypt during the two successive growing seasons of 2012/2013 and 2013/2014. The physical and chemical characteristics of experimental soil are presented in Table (1). These experiments were conducted to investigate the effect of some bio-stimulants (amino acids, chitosan and potassium silicate) on potato growth and productivity. Certified potato seed tubers of cultivar Diamonte (locally produced and cold stored), obtained from General Authority for Producers and Exporters of Horticulture Crops, Cairo, Egypt, were used in this study. The tubers were planted on the first week of October during both seasons on one side of drip irrigated ridge at distance of 25 cm between hills and 75 cm within rows.

This experiment included 4 treatments which were spraying with three bio-stimulant substances, i.e. amino acid mixture (2.5 cm^3/l), chitosan (5 cm^3/l) and potassium silicate (2 cm^3/l) in addition to tap water served as a control treatment. Amino mix (naturally amino acid stimulant, obtained from AGRICO International Co., Egypt), is a mixture of amino acids, vitamins and micronutrients. The chemical consistent of amino mix is shown in Table (2). Chitosan (2-Amino-2-deoxy-beta-D-glucosasmine) solution was prepared by dissolving 5 cm^3/l of chito-Care®, an Egyptian commercial product of chitosan. The chemical composition of chitosan is shown in Table (3). Potassium silicate ($K_2Si_2O_2$) spayed on plants at rate of 2 cm^3/l. Moreover, All three bio-stimulant substances were sprayed for 3 times with 10 days interval starting 40 days after planting date.

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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^{-}	53.0
SO_4^{-}	55.65

Table (2): The chemical composition of amino mix compound.

Nutritional elements		Amino acid				Vitamins	
Zn	2.0	Aspartic acid	249	Methionine	180	Vitamin B_1	0.8
Fe	1.5	Threonine	45	Iso-Leucine	52	Vitamin B_2	2.4
Mn	0.5	Serine	56	Tyrosine	38	Vitamin B_6	1.2
Mg	0.004	Glutamic acid	55	Phenylalanine	22	Vitamin B_{12}	0.82
Cu	0.004	Glycine	50	Histidine	12	Folic acid	4.2
Ca	0.025	Alanine	100	Lysine	40	Pantothenic acid	0.52
Br	0.056	Proline	38	Arginine	20	Nicotine B_5	1.14
S	0.01	Valine	68	Tryptophan	20	Ascorbic	1.0
Co	0.03	Cysteine	44				

Table (3): The chemical composition of chitosan compound.

Nutritional elements	ppm
N	1000
P_2O_5	500
K_2O	500
Fe	100
Zn	100
Cu	50

Experimental design:

A complete randomized block design with four replicates was used during the two seasons. Each experiment each block contained 5 rows with 6 m in length and 0.75 width with a net area of 22.5 m^2. The normal agricultural practices for the potato production, i.e. 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 sample of 5 plants was randomly taken at 70, 80 and 90 days after planting date for determination of the following characters.

1. Plant height (cm).
2. Number of leaves/plant
3. Number of shoots/plant
4. Fresh weight of whole/plant and its leaves and shoots.
5. Dry weight of whole/plant and its leaves and shoots.
6. Leaf area/plant m^2/plant
7. Leaf area index.
8. Net Assimilation rate (g/m^2/day) was determined by using the equation as suggested by **Gardner *et al.*[16]**.
9. Relative growth rate (mg/g/day) was determined according the method described by **Gardner *et al.* [16]**.

B- Photosynthetic pigments: Total chlorophyll and carotenoids of fresh leaves tissue were calorimetrically determined as mg/g fresh weight according the method described by **Rami Moran [17]**.

C- Tubers yield and its components:

- 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).
- Unmarketable tubers yield (off shape, blemished, green and diseased).

D- 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.
- Specific gravity as g/cm3.

