Annals of Agric. Sci., Moshtohor ISSN 1110-0419
Vol. 56(4) (2018), 1121 –1132 http://aasj.bu.edu.eg/index.php

Effect of Humic Substances Addition and Foliar Spraying with Biostimulants on Growth, Yield and Quality of Potato (*Solanum Tuberosum*)

Mohamed I. Mohaseb , hamdy. a. khafagy, mohsen. S. Mahrous and seham.m.abdel-azeem
Soil, Water and Environment Res. Inst., Agric. Res. Center (ARC).Giza, Egypt.
Correspondence author: mohasebmohamed@yahoo.com

Abstract

Two field experiments were conducted at private farm in Ismailia Governorate during two winter seasons of 2017 and 2018 to study the response of potato tuber (*Solanum tuberosum* L. cv Spunta) to application of humic substances from different sources *i.e*, potassium humate (solid HKS and liquid HKL) and humic acid (HA) and foliar spray with bio-stimulants of., dry yeast, compost tea and seaweed extract. HA combined compost tea in increased plant height with highest value of 60.3 cm plant^{-1}. Humic substances and biostimulants increased, total chlorophyll, vitamin C, starch and protein with highest value due to HA with combined foliar spray with seaweed extract. Contents of N, P and K their uptake increased due to HA with or without biostimulants with highest values due to HA with foliar sea weed extract spray. Humic substances and biostimulants increased soil available N, P and K after potato harvest. Soil treated with HKS + seaweed extract gave the highest of available N and P while, HKS + Compost Tea gave the available N.

Key words: bio stimulants, humic acid, yield and potato

Introduction

Potato (*solanum tuberosum* L.) is the fourth most important food crop in the world after rice, maize and wheat in terms of human consumption **(Karam *et al*., 2009 and Kandil *et al*., 2011).** The area of potatoes in 2014 in Egypt was about, 381000 fed.$^{-1}$ producing about 4.27 million ton **(CAMS, 2014).** In recent years, many efforts were done for improving fertilization systems, with lower fertilizer inputs. This would improve the quality, productivity and environmental conondistions. For such purposes, biostimulant products including some plant extracts, seaweed, fungi, bacteria or animal hydrolysates, which contain oligosaccharides, vitamins, humic substances were used in fertilization, **(Cavani and Ciavatta, 2007).** The use of biostimulants to remote plant growth has been widely studied. some soluble organic molecules have positive effects on metabolic processes of plants, due to their particular molecular structures, (**Eyheraguibel, *et al.* 2008; Morard, *et al.* 2011and Khaled and Fawy, 2011).**

Biostimulants are usually applied to plants though foliar spray using a solution. These are not used to provide nutrition, but to encourage and stimulate plant metabolism and increase nutrient use efficiency, or leading to yield increase and quality improvement, and to reduce the negative impact on the environment,(**Chen, *et al.* 2003, Tagliavini and Kubiokin 2006 and Parrado *et al.* 2008).**

Biostimulants improve plant physiology and nutrition processes, (**Selim *et al.* 2009, Hartz and Bottoms 2010 and Mora *et al.* 2010).** Humic acids can stimulate vegetative growth of chicory, increase root growth of pepper, (**Arancon *et al.* 2003)** and growth of cucumber and tomato, (**Atiyeh *et al.* 2002).** Application of biostimulants to leaf vegetables can increase the chlorophyll content, thus enhancing the attractiveness for consumers (**Ferrante, *et al.* 2004).**

Using biostimulants to promote plant growth has recently gained increasing attention worldwide **(Farouk, *et al*., 2012, Calvo *et al*., 2014 and Isaac, 2000).**

Seaweed (*Ascophyllum nodosum* Jol.) extracts ,SWE as organic biostimulants is fast becoming accepted practice in modern agriculture for are used in sustainable production agriculture. With 15 million Mg being is used an the world in 2006 as supplementary **(FAO 2006).** The beneficial effect of SWE is as a result of many components that work synergistically. They contain phytohormones **(Kurepin *et al*., 2014),** nutrients **(Zhang and Ervin, 2008),** and secondary metabolites as quaternary ammonium molecules, such as betaines and proline **(Mac kinnon *et al*., 2010).** They are used as a foliar sprays on many crops including potato **(Arafa *et al*., 2011, 2012, 2013, Calvo *et al*., 2014).**

Compost tea in and manure tea are water extract of compost and manure obtained by soaking or steeping the compost or manure in water. They can be as either a foliar application or soil application **(Yeggie, 2011).**

Potassium humate fertilizer is an effective organic potash which is useds as fertilizer or a growth promater quality, and was used on many crops, (**Patil *et al.* 2010).** Humic substances are hormones–like substances **(Pizzeghello *et al*., 2002),** which improve plant nutrient uptake **(Bryan and Stark, 2003),** increase root growth and enhance enzyme activity **(Mikkelsen 2005, Mart, 2007),** and increase yield **(Farouk *et al*., 2012, Rafell and Pakkish, 2014)**. **(Sanli *et al*. 2013)** found that exogenous application of leonardite (a concentrated form of humic and fulvic acids) increased plant height, number of tubers per plant, and tuber yield .**Arafa *et al.* (2011, 2012, 2013)** found the application of humic acid increased lettuce plant growth yield total chlorophyll and total carbohydrates.

The aim of the current investigation was to assess response of potato (Solanum tuberosum) to (dry yeast, compost tea seaweed extract) and humic acid sources.

Materials and Methods

Two field experiments were conducted on a newly reclaimed sandy loam soil in Ismailia Governorate during winter 2016/2017 and 2017/2018,(Table 1) to study the response of potato (*Solanum tuberosum* L. cv Spunta) to application of humic acid (as potassium humate or humic acid) as well as foliar spray with bio-stimulant *extract of* yeast, seaweed and compost on soil properties were analysed according to **Page *et al.* (1982).** The experimental design was a randomized complete block, factorial (Two factors). Factors and their treatments were (A) humic forms with treatments of (1) K- humate solid, soil application (2) K-humate liquid foliar spray and (3) humic acid. (B) Foliar spray treatments with extracts of (1), yeast (2) Compost (3) seaweed.

