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Studies on Improving Potato Growth, Yield and Quality

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Abstract

Two field experiments were carried out to study the effect of some stimulant substances, *i.e*., benzyladenine at 25, 50 ppm and blue green algae "*Spirulina platensis*" extract at 0.3, 0.6 % as well as yeast extract at 5, 10 % as individual treatments on growth and yield traits in addition to anatomical and chemical constituents of *Solanum tuberosum* L. The results showed a significant improving in the most of vegetative growth and yield characteristic with applied treatments compared with the control. Consequently, treating potato plants with spirulina algae extract at 0.6 or 0.3 % or yeast extract at 10 %, respectively three times lead to obtain vigorous vegetative growth of *Solanum tuberosum* L. plant with increasing in both of tuber yield and its quality characteristics.

Key words: potato, benzyladenine, algae extract, yeast extract, growth, anatomy, phytohormones, yield and tuber quality.

Introduction

Potato is one of the important vegetable crops in Egypt (**Ahmed, 1994**). It is consider fourth largest in the world, after rice, wheat and Maize (**Ewing, 1997**). It is from the richest starchy vegetable crops in terms of energy and nutritional value, it contains a high carbohydrates level and large amounts of vitamins B and C, minerals, fiber, fats and protein (**Bach *et al*., 2012)**. Potato is used in several food industries as starch production and alcohol, chips making as well as fried and half-fried potato (**Abdel-Aal *et al.*, 1977**). Furthermore, potato is contributing in the economy pushing forward through exports as well as it is generating large foreign exchange revenue in addition to the local market needs (**Pervez *et al.*, 2000**). Researchers are now turning to use modern technologies for increasing production quantity and quality in order to fill the nutritional gap resulting from the population steady increasing *viz*., utilization of biological fertilizers, natural extracts and growth regulators. Growth regulators are considered one of the most important factors which should be taken in consideration for increasing potato production and tuber quality. Growth regulators are used for increasing production or activate branching which increase vegetative growth which leads to increasing yield. In this respect, benzyl-adenine is plant growth regulators (cytokinins). It is an important plant hormone regulating various processes of plant growth and development including cell division and differentiation, enhancement of leaf expansion and nutrient mobilization as well as increases yield and improves crop quality (**Davies, 1995).** However, benzyladenine affect plant growth and development and, also implicated in the synthesis of secondary metabolites, vascular development, influences chlorophyll biosynthesis and chloroplast differentiation (**Duszka *et al.*, 2009).** When exogenously applied, it increases plant height (**Letham, 1969)**, leaf area (**Abdullah *et al.*, 1986)** and branching (**Hrotko *et al.*, 1996)**. Moreover, the stem end contains an apical bud which causes apical dominance when the stem apex prevents the growth of lateral shoots so that the plant can grow vertically. Once the apical dominance released, elongation and lateral growth is promoted and the lateral buds grow into new branches. The role of cytokinins in lateral growth could be defined into stages, e.g., 1) cytokinin promote lateral bud growth via cell division; 2) auxin is promoted resulting in apical dominance ("imposition of inhibition"); 3) cytokinin released resulting in outward growth of the lateral bud; and then 4) auxin is decreased and gibberellic acid is promoted which results in cell division, enabling the bud or branch to continue outward growth (**Cline, 1994**). Shoot branching from axillary buds is regulated by a network of inhibitory and promotive forces, which includes hormones (**Domagalska and Leyser, 2011**). Developmental stages of bud outgrowth are likely associated with checkpoints for feedback regulation and hence enable the homeostasis of shoot number. These stages may also account for the observation that buds at different locations show different responses to signals such as auxin and cytokinin (**Dun et al 2006**). Whereas, **Cline (1994)** stated that auxin appears to inhibit axillary bud outgrowth whereas cytokinins will often promote it while, the manipulation of endogenous hormone levels has demonstrated powerful effects of auxin and cytokinin on axillary bud outgrowth.

