

## **RESPONSE OF TUBER YIELD QUANTITY AND QUALITY OF POTATO PLANTS AND ITS ECONOMIC CONSIDERATION TO CERTAIN BIOREGULATORS OR EFFECTIVE MICROORGANISMS UNDER POTASSIUM FERTILIZATION**

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### **ABSTRACT**

Increasing potassium fertilizer rate up to 80 kg K<sub>2</sub>O/fed significantly increased yield and improved its quality as well as increased the net income and investment rate. The highest values were obtained due to application of 40 kg K<sub>2</sub>O/fed in the first and second seasons as compared with untreated plants. Exogenous application of biostimulants, in particular, seaweed extract significantly increased yield and improved its quality as well as increased the net income and investment rate as compared to control in both seasons. Addition of effective microorganisms to the soil significantly increased yield and improved its quality as well as increased the net income and investment rate.

As for the interactions, application of biostimulants, in particular, seaweed extract, significantly increased yield and improved its quality as well as increased the net income and investment rate under all potassium fertilizer rates with or without an addition of effective microorganisms. The highest value was obtained under the treatment of 40 kg K<sub>2</sub>O/fed with an addition of effective microorganisms and spraying plants with 500 mg/l seaweed extract as compared to control plant during the first and second growing seasons.

### **INTRODUCTION**

Potato (*Solanum tuberosum* L.) is a major source of inexpensive energy. It contains high levels of carbohydrates and significant amounts of vitamins B and C and other minerals (Pondey and Chadha 1996). It is an important crop in terms of human food and starch industry. In Egypt, the cultivated area is still small and difficult to disturb or to change the crop relation in the cultivated land. So, it must be pay attention to increase the productivity of the unit area of land. The production of the best fields requires that the soil must have favorable physical, chemical nutritional and biological conditions. Growers are continually seeking to overcome nutrient deficiencies as well as use improved management practices in order that yields may more nearly approach the genetic limit of crop plants.

Potato crop is a heavy remover of soil potassium and is the nutrient taken up in the greatest quantity; the tuber removes 1.5 times as much potassium as nitrogen and 4-5 times the amount of phosphate (Perrenoud 1993). Potassium increases the photosynthetic rate of crop leaves and carbon dioxide (CO<sub>2</sub>) assimilation, and facilitates carbon movement (Sangakkara *et al.* 2000). Furthermore, K<sup>+</sup> plays an important role in the translocation of photosynthates from source to sink (Cakmak *et al.* 1994).

Using biofertilizers in potato production in Egypt to produce safety yield and free of harmful chemicals and toxic materials is well recommended to take place in European market, and to have the consumer who is willing to pay high rate price for healthy safe product. Effective micro-organisms (EM) stock solution is one of many biofertilizers used in this concern. It contains a group of beneficial microorganisms (primary photosynthetic and lactic acid bacteria, yeast, actinomycetes and fermenting fungi) which are cultured and used to promote germination, flowering, fruiting and ripening in plants. Moreover, it improves physical, chemical and biological environments of the soil and enhances the photosynthetic capacity of crops.

Seaweed extracts (SE) (*Ascophyllum nodosum* Jol.) and humic acid (HA) are in common use as major components of vegetable and crop biostimulant formulations. Chemical analysis of seaweeds and their extracts have revealed the presence of a wide variety of plant growth regulators such as auxins and cytokinins in varying amounts (Zhang and Ervin 2004, 2008). Humic acid is considered to increase the permeability of plant membranes and enhance the uptake of nutrients. Moreover, humic acid is also considered to improve soil nitrogen uptake and encourage the uptake of potassium, calcium, magnesium and phosphorus, making these more mobile and available to plant root system (Pascual *et al.* 1999). In this concern, Ezzat *et al.* (2011) on potato plants, found that application of seaweed extract or humic acid plus 50% of recommended NPK significantly increased plant growth, yield and its components as well as tuber quality.

The aim of the present study was to find out the most favourable treatments producing more quality and quantity of potato yield. Furthermore, it was hoped that the results may lead to the utilization of one or more of the applied materials for large scale cultivation of potato under field condition.

## MATERIALS AND METHODS

Two field experiments were conducted during the two successive winter seasons of 2007/2008 and 2008/2009 at the EL-Maniel village, Dakahlia Governorate to study the influence of effective microorganisms, biostimulants, and potassium levels as well as their combinations on the potato yield quantity and quality and its economic consideration.

Soil samples and analysis: Twenty surface samples (0-20 cm depth) were taken at ten different locations. The mechanical and chemical analyses of the soil used were carried out in the two growing seasons and presented in Table (1).

**Table (1): Mechanical and chemical soil characteristics at the experimental sites during 2007/2008 and 2008/2009**

Physical properties	Value		Chemical properties	Value		Available nutrients (mg Kg <sup>-1</sup> )	Value	
	1 <sup>st</sup> season	2 <sup>nd</sup> season		1 <sup>st</sup> season	2 <sup>nd</sup> season		1 <sup>st</sup> season	2 <sup>nd</sup> season
Sand %	21.0	21.1	Field capacity %	32	33	Nitrogen	19	18
Silt%	32.3	33.0	EC(dSm-1)	1.64	1.70	phosphorous	8	7
Clay %	46.0	45.8	pH (Soil paste)	7.82	7.75	Potassium	140	135
Soil texture	Clay		Organic matter(%)	2.69	2.80			

**Plant Material, EM, Humic acid, and Seaweed Extract:** Potatoes tubers; cv Spunta (imported from Holland) were used in the present investigation and obtained from Agric. Res. Center (ARC), Ministry of Agric., Egypt. Tubers were divided into pieces, averaging approximately 50 g weight. As recommended by the Pathology Dept. Ministry of Agric. Egypt, potato tubers pieces were sterilized with Vitavax Kapetan 1% at the rate of 1.25 kg/ton. Effective micro-organisms were used under the name of EM which consists of a mixed culture of beneficial micro-organisms primarily photosynthetic and lactic acid bacteria, yeast and streptomycetes. The number of each component was recorded in table (2)

**Table (2): Components of EM used in the experiments**

Total bacterial	Lactic acid bacteria	Yeasts	Streptomycetes
2.5-9.6 x 10 <sup>4</sup> cfu/ml	6.6-9.9 x 10 <sup>6</sup> cfu/ml	105 - 106 cfu/ml	8.5 x 10 <sup>3</sup> cfu/ml

Seaweed extract is derived by an alkaline hydrolysis procedure from the fresh, intact *Ascophyllum nodosum* and 100% soluble in cold water. Seaweeds contained all the trace elements and plant growth hormones, vitamins, amino acids, antibiotic and micronutrients (Crouch and Van Staden, 1993). Also seaweed extract contained protein/amino acids 3–5%, lipid 1%, alginic acid 12–18%, fucose-containing polymers 12–15%, mannitol 5–6%, other carbohydrates 10–15% (Acadian Seaplants Limited, Dartmoth, Nova Scotia, Canada), As described by Fike *et al.*, (2001).