E- Chemical composition:

- Dry weight where potato tubers were calculated as described by AOAC [18].
- Total carbohydrates, it was determined according to Dubois et al. [19].
- - Starch content: it was determined in dry tubers tissue using the method of Somogyi [20].
- Total sugars: it determined using according to the method described by Dubois et al. [19].
- Total nitrogen was determined using the modified micro Kjeldah method (Hanon 8910, digital) according to the procedures described by Cottenie et al.[21].
- Phosphorus content was determined according to the procedures described by Cottenie et al. [21].
- Potassium and calcium content was measured using flame photometer method (JENWAY, PFP-7, ELE Instrument Co. Ltd., UK) as described by Chapman and Pratt [22].
- Fe, Zn, Mn and Cu were determined using Atomic-absorption (Analyst 200, Perkin Elmer, Inc., MA, USA), as described by Chapman and Pratt [22].
- 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. The least significant differences (LSD) test at 5% level of probability was used to verify differences between treatments according to **Gomez and Gomez [23]**.

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RESULTS AND DISCUSSIONS

Plant growth characteristics

Plant height and number of leaves and shoots/plant

Results in Table (4) showed the effect of some bio-stimulant substances (potassium silicate, chitosan, amino acids as well as plant control treatment) on height of plant, number of leaves and shoots per plant during the two experimental seasons of 2012/2013 and 2013/2014. As a general obtained results demonstrated that potato plants which treated with stimulated substances i.e. potassium silicate, chitosan and amino acids gained a significant better values of height of plant, as well as number of leaves and shoots compared with control plants.

It could be concluded that, the vigor potato plants which had the highest values of plant height, leaves and shoots number was showed with those plants treated with amino acids, followed in descending order by those treated with chitosan and lastly those treated with potassium silicate. Furthermore, the statistical analysis for the obtained data revealed that no significant differences between amino acids and chitosan treatments. These findings were held well in both experiments of 2012/2013 and 2013/2014.

Fresh weight of whole plant and its leaves and shoots

The effect of some growth stimulant substances on fresh weight of potato plant and its leaves and shoots were shown in Table (5). Data revealed that, it had a great and significant effect during various plant stages (sampling dates 70, 80 and 90 days after planting date) in both seasons. First of all, the foliar spraying of potassium silicate or chitosan or amino acids caused an enhancement in plant growth as expressed by fresh weight of whole plant and its leaves and shoots compared with those plants sprayed by tap water (control). These held good at various plant growth stages of the two experiments. In addition, among the growth stimulant substances, using amino acids as foliar spraying at rate 5 cm^3/l gained the best results, followed in descending order by using chitosan at rate of 5 cm^3/l. and lastly by using potassium silicate at rate of 2 cm^3/l. Moreover, the statistical analysis of the collected data reported that no significant variations were detected within using either amino acids or chitosan. These findings were clearly shown in the first season, but in the second one, there no significant was analyzed only with regard fresh weight of shoots. Generally, it could be stated that, the vigor potato plant was associated with that plants sprayed by amino acids or chitosan.

Dry weight of whole plant and its leaves and shoots

Foliar spraying with some growth stimulant substances i.e. potassium silicate, chitosan and amino acids mixture had a significant effect on dry weight of potato plant and its leaves and shoots (Table 6). These were true at various growth stages during the two experimental seasons. Whereas, the foliar spraying by amino acids mixture gained the highest values of dry weight of whole plant and it leaves and shoots, followed in descending order by those plants which sprayed by chitosan and lastly by those received potassium silicate. It means, that the vigor potato plant was noticed with those plants treated with amino acids, but the lowest values was recorded with those plants which sprayed by tap water (control plants). In addition, the statistical analysis of the obtained data revealed that, the differences within those plants received any of the three growth stimulant substances (in the first season) were no recorded any significant values, but in the second season there no significant value was noticed within using amino acids or chitosan in most cases.

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Table (4): Effect of some bio-stimulant substances on plant height, number of leaves and number of shoots per plant at different growth stages of potato plant during both seasons.