Table 1. Physical and chemical properties of the investigated soil

Course sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Texture		O.M gkg^{-1}		$CaCO_3$ gkg^{-1}
14.25	61.55	5.36	18.84	Sandy loam		7.2		18.9
pH (1:2.5)	**EC ($dS\ m^{-1}$)**	**Soluble cations ($mmol_c\ L^{-1}$)**				**Soluble anions ($mmol_c\ L^{-1}$)**		
		Ca^{++}	**Mg^{++}**	**Na^{+}**	**K^{+}**	**HCO^{-}_3**	**Cl^{-}**	**SO^{--}_4**
8.05	1.58	6.18	3.19	4.44	1.99	3.38	6.89	5.53
Available macronutrients ($mg\ kg^{-1}$)								
N			**P**			**K**		
40.2			4.18			189		

Available nutrients extract ants N: Kcl, P: Na-bio carbonate extract, K: NH_4-acetate extract

Compost extract preparation:
Compost extract (compost) was done through three stages:
1- Preparation: Compost was blended with distilled water in 1:10 (W/V) dilution ratio, then homogenized using an aquarium pump for 48 h until extract turned brown then the extract was filtered using cheesecloth properties of extract are shown at Table 2.

Table 2. Chemical analysis of compost extract (compost tea)

EC (dSm^{-1})	pH	Soluble macronutrients ($mg\ L^{-1}$)			Soluble micronutrients ($mg\ L^{-1}$)		
		N	P	K	Fe	Mn	Zn
2.3	7.40	70.0	9.51	133	125	79	66

* composet : water extract (1 :10 W/V)

Seaweed extract preparation
Three seaweed species (*Ascophyllum nodosum, Laminaria spp* and *Sargassum sp.*) were extracted by 1:200 (w: v). Analysis of extract is in Table 3.

Table 3. Main properties of seaweed extract.

Density(g cm^{-3})	OM gL^{-1}	pH	Macronutrients content gL^{-1}			Cytokines. Auxins and Gibberellins (gL)	Free amino acids, $mg\ kg^{-1}$
			N	P	K		
0.633	450	4.5	15	8	120	600	20.4
Algenic acid (%)		**Manitol (%)**		**Water solubility (%)**		**Appearance**	
12		5		100		Black powder	

Yeast extract:
Dry yeast was extracted by water at a ratio of 1:1 (w/w), and then kept overnight at room temperature. Spraying started one month after the planting and repeated 3 times at 15 days intervals. Analysis of dry yeast is in Table 4.

Table 4. Some components of dry yeast used.

Macronutrients content gkg^{-1}			Total protein	Carbohydrates	Auxin, IAA	Gibberellin
N	P	K	gkg^{-1}	gkg^{-1}	gkg^{-1}	gkg^{-1}
16	**1.3**	**12**	**103**	**56.1**	**5.1**	**0.3**
Vitamin B gkg^{-1}			**Glycin gkg^{-1}**	**Tryptophan gkg^{-1}**		**Lysine gkg^{-1}**
32.4			**31.1**	**5.2**		**43.1**

Humic acid was applied in different sources as follows:

1- Potassium humate a solid powder applied through soil, with 850 g K-humate, 100 gK Kg^{-1},10g Fe kg^{-1} 9.9 kg^{-1} No. Rate of addition as soil application at 48 kg ha^{-1} 3 days after sowing.

2- Potassium humate (25%) as liquid form. The compound contained 250 g humate L^{-1}, 58gkL^{-1}, 6g Fe$L^{-1}$and 6g total NL^{-1} and added at rate of 9.52L $ha.^{-1}$/952 L after dilution with water (1:100 v/v) at a rate of 1000 L ha^{-1}, through the foliar spray 21, 55 and 65 after seeding.

3- Humic acid liquid extracted from plant sources added at rate of 9.52L $ha.^{-1}$/952 L water within irrigation system three times after 21, 55 and 65 DAS and its properties are shown in Table 5.

Table 5. Humic acid analysis (plant source)

Density g cm^{-3}	pH	Total macronutrients (g kg^{-1})			Humic acid (g kg^{-1})	O.M (g kg^{-1})	Total micronutrients (mg kg^{-1})		
		N	P	K			Fe	Mn	Zn
1.43	7.85	21.6	6.21	66.2	160	450	398	268	83.9

The experiment included two factors as follows:

1. Humic acid sources (HS): (a) Soild Potassium humate, KHS; (b) Liquid Potassium humate, KHL and (c) Humic acid from plant sources, HA.
2. Foliar spray of bio stimulants used as follow:

Compost tea (CT) at rate of 119 L / 952 L $ha.^{-1}$ three times after 21, 55 and 65 DAS.

Yeast (YST) at a rate of 19.04 g L^{-1} 952 L water $ha.^{-1}$ three times after 30, 45 and 60 DAS.

A) Seaweed (SW) extract at rate 11.9 g L^{-1} /952 L water $ha.^{-1}$ /952 L water $ha.^{-1}$ three times after 30, 45 and 60 DAS. The control treatment was the treatment which received only the entire N, P and K doses as recommended by Ministry of Agriculture.

A non- treated treatment was a treatment which did not receive any of the mentioned treatment but received N, P, K doses as recommended by Ministry of Agriculture.

Planting procedures:

The treated potato tuber pieces were sown in the ridges at 12to15 cm in depth on October 9th and 15th in both seasons 2017 and 2018, respectively. As recommended by the Agric. Res. Center, Egypt, Nitrogen fertilizer was applied as ammonium sulphate (20.5 %) at the rate of 428.4 Kg N $ha.^{-1}$ in three equal splits, after emergence, two and four weeks later. Phosphorous and potassium were applied during the preparation in the form of calcium superphosphate (6.6% P) a rate of 78.54 kg P $ha.^{-1}$ and potassium sulphate (40 % K) at a rate of 47.6 kg K ha^{-1} in two equal splits, 30 and 45 days after sowing (DAS). Agricultural practices for growing potato were carried out as recommended by the Ministry of Agriculture.

Sampling and data recorded:

At the developmental stage of 15 leaves, dated at the active growth period (after 80 days from planting), a random sample of four plants was taken from each experimental unit to determine the growth parameters, *i.e.* (plant height "cm" and tuber diameter). In addition, some physiological parameters like vitamin C and total chlorophyll in the 3rd upper fresh leaf (mg g^{-1} fw).