**Experimental design:** Farm yard manure has been added during soil preparation in organic fertilization at dose (40 m<sup>3</sup>/fed.). The experiment comprised of 18 treatments including three different rates of potassium fertilizers used individually or in combinations with EM and biostimulants (Humic acid at 150 mg/l or seaweed extract at 500 mg/l). A randomized complete block design in factorial arrangement was used with three replicates. Each plot was 7.2 m<sup>2</sup> (2.25 x3.20 m<sup>2</sup>) included three ridges, each three meters long and 70 cm apart; the distance between hills was 30 cm apart.

**Planting procedure:** Potato tuber cv. Spunta was planted in the ridges at 12-15 cm in depth (30-40 cm apart) on October 27<sup>th</sup> in the first season 2007/2008 and on November 9<sup>th</sup> in the second season 2008/2009 respectively. Potassium (K) levels occupied the main plots, while the effective microorganisms (EM) were assigned to the sub-plots, in each EM sub-plot the plants were divided into three groups which sprayed with either water (W), seaweed extract (SW) or humic acid (HA). The plot area was 7.2 m<sup>2</sup> ridged 70 cm apart. As recommended by the Agric. Res. Center, Egypt, Nitrogen fertilizer was added at three equal portions, the 1st was applied after emergence (18-21 days from planting), in the form of ammonium sulphate (20.5 %), then two and four weeks later in the form of ammonium nitrate (33.5 %) at the rate of 180 Kg N/ fed. Phosphorous and potassium were applied during the soil preparation in the form of calcium superphosphate (15.5% P<sub>2</sub>O<sub>5</sub>) and potassium sulphate (48 % K<sub>2</sub>O) at rate of 75 kg P<sub>2</sub>O<sub>5</sub>/fed and 20 kg K<sub>2</sub>O fed<sup>-1</sup> respectively. The respective EM treated plots received dilute EM solution 2 liter/m<sup>2</sup> before the first irrigation. Potassium fertilizers applied at three levels 0, 40 and 80 kg K<sub>2</sub>O fed<sup>-1</sup> using potassium sulphate (48 % K<sub>2</sub>O).

The quantity was divided into two equal doses to be added before the first irrigation and before the second irrigation. Plants were sprayed with an aqueous solution of SW or HA two times at 60 and 75 days from planting. Irrigation was done immediately. All usual cultural practices of potatoes cultivation were carried out according to the procedures that recommended by the Ministry of Agric. Egypt. Harvesting was done after 115 days from planting dates in both seasons.

**Sampling dates and data recorded:** At harvest, which was carried out 115 days from planting a sample of 5 plants during the two growing seasons were chosen at random from each treatment to determine yield and its quality. Fresh tuber yield and its quality were recorded in terms of weight of tubers per plant and expected total yield per feddan (ton/fed) which was calculated according to the equation; total yield (ton/fed.)= (yield of experimental unit 'kg' X net area of feddan '4000 m<sup>2</sup>') /area of experimental unit 'm<sup>2</sup>'. Tuber quality (protein and ions percentage, soluble sugars, starch, organic acid, ascorbic acid, and phenol concentration as well as specific gravity and total soluble solid percentage) was determined as indicated below. Protein percentage "multiplying total nitrogen value with 6.25 will give the crude protein content". For ion determination, ground tuber samples were wet digested with HClO<sub>3</sub>/H<sub>2</sub>SO<sub>4</sub> until the solution was clear (Peterburgski, 1968), cooled, and brought to volume at 100 ml using deionized water and kept for determinations. Nitrogen was determined calorimetrically by Nessler's methods as described by Gedroits (1963), phosphorous was determined spectrophotometrically (Spekol 11, Uk) by the methods described by Cooper (1977) using ammonium molybdate and ascorbic acid. Potassium was determined by Jenway Flamephotometer model CORNING 400 (UK) (Peterburgski, 1968). Soluble sugars and starch were estimated following Malik and Srivastava (1979). For the estimation of soluble sugars and starch, 0.1 g of well ground dry materials 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 filtrate thus obtained was used for the determination 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. With the residue, the above step was repeated using fresh perchloric acid and the extract of this step was combined with the extract of the first step and then the volumes of each of the sugar and starch extracts were made up to 100 ml by the addition of distilled water. The extracts for both soluble sugars and starch (0.1 ml) were determined by the phenol-sulphuric acid methods using spectrophotometer (Spekol 11, Uk) as described by Sadasivam and Manickam, (1996).

Specific gravity was calculated according to Abdel-Aal (1971) as follows: Specific gravity (g/cm<sup>3</sup>) = Tuber mass (g)/ tuber volume (cm<sup>3</sup>); TSS was determined in potato juice by refractometer according to AOAC (1990). Total organic acids in potato tuber, were extracted from frozen tuber with distilled water then filtered through filter paper. A known volume from the filtrate was transferred in vials and determined by titration with NaOH using

PHTH as an indicator. Ascorbic acid was extracted from plant material (tuber) with oxalic acid then titrate using 2,6-Dichlorophenol indophenole as described by Sadasivam and Manickam (1996). Potato tuber samples were extracted with 80% cold ethanol (v/v) for three times at 0°C, then put it in water bath for 30 min. The combined extracts were collected and filtered through whatman No 1 filter paper. Then the volume of sample was raised up to 10 ml with cold ethanol. Total phenolic content in the potato tuber extracts were determined with Folin-Ciocalteu reagent by the of Slinkard and Singleton method (1977) using catecol as a standard phenolic compound. Briefly, 1 ml of extract solution was mixed with distilled water. One ml of Folin-Ciocalteu reagent was added to the content of the flask and mixed thoroughly. After 3 min, 3 ml of Na<sub>2</sub>CO<sub>3</sub> was added then the mixture was allowed to stand for 2 h. The absorbance was measured at 660 nm. The concentration of total phenolic compounds in the extracts was determined as microgram of catecol equivalent by using an equation that was obtained from the standard catecol acid graph.