Treatments	Plant height (cm)			Number of leaves/plant			Number of shoots/plant		
First season (2012/2013)									
Bio-stimulant substances	Estimation period (days after planting)								
	70	80	90	70	80	90	70	80	90
Control	69.67	70.33	70.72	69.33	69.89	71.00	5.11	5.33	5.44
Potassium silicate	74.33	74.89	75.17	76.22	76.67	77.89	6.56	6.78	7.11
Chitosan	75.33	76.11	76.72	76.67	77.33	78.56	7.00	7.22	7.44
Amino mix	76.11	76.83	77.28	78.00	78.89	79.78	7.56	7.67	8.00
LSD at 5%	**2.45**	**1.999**	**1.988**	**5.01**	**5.047**	**5.193**	**1.154**	**0.999**	**1.040**
Second season (2013/2014)									
Control	68.89	69.89	71.00	58.78	64.67	66.00	4.89	4.89	4.89
Potassium silicate	72.33	73.11	74.00	64.44	68.00	69.33	5.78	5.78	5.78
Chitosan	74.22	75.33	76.89	68.44	71.89	73.67	6.33	6.44	6.67
Amino mix	75.67	76.67	78.00	71.33	75.11	77.33	6.67	6.89	7.22
LSD at 5%	**1.258**	**1.847**	1.499	**2.040**	**4.059**	**3.510**	**0.957**	**0.999**	**0.999**

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Table (5): Effect of some bio-stimulant substances on plant fresh weight at different growth stages of potato plant during both seasons.

Treatments	Fresh weight g/plant								
	Leaves			Shoots			Total		
First season (2012/2013)									
Bio-stimulant substances	Estimation period (days after planting)								
	70	80	90	70	80	90	70	80	90
Control	343.12	350.34	358.12	177.04	182.82	188.15	520.16	533.16	546.27
Potassium silicate	413.24	420.87	428.98	232.36	238.25	243.28	645.60	659.12	672.25
Chitosan	415.39	425.17	432.62	238.36	246.14	251.58	653.76	671.31	684.20
Amino mix	432.84	441.51	447.96	248.46	255.46	260.68	681.31	696.97	708.64
LSD at 5%	**34.81**	**35.101**	**32.654**	**13.79**	**17.418**	**17.728**	**43.97**	**45.325**	**44.855**
Second season (2013/2014)									
Control	300.66	312.87	321.55	171.77	185.20	191.66	472.43	498.07	513.21
Potassium silicate	351.02	363.03	373.42	213.01	223.35	230.79	564.03	586.37	604.21
Chitosan	389.14	400.68	410.46	236.00	249.17	254.73	625.15	649.85	665.18
Amino mix	410.21	422.04	432.48	241.95	254.90	263.45	652.16	676.94	695.93
LSD at 5%	**17.507**	**19.899**	**19.156**	**8.445**	**19.300**	**19.993**	**18.253**	**22.846**	**23.617**

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Table (6): Effect of some bio-stimulant substances on plant dry weight at different growth stages of potato plant during both seasons.

Treatments	Dry weight g/plant								
	Leaves			Shoots			Total		
First season (2012/2013)									
Bio-stimulant substances	Estimation period (days after planting)								
	70	80	90	70	80	90	70	80	90
Control	42.61	44.83	47.39	18.34	19.45	20.45	60.95	64.29	67.84
Potassium silicate	52.05	54.17	57.05	24.05	25.16	26.46	76.10	79.32	83.52
Chitosan	53.15	55.82	58.93	24.91	26.19	27.50	78.06	82.00	86.42
Amino mix	53.87	57.31	60.87	25.55	26.89	28.20	79.42	84.20	89.06
LSD at 5%	**4.237**	**8.627**	**10.672**	**1.315**	**3.518**	**4.209**	**4.599**	**8.790**	**11.866**
Second season (2013/2014)									
Control	35.23	39.49	44.71	17.91	20.90	24.09	53.14	60.40	68.80
Potassium silicate	39.54	42.68	49.29	20.26	23.51	30.06	59.80	66.19	79.36
Chitosan	44.49	48.88	55.66	22.46	26.58	34.58	66.94	75.46	90.24
Amino mix	47.75	53.60	59.83	23.94	27.05	39.94	71.69	80.66	99.77
LSD at 5%	**1.312**	**3.679**	**5.357**	**0.636**	**2.853**	**4.741**	**1.465**	**5.291**	**5.769**

