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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

Growth stimulants have the ability to stimulate growth of roots, shoots and leaves consequently enhanced yield components of various vegetable crops. Therefore, two field experiments were conducted during seasons of 2012/2013 and 2013/2014 under newly reclaimed sandy soil conditions at a private farm (Taba farm), Sadat city, Egypt. In order tostudy the effect of foliar application of some plant growth stimulants (amino acid, 2.5 $cm^3$/l, chitosan, 5 $cm^3$/l, potassium silicate, 2 $cm^3$/land control treatment), for 3 times in 10 days interval starting at 40 days after planting date, on growth and productivity of potato plants cv. Diamonte. The experiments of a complete randomized block design with four replicates were used. The obtained results indicated that foliar spraying by amino acids mixture or chitosan at rate of 2.5 and 5.0 $cm^3$/l, respectively, gained significantly vigorous plant growth at all sampling dates, 70, 80 and 90 days after planting date, 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. Furthermore, 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 plant growth stimulant substances compared with those of control. Foliar spraying of amino acids mixture (2.5 $cm^3$/l)or chitosan (5.0 $cm^3$/l) was the most efficient treatment in improving plant vegetative growth, tubers yield and yield quality parameters.

**Keywords:** Potato, Stimulant substances, Relative growth rate, Net assimilation rate, Vegetative growth, Tuber yield and Yieldquality properties.

## INTRODUCTION

Potato (*Solanumtuberosum* 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 (2012). It represents a cheap source of carbohydrates in human diets. Whereas, it contains high levels of carbohydrates (Muthoni and Nyamongo, 2009).It is considered as one of the national income resources. Globally, Egypt is ranked as number twelfth among potato top producers. The exported potato from Egypt remarkably increased in 2015, the total quantity exported were 632 thousand tons compared to the 289 thousand tons in 2012according to Agricultural Statistics Bulletin (2015),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 micro-organisms to protect plants (Rai, 2002).Amino acids can directly or indirectly influence the physiological activities of the plant(Kowalczyk and Zielony, 2008).

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(Ali *et al.,* 2011). Chitosan has been used in seed, leaf, fruit and vegetable coating, as fertilizer and in controlled agrochemical release (Sukwattanasinitt *et al.,* 2001).

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(Kamenidou *et al.,* 2008).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(El-Zohiri and Asfour, 2009); onion (Shaheen *et al.,* 2010) and beans (Abdel-Mawgoud *et al.,*2011). Moreover, other investigators reported that chitosan was mainly used for stimulation of plant defense mechanisms

against micro-organisms to protect plants(Khin *et al.,*2006; El-Mohamedy *et al.,* 2017). However, chitosan plays a great role in enhancing plant growth and yield of many vegetable crops (Chibu and Shibayama, 2001; Ghoname*et al.,* 2009; Mahmoud, 2011 andMohamedy *et al.,* 2017).

Increasing agricultural productivity to meet the food demand of growing population is a real challenge for Egyptian governmental. Land reclamation program aimed to addaround 422 thousand hectare to cultivated area (SADS, 2009). Most of these areas are located in desert with sandy soil texture. Newly reclaimed sandy areas are characterized by high evaporation, very low rainfall and depend mainly on underground water in irrigation. Moreover, sandy soil has a low water holding capacity and low fertility but it is free of soil borne diseases especially brown rot. Therefore, evaluation of different agronomic practices and/or agrochemical substances able to significantly raise plant productivity is highly recommended to obtain an economical yield.

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

## MATERIALS AND METHODS

These experiments were conducted to investigate the effect of foliar application of some plant growth stimulants (amino acid, 2.5 $cm^3$/l, chitosan, 5 $cm^3$/l, potassium silicate, 2 $cm^3$/l and control treatment), for 3 times in 10 days interval starting at 40 days after planting date, on potato growth and productivity. Two field experiments were carried out in newly reclaimed sandy soil at Taba farm, Sadat city, EL-Menofyia Governorate, Egypt during two successive growing seasons of 2012/2013 and 2013/2014. The physical and chemical characteristics of experimental soil are presented in Table (1).