Economic and Statistical analysis: Data were subjected to statistical analysis of variance according to Norman and Streiner (2003). LSD value was used to test the difference between treatment means at 5%. For economic analysis, after considering the cost of fertilizer and all chemical used, the incomes from potato yield were used for economic analysis. Net income (NI) generated by a crop was the amount of money left when total costs (TC) were subtracted from total return (TR).  $NI = TR - TC$ . TR corresponds to the value of the harvested crop. TC includes the costs of all inputs, such as seed potatoes, fertilizer, pesticides, labour and capital. The variable component in the total costs was K fertilizers, effective microorganisms and biostimulants.

## RESULTS

### **Tuber yield:**

Data illustrated in Figure (1 and 2) indicate that, tuber yield (measured as tubers yield (kg) per plant and total yield (ton/fed.) during the two growing seasons were significantly increased with increasing potassium fertilizer rate up to 40 kg K<sub>2</sub>O/fed, thereafter decreased but still higher than that of the control plants (20 kg K<sub>2</sub>O/fed).

Bio-fertilization exerted positive effects in this respect. An addition of effective microorganisms in both seasons significantly increased tuber yield per plant and tuber yield per fed. in both growing seasons. Regarding the effect of biostimulants on potato yield, the data illustrated in Figures (1 and 2) proved that, foliar application of biostimulants; in particular, seaweed extract at 500 mg/l significantly increased the yield of potato plants represented as tuber yield per plant and per fed. In this regard, application of seaweed extract increased tuber yield per plant from 0.902 and 1.041 to 1.275 and 1.491 kg. and tuber yield per fed from 9.936 and 10.416 to 13.844 and 14.916 ton in both growing season respectively. With respect to the interaction effects, the data in tables (3 and 4) showed an additive effect on potato tuber yield parameters during the two growing seasons compared with the corresponding control. In this concern, tubers yield per plant was

significantly increased when the plants inoculated with effective microorganisms under addition of potassium fertilizers from 20 to 80 kg K<sub>2</sub>O/feddan and spraying plants with biostimulants, in particular, seaweed extract.

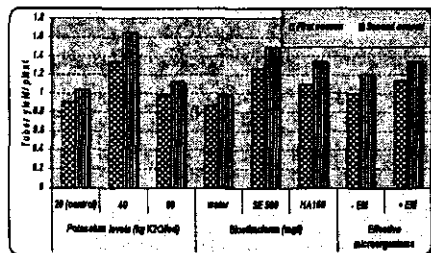


Figure (1): Tuber yield per potato plant (Kg) as affected by potassium fertilizer, biostimulants or effective microorganisms in both growing season

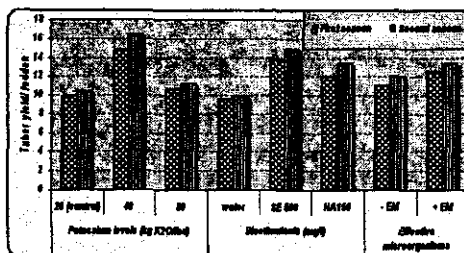


Figure (2): Tuber yield per feddan (ton) as affected by potassium fertilizer, biostimulants or effective microorganisms in both growing season (SE, Seaweed extract; HA, Humic acid)

Table (3): Tuber yield per potato plant (kg) as affected by the interactions between potassium fertilizer (A), effective microorganisms (B) and biostimulants (C) during the two growing season

Treatment	First season					
	- EM			+ EM		
	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>
Water	0.717	0.939	0.818	0.808	1.060	0.838
SE	0.979	1.484	0.990	1.040	1.879	1.171
HA	0.879	1.313	0.929	0.990	1.363	1.101
LSD 5%	A 0.047		B 0.0114		C 0.023	
	Second season					
Water	0.783	1.166	0.866	0.850	1.283	0.933
SE	1.166	1.849	1.166	1.199	2.183	1.383
HA	1.066	1.633	1.116	1.183	1.750	1.300
LSD 5%	A 0.082		B 0.013		C 0.028	
	ABC 0.070					

(K<sub>20</sub>, 20 kg K<sub>2</sub>O/ fed; K<sub>40</sub>, 40 kg K<sub>2</sub>O/ fed; K<sub>80</sub>, 80 kg K<sub>2</sub>O/ fed; SE, seaweed extract; HA, humic acid)

Data in the same tables showed that, plants inoculated with effective microorganisms and received 40 kg K<sub>2</sub>O per fed. then shoot spraying with seaweed extract gave higher values than that of control plants. This treatment significantly increased tuber yield per plant from 0.717 and 0.783 kg to 1.879 and 2.183 kg and tuber yield per fed. from 7.880 and 7.833 ton to 20.657 and 21.833 ton in both growing seasons respectively. It is worth mentioning that, an addition of 40 kg K<sub>2</sub>O/fed may be substituted by the inoculation with effective microorganisms and spraying plants with seaweed extract when used in combinations without significant reduction in the tuber yield.

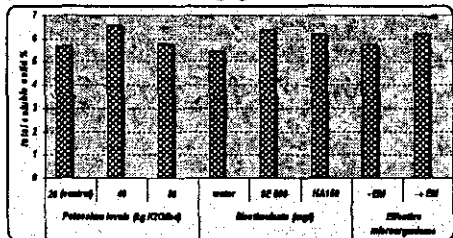
**Table (4):Tuber yield per fed. (ton) as affected by the interactions between potassium fertilizer (A), effective microorganisms (B) and biostimulants (C) during the two growing season**

Treatment	First season						
	- EM			+ EM			
	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>	
Water	7.880	10.327	8.993	8.880	11.657	9.217	
SE	10.770	16.327	10.880	11.550	20.657	12.880	
HA	9.657	14.437	10.217	10.880	14.997	12.107	
LSD 5%	A 0.578		B 0.144		C 0.259		ABC 0.634
Second season							
Water	7.833	11.666	8.666	8.499	12.833	9.333	
SE	11.666	18.499	11.666	11.999	21.833	13.833	
HA	10.666	16.333	11.166	11.833	17.499	12.999	
LSD 5%	A 0.829		B 0.130		C 0.287		ABC 0.703

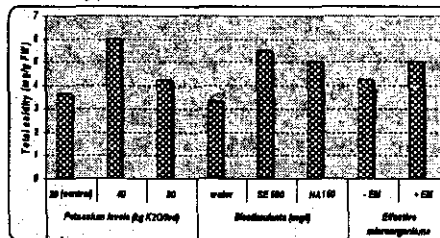
(K<sub>20</sub>, 20 kg K<sub>2</sub>O/ fed; K<sub>40</sub>, 40 kg K<sub>2</sub>O/ fed; K<sub>80</sub>, 80 kg K<sub>2</sub>O/ fed; SE, seaweed extract; HA, humic acid)