Leaf area, Leaf area Index, relative growth rate and Net assimilation rate

Data presented in Table (7) showed the response of some plant growth measurements i.e. LA, LAI, RGR and NAR to foliar application by some growth stimulant substances of potato plants at various growth stages during the two experimental seasons. All growth stimulant substances used caused an enhancement in all calculated characters. Within the plant growth stimulant substances used the obtained results indicated that, the highest values of LA, LAI, RGR and NAR were estimated with spraying plants by amino acids mixture at rate of 2.5 cm^3/l (foliar application for 3 times with 10 days interval, starting at 40 days after planting date), followed in descending order by those plants sprayed by chitosan at rate of 5.0 cm/l, then by those plants treated by potassium silicate at rate of 2.0 cm/l. In addition the collected results clearly indicated that the differences within the three growth substances failed to be significant for most studied parameters in both seasons of 2012/2013 and 2013/2014.

Generally, it could be summarized that, spraying potato plants by amino acid mixture or chitosan resulted in the highest values of LA, LAI, RGR and NAR, where the differences between amino acid mixture and chitosan were no great enough to be significant.

Finally, it could be concluded that, the best plant growth characters i.e. plant height, number of leaves and/or shoots fresh and dry weight of whole plants and its leaves or shoots as well as the values of LA, LAI, RGR and NAR, all of these parameters recorded their highest values when potato plants sprayed by amino acids mixture, followed by no significant differences by those plants which sprayed by chitosan in most the above mentioned measurements .

Generally, it could be concluded that, this superiority might be attributed to the content of amino acid mixture which shown in Table (2). Whereas, **[24]** stated that amino acids can directly or indirectly influence the physiological activities in plant growth and development such as exogenous application of amino acids have been reported to modulate the growth, yield and biochemical quality of some vegetable plants. Moreover, **[4]** reported that, amino acids are considered as precursors and constituents of proteins which are important for stimulation of cell growth. They contain both acid and basic groups and act as buffers, which help to maintain favorable pH value within the plant cell. Functionally amino acid are involved in the enzymes responsible for the structural photosynthesis process.

Shortly, it could stated that, the results which written herein are in good accordance with that recorded previously on potato **[9]**; on tomato **[25]**; on onion **[10]**; on strawberry **[26]**; on snap beans **[27]** and on beans **[11]**.

From other side, the application of chitosan as foliar for potato plants resulted absolutely same effect on all or at least on the most parameters recorded in this script. Whereas, **[3 and 28]** reported that chitosan is environmental-friendly product. It has been widely used in agricultural applications. Chitosan was mainly used for stimulation of plant defense to protect plants against microorganisms. Chitosan can also induce a multitude of biological processes in plant tissues, including the stimulation of chitinases, accumulation of phytoalexins, synthesis of proteinase inhibitors, and increasing lignifications. Also, **[29 and 12]** reported that Chitosan used as stimulate the immunity of plants and to stimulate plant growth. However, Chitosan plays a great role in enhancing plant growth, where it is a natural polysaccharides which consists of a copolymer of N-acetyl-D-glucosamine and D-glucosamine residues linked by β-1-4 glycosides bonds.

Finally, it could be stated that the enhancement in plant growth characters of potato which obtained herein are in good harmony with that obtained by other investigators. Whereas, **[13]** stated that growth as expressed by leaf area, number of leaves, plant length and dry matter weight of tomato plant and many other crops were improved by chitosan application. The results of **[30]** on tomato; **[14]** on sweet pepper; **[31]** on strawberry and **[15]** on onion plants, are in supporting of the obtained results of this script.

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Table (7): Effect of some bio-stimulant substances on leaf area, leaf area index, relative growth rate and net assimilation rate at different growth stages of potato plant during both seasons.