As for yeast treatment, it is suggested to have a beneficial role during growth and yield due to cytokinins content (**Barnett *et al.*, 1990),** cell division stimulation, enlargement and synthesis of protein, nucleic acids and chlorophyll (**Fathy and Farid, 1996)**, in addition to its contents of protective components, *i.e*., sugars, proteins, amino acids and several vitamins (**Shady, 1978**). Improving growth and yield and overall quality of horticultural plants by yeast application was reported by **Gomaa *et al.*, (2005), Hussain and Khalaf (2007), Ahmed *et al.*, (2011) and El-Desouky *et al.*, (2011) and Taha and Helal (2019).** Concerning to algae extract the beneficial effects of algae extract is a result of many components that may work synergistically at different concentrations **(Fornes *et al.*, 2002). Also,** algae have contains high levels of organics , micro elements, vitamins, amino acids in addition to growth regulators such as auxins, cytokinin and gibberellins (**Blunden, 1991; Crouch and Van Staden, 1994 and Khan *et al.*, 2009)**. In this respect, **El-Sheekh and El- Saied, (1999)** stated that the crude extracts of algae increase protein content in foliage, total soluble sugars and chlorophyll in faba bean leaves. Foliar spray with algae extract has been shown to enhance plant growth, yield and its quality on watermelon **(Featonby and Van Staden, 1983; Sivasankari *et al.*, 2006** and **Abdel Mawgoud *et al.*, 2010),** celeriac plant (**Shehata *et al.*, 2011),** ananas melon (**Abd El-Aal, 2012)** and garlic **(Osman, 2015)**. Hence, the aim of our research is to study the effect of cytokinin in reduces apical dominance and improving vegetative growth characteristics, tubers yield and quality of potato using some environmentally friendly natural extracts.

Material and Methods

A field experiment was carried out during two successive summer seasons of 2017 and 2018 at Kaha Vegetable Research Farm, Qalyubia Governorate. The soil was clay loam in texture with pH 7.49, EC 1.94 dS.m^{-1}. Experiment soil physical and chemical analyses (Table 1) were determined according to procedures described by **Jackson (1973)**. Good quality potato (*Solanum tuberosum* L.) cv. Picasso seed tubers were used in both seasons. Tubers were planted at a distance of 30 cm apart on January 27 and 26 of 2017 and 2018, respectively. All agricultural practices were performed as recommended by Ministry of Agriculture and Land Reclamation.

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

			Chemical properties		
	2017	2018		2017	2018
Sand %	18.95	19.17	Available N mg l^{-1}	85.56	76.77
Silt %	17.25	19.09	Available P mg l^{-1}	6.13	4.63
Clay %	59.78	60.00	Available K mg l^{-1}	189.44	200.76

The experiment treatments:

The experiment included seven treatments with three replicates arranged in a randomized complete blocks design, *i.e*., 25, 50 ppm of benzyladenine (BA); 0.3, 0.6 % of algae extract; 5, 10% of yeast extract and control (distilled water), were sprayed three times using atomizer at 30, 45 and 60 days after planting along with triton B as a wetting agent at 0.1% to improve adherence of the spray to the plant foliage for increasing absorption by the plants. Each experimental plot (12 m^2) contained four ridges; each was 4 meter in length and 0.75 meter in width. Each plot received 1.5 - 2 liter solution of each concentration according to the age of the plant. The untreated plants (control) were sprayed with tap water and spreading agent. One line was left between each two experimental plots without spraying as a guard row to avoid the overlapping of spraying solution. *Spirulina platensis* algae powder was obtained from Algal Biotechnology Unit, National Research Center, Dokki ,Giza , Egypt, , while both benzyladenine ($C_{12}H_{11}N_5$) and yeast (*Saccharomyces cerevisiae*) were obtained from El-Gomhoria Company for Chemicals, Egypt.

Extracts Preparing:

Yeast extract was prepared from active dry yeast according to the method of **Morsi *et al*. (2008)** by dissolving amount of dry yeast in water followed by adding sugar at a ratio of 1:1 and kept 24 hours in a warm place for reproduction. Algal aqueous extract was prepared by macerating 100 g of *S. platensis* powder with 1000 ml of distilled water. This mixture was then placed on intermittent agitation for 24 hours, and Supernatant was separated and treated as an algal filtrate (100%) and then foliarly applied to the plants as an aqueous solution at both different concentrations (0.3 and 0.6%, v/v). Chemical composition of both *Spirulina platensis* and yeast extracts are shown in Table (2).