At harvesting time (115 days from planting), a representative sample of 10 healthy tubers from each experimental plot was selected from the larger sizes to obtain the quality of tuber as follows:

1. Tuber yield.
2. Total Starch content.
3. Crude protein percentage "multiplying total nitrogen percentage by 6.25 to give the crude protein content' **(Ranganna, 1977).**
4. Vitamin C, Ascorbic acid concentration in fresh tissues**.**
5. Total chlorophyll content in fresh tissues**.**
6. N, P and K content and uptake

Biochemical determination

Total chlorophyll content: Chlorophylls a, b and their total, were extracted from the blade of the 3rd terminal upper compound leaf of the main stem for 24 hr at laboratory temperature by methanol after adding a trace from sodium carbonate **(Robinson and Britz, 2000),** then photosynthetic pigments were determined spectrophotometrically **(Lichtenthaler and Wellburn, 1985).**

Starch content: Soluble starch content was determined following **Malik and Srivastava (1979**). For of soluble starch,a plan sample of 0.1 g of ground dry material was homogenized in 80% ethanol and centrifuged, the residue was retained which was repeatedly washed with 80% ethanol to remove all traces of soluble sugars. The residue was used for the determination of starch. Five mL of distilled water and 6.5 mL of 52% perchloric acid were added to the residue. Extraction of starch with perchloric acid was carried out at 0 C° for 20 min, and then centrifuged, and the extract was retained. The extract for starch (0.1 mL) was determined by the phenol- sulphoric acid methods using spectrophotometer as described by **Sadasivam and Manickam, (1996).**

Total ascorbic acid (Vitamin C): was determined in fresh tissues as described by **Sattar, (1999)**

NPK contents:

Ground dried tuber samples were wet digested with $HClO_3/H_2SO_4$ until the solution was clear, cooled, and brought to volume at 100 mL using deionized water and kept for ion determinations. Total nitrogen was determined by the kjeldahl method. Potassium was determined by flame photometer **(Kalra, 1998),** and phosphorous was determined using ammonium molybdate and ascorbic acid **(Cooper , 1977) .**

Results and Discussion

Yield and yield attributes

Data in Table 6. Show the effect of humic and biostimulants addition on plant height, tuber diameter and tuber yield. Plant highet ranged between 46.6 and 60.3 cm plant^{-1} for non treated and the HA + compost tea treatment, respectively The HA caused 29.4% increase. This is a of humic a positive response of the humic cids and thier role in supplying essential nutrients and organic matter for the plant and improve the growth parameters, **(Robert, 2004). Patil *et al.* (2010)** observed an increase in growth parameter with an increase in potassium humate. The effect of foliar spray with biostimulants was can be arranged as follows: compost tea > seaweed > yeast > non, effect of humic addition effect was not stalistically. As for tuber diameter, addition of humic substances and biostimulants under study increased tuber diameter. The tuber diameter ranged between 2.45 cm (by non spray) and 4.23 (HA + Seaweed extract spray giving) the increase of highest value was main effect of 72.7% increase. The increases of tuber diameter as affected by humic addition treatments were as: HA ≥ KHL > KHS were, 51.8, 43.3 and 34.3%, respectively The average increased caused by seaweed > compost tea > yeast > control causing relative increases (63.3, 44.8 and 21.2%), respectively over the control treatment.

Table 6. Effect of humic and bio addition on plant height, tuber diameter and potato tuber yield

Humic form (H)	Bio Source (B)											
	YST	CT	SW	mean	YST	CT	SW	mean	YST	CT	SW	mean
	Plant height (cm)				Yield (Mg ha^{-1})				Tuber diameter (cm)			
KHS	**54.8**	**57.1**	**53.0**	**55.0**	**20.81**	**19.00**	**20.33**	**20.64**	**2.97**	**3.07**	**3.84**	**3.29**
KHL	**48.6**	**54.7**	**50.2**	**51.4**	**14.35**	**16.08**	**20.02**	**16.90**	**16.90**	**2.89**	**3.69**	**3.94**
HA	**52.5**	**60.3**	**54.1**	**55.6**	**18.22**	**19.58**	**24.72**	**20.83**	**3.06**	**3.88**	**4.23**	**3.72**
Mean	**52.0**	**57.4**	**52.4**		**17.71**	**18.24**	**21.70**		**2.97**	**3.55**	**4.00**	
Non treated	46.6				12.19				2.45			
LSD:-	H: ns					*				**		
	Bio **					**				**		
	HxBio ns					**				**		

* KHS: solid K- humate, KHL: liquide K- humate, HA: humic acid, YST: yiest, CT: compost tea, SW: sea weed extract

With respect to tuber yield, the effect was significant for humic and bio treatments in increasing tuber yield from 12.19 Mg ha.$^{-1}$ with control treatment to the maximum value (24.72 Mg ha.$^{-1}$) obtained owing to the treatment of HA when potato plants sprayed with seaweed extract and giving an increase of 103%. The relative increases for humic substances were: 70.9, 64.6 and 38.0% for HA, KHS and KHL, respectively, and 78.0, 49.6 and 45.9% for seaweed, compost tea and yeast, respectively. **Siddique, *et al.* (2008)** suggested that the use of compost tea would be beneficial and safe a in increasing plant growth. Increasing growth by improving nutrient availability and promoting plants cation exchange capacity **(Ingham, 2005).** The role of dry yeast in increasing the growth parameters may be due to the content of yeast to essential nutrients and production of some growth regulators such as Auxin and Gibberellin and cytokinin, which stimulate biological processes in plants and increasing plant growth, **Twfig (2010).** These results are in agreement with those obtained by **(Sarhan *et al.*, 2011 and Kahlel, 2015).**

As a conclusion of the previous results, the treatment of HA under foliar spray with seaweed extract was superior to the other treatments in increasing tuber diameter and tuber yield, while the treatment HA+ compost tea was superior to the other treatments in increasing plant height.

Tuber quality

The effect of humic substances and biostimulants on tuber quality is shown in Table 7 contents of chlorophyll (a+b), vitamin C and starch increased by the applied treatments. The better impact of biostimulants may be explained as; 1) All biostimulants containing a considerable amount of micro and macro-nutrients, which are required for chlorophyll biosynthesis **(Murillo *et al.*, 2005 Sridhar and Rengasamy, 2010)**,. In a study on responses of plants to with seaweed extract, **Jannin *et al.*, (2013)** attributed the increase in chlorophyll content was owing to an increase in the biogenesis of chloroplasts.