**Tuber quality:**

**Total soluble solids (TSS), total acidity, and specific gravity:** The effects of EM, biostimulants and potassium fertilizers as well as their combinations on the percentages of total soluble solids, total acidity and specific gravity of potato tubers during the second season are illustrated in figures (3,4,5) and presented in Table (5). Data revealed that studied characteristics were significantly affected by the application of EM, biostimulants and potassium fertilizers. The figures indicate that potassium fertilizer rate at 40 kg K<sub>2</sub>O/fed gave the highest values of total soluble solids, total acidity and specific gravity (6.533%, 5.973mg/g FW and 1.117 respectively) as compared with 20 kg K<sub>2</sub>O/fed represented as control plant (5.639%, 3.623 mg/g FW and 1.117 respectively).



**Figure (3): Total soluble solid of potato tuber as affected by potassium fertilizer, biostimulants or effective microorganisms in the second season**



**Figure (4): Total acidity of potato tuber as affected by potassium fertilizer, biostimulants or effective microorganisms in the second season (SE, Seaweed extract; HA, Humic acid)**

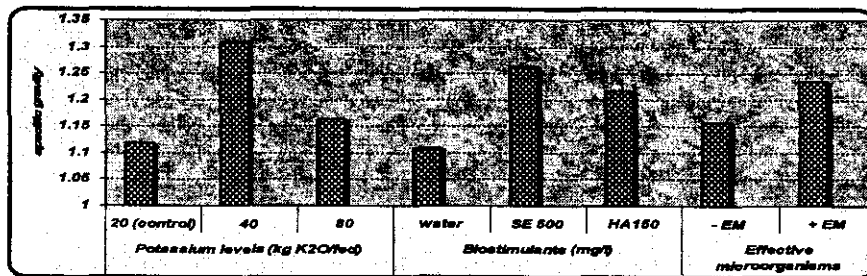


Figure (5): Specific gravity of potato tuber as affected by potassium fertilizer, biostimulants or effective microorganisms in the second season (SE, Seaweed extract; HA, Humic acid)

The data illustrated in the same figures clearly showed that application of both biostimulants significantly increased all studied characteristics as compared with untreated plants. The most effective treatment in this concern was seaweed extract which gave the highest values of total soluble solid percentage, total acidity (mg/g FW) and specific gravity (6.361, 5.505 and 1.264 respectively) as compared with control plants (5.417, 3.327 and 1.108 respectively). Inoculated potato plants with effective microorganisms increased total soluble solids, total acidity and specific gravity from 5.741, 4.22 and 1.157 to 6.201, 5.01 and 1.236 respectively.

Table (5): Total soluble solids, total acidity and specific gravity in potato tuber as affected by the interactions between potassium fertilizer (A), effective microorganisms (B) and biostimulants (C) at 115 days from planting during the second season

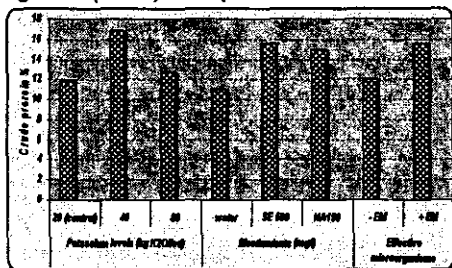
Treatment	Total soluble solid						
	- EM			+ EM			
	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>	
Water	4.833	5.500	5.167	5.333	6.333	5.333	
SE	6.000	7.000	6.000	6.167	6.833	6.167	
HA	5.167	6.500	5.500	6.333	7.033	6.333	
LSD 5%	A 0.4852		B 0.3152		C 0.3409		ABC NS
	Total acidity						
Water	2.434	4.017	2.800	2.434	5.113	3.165	
SE	4.139	6.696	4.383	4.748	7.227	5.844	
HA	3.530	6.331	3.652	4.505	6.452	5.600	
LSD 5%	A 0.1197		B 0.0896		C 0.1120		ABC 0.2743
	Specific gravity						
Water	1.047	1.111	1.076	1.052	1.234	1.127	
SE	1.116	1.359	1.174	1.206	1.471	1.261	
HA	1.103	1.326	1.105	1.178	1.358	1.234	
LSD 5%	A 0.1366		B NS		C 0.0793		ABC NS

(K<sub>20</sub>, 20 kg K<sub>2</sub>O/ fad; K<sub>40</sub>, 40 kg K<sub>2</sub>O/ fad; K<sub>80</sub>, 80 kg K<sub>2</sub>O/ fad; SE, seaweed extract; HA, humic acid)

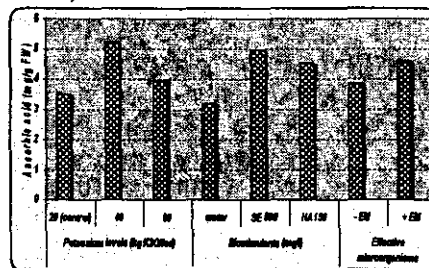
Regarding the interaction effects between potassium fertilizer rate, biostimulants spraying and effective microorganisms inoculation, the data presented in Table (5) indicated that all combinations insignificantly increased

total soluble solids and specific gravity. Meanwhile, they significantly increased total acidity in potato tuber. The most effective in this concern was inoculation with effective microorganisms and addition of 40 kg K<sub>2</sub>O/fed as well as spraying plant shoots with humic acid which increased total soluble solids from 4.833 to reach 7.033. On the other hand, the highest values for total acidity and specific gravity were obtained due to addition of 40 kg K<sub>2</sub>O/fed and inoculated potato plants with effective microorganisms beside the foliar spraying with seaweed extract. This treatment increased total acidity and specific gravity from 2.434 and 1.047 to 7.227 and 1.471 respectively.

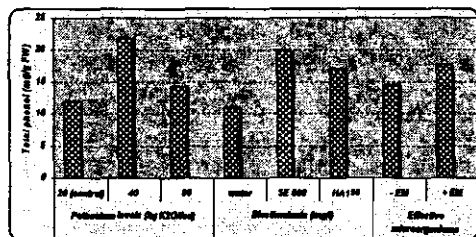
**Crude protein, ascorbic acid, phenol, soluble sugars and starch:** The effects of potassium fertilizer rates, inoculation with effective microorganisms and/or biostimulants foliar application as well as their interactions on crude protein (%), ascorbic acid concentration (mg/g FW), phenol concentration (mg/g FW), soluble sugars concentration (mg/g FW) and starch concentration (mg/g FW) of potato tubers plants during the second season are illustrated in figures (6-10) and presented in Tables (6 and 7).