Treatments	Leaf area m^2/plant			Leaf area index m^2/m^2		Relative growth rate mg/g/day		Net assimilation rate mg/m^2/day	
First season (2012/2013)									
Bio-stimulant substances	After planting			Estimation period (day)					
	70	80	90	80-70	90-80	80-70	90-80	80-70	90-80
Control	1.39	1.54	1.66	8.07	8.38	3.98	5.92	0.15	0.23
Potassium silicate	1.51	1.67	1.75	8.48	8.69	5.43	6.89	0.22	0.30
Chitosan	1.54	1.70	1.86	8.68	9.10	5.19	7.79	0.23	0.37
Amino mix	1.57	1.73	1.96	8.74	9.35	5.33	8.23	0.25	0.40
LSD at 5%	0.142	0.155	0.184	0.58	0.67	N.S.	N.S.	0.086	0.117
Second season (2013/2014)									
Control	1.37	1.54	1.66	7.74	11.70	4.64	5.62	0.18	0.23
Potassium silicate	1.50	1.61	1.75	8.30	12.66	4.81	6.08	0.20	0.26
Chitosan	1.55	1.70	1.86	8.68	13.24	4.71	6.39	0.21	0.29
Amino mix	1.61	1.78	1.96	8.98	13.66	4.70	7.05	0.21	0.34
LSD at 5%	0.170	0.116	0.184	0.599	1.004	N.S.	N.S.	N.S.	0.079

Photosynthetic pigments

It is obvious from the presented data in Table (8) that the contents of total photosynthetic pigments and its fractions (chlorophyll a, b and carotenoids) was significantly affected by the application of growth stimulant substances. Whereas, the highest total pigments and it's contents were determined with those plants sprayed by amino acids mixture 2.5 cm^3/l followed in decreasing order by those plants treated by chitosan (5.0 cm^3/l). It could be concluded that either amino acid mixture or chitosan treatments gained the highest values of photosynthetic pigment, but control treatment (sprayed by tap-water) recorded the lowest values. These hold good in both seasons. In this concern, **[27]** explained the superiority of applying amino acids on pigments of snap bean, due to referred senescence, regulated cell proliferation and differentiation. Also, amino acids were important factor for growth regulation, protein biosynthesis as well as stabilizing chloroplasts membranes and regarding degradation. Moreover, amino acids affect plant pigments might be attributed to their role in improve mineral uptake by plant shoots. As general, that results which demonstrated by **El-Awadi and Abd El Wahed [32]** and **Shafeek *et al.* [33]** are supported that obtained data. Moreover, Chitosan caused an enhancement in photosynthetic pigments this might due to the amino components in chitosan **[31]**. The obtained results concerning the response of photosynthetic pigment to the foliar spraying by chitosan are in good accordance with that obtained by **El-Tantawy [30]** on tomato and **Abdel-mawgoud *et al*. [31]** on strawberry.

Tubers yield and its components

The effect of foliar spraying by some bio-simulative substances on the total marketable and un-marketable tubers yield in the two experiments, are presented in Table (9). Whereas, a significant effect were found regarding to total yield and its components. The foliar spraying by all used substances, caused an enhancement in total tubers yield and its marketability, as well as average number and weight of tubers per plant over the control treatment in both seasons. Moreover, the amino acids mixture used at rate of 2.5 cm^3/l, gained the highest tuber yield and its components (except un-marketable yield), followed by no significant order by Chitosan. Concerning the un-marketable yield followed an opposite trend, whereas, the lowest un-marketable yield was recorded with the foliar spraying of amino acids. Generally, it could concluded that, the foliar spraying of potato plant by amino acids mixture or chitosan resulted in the heaviest total and marketable tuber yield and the lowest value of un-marketable yield. These results were absolutely similar in both experimental seasons.

The superiority of total tuber yield and its marketable yield might be attributed to that amino acids mixture contains many amino acids as well as some growth regulators and vitamins as shown in Table (2) which stimulated and enhanced the metabolism processes in plant tissues. Whereas, the previous studies have proved that, amino acids, can directly or un-directly influenced the physical activities which in turn on total tuber yield. The obtained results are in harmony with these before applied on potato **[9]**; on onion **[10 and 33]**; on strawberry **[26]** and on celeriac **[34]**.

Concerning to the superiority of chitosan, this might be attributed to that contains organisms such as fungi, algae and yeast and due to its multitude increasing of biological processes in the plant tissue, including the stimulation of chitinases, accumulation of phytoalexins, synthesis of proteinase inhibitors and increasing lignifications **[28]**. The results written herein are in good accordance with those obtained by **El-Tantawy [30]** on tomatoes as well as by **Ghoname *et al*. [14]** on sweet pepper and **Abdel-mawgoud *et al*. [31]** on strawberry.