The highest total chlorophyll, vitamin C and starch contents were obtained with humic acid in presence of seaweed extract as foliar spraying with increases of 83.1, 46.3 and 15.9%, respectively. This is an indication of the positive effect on caused by the plant growth contained in the humic substances and seaweed extract, **(Kurepin *et al.* 2014).** Seaweed extract contains a number of betaines and betain analogues which enhance plant growth **(Mac kinnon *et al.*, 2010).**

Table 7. Effect of humic and bio addition on chlorophyll (a+b), tuber vitamin-C,and starch content

Humic form (H)	**Bio Source (B)**											
	YST	CT	SW	mean	YST	CT	SW	mean	YST	CT	SW	mean
	Total chlorophy ll, 100 mg g^{-1}				Tuber Vitamin C 100 mg g^{-1}				Starch g kg^{-1}			
KHS	51.7	62.2	70.8	54.7	13.1	13.7	15.3	13.2C	137	139	146	141C
KHL	46.9	55.4	61.4	54.6	12.7	13.2	14.6	14.0B	135	137	141	138 B
HA	57.2	68.3	75.8	67.1	13.9	15.0	17.7	15.9A	138	141	153	144A
Mean	51.9C	62.1B	69.3A		13.2C	14.0B	15.9 A		137 C	139 B	147 A	
Non treated	41.4 d				12.1 d				132 c			
LSD:-	H: **				**				**			
	Bio **				**				**			
	HxBio **				*				**			

Seaweed extract was reported to increase chlorophyll content in the treated plants **(Arafa *et al.*, 2011 and Jannin *et al.*, 2013).** The second highest increases were obtained by the plants sprayed with seaweed extract in presence of potassium humate as soild phase (KHS). Potassium in K-humate was reported to increase the number of cells leaf^{-1} and the number of chloroplasts cell^{-1} which increase the photosynthetic pigment concentrations, **(Pizzeghello *et al.*, 2013).**

As for humic substances, the increases followed the order: HA > KHS > KHL for total chlorophyll and starch, and well as HA > KHS > KHL for vitamin C.

With regard to biostimulants, the order was: seaweed extract > compost tea > yeast for total chlorophyll and vitamin C and seaweed extract > compost tea ≥ yeast.

Protein content

Protein content increased by addition of humic substances and foliar spraying with biostimulants Table 8. The trend followed the same for chlorophyll and starch hence, the treatment of HA + foliar spray with seaweed extract was superior to the other treatments followed by the treatment of KHS + seaweed extract. These increases reflect the effect of the non-symbiotic bacteria present in the biostimulants with beneficial effects on roots enhancing N_2–fixation and mineral uptake, and increasing the chlorophyll content (Table 7) which, in turn, promoted the synthesis of more photosynthetic required for tuber protein formation. **(Abd El-Nabi *et al.* 2016).**

Table 8. Effect of humic and bio addition on potato tuber protein content,N content and N-uptake

Humic form (H)	**Bio Source (B)**											
	YST	CT	SW	mean	YST	CT	SW	mean	YST	CT	SW	mean
	Protein content (%)				N- content (%)				N- uptake (Kg ha^{-1})			
KHS	8.23	8.38	9.25	8.62	1.32	1.34	1.48	1.38	271.3	254.7	297.5	274.5
KHL	7.86	7.77	8.69	8.11	1.26	1.24	1.39	1.30	178.9	198	276.1	217.7
HA	8.87	8.50	9.33	8.90	1.42	1.36	1.49	1.42	257	264.2	366.5	295.9
Mean	8.32	8.22	9.09		1.33	1.31	1.45		235.9	238	314.2	
Non treated	7.31				1.17				141.4			
LSD:-	H: **				**				**			
	Bio **				**				**			
	HxBio **				**				**			

As for humic substances, the increases followed the order: HA > KHS > KHL. The relative increases were 21.8, 17.9 and 10.9% for HA, KHS and KHL, respectively. With regard to biostimulants, the order was: seaweed extract > compost tea > yeast causing 24.4, 12.4 and 13.4% increases, respectively.

NPK uptake

Results of N-content and uptake in Table (8) as well as P and K contents and uptake in Table (9) Show that values of content and uptake followed the same trend of that observed for protein content hence, the values were significantly increased duo to the treatments effect. Highest increases for N, P and K contents (27.4, 87.0 and 17.3%), respectively and (159, 276 and 138%) for N, P and K uptake, respectively were obtained due to the addition treatment of HA and foliar spraying with seaweed extract over the control treatment (fertilized with N, P and K recommended only).

Statistically, the increases in N and K-uptake as affected by humic substances followed the trend of: HA ≥ KHS > KHL within insignificant differences between HA and KHS effect with (109, 93.6 and 54.0 increases over the control value, respectively for N-uptake) and (98.2, 83.9 and 52.7% increases, respectively for K-uptake), while the order was: HA > KHS > KHL for P-uptake causing (195, 158 and 96.6% increases, respectively) over the control treatment.

As for biostimulants effect, the increases followed the trend of: seaweed extract > compost tea ≥ yeast within insignificant effect among compost tea and yeast for N and K-uptake values giving 122, 68.4 and 66.8% increases, respectively for N-uptake and 104, 67.0 and 64.3% increases, respectively for K-uptake as well as the order: seaweed extract > compost tea ≥ yeast within insignificant effect between compost tea and yeast for P-uptake values with 209, 123 and 118% increases, respectively over the control treatment.

As well as, the combinations effect between H x bio on all data was show the significant effect between them for all measurements under study except, for their effect on plant height and starch content.

Table 9. Effect of humic and bio addition on P contents and uptake by potato tuber

Humic form (H)	Bio Source (B)							
	YST	CT	SW	mean	YST	CT	SW	mean
	P- content (%)				P- uptake (Kg ha^{-1})			
KHS	0.35	0.34	0.40	0.36	72.83	63.78	80.92	72.51
KHL	0.31	0.30	0.37	0.33	43.79	48.08	74.02	55.30
HA	0.39	0.37	0.43	0.40	70.92	71.88	105.67	82.82
Mean	0.35	0.34	0.40		62.59	61.17	86.87	
Non treated	0.23				28.08			
LSD:-	H:	**			**			
	Bio	**			**			
	HxBio	*			**			

Table 10. Effect of humic and bio addition on K contents and uptake by potato tuber

Humic form (H)	Bio Source (B)							
	YST	CT	SW	mean	YST	CT	SW	mean
	K- content (%)				K- uptake (Kg ha^{-1})			
KHS	2.46	2.44	2.51	2.47	506.94	461.72	504.56	491.07
KHL	2.41	2.42	2.50	2.44	342.72	385.56	495.04	407.78
HA	2.55	2.51	2.58	2.55	461.72	487.9	633.08	527.57
Mean	2.47	2.46	2.53		437.92	445.06	545.02	
Non treated	2.20				266.56			
LSD:-	H:	*			**			
	Bio	**			**			
	HxBio	*			**			