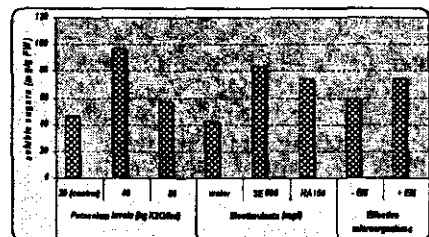
**Figure(6): Crude protein percentage in potato tuber as affected by potassium fertilizer, biostimulants or effective microorganisms in the second season**



**Figure(7): Ascorbic acid concentration (mg/gFW) in potato tuber as affected by potassium fertilizer, biostimulants or effective microorganisms in the second season**



**Figure(8): Total phenol concentration (mg/gFW) in potato tuber as affected by potassium fertilizer, biostimulants or effective microorganisms in the second season**



**Figure(9): Soluble sugar concentration (mg/g FW) in potato tuber as affected by potassium fertilizer, biostimulants or effective microorganisms in the second season**

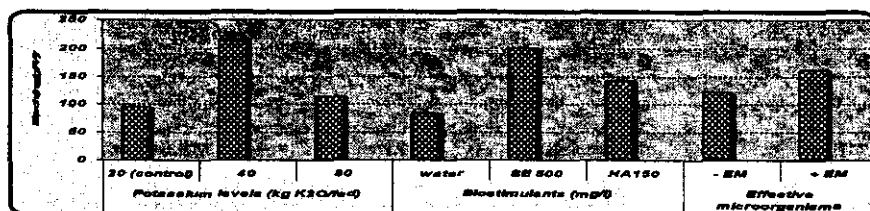


Figure (10): Starch concentration (mg/g FW) in potato tuber as affected by potassium fertilizer, biostimulants or effective microorganisms in the second season (SE, Seaweed extract; HA, Humic acid)

It is well noted from the figures that an addition of potassium fertilizer rate increased significantly crude protein percentage, ascorbic acid concentration, phenol concentration, soluble sugars concentration and starch concentration in potato tuber. The highest value for the quality characteristics was obtained due to addition of 40 Kg K<sub>2</sub>O/fed as compared with control plants having 20 Kg K<sub>2</sub>O/fed. Regarding the beneficial effects of biostimulants on crude protein percentage and concentration of ascorbic acid, phenol, soluble sugars and starch in potato tuber, the same figures clearly showed that application of biostimulants, in particular seaweed extract significantly increased the studied characteristics from 10.940 %, 3.181 mg/g FW, 11.093 mg/g FW, 42.253 mg/g FW and 83.516 mg/g FW to 14.913%, 4.515 mg/g FW, 17.038 mg/g FW, 74.029 mg/g FW and 142.378 mg/g FW respectively. Also, the inoculation of potato plants with effective microorganisms improved the potato quality due to a significant increase in all tuber quality characteristics under investigation.

Table (6): Crude protein percentage, phenol concentration (mg/g FW), ascorbic acid concentration (mg/g FW) in potato tuber as affected by the interactions between potassium fertilizer (A), effective microorganisms (B) and biostimulants (C) at 115 days from planting during the second season

Treatment	Crude protein %					
	- EM			+ EM		
	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>
Water	8.975	10.570	9.674	9.463	16.768	10.188
SE	10.873	18.548	11.388	16.545	18.841	17.506
HA	10.096	17.888	10.188	15.515	18.416	17.374
LSD 5%	A 2.5652		B 1.1140	C 1.8246		ABC 4.4692
Phenol concentration (mg/g FW)						
Water	7.456	13.288	9.699	8.757	16.900	10.461
SE	13.871	25.670	14.252	15.845	29.259	20.825
HA	11.763	21.117	12.570	14.320	24.212	18.247
LSD 5%	A 0.3537		B 0.3457	C 0.4731		ABC 1.1588
Ascorbic acid concentration (mg/g FW)						
Water	2.422	3.755	2.700	2.555	4.711	2.944
SE	3.944	5.722	4.166	4.533	6.155	5.278
HA	3.133	5.400	3.500	4.333	5.600	5.122
LSD 5%	A 0.1472		B 0.0647	C 0.0890		ABC 0.2183

(K<sub>20</sub>, 20 kg K<sub>2</sub>O/ fed; K<sub>40</sub>, 40 kg K<sub>2</sub>O/ fed; K<sub>80</sub>, 80 kg K<sub>2</sub>O/ fed; SE, seaweed extract; HA, humic acid)

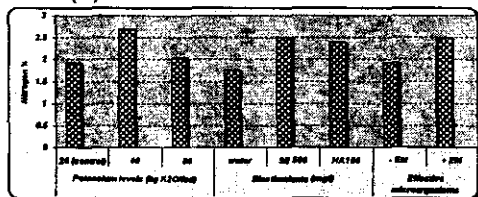
As regard to the interaction effects between potassium fertilizer rate, effective microorganisms and foliar application of biostimulants on crude protein percentage, and the concentration of phenol, ascorbic acid, soluble sugars and starch in potato tuber, the data presented in Tables (6 and 7) revealed that an addition of 40 Kg K<sub>2</sub>O/fed as soil addition plus inoculation with effective microorganisms theraffer, spraying the plants with seaweed extracts gave the highest values of studied characteristics as compared with untreated plants. since it significantly increased crude protein percentage, phenol concentration, ascorbic acid concentration, and soluble sugar as well as starch concentrations from 8.975%, 7.456 mg/g FW, 2.422 mg/g FW, 29.276 mg/g FW and 50.793 mg/g FW to 18.841%, 29.259 mg/gFW, 6.155 mg/g FW, 124.79 mg/g FW and 364.94 mg/g FW respectively.