Experimental soil was prepared for cultivation by land plough and ridges construction. Full dose of both organic matter as compost with a rate 20 ton/ha and phosphorus at rate of 140 kg $P_2O_5$/ha as calcium super phosphate (15.5% $P_2O_5$) were added during the final preparation of land and thoroughly mixed with the soil before construction of ridges. Nitrogen was added at rate of 285 kg N/ha as ammonium sulphate (20.6% N) in three equal doses at 30, 45 and 60 days after sowing date. Whereas, potassium was added twice at rate of 215 kg $K_2O$/ha as potassium sulphate (48% $K_2O$) at 50 and 75 days after planting date.

Certified potato seed tubers cv. 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 3rd and 2ndof October during the first and second seasons, respectively, on one side of drip irrigated ridge at distance of 25 cm between hills.

The experiments included 4 treatments which were spraying of the three plant growth stimulant substances (amino acid mixture,2.5 $cm^3$/l, chitosan, 5 $cm^3$/l, potassium silicate, 2 $cm^3$/l and distilled 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 micro nutrients. 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 ($K_2Si_2O_2$) is locally produced. Moreover, the three plant growth stimulant substances were sprayed for 3 times with 10 days interval starting at 40 days after planting date. All sprays were done in the morning using a hand pressure sprayer.

**Experimental design:** A completely randomized block design with four replicates was used during the two growing seasons. Each experiment block contained 5 ridges with 6 m in length and 0.75 m width with a net area of 22.5 $m^2$. The sown potato tubers were drip irrigated regularly for 40 min every day for 1 week. Then germinated potato seedlings were drip irrigated for 120 min every 2 days throughout the entire experiment. Furthermore, the standard agricultural practices of hoeing, fertilization, controlling of pest, disease and weed for potato crop production in the growing area were applied according to the recommendations of Ministry of Agriculture.

**Recorded data**

**A. Vegetative growth parameters:** A random sample of 6 plants was randomly taken from each experimental block at 70, 80 and 90 days after planting date and then transferred to the laboratory to determine the following characters; plant height (cm), number of leaves/plant, number of shoots/plant, fresh weight of whole/plant and its leaves and shoots (g), dry weight of whole/plant and its leaves and shoots (g), leaf area/plant ($m^2$/plant) and leaf area index.Moreover, net assimilation rate (g/$m^2$/day) and relative growth rate (mg/g/day) was determined according the method described by Gardner *et al*. (1985).

**B. Photosynthetic pigments:** Total chlorophyll and carotenoids of fresh leaves tissue (fourth and fifth leaf from the top) were calorimetrically determined as mg/g fresh weight according the method described by Moran (1982).

**C. Tubers yield and its components:** At harvesting stage the following characters were determined for each experimental block; weight of tubers (g/plant), number of tubers/plant, average weight of tuber (g/tuber), average weight of tubers (tons/ha), marketable tubers yield (good shapes and healthy tubers) and unmarketable tubers yield (off shape, blemished, green and diseased tubers).

**D. Physical properties of tubers yield:** At harvesting stage a sample of 20 tubers was randomly taken from each experimental block for determination of physical tuber properties as following; average of tuber diameter (cm), average of tuber length (cm), average of tuber volume ($cm^3$/tuber) and average of tuber specific gravity ($g/cm^3$).

**E. Chemical compositions**

- Dry matter of potato tuber was calculated as described by AOAC (1990).
- Total carbohydrates, was determined according to DuBois *et al.* (1956).
- Starch content, was determined in dry tissue of tubers using the method of Somogyi (1952).
- Total sugars, was determined according to the method described by DuBois *et al.* (1956).
- Total nitrogen was determined using the modified microKjeldahl method according to the procedures described by Cottenie*et al.* (1982).
- Phosphorus content was determined using spectrophotometer (SPECTRONIC 20D, Milton Roy Co. Ltd., USA) according to the procedures described by Cottenie*et al*. (1982).
- Potassium and calcium content was measured using flame photometer method (JENWAY, PFP-7, ELE Instrument Co. Ltd., UK) as described by Chapman and Pratt (1982).
- Concerning micro-elements contents, Fe, Zn, Mn and Cu were determined using Atomic-absorption (Analyst 200, Perkin Elmer, Inc., MA, USA), as described by Chapman and Pratt (1982).
- Sulphur was determined using the modified colorimetric method using spectrophotometer (SPECTRONIC 20D, Milton Roy Co., Ltd, USA).