Soil available N, P and K after harvest

Data presented in Fig 1, show the available N, P and K (mg kg^{-1}) content as affected by the used treatments and their combinations on the studied soil. Data revealed that available N, P and K increased as affected by the addition of humic substances and foliar spraying with biostimulants. Available N ranged between 40.1 to 47.1 mg kg^{-1}. Available P ranged between 4.01 to 4.77 mg kg^{-1}. Available K ranged between 156 to 214 mg kg^{-1} for humic substances addition in combination with different biostimulants. The soil treated with HKS + seaweed extract gave the highest values of available N and P contents while, the soil treated with HKS + Compost Tea gave the highest value for available N content. The used humic substances could be arranged according to their effects in the following descending order: HKS > HA > HKL > control for available N and P contents and HKS > HKL > HA > control for available K content. As for bio stimulants addition, the order was: Compost Tea > Seaweed > Yeast for available N content and the order was: Seaweed > Compost Tea > Yeast for available P and K content.

The production of organic and inorganic acids as a result of the microorganisms activities must have contributed to a decrease in soil pH which produce more chelating ions, leading to an increase in available forms of elements in the rhizosphere zone. These results are in agreement with those obtained by **Ewees and Abdel Hafeez (2010).**

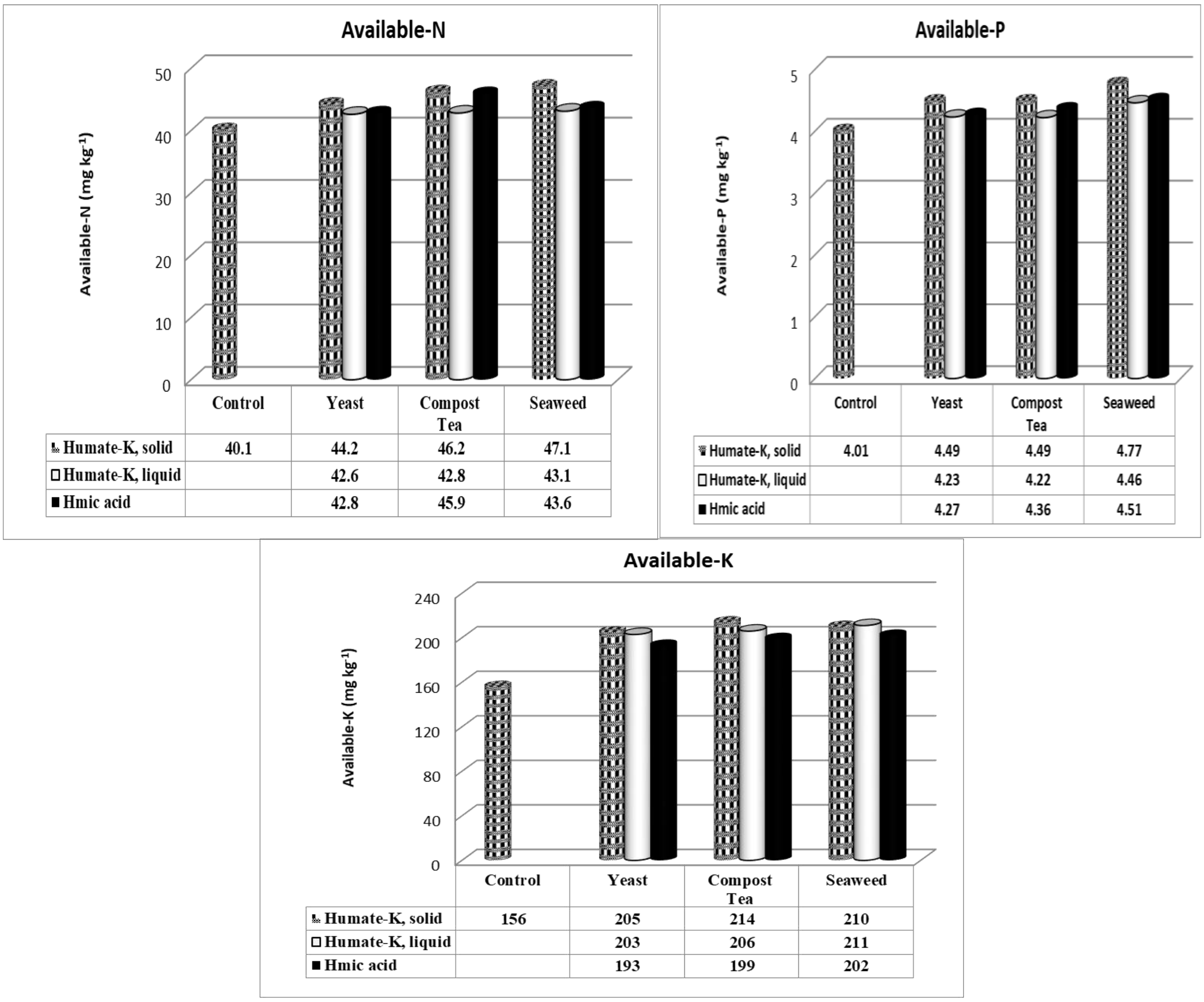

Fig. 1 N, P and K contents (mg Kg^{-1}**) in soil after harvest as affect by addition treatments**

Hussein and Hassan (2011) indicated that humic acids are important soil components that can improve nutrient availability and have impact on other important chemical, biological, and physical properties of soils. **Nasef,** ***et al.*** **(2009)** reported that the applied bio-fertilizer resulted in reduction of soil pH due to various acids (amino acids such as glycine and cysteine as well as humic acid) or acid forming compounds and active microorganisms released from the addition of organic materials and bio-fertilizer hence increase nutrients content in soil.

The corresponding relative increases as affected by KHS, KHL and HA were 14.5, 6.73 and 9.98%, respectively for available-N, 14.2, 7.48 and 9.23%, respectively for available-P and 34.6, 32.7 and 26.9%, respectively for available-K as compared to control treatment.

Conclusion

There is more promise for the use of non-chemical approaches in crop production in the light of the recent shift towards organic farming and growing public concern to minimize the use of chemicals. This particular potential widens the scope of biostimulants for use in other crops also. The results of this study showed that foliar spray of seaweed extract plus humic acid enhanced potato growth, yield and improved tuber quality of potato plants.