Very little literature was published concerning the effect of foliar spraying by potassium silicate on vegetable crops. Whereas, **[35, 36 and 37]**. They reported that K silicate had a slow increase on total yield.

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Table (8): Effect of some bio-stimulant substances on photosynthetic pigments of potato leaves during both seasons of 2012/2013 and 2013/2014.

Bio-stimulant substances	First season (2012/2013)				Second season (2013/2014)			
	Leaf pigments mg/g fresh weight							
	Chloro. a	Chloro. b	Chloro. a + b	Carot.	Chloro. a	Chlor. b	Chlor. a + b	Carot.
Control	1.461	0.410	1.871	1.227	1.463	0.406	1.869	1.213
Potassium	1.523	0.533	2.056	1.317	1.533	0.510	2.044	1.230
Chitosan	1.651	0.832	2.483	1.403	1.615	0.811	2.426	1.380
Amino mix	1.849	1.001	2.851	1.497	1.839	0.971	2.810	1.463
LSD at 5%	**0.113**	**0.231**	**0.238**	**0.140**	**0.115**	**0.266**	**0.289**	**0.125**

Table (9): Effect of some bio-stimulant substances on tubers yield of potato plant during both seasons of 2012/2013 and 2013/2014.

Bio-stimulant substances	Tubers/plant		Wt. of tuber (g)	Total yield Ton/fed	Tuber yield ton/fed.	
	Wt. (g)	No.			Marketable	Un marketable
First season (2012/2013)						
Control	528.22	6.00	87.28	8.45	7.01	1.44
Potassium silicate	727.48	7.44	97.39	11.64	10.37	1.27
Chitosan	709.11	7.33	96.22	11.35	10.06	1.28
Amino mix	756.78	7.67	98.33	12.11	10.85	1.25
LSD at 5%	**145.74**	**1.290**	**5.505**	**2.33**	**2.325**	**0.106**
Second season (2013/2014)						
Control	571.33	6.44	88.00	9.14	7.77	1.37
Potassium silicate	707.33	7.11	98.78	11.32	10.20	1.11
Chitosan	686.78	7.11	95.89	10.99	9.82	1.17
Amino mix	748.67	7.56	98.67	11.98	10.85	1.13
LSD at 5%	**97.47**	**0.816**	**8.548**	**1.560**	**1.594**	**0.203**

Tubers yield properties

Physical quality

Concerning to the effect of foliar spraying by some bio-simulant substances on the physical properties of potato tubers, the obtained data revealed that the 3 active growth substances used herein caused an encouragement in length, diameter, size and specific gravity values of potato tubers compared to control treatment (Table 10). Moreover, within these substances, the foliar spraying by amino acids mixture at rate of 2.5 cm^3/l (for 3 times, with 10 days intervals starting from 40 days after plating date) gained the highest values of length, diameter, size and specific gravity of potato tubers, followed by chitosan treatment applied at rate of 5 cm^3/l, but the statistically analysis recorded no significant differences between both of them on all studied physical properties of potato tubers during the two seasons of 2012/2013 and 2013/2014. It could be stated that, foliar spraying by either amino acids mixture or chitosan was more beneficial than using potassium silicate for obtaining the better physical properties of potato tubers. Whereas, the obtained results of this script are in good agreement with that obtained by **El-Zahri and Asfour [9]** on potato; **Abo-Sadra *et al*. [26]** on strawberry; **Shehata and El-Helaly [38]** on snap bean and **Ghoname *et al*. [14])** on sweet pepper.

Nutritional values

The foliar spraying by the 3 growth stimulant substances, i.e. chitosan, amino mix, and potassium silicate as well as tap-water as control treatment gained a significant effect on the nutritional values of potato tubers as shown in Table (11). Whereas, the contents of starch, total carbohydrates, total sugar, dry matter, N, P, K, Ca, Fe, Mn, Zn and Cu, all of them resulted a superior when potato plants sprayed by the bio-simulative substances if compared with those plants treated by tap-water (control). Moreover, the foliar spraying by amino acid mixture at a concentration of 2.5 cm^3/l (for 3 times with 10 days interval starting from 40 days after planting) resulted in the highest values of all nutritional elements, but without significant variations between amino mix and chitosan. The results mean the foliar spraying of potato plants by each amino acids mixture or chitosan as individually gained the best nutritional values. The statistically analysis of the collected data revealed that no great difference within using amino acid max and chitosan. The results were completely similar in both experimental seasons.