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

| Properties | Values |
|---|---|
| **Physical property** | |
| Sand % | 90 |
| Silt % | 5 |
| Clay % | 5 |
| Texture Sandy | Sandy |
| **Available nutrients** | |
| 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 compositions of AMINO MIX compound.**

| Nutritional elements/100 ml | | Amino acids mg/100 ml | | | | Vitamins mg/100 ml | |
|---|---|---|---|---|---|---|---|
| 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 compositions of chitosan compound.**

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

**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 (1984).

## RESULTS AND DISCUSSION

**Plant growth characteristics**

**Plant height and number of leaves and shoots/plant:** Generally results demonstrated that potato plants treated with plant growth stimulant substances i.e. amino acids, chitosan and potassium silicate gained significant higher values of plant height as well as number of leaves and shoots compared with those plants of control treatment (Table 4).

It could be concluded that, the vigor potato plants which had the highest values of plant height, leaves and shoots number 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. The same trends were obtained in both seasons of 2012/2013 and 2013/2014.

**Fresh weight of whole plant and its leaves and shoots:** Data revealed that, it had a great and significant effect during various plant stages (sampling dates 70,80and 90 days after planting date) in both seasons of study (Table 5). First of all, the foliar spraying of amino acids or chitosan or potassium silicate 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 distilled water (control). These held good at various plant growth stages of the two experiments. In addition, among the plant 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 clear and visible in the first season, but in the second one, no significance was analyzed only with regard fresh weight of shoots. Generally, it could be stated that, the vigor potato plant was associated with those plants sprayed by amino acids or chitosan.

**Dry weight of whole plant and its leaves and shoots:** Foliar spraying with some plant growth stimulant substances i.e. amino acids, chitosan and potassium silicate 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 its 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 distilled water (control plants). In addition, the statistical analysis of the obtained data sharply revealed that, potato plants received any of the three plant growth stimulant substances recorded no significant difference, a significant difference was detected only between plant growth stimulant substances and control treatment in the first season of 2012/2013. While, in the second season of 2013/2014, significant difference was detected only between amino acids and chitosan treatments in most sampling dates.

**Table 4.Effect of some plant growth stimulant substances on vegetative growth of potato plant at different sampling dates during both seasons of 2012/2013 and 2013/2014.**

| Treatments | Plant height (cm) | | | Number of leaves/plant | | | Number of shoots/plant | | |
|---|---|---|---|---|---|---|---|---|---|
| Plant growth stimulant substances | First season (2012/2013) | | | | | | | | |
| | 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** |

**Table 5.Effect of some plant growth stimulant substances on fresh weight of potato plant at different sampling dates during both seasons of 2012/2013 and 2013/2014.**

| **Treatments** | **Fresh weight (g/plant)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Leaves** | | | **Shoots** | | | **Total** | | |
| **Plant growth stimulant substances** | **First season (2012/2013)** | | | | | | | | |
| | **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** |

**Table 6.Effect of some plant growth stimulant substances on dry weight of potato plant at different sampling dates during both seasons of 2012/2013 and 2013/2014.**

| **Treatments** | **Dry weight (g/plant)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Leaves** | | | **Shoots** | | | **Total** | | |
| **Plant growth stimulant substances** | **First season (2012/2013)** | | | | | | | | |
| | **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:** All plant growth stimulant substances used caused an enhancement in all calculated characters (Table 7). 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, followed in descending order by those plants sprayed by chitosan at rate of 5.0 $cm^3$/l, and then by those plants treated by potassium silicate at rate of 2.0 $cm^3$/l. In addition the collected results clearly indicated that the differences among the plant growth stimulant 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 not significant.

Finally, it could be concluded that, the plant growth characters, 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 the highest values when potato plants sprayed by amino acids mixture, followed insignificantly in most the above mentioned characters by those plants sprayed by chitosan.

Generally, it could be concluded that, this superiority amino acid treatment might be attributed to the content of amino acid mixture which shown in Table (2). Whereas, Shiraishi *et al.* (2010) 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, Rai (2002) 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 acids 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 (El-Zohiri and Asfour, 2009); on tomato (Tantawy *et al*., 2009); on onion (Shaheen *et al.,* 2010); on strawberry (Abo Sedera *et al.,* 2010); on snap beans (Hanafy *et al.,* 2010; Shaheen *et al.,* 2018**)** and on beans (Abdel-Mawgoud *et al.,* 2011).