The promotive effects of biostimulants on plant growth are not fully clear, although there are some theories which probably work together, and can be summaried:

1) Biostimulant's effects on physiological processes in plants like macro- and micro- nutrient uptake, cell elongation, enzymatic activity and protein synthesis and finally activation of biomass production **(Calvo *et al.*, 2014, Rady and Mohamed, 2015).** In this concern, biostimulants increased ion percentage, in special, phosphorous, which play an important role in the biosynthesis and translocation of carbohydrates and stimulation cell division as well as formation of DNA and RNA **(Taiz and Zeiger, 1991)**.

2) Activate root cells and stimulate the biosynthesis of endogenous cytokinin **(Schmidt, 2005).** Cytokinin are known to promote cell division, inhibit leaf senescence by blocking export of photosynthate to new tissue and stimulating translocation of resources to treated leaves.

3) Altering hormonal balance and favor cytokinin and auxin production **(Stirk *et al.*, 2004, Schmidt, 2005** for Seaweed extract and **Pizzeghello *et al.*, 2002** for humic substancis),

4) Stimulation the biosynthesis of ascorbic acid, αt-tocopherol and carotenoids in chloroplasts which protect photosynthetic and stimulation of chlorophyll biosynthesis **(Zhang and Schmodt, 2000)**.

5) Stimulation of chloroplast development and enhancing phloem loading and delay senescence **(Demir *et al.*, 2004)**.

6) Enriched content of seaweed extract in crude protein and growth promoting hormones, in special, auxin and cytokinin **(Abdalla, 2015).** Proteins are essential for the formation of protoplasm, while growth substances favored rapid cell division and cell multiplication as well as elongation.

References

Abdalla, M.M. (2015). The potential of *Moringa oleifera* extract as a biostimulant in enhancing the growth, biochemical and hormonal contents in rocket (*Eruca vesicaria* subsp. sativa) plants. African J. Crop Sci., 3 (2): 116-122.

Abd El-Nabi, H.M.E., El-Gamily, E.I. and Nahla A.R. K. (2016). Response of potato plants to organic, bio and mineral fertilization J. Plant Production, Mansoura Univ., 7 (8): 861 – 867.

Arancon, N.Q., Lee, S., Edwards, C.A. and Atiyeh, R. (2003). Effects of humic acids derived from cattle, food and paper-waste-vermicomposts on growth of greenhouse plants. *Pedobiologia,* 47: 741-744.

Arafa A.A., Farouk, S. and Hager S. M. (2011). Effect of potassium ertilizer, biostimulants and effective microorganisms as well as their interactions on potato growth, photosynthetic pigments and stem anatomy. J. Plant Production, Mansoura Univ., 2(8):1017-1035.

Arafa A.A., Farouk, S. and Hager S. M. (2012). Response of tuber yield quantity and quality of potato plants and its economic consideration to certain bioregulators, effective microorganisms under potassium fertilization. J. Plant Production, Mansoura Univ., 3(1):131 -150.

Arafa A.A., Farouk, S. and Hager S. M. (2013). Effect of potassium fertilizers, biostimulants and effective microorganisms of growth, carbohydrates concentration and ion percentage in the shoots of potato plants. J. Plant Production, Mansoura Univ., 4 (1):15 - 32.

Atiyeh, R.M, Lee, S., Edwards, C.A., Arancon, N.Q and Metzger, J.D. (2002). The influence of humic acids derived from earthworm processed organic wastes on plant growth. Bioresource Technology, 84: 7-14.

Bryan, H. and Stark, J. (2003). Humic acid effects on potato response to phosphorous. Idaho Potato Conference, USA, January 22-23, pp 5.

Calvo P., Nelson, L. and Kloepper, J.W. (2014). Agricultural uses of plant biostimulants. Plant Soil, 383: 3–41.

CAMS, (2014). Central Agency for Mobilization and Statistics. Statistics year book, Egypt.

Cavani, L. and Ciavatta, C. (2007). Attività biostimolante negli idrolizzanti proteici. L'Informatore Agrario, 44: 46-52.

Chen, S.K, Edwards, C.A. and Subler, S. (2003). The influence of two agricultural biostimulants, microbial activity and plant growth in soil microcosms. Soil Biology and Biochemistry, 35: 9-19.

Cooper T.G. (1977). The tools of biochemistry. A Wiley-Interscience Pub. John Wiley and Sons, New York.

Demir, D., Günes, A., Inal, A., and Alpaslan, M. (2004). Effects of humic acids on the yield and mineral nutrition of cucumber (*cucumis sativus* l.) grown with different salinity levels. Acta Horticulturae, 492.

Duncan, D.E. (1955). Multiple ranges and multiple F test. Biometrics, 2: 1-42.

Ewees, M.S.A. and Abdel Hafeez, A.A.A. (2010). Response of maize grain yield to a partial substitution of N-mineral by applying organic manure, bio-inoculation and elemental sulphur as an alternative strategy to avoid the possible chemical pollution. Egypt J. Soil Sci., 50(1): 141 – 166.

Eyheraguibel, B., Silvestre, J. and Morard, P. (2008). Effects of humic substances derived from organic waste enhancement on the growth and mineral of maize. Bioresource Technology, 99: 4206-4212.

FAO (2006). Year Book of Fisheries Statistics. Food and Agricultural Organization of the United Nations, Rome, 98(1 and 2).

Farouk S., Safaa A. Youssef and Abeer A. A. (2012). Exploitation of biostimulants and vitamins as an alternative strategy to control early blight of tomato plants. Asian J Plant Science 11(1): 36-43.

Ferrante, A., Incrocci, L., Maggini, R., Serra, G.and Tognoni, F. (2004). Colour changes of fresh-cut leafy vegetables during storage. J. Food, Agri. and Environ., 2(3and4).40-44.

Hartz, T.K. and Bottoms, T.G. (2010). Humic substances generally ineffective in improving vegetable crop nutrient uptake or productivity. Hort. Science 45: 906-910.

Hussein, Kh. and Hassan, A.F. (2011). Effect of different levels of humic acids on the nutrient content, plant growth and soil properties under conditions of salinity. Soil and Water Res., 6(1): 21-29.

Ingham, E.R. (2005). The compost tea brewing manual. 5th ed., Soil Food web Inc, Corvallis, Oregon.