**Table (7):Soluble sugars concentration (mg/g FW) and starch concentration (mg/g FW) in potato tuber as affected by the interactions between potassium fertilizer (A), effective microorganisms (B) and biostimulants (C) at 115 days from planting during the second season**

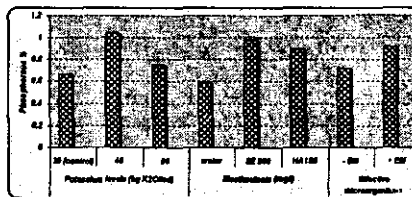
Treatment	Soluble sugars (mg/g FW)					
	- EM			+ EM		
	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>
Water	29.276	50.071	34.359	32.491	67.670	39.654
SE	51.765	117.32	56.579	62.914	124.79	88.695
HA	41.676	106.77	44.949	60.083	113.60	77.086
LSD 5%	A 2.0226		B 1.3155	C 1.4802		ABC 3.6259
Treatment	Starch (mg/g FW)					
	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>
	Water	50.793	104.19	64.040	62.114	148.68
SE	114.64	279.38	122.80	136.44	364.94	182.18
HA	78.673	195.97	84.450	129.96	206.05	159.15
LSD 5%	A 20.305		B 6.2133	C 9.287		ABC 22.750

(K<sub>20</sub>, 20 kg K<sub>2</sub>O/ fed; K<sub>40</sub>, 40 kg K<sub>2</sub>O/ fed; K<sub>80</sub>, 80 kg K<sub>2</sub>O/ fed; SE, seaweed extract; HA, humic acid)

**Ion percentage in the tubers:** The effects of potassium fertilizer and/or effective microorganisms on nitrogen, phosphorus and potassium percentages in potato tubers at harvesting; 105 days from planting during the second growing season are illustrated in figures (10,11,12) and presented in table (8).



**Figure (11): Nitrogen percentage in potato tuber as affected by potassium fertilizer, biostimulants or effective microorganisms in the second season**



**Figure (12): Phosphorous percentage in potato tuber as affected by potassium fertilizer, biostimulants or effective microorganisms in the second season**

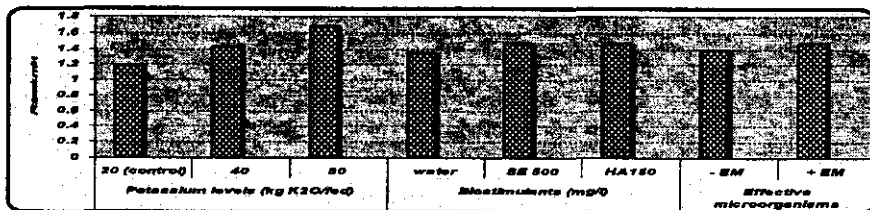


Figure (13): Potassium percentage in potato tuber as affected by potassium fertilizer, biostimulants or effective microorganisms in the second season (SE, Seaweed extract; HA, Humic acid)

The data indicated that increasing potassium fertilizer rates from 20 to 80 kg K<sub>2</sub>O/fed significantly increased nitrogen, phosphorous and potassium percentages in potato tuber, and the highest values for nitrogen and phosphorous percentage were obtained due to an addition of 40 kg K<sub>2</sub>O/fed. On the other hand, the highest potassium percentage was obtained due to an addition of the highest rate of potassium fertilizer (80 kg K<sub>2</sub>O/fed). Concerning the effects of foliar spraying with either seaweed extract or humic acid on tuber ion percentage comparing with control, the figures (10,11,12) clearly showed that foliar application of biostimulants significantly increased ion percentage in potato tuber.

Table (8): Nitrogen, potassium and phosphorous percentage in potato tuber as affected by the interactions between potassium fertilizer (A), effective microorganisms (B) and biostimulants (C) during the second season (SE, Seaweed extract; HA, Humic acid)

Treatment	Nitrogen					
	- EM			+ EM		
	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>	K <sub>20</sub>	K <sub>40</sub>	K <sub>80</sub>
Water	1.436	1.691	1.548	1.514	2.683	1.630
SE	1.739	2.967	1.822	2.647	3.014	2.801
HA	1.615	2.862	1.630	2.482	2.979	2.780
LSD 5%	A 0.3988		B 0.1761		C 0.2898	
	Phosphorous					
Water	0.434	0.693	0.453	0.448	1.014	0.519
SE	0.708	1.134	0.773	0.984	1.193	1.050
HA	0.517	1.076	0.672	0.923	1.120	1.025
LSD 5%	A 0.0671		B 0.0314		C 0.0507	
	Potassium					
Water	1.044	1.346	1.539	1.128	1.414	1.649
SE	1.212	1.439	1.649	1.321	1.481	1.800
HA	1.178	1.464	1.716	1.304	1.472	1.750
LSD 5%	A 0.0553		B NS		C 0.0334	
	ABC NS					

(K<sub>20</sub>, 20 kg K<sub>2</sub>O/ fed; K<sub>40</sub>, 40 kg K<sub>2</sub>O/ fed; K<sub>80</sub>, 80 kg K<sub>2</sub>O/ fed; SE, seaweed extract; HA, humic acid)

The highest percentage of ions in potato tuber was obtained due to spraying potato shoot with seaweed extract. This treatment increased nitrogen, phosphorous and potassium percentages from 1.750, 0.593 and 1.353% to 2.498, 0.974 and 1.484 % respectively. It was also revealed from the figures

that inoculation of potato plants with effective microorganisms significantly increased the percentage of nitrogen (2.503%) and phosphorous (0.919%) and insignificantly increased potassium (1.480%) percentage in potato tuber as compared with untreated plants (1.923, 0.718 and 1.399% respectively).

Regarding the interactions between potassium fertilizer rates, biostimulants foliar spraying and effective microorganism's inoculation, the data presented in table (8) proved that all interactions significantly increased nitrogen and phosphorous in potato tuber. The highest percentages were obtained due to an addition of 40 kg K<sub>2</sub>O/fed beside inoculation of potato plants with effective microorganisms then foliar spraying the potato shoots with seaweed extract. This treatment increased the percentage of nitrogen and potassium from 1.436 and 0.434% to 3.014 and 1.193% respectively. The data in the same table showed that potassium percentage in potato tuber insignificantly increased due to effective microorganism's inoculation and spraying plants with biostimulants in particular seaweed extract and an addition of the potassium fertilizer. The highest percentage (1.800%) was obtained due to an addition of 80 kg K<sub>2</sub>O/fed, inoculated with effective microorganisms and seaweed extract spraying as compared with untreated control plants (1.044%).

**Economic considerations:**

Data in Table (9) indicated that addition of potassium fertilizer rates, inoculated potato plants with effective microorganisms and foliar application of biostimulants as well as their interactions increased the economic consideration relative to that of control.