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, Wojdyla (2001) 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 micro-organisms. 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, New *et al.* (2004);Khin*et al.* (2006);El-Mohamedy*et al.* (2017) they reported thatchitosan used to potentiate 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, Chibu and Shibayama (2001) 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 El-Tantawy (2009) on tomato; Ghoname *et al.* (2009) on sweet pepper; Abdel-Mawgoud *et al.* (2010) on strawberry; Mahmoud (2011) on onion and El-Mohamedy *et al.* (2017) on green bean plants, are in supporting of the obtained results of this script.

**Photosynthetic pigments:** The contents of total photosynthetic pigments and its fractions (chlorophyll a, b and carotenoids) were significantly affected by the application of plant growth stimulant substances (Table 8). Whereas, the highest total pigments and its 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, whereas, control treatment (sprayed by distilled water) recorded the lowest values. This trend was obtained in both seasons of study. In this concern, Hanafy *et al.* (2010) 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 improving mineral uptake by the plant. As general, results which demonstrated by El-Awadi and Abd El Wahed (2012); Shafeek *et al.*(2012); Akladious and Hanafy (2018) are supported the obtained results. Moreover, chitosan caused an enhancement in photosynthetic pigments this might due to the nutritional components of chitosan (Abdel-Mawgoud *et al.,* 2010). 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 (2009) on tomato and Abdel-Mawgoud *et al*. (2010) on strawberry.

**Tubers yield and its components:** The significant effects were found regarding to total yield and its components (Table 9). The foliar spraying by plant growth stimulant substances used, 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 tubers yield), followed insignificantly by chitosan treatment. Concerning the un-marketable tubers yield followed an opposite trend, whereas, the lowest un-marketable tubers yield was recorded with the foliar spraying of amino acids. Generally, it could concluded that, the foliar spraying of potato plants by amino acids mixture or chitosan resulted in the heaviest total and marketable tubers yield and the lowest value of un-marketable tubers yield. These results were absolutely similar in both experimental seasons.

**Table 7.Effect of some plant growth stimulant substances on some growth parameters of potato plant at different sampling dates during both seasons of 2012/2013 and 2013/2014.**

| 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) | |
|---|---|---|---|---|---|---|---|---|---|
| Plant growth stimulant substances | First season (2012/2013) | | | | | | | | |
| | Estimation period (days After planting) | | | | | | | | |
| | 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 |

**Table 8.Effect of some plant growth stimulant substances on photosynthetic pigments of potato leaves during both seasons of 2012/2013 and 2013/2014.**

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

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 indirectly influenced the physical activities which in turn on total tuber yield. The obtained results are in harmony with these applied on potato (El-Zohiri and Asfour, 2009); on onion (Shaheen *et al.,* 2010; Shafeek *et al.,* 2012); on strawberry (Abo Sedra *et al.,* 2010) and on celeriac (Shehata *et al.,* 2011).

Concerning to the superiority of chitosan, this might be 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 (Wojdyla, 2001). The results written herein are in good accordance with those obtained by El-Tantawy (2009) on tomato; Ghoname *et al*. (2009) on sweet pepper; Abdel-Mawgoud *et al*. (2010)on strawberry and El-Mohamedy *et al.* (2017) on green bean plants.

Very little literatures were published concerning the effect of foliar spraying by potassium silicate on vegetable crops. Whereas, Yanishevskaya and Yagodin (2000); Bacchus (2010) and Shahein *et al.* (2013) reported that potassium silicate had a slow increase effect on total yield.

**Tubers yield properties**

**Physical quality:** The obtained data revealed that the three plant growth stimulant substances used herein caused an enhancement in length, diameter, size and specific gravity values of potato tubers compared to control treatment (Table 10). Moreover, among these stimulant substances, the foliar spraying by amino acids mixture at rate of 2.5 $cm^3$/l gained the highest values of

length, diameter, size and specific gravity of potato tubers, followed by chitosan treatment applied at rate of 5.0 $cm^3$/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-Zohiri and Asfour (2009) on potato; AboSedera*et al.*(2010) on strawberry; Shehata and El-Helaly (2010); Shaheen *et al.* (2018) on snap bean and Ghoname *et al.*(2009) on sweet pepper.