Isaac S. (2000). Microbial Stimulants. Turf. Bull. 208:28-30 Kitajima, M., and Butler, W.L. 1975. Quenching of chlorophyll fluorescence and primary photochemistry in chloroplasts by dibromothymoquinone. Biochim. Biophys. Acta 376:105-115.

Jannin L., Arkoun, M., Etienne, P., Laîné, P., Goux, D., Garnica, M., Fuentes, M., Francisco S.S., Baigorri, R. and Cruz, F. (2013). *Brassica napus* growth is promoted by *Ascophyllum nodosum* (L.) Le Jol. Seaweed extract: microarray analysis and physiological characterization of N, C, and S metabolisms. J. Plant Growth Regul. 32, 31 –52.

Kahlel, A.S., (2015). Effect of organic fertilizer and dry bread yeast on growth and yield of potato (*Solanum tuberosum* L.). J. Agric. Food. Tech., 5(1):5-11.

Kalra Y.P. (1998). Handbook of reference method for plant analysis. CRC Press, Washington, DC.

Kandil, A.A., Attia, A.N., Badawi, M.A., Sharief, A.E. and Abido, W.A.H. (2011). Effect of Water Stress and Fertilization with Inorganic Nitrogen and Organic Chicken Manure on Yield and Yield Components of Potato. Australian J. Basic and Applied Sci., 5(9): 997 - 1005.

Karam, F., Rouphacl, Y., Lahoud, R., Breidi, J. and Coll, G. (2009). Influence of Genotypes and potassium Application Rates on Yield and potassium Use Efficiency of Potato. J Agro; 8(1):27- 32.

Khaled, H. and Fawy, H. A. (2011). Effect of different levels of humic acids on the nutrient content, plant growth, and soil properties under conditions of salinity. Soil and Water Res., 6: 21-29.

Kumar P. (2011). Nanotechnology in agriculture. Financing Agriculture, 34:8-10.

Kurepin L.V., Zaman, M. and Pharis, R.P. (2014). Phytohormonal basis for the plant growth promoting action of naturally occurring biostimulators. J. Sci. Food Agric., 94:1715–1722.

Lichtenthaler H.K. and Wellbum, A.R. (1985). Determination of total carotenoids and chlorophylls A and B of leaf in Different Solvents. Biol. Soc. Trans., 11: 591 -592.

Mac Kinnon S.A., Craft, C.A., Hiltz, D. and Ugarte, R. (2010). Improved methods of analysis for betaines in *Ascophyllum nodosum* and its commercial seaweed extracts. J. Appl. Phycol. 22, 489–494.

Malik C.P. and Srivastava, A.K. (1979). Text book of plant physiology. New Delhi, India: Kalyani Publishers.

Mikkelsen, R.L. (2005). Humic materials for Agriculture. Better Crops, 89(3): 6-10.

Mart, I. (2007). Fertilizers, organic fertilizers, plant and agricultural fertilizers. Agro and Food Business Newsletter. pp: 1-4.

Mora, V., Bacaicoa, E., Zammareno, A.M., Aguirre, E., Garnica, M., Fuentes, M, and Garcia-Mina J. (2010). Action of humic acid on promotion of cucumber shoot growth involves nitrate related changes associated with the root-to-shoot distribution of cytokinins, polyamines and mineral nutrients. J. Plant Physiol., 167: 633-642.

Morard, P., Eyheraguibel, B., Morard, M. and Silvestre, J. (2011). Direct effects of humic-like substance on growth, water and mineral nutrition of various species. J. Plant Nutr., 34: 46-59.

Murillo J.M., Madej, N.E., Madejn, P. and Cabrera, F. (2005). The response of wild olive to the addition of a fulvic-rich acid amendment to soils polluted by trace elements. J. Arid Environments, London, 63:284-303.

Nasef, M.A., Shaban, Kh.A. and Abdel Hameed, A.F. (2009). Effect of compost and bio-fertilizer application on some chemical soil properties and rice productivity under saline soil condition. J. Agric. Mansoura Univ., 34 (4): 2609- 2623.

Page, A.L., Miller, R.H. and Keeney, D. R. (1982). "Methods of Soil Analysis". Part2: Chemical and microbiological properties, (2nd Ed.). Am. Soc. at Agron. Inc. Soil Sci. Soc. of Am. Inc., Madison, Wisconsin, VSA.

Patil, R., Junne, S., Mokle, S. and Santuk, W. (2010). Effect of potassium humate on vegetative growth and protein contents of *Glycine max* (L.) Merill and *Phaseolus mungo* (L.). Arch. Appl. Sci. Res., 2: 76—79.

Parrado, J., Bautista, J., Romero, E.J., Garcia-Martinez, A.M., Friaza, V. and Tejada, M. (2008). Production of a carob enzymatic extract:

potential use as a biofertilizer. Bioresour. Technol., 99: 2312-2318.

Pizzeghello D., Nicolini, G. and Nardi, S. (2002). Hormone-like activities of humic substances in different forest ecosystems. New Phytologist 155: 393-402.

Pizzeghello D., Francioso, O., Ertani, A., Muscolo, A. and Nardi, S. (2013). Isopentenyladenosine and cytokinin-like activity of four humic substances. J. Geochemical Exploration 129: 70-75.

Rady M.M. and Gamal F.M. (2015). Modulation of salt stress effects on the growth, physio-chemical attributes and yields of *Phaseolus vulgaris* L. plants by the combined application of salicylic acid and *Moringa oleifera* leaf extract. Scientia Horticulturae 193:105–113.

Rafell, S. and Pakkish, Z. (2014). Improvement of vegetative and reproductive growth of 'Camarosa' strawberry: Role of humic acid, Zn, and B. Agriculture Conspectus Scientifi Cus., 79(4): 239-244.

Ranganna S. (1977). "Manual of Analysis of Fruits and Vegetable Products". Central Food Technological Research Institute Mysore.

Robert, E. P. (2004). Organic matter, humus, humate,humic acid, fulvic acid and humin. Their importance in soil fertility and plant health [Online]. Available at www. umate.info/mainpage.htm

Robinson, J.M. and Britz, S.J. (2000). Tolerance of a field grown soybean cultivars to elevated ozon level is concurrent with higher leaflet ascorbic acid level, higher ascorbate-dehydro ascorbate redox status and long term photosynthetic productivity. Photosynthetic Res., 64:77-87.

Sadasivam, S. and Manickam, A. (1996). Biochemical methods, 2nd ED., New age international. India.