Sampling and Collecting Data

Five plants from each replicate were randomly taken at 75 days after planting (DAP) and then separated into their organs and the following characteristics were recorded: Plant length (cm), main stems number, lateral stems number, leaves number, fresh and dry leaves weight (g), fresh and dry stems weight (g) and leaf area (cm^2). Determination of photosynthetic pigments in *Solanum tuberosum* L. leaves *i.e*., chlorophyll A, B, A+B and carotenoids mg g^{-1} FWt. were calorimetrically determined according to **Wettestein (1957).** Endogenous phytohormones *i.e*., gibberellins, auxins, cytokinins and total promoters as well as salicylic acid were quantitatively determined in potato shoot at 75 days after planting during season of 2018 using High Performance Liquid Chromatography (HPLC) according to **Koshioka *et al.*, (1983)** for auxins (IAA), gibberellins, salicylic Acid and abscisic acid (ABA) while cytokinins were determined according to **Nicander *et al.*, (1993)**.

Table 2. Chemical composition of *Spirulina platensis* and yeast

Composition	Spirulina	Yeast
Protein (%)	56.79	5.3
Carbohydrates (%)	13.60	4.7
Essential amino acids (mg/100 g)		
Leucine	29.11	3.09
Phenylalanine	23.78	2.01
Lysine	19.10	2.95
Valine	18.40	2.19
Isoleucine	14.12	2.31
Threonine	13.59	2.09
Histidine	13.46	2.63
Methionine	5.31	0.72
Non-Essential amino acids (mg/100 g)		
Glutamic acid	47.03	2
Arginine	44.91	1.99
Aspartic	36.69	1.33
Alanine	33.8	1.51
Cysteine	3.30	0.23
Tyrosine	19.74	1.49
Serine	18.43	1.59
Glycine	15.0	1.35
Proline	14.88	1.53
Vitamins (mg/100 g)		
Niacin	15.0	0.029
Vitamin B1	4.8	2.23
Vitamin B2 Riboflavin	5.5	1.33
Vitamin B6	0.8	1.25
Vitamin B12	0.36	0.15
Inositol	70	0.26
Folic acid (µg/100 g)	71	1.43×10^3
Pantothenic acid	0.2	7.82

All Chemical composition of yeast after **Mahmoed (2001)** except niacin, folic acid (µg/100g) and Pantothenic acid according **to Xi *et al*., 2019.** Amino acids and Vitamins for alga after **El-Moataaz *et al*., (2019)** and **Liestianty *et al.* 2019, respectively**

Anatomical studies:

It was intended to carry out a comparative anatomical study on stems and leaves of treated potato plant at 75 days after planting (DAP) during 2018 season and those of the control. Specimens of stems were taken from main stem fifth apical internode while, those of the leaves were taken from the certain leaf of the 4th apical leaf on the main stem. These vegetative specimens were then killed and fixed in F.A.A. (10 ml formalin, 5 ml glacial acetic acid and 85 ml 70% ethyl), washed using 50% ethyl alcohol, dehydrated in a series of ethyl alcohols 70, 90, 95 and 100%, infiltrated in xylene embedded in paraffin wax with a melting point 60-63°C, sectioned 12 µ in thickness for stem and 15 µ for the leaf (**Sass, 1951)**, stained with the double stain method (Fast green and safranin), cleared in xylene and mounted in Canada balsam (**Johanson, 1940).** Four sections of each treatment were microscopically inspected to detect histological manifestations of noticeable responses resulted from treatments. Counts and measurements (µ) were taken using a micrometer eye piece. Averages readings from 2 slides per treatment were calculated.

At harvest time (120 DAP), tubers yield of five randomly plants/plot were taken for estimating the following characteristics: tubers number and tubers fresh weight (g) ، in addition to both dry matter (%) and starch content of tubers according to **A.O.A.C. (1990**) and specific gravity (%) as **Murphy and Goven (1959**). Total nitrogen was determined in the digested tubers dry matter using micro-kjeldahl method according to methods described by **Pregl (1945)**. Also, Phosphorous was estimated according to the method described by **Murphy and Riley (1962)** modified by **John (1970)** and Potassium was determined by the flame-optical method as described by **Brown and Lilleland (1946)**. The total protein content was calculated by multiplying the nitrogen % in tuber with the conversion factor of 6.25 (**Ranganna, 1977**).