**Table (9): Comparative analysis of various treatments for their potential to give an optimum economic yield**

Treatment		Constant cost	Variable cost	Total cost	Total income	Net income	Investment rate	
K20	-EM	W (1)	163.17	0	163.17	176.25	13.08	0.080
		SE (2)	163.17	1.566	164.736	263.25	98.514	0.598
		HA (3)	163.17	11.25	174.42	240	65.58	0.375
	+EM	W (4)	163.17	4.50	167.67	191.25	23.58	0.140
		SE (5)	163.17	6.066	169.236	270	100.764	0.595
		HA (6)	163.17	15.75	178.92	266.25	87.33	0.488
K40	-EM	W (7)	163.17	1.491	164.661	262.5	97.839	0.594
		SE (8)	163.17	3.057	166.227	416.25	250.023	1.504
		HA (9)	163.17	12.741	175.911	367.5	191.589	1.089
	+EM	W (10)	163.17	5.991	169.161	288.75	119.589	0.706
		SE (11)	163.17	7.557	170.727	566.25	395.523	2.316
		HA (12)	163.17	17.241	180.411	393.75	213.339	1.182
K80	-EM	W (13)	163.17	2.997	166.167	195	28.833	0.173
		SE (14)	163.17	4.563	167.733	262.5	94.767	0.564
		HA (15)	163.17	14.247	177.417	251.25	73.833	0.416
	+EM	W (16)	163.17	7.497	170.667	210	39.333	0.230
		SE (17)	163.17	9.062	172.232	311.25	139.018	0.807
		HA (18)	163.17	18.747	181.917	292.5	110.583	0.607

The data presented in the same Table clearly proved that addition of potassium fertilizer rate up to 80 kg K<sub>2</sub>O/fed increased all economic characters represented as total cost, total income, net income and investment

rate. Addition of 40 kg K<sub>2</sub>O/fed gave the highest values 174.661, 262.5, 97.839 and 0.594 LE relative to control or high potassium fertilizer rate. Inoculated potato plants with effective microorganisms increased total income, net income and investment rate from 176.25, 13.08 and 0.080 to 191.25, 23.58 and 0.140 LE.

Regarding the effect of both biostimulants, the data in Table (9) proved that application of either seaweed extract or humic acid increased the total income, net income and investment rate as compared to untreated plants. Seaweed extract was more effective than humic acid which increased total income, net income and investment rate from 176.25, 13.08 and 0.080 to 263.25, 98.514 and 0.598 LE. Regarding the interactions effect, the data presented in Table (9) indicated that all interactions having a positive effect on increasing all economic consideration. The data indicated that foliar application of seaweed extract with or without addition of effective microorganisms under all potassium fertilizer rates gave the higher values than humic acid application under the same conditions. The highest values were obtained due to foliar application of seaweed extract with effective microorganisms and addition of 40 kg K<sub>2</sub>O/fed; this treatment gave the highest total income (566.25 LE compared with control 176.25 LE) and net income (395.525 comparing with control 13.08LE) as well as high rate of investment (2.316) as compared with control (0.080).

## **DISCUSSION**

### **Tuber yield:**

An increase in potato yield as indicated in the present investigation due to applying potassium was reported by Radwan *et al.* (2011) who indicated that potassium fertilization in potato resulted in significant increase in tuber yield. The role of K in increasing the yield and its components might be attributed to its function in plants which includes energy metabolism and enzyme activation on exchange rate and nitrogen activity as well as enhanced carbohydrates movement from shoot to storage organs (Marschner 1997). Moreover, potassium application enhanced the stomatal resistance coupled with reduced transpiration rate and increased relative water content, thus, may improve water storage capacity of the cells and providing favorable conditions for better yields (Umar and Bansal 1995).

Concerning the effect of effective microorganisms, Lin (1991) indicated that soils that are treated with EM became more friable, less compact and better drained. These providing a more favorable environment for crop growth and tuber production. Similarly, In a field experiment Sherchand (2000) observed 15-20% and 3-12 % increase in rice and wheat yield by EM applications. The enhancing effect of EM on yield and its component may be attributed to one or more of the following factors: improving root growth and functions and enhancing mineral uptake in the plant (Stancheva *et al.* 1995), producing the phytohormones indole acetic acid, gibberellins and cytokinin, also reduce of abscisic acid, these phytohormones, particularly IAA, play an essential role in plant growth stimulation (Kawthar *et al.* 2002) and producing amino acids as well as

phenolic compounds (El-Morsi *et al.* 2000). The increase of tuber numbers and tuber dry weight (g) per plant may be due to the EM application stimulated plant roots, absorption of nutrients and photosynthesis process which led to produce vigorous plants, numerous tubers, bigger tuber size and total tuber yield (Hammad and Abdel-Ati 1998).

The influence of humic acid on plant growth and yield, have been investigated on biometric factors and numerous studies have shown that humic substances enhance plant growth, increased grain yield and its quality in various cereal crops (Radwan *et al.* 2011). The positive responses of yield of potato to application of humic acid have reported earlier (Zhang and Ervin 2004). The favorable effect of foliar spraying of humic acid on the crop yield was attributed to the increased content of chlorophyll in the leaves and enhanced photosynthetic activity and higher uptake of nutrients like P (Senthilkumar 1995). The mechanism of humic acid which stimulate plant growth, yield and quality is not fully clear, although there are some theories which probably work together. a) Application of HA stimulate root growth, increase proliferation of root hairs, production of smaller but more ramified secondary roots and enhancement of root initiation (Canellas *et al.* 2002). b) The positive effect of humic on plant growth and productivity, which seem to be mainly due to hormone-like activities of the humic acids through their involvement in cell respiration, photosynthesis, oxidative phosphorylation, protein synthesis and various enzymatic reactions (Muscolo *et al.* 1999).

The enhanced effect obtained by seaweed extract may be brought about by more assimilates going to the tubers and/or more enhancement in sink strength of the tubers to attract more water and assimilates due to higher concentrations of promoting substances. Similar results with application of seaweed extract are reported (Ezzat *et al.* 2011, Zodape *et al.* 2011). Increase in yield and yield attributes may be due to the presence of plant growth regulators in the extract. In this concern, seaweed (*Ascophyllum nodosum* (L.) Le Jolis] extract has been shown to contain biologically active concentrations of natural cytokinins such as trans-zeatin riboside (t-ZR) and isopentenyl-adenine (Zhang and Ervin 2004).