As a general, it could be explained the highest nutritional values of potato tubers tissue which were associated with those plants treated with amino acids mix or chitosan might be attributed to the great role of both two substances for enhancing plant growth criteria which had a favorable effect on uptake the nutrition elements through rooting system. Moreover, the amino acid mix contains more amino acids, vitamins as well as some growth regulators as shown in Table (2). Whereas, the previous studies have been proved that, amino acids, can directly or indirectly influenced the physiological activities of the plants. However, the effect of amino acids on the nutritional values of some vegetable fruits were studied before and its data are in good accordance with that obtained herein **[26]** on strawberry; **[34]** on celeriac and **[39]** on garlic.

Also, chitosan plays the same great role in enhancement plant growth, which reflected on the absorption the nutritional elements from soils media extract, where chitosan is a natural polysaccharide which consists of copolymer of N-acetyl-D-glucosamine and residues, linked by B-1,4 glycoside bonds **[12]**. The available literature on the effect of chitosan and/or K silicate on nutritional values of vegetable crops was scantly.

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Table (10): Effect some bio-stimulant substances on potato tuber quality during both seasons of 2012/2013 and 2013/2014.

Bio-stimulant substances	First season (2012/2013)				594Second season (2013/2014)			
	Diameter (cm)	Length (cm)	Volume (cm^3 / tuber)	Specific Gravity (g/cm^3)	Diameter (cm)	Length (cm)	Volume (cm^3 / tuber)	Specific Gravity (g/cm^3)
Control	5.94	6.33	183.33	0.63	5.42	6.56	183.33	0.55
Potassium silicate	6.73	7.26	200.00	0.69	6.06	7.56	199.89	0.63
Chitosan	7.27	7.80	213.44	0.74	4.89	6.11	210.00	0.70
Amino mix	7.49	8.39	220.00	0.77	6.83	9.06	210.00	0.73
LSD at 5%	**0.479**	**0.413**	**0.288**	**0.086**	**N.S.**	**N.S.**	**0.288**	**0.037**

Table (11): Effect of some bio-stimulant substances on nutritional values of potato tubers during both seasons of 2012/2013 and 2013/2014.

Bio-stimulant substances	%									ppm			
	Dry matter	Starch	Carbohy-drate	Total sugars	N	P	K	Ca	S	Fe	Mn	Zn	Cu
First season (2012/2013)													
Control	14.88	46.79	51.00	0.579	1.31	0.506	2.85	0.98	0.24	281	35.70	31.20	23.02
Potassium silicate	15.91	57.31	55.90	0.653	1.46	0.592	3.81	1.20	0.28	364	40.24	33.72	36.61
Chitosan	16.56	57.15	58.08	0.643	1.57	0.662	3.70	1.32	0.31	375	41.17	35.39	35.98
Amino mix	17.17	61.19	60.36	0.666	1.60	0.661	3.67	1.34	0.31	352	41.37	35.39	35.94
LSD at 5%	**0.743**	**10.787**	**1.872**	**0.063**	**0.07**	**0.056**	**0.32**	**0.178**	**0.03**	**31.04**	**3.847**	**1.902**	**6.097**
Second season (2013/2014)													
Control	15.32	46.43	52.65	0.579	1.34	0.61	3.20	1.04	0.25	300	37.20	32.22	27.08
Potassium silicate	16.00	56.32	57.43	0.656	1.50	0.73	4.27	1.30	0.29	376	41.36	34.31	38.14
Chitosan	16.89	57.09	59.54	0.645	1.62	0.78	4.06	1.39	0.32	376	42.21	36.36	38.12
Amino mix	17.30	59.46	61.81	0.668	1.67	0.80	4.07	1.40	0.322	357	42.72	36.54	37.82
LSD at 5%	**1.020**	**7.007**	**1.715**	**0.064**	**0.07**	**0.07**	**0.28**	**0.184**	**0.026**	**22.63**	**3.966**	**1.744**	**3.829**

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