Sanli A., Karadogan, T. and Tonguc, M. (2013). Effect of leonardite applications on yield and some quality parameters of potatoes (*Solanum tuberosum* L.). Turkish J. Field Crops, 18(1): 20-26.

Sarhan, T.Z., Smira, T.A. and Rasheed, S.M.S. (2011). Effect of bread yeast application and seaweed extract on cucumber (*Cucumis sativus* L.) plant growth, yield and fruit quality. Mesopotamia J. Agric., 39 (2): 26-32.

Sattar, A. (1999). Effect of foliar application of urea as supplement on the fruit drop and quality of kinow mandarien (*Citrus reticulate* Blanco). MSc. Thesis, Institute of Horticultural Sci., Univ. Agric. Faisalabad, Pakistan.

Schmidt, R.E. (2005). Biostimulants function in turfgrass nutrition. Ph.D thesis. Emeritus Virginia Tech. USA.

Siddiqui, Y., Sariah, M., Razi, I., Mawardi, R. and Asgar, A. (2008). Bio-efficiency of compost extracts on the wet rot incidence, morphological and physiological growth of okra (*Abelmoschus esculentus).* Scientia Horticult., 117: 9–14.

Selim, E.M., Mosa, A.A. and El Ghamr, A.M. (2009). Evaluation of humic substances fertigation through surface and subsurface drip irrigation systems on potato grown under Egyptian sandy soil conditions. Agr. Water Management, 96: 1218-1222.

Sridhar S. and Rengasamy, R. (2010). Effect of seaweed liquid fertilizers on the growth, biochemical constituents and yield of Tagetes erecta, under field trial. J. Phytology. 2(6): 61 - 68.

Stirk, W.A., Arthur, G.D., Lourens, A.F., Novak, O., Strnad, M. and Van Staden, J. (2004). Changes in cytokinin and auxin concentrations in seaweed concentrates when stored at an elevated temperature. J. Appl. Phycol. 16, 31 –39.

Tagliavini, S. and Kubiokin, C. (2006). Effetti della biostimolazione in Ortofrutticoltura: alcune esperienze a confronto. Fertilitas Agrorum, 1:23-28.

Taiz, L. and Zeiger, E. (1991). Plant Physiology. Benjamin/Cummings, Redwood City, CA., pp 452-472.

Twfiq, A. A. (2010). Estimation levels of Indole acetic acid (IAA) and Gibberellic acid (GA3) in dry bakery yeast *Saccharomyces cereviciae*. J. bio-Technology Research Center. 4 (2): 94-100.

Yeggie, D. (2011). Compost tea. Literature review on production, application and plant disease management. Toxic Reduction Program, San Francisco CA: 3-18.

Zhang X. and Schmidt, R.E. (2000). Hormone-containing products' impact on antioxidant status of tall fescue and creeping bent grass subjected to drought. Crop Science, 40:1344-1349.

Zhang, X. and Ervin, E.H. (2008). Impact of seaweed extract-based cytokinins and zeatin riboside on creeping bent grass heat tolerance. Crop Sci. 48:364–370.

تأثير أضافة المركبات الهيومية و الرش الورقي بالمنشطات الحيوية علي النمو و الأنتاجية وجودة محصول البطاطس

محمد ابراهيم محسب– حمدى عبد المنعم خفاجى– محسن صبرى محروس– سهام محمد عبدالعظيم
معهد بحوث الأراضي و المياه و البيئة – مركز البحوث الزراعية – الجيزة – مصر

أجُريت تجربتان حقليتان في مزرعة خاصة بمحافظة الأسماعيلية – مصر خلال موسمي الشتوى لعامي 2017/2016 و2018 /2017م لدراسة مدي أستجابة نباتات البطاطس ودرناتها (*Solanum tuberosum* L. cv Spunta) لإضافة المركبات الهيومية من بعض المصادر المختلفة ومنها هيومات البوتاسيوم (الصلبة والسائلة) و حامض الهيومك العضوي المستخلص من مصدر نباتي وكذلك الرش الورقي ببعض المنشطات الحيوية (الخميرة الجافة ، شاي الكمبوست و مستخلص الطحالب البحرية) علي أنتاجية البطاطس وجودتها وكذلك محتواها و الممتص من بعض العناصر الغذائية الكبري (ن ، فو و بو) . يمكن تلخيص أهم النتائج المتحصل عليها كما يلي:

- كان لإضافة حامض الهيومك تأثير غير معنوي علي زيادة أرتفاع النبات وكانت أعلي قيمة (60.3 سم نبات $^{-1}$) قد تحصل عليها نتيجة لأضافة حامض الهيومك ورش النباتات بشاي الكمبوست معطياً 29.4% زيادة مقارنة بمعاملة المقارنة.
- .أدي إضافة المركبات الهيومية و الرش الورقي بالمنشطات الحيوية إلي زيادة معنوية لجودة المحصول الناتج للبطاطس مثل (الكلوروفيل الكلي ، فيتامين C ، محتوي النشا و محتوي البروتين وكانت أعلي القيم لها جميعا للنباتات التي عوملت بحامض الهيوميك و الرش الورقي بمستخلص الطحالب البحرية.
- أزدادت قيم محتوي درنات البطاطس من العناصر الكبري و الكميات الممتصة منها معنويا نتيجة المعاملات تحت الدراسة وكانت أعلي القيم لها قد لوحظت مع المعاملة بحامض الهيوميك و الرش الورقي بمستخلص الطحالب البحرية.
- إضافة مركبات الهيومك و الرش الورقي بالمنشطات الحيوية أدت إلي زيادة الكميات الميسرة من عناصر النيتروجين ، الفسفور و البوتاسيوم بالتربة بعد حصاد البطاطس مقارنة بمعاملة المقارنة. معاملة التربة هيومات البوتاسيوم (الصلبة) مع الرش الورقي بمستخلص الطحالب البحرية أعطي أعلي القيم للنيتروجين و الفسفور الميسرين بالتربة بينما معاملة التربة بهيومات البوتاسيوم (الصلبة) مع الرش الورقي بشاي الكمبوست أعطت أعلي قيم للبوتاسيوم الميسر بالتربة بعد الحصاد.

يمكن التوصية تحت نفس ظروف التجربة بأستخدام المركبات الهيومية وبخاصة حامض الهيوميك مع الرش بالمنشطات الحيوية وذلك لرفع جودة وأنتاجية البطاطس وخاصة مع الرش بمستخلص الطحالب البحرية.