#### **Tuber quality:**

Results of the present experiment and others indicated that potassium nutrition influences tuber size, specific gravity, reducing sugar content and storage quality (Karam *et al.* 2009, and Rai *et al.* 2010). With a shortage of potassium many metabolic processes are affected, like the rate of photosynthesis, thereafter of translocation and enzyme systems (Marschner 1997). Moreover, potassium enhanced quality as it facilitates the uptake and assimilation of nitrogen into simple amino acids and amide which favor peptide synthesis leading to protein synthesis. Potassium improves the transfer of radiation energy into primary chemical energy in the form of ATP (Photophosphorylation) and NADPH. This energy is required for all synthetic process in plant metabolism, resulting in production of carbohydrates, proteins, and lipids, which express the quality of the crops. The high energy status in crops well supplied with potassium also promotes synthesis of secondary metabolites, like vitamin C (Mengel 1997). Potassium plays an important role in the transport of assimilates and nutrients (mainly sucrose) to

the tuber (Mengel 1997). It is generally agreed that starch content is enhanced by potassium application, so long as this is to correct potassium under-nutrition, whilst heavy doses of potassium may decrease starch content (Martin-Prevel 1989). In order to receive chips with a desirable light color, soluble sugars content of potato should not exceed 0.25% (Perrenoud 1993). Accumulation of soluble sugars and decrease of starch in potato tubers are the cause of undesired dark-colored potato chips which occur under low potassium nutrition level (Perrenoud 1993). Concerning the ion percentage in potato tuber, there are many reports agree with the observations in the present study which indicated that addition of potassium fertilizer increased the percentage of ions in the tuber (Karam *et al.* 2009). As regard to protein, carbohydrate and ascorbic in potato tuber, there are many reports indicate that, in most cases, application of potassium fertilizers increased tuber quality represented as protein, carbohydrates and ascorbic acid. This observation was agreement with some authors i.e. Ahmed *et al.* (2009) and Rai *et al.* (2010). The specific gravity is a measure of quality in potato tuber which is related to the dry matter contents in the tubers. The specific gravity was more in potato tubers harvested from potassium treated plants (Malik 1995). Potatoes with high specific gravity are preferred for preparation of chips and French fries.

The obtained results related to the positive effect of EM inoculation on tuber quality are in agreement with those found by Mohamed, Faten (2007) who reported that application of EM increased significantly TSS%, TSS/acid ratio but decreased acidity% and total carbohydrates content. Ascorbic acid (AsA) plays important roles in the human organism, such as conjunctive tissue formation, ion transportation, and cell protection against free radicals. The beneficial effects of EM on increasing tuber protein may be attributed to their effects on reducing nitrate concentration in the tubers. This reduction may be inducing the accumulation and utilization of nitrate in plant to produce proteins (Hanafy Ahmed *et al.* 2002). It is important here to mention that the beneficial effects of EM inoculation with appropriate strains might be attributed to increase; 1) the symbiotic N fixation in the soil, 2) levels of free amino acids in the cell-sap, development and physiological enzymatic activity and growth rate of roots (Ghallab and Salem 2001). Inoculation with EM enhanced the plant growth and nutrients uptake (El-Shahawy 2003). The increase of phosphorus content in potato tubers due to the interaction between bio-fertilizers may be attributed to their effects on the availability of soil phosphorus which caused an increase in absorbing various nutrients (El-Agroudi *et al.* 2003). The increase in tubers potassium content under EM reflects an enhanced growth which might be possibly due to the role of microorganisms in supplying great amounts of both water-soluble and amorphous potassium which was reflected in plant uptake (Afify and Bayoumy 2001). It could be concluded that, the increasing values of nitrogen, phosphorus and potassium as a result of inoculation with EM used under different doses of NPK may be due to the favorable effect of EM on the absorbing various corresponding nutrients during the two growing seasons.

The favorable influences of seaweed extract on chemical characteristics of potato tuber may be ascribed to its simulative effect on

photosynthesis process and its concentration of some promoter hormones such as cytokinin which is closely involved in cell division, protein, carbohydrates and chlorophylls formation (Featonby-Smith and Van Standen 1984). The increase in the protein content might be due to absorption of most the necessary elements by the seedlings (Sivasankari *et al.* 2006). Recently, Ezzat *et al.* (2011) on potato found that foliar application of seaweed extract with 50% NPK fertilizer significantly increased yield characters i.e. specific gravity and starch and reduced reducing sugars. Zodape *et al.*, (2011) found that, foliar application of seaweed extract led to an increase in tomato yield and yield contributing characters in almost all concentrations, as well as fruit quality. Enhancement in vitamin C of *Trigonella foenum-graecum* (Khemnar and Chaugule (2000), increase in N of beans (Beckett *et al.* 1994) and carbohydrates, protein, vitamin C and ions in tomato plant (Zodape *et al.* 2011) has been reported for plants treated with seaweed extract.

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**إستجابة نوعية وكمية درنات نبات البطاطس وبعض القياسات الاقتصادية للمنشطات الحيوية أو الكائنات الدقيقة الفعالة تحت تأثير التسميد البوتاسي**  
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زيادة التسميد البوتاسي حتى ٨٠ كجم بصورة أكسيد بوتاسيوم للفدان تزيد معنويا محصول البطاطس مع تحسين جودة بالإضافة لزيادة صافي الربح ومعدل الإستثمار. وكانت أعلى القيم بإستخدام ٤٠ كجم أكسيد بوتاسيوم للفدان خلال موسمي الزراعة مقارنة بالكنترول. الرش بالمنشطات الحيوية خاصة مستخلص الطحالب يزيد معنويا المحصول مع تحسين جودة مع زيادة صافي الدخل ومعدل الإستثمار مقارنة بالكنترول بكلا موسمي الزراعة. تلقح التربة بالكائنات الدقيقة الفعالة تزيد معنويا محصول وجودة نبات البطاطس مع زيادة صافي الدخل ومعدل الإستثمار. بالنسبة للتداخل بين عوامل الدراسة، وجد أن رش النباتات بالمنشطات الحيوية خاصة مستخلص الطحالب يزيد محصول النبات ويحسن جودة مع زيادة صافي الدخل ومعدل الإستثمار تحت مستويات البوتاسيوم جميعا في وجود أو غياب الكائنات الدقيقة الفعالة. يمكن التوصية بأنة يمكن الحصول علي اعلي محصول وصفات جودة للدرنات بإضافة ٤٠ كجم اكسيد بوتاسيوم في وجود الكائنات الدقيقة الفعالة ورش النباتات بمستخلص الطحالب بتركيز ٥٠٠ ملليجرام/لتر.

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