**Nutritional values:** The foliar spraying by the three growth stimulant substances, i.e. chitosan, amino mix, and potassium silicate as well as distilled 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 plant growth stimulant substances if compared with those plants of control treatment. Moreover, the foliar spraying by amino acid mixture at rate of 2.5$cm^3$/l resulted in the highest values of all nutritional elements, but without significant differences between amino mix and chitosan. In another means, foliar spraying of potato plants individually by amino acid mixture or chitosan gained the best nutritional values, without a significant difference between both of them. These results were completely similar in both experimental seasons.

As a general, it could be explained the highest nutritional values of potato tubers tissue were associated with those plants treated with amino acids mixture or chitosan might be attributed to the great role of both plant growth stimulant substances in enhancing plant growth criteria which had a favorable effect on uptake of nutrients through rooting system. Moreover, the amino acid mixture 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 crops were studied and its data are in good accordance with that obtained herein, Abo Sedra *et al*. (2010) on strawberry; Shehata *et al*. (2011) on celeriac and Fawzy *et al*. (2012) on garlic.

Also, chitosan plays the same great role in enhancement plant growth, which reflected on the absorption the nutritional elements from soil solution, where chitosan is a natural polysaccharide which consists of copolymer of N-acetyl-D-glucosamine and residues, linked by B-1,4 glycoside bonds (Khin *et al.,* 2006). The available literature on the effect of chitosan and/or potassium silicate on nutritional values of vegetable crops was scantly.

**Table 9.Effect of some plant growth stimulant substances on yield and some physical properties of potato tubers during both seasons of 2012/2013 and 2013/2014.**

| Plant growth stimulant substances | Tuber/plant | | Wt. of tuber (g) | Total yield Ton/ha | Tuber yield ton/ha | |
|---|---|---|---|---|---|---|
| | Wt. (g) | No. | | | Marketable | Un marketable |
| **First season (2012/2013)** | | | | | | |
| **Control** | 528.22 | 6.00 | 87.28 | 20.11 | 16.68 | 3.43 |
| **Potassium silicate** | 727.48 | 7.44 | 97.39 | 27.70 | 24.68 | 3.02 |
| **Chitosan** | 709.11 | 7.33 | 96.22 | 27.01 | 23.94 | 3.05 |
| **Amino mix** | 756.78 | 7.67 | 98.33 | 28.82 | 25.82 | 2.98 |
| **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 | 21.75 | 18.49 | 3.26 |
| **Potassium silicate** | 707.33 | 7.11 | 98.78 | 26.94 | 24.28 | 2.64 |
| **Chitosan** | 686.78 | 7.11 | 95.89 | 26.16 | 23.37 | 2.78 |
| **Amino mix** | 748.67 | 7.56 | 98.67 | 28.51 | 25.82 | 2.69 |
| **LSD at 5%** | **97.47** | **0.816** | **8.548** | **1.560** | **1.594** | **0.203** |

**Table 10.Effect of some plant growth stimulant substances on the quality of potato tubers during both seasons of 2012/2013 and 2013/2014.**

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

**Table 11.Effect of some plant growth stimulant substances on some nutritional values and minerals contents of potato tubers during both seasons of 2012/2013 and 2013/2014.**

| Plant growth 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 |
| **K 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 |
| **K 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** |

**Conclusions:** From the above mentioned results, it could be concluded that, a significant increase in all measurements of plant vegetative growth parameters, tuber yield and its components, tuber physical properties and nutritional values of potato tuber, except for unmarketable tubers yield, was noted with foliar application of both plant growth stimulant substances, amino acids mixture at rate of 2.5 $cm^3$/l and chitosan at rate of 5.0 $cm^3$/l as compared to control treatment. Without significant difference between them in most cases during both seasons. The most effective treatment in enhancement of vegetative growth, tubers yield and yield quality properties of potato plants grown under newly reclaimed sandy soil conditions was foliar spraying of amino acids (2.5 $cm^3$/l) or chitosan (5.0 $cm^3$/l).

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