Statistical Analysis: The obtained data in both seasons were subjected to analysis of variance as a simple experiment in a randomized complete block design. The differences between means were evaluated using LSD according to **Snedecor and Cocharn (1980)**.

Results and Discussion

Vegetative growth and photosynthetic pigments content:

Data in Table (3) clearly show the effect of the foliar spray treatments of benzyladenine, *Spirulina* alga extract and yeast extract on vegetative growth characteristics of potato plant at 75 DAP during the two growing seasons of 2017and 2018 compared with the control. In this respect, the solely treatments of 0.6% algae extract followed by 0.3% algae extract, 10% yeast extract and 50 ppm benzyladenine(BA) recorded the highest values of vegetative growth parameters of potato plant. These results are of great interest, as at this stage of growth great simulative effects existed with applied treatments. Hence, that could be prolonged to the advanced stage of the final tubers yield and quality of yielded tubers. In addition, increment of haulm (stems and leaves) fresh and dry weights due to leaves number and total leaf area. Increment of leaf (number and area) could be reflected upon the efficiency of photosynthesis by more assimilates accumulating and high rates of translocation toward tubers. Also, it could be observed that increase of this area was preceded with high number of leaves as well. Moreover, alga extract treatment suggested to participate beneficial roles due to its high levels of organic matter, micro nutrients, vitamins, amino acids and also, rich in growth regulators such as auxins, cytokinin and gibberellins (**Blunden, 1991; Crouch and Van Staden, 1994 and Khan *et al.*, 2009)** and that may work synergistically at different concentrations (**Fornes *et al.*, 2002)**. Foliar application with algae extract has already been shown to improve plant growth by **Featonby and Van Staden (1983), Sivasankari *et al.*, (2006), Abdel Mawgoud *et al.*, (2010**) on watermelon, **Shehata *et al.*, (2011)** on celeriac plant and **Abd El-Aal (2012)**. On the other hand, yeast extract known to have stimulative effects on plant growth due to cytokinins content (**Barnett *et al.*, 1990)** and improves carbohydrates accumulation (**Winkler *et al.*, 1962),** cell division and enlargement, protein and nucleic acid synthesis (**Fathy and Farid, 1996)**.

Table 3. Effect of foliar application treatments on morphological traits of potato plant at 75 days after planting during 2017 and 2018 seasons.

Item	Plant length (cm)	Number plant			Leaf area (cm^2 plant)	Fresh weight (g plant)		Dry weight (g plant)	
		Leaves	Main stems	Lateral stems		Leaves	stems	Leaves	Stems
					Season 2017				
Control	**50.22**	**82.22**	**3.00**	**20.44**	**2062.6**	**237.96**	**112.62**	**18.84**	**13.02**
25 ppm BA	**52.00**	**99.13**	**3.00**	**21.33**	**2855.5**	**258.60**	**121.30**	**20.54**	**16.42**
50 ppm BA	**57.32**	**100.22**	**3.00**	**23.44**	**3003.8**	**260.41**	**122.62**	**24.31**	**17.40**
5% Yeast	**56.21**	**100.28**	**3.00**	**21.11**	**2509.4**	**251.57**	**118.94**	**20.08**	**15.09**
10% Yeast	**59.50**	**104.50**	**4.22**	**24.99**	**3282.1**	**261.35**	**125.01**	**24.52**	**18.10**
0.3 % Algae	**63.42**	**102.72**	**3.33**	**25.10**	**3360.3**	**275.18**	**126.54**	**24.58**	**19.25**
0.6% Algae	**62.22**	**106.11**	**4.10**	**26.22**	**3387.2**	**276.33**	**126.91**	**25.86**	**19.77**
L.S.D. 5%	**0.96**	**0.92**	**0.11**	**1.97**	**156.3**	**5.99**	**5.83**	**1.48**	**0.53**
					Season 2018				
Control	**45.77**	**79.22**	**2.83**	**17.99**	**2110.7**	**220.15**	**100.12**	**19.34**	**14.28**
25 ppm BA	**53.77**	**91.22**	**3.11**	**22.66**	**2980.3**	**251.43**	**116.12**	**21.25**	**17.06**
50 ppm BA	**59.10**	**98.33**	**3.22**	**23.33**	**2989.8**	**253.35**	**116.55**	**21.35**	**18.03**
5% Yeast	**55.33**	**95.11**	**3.22**	**22.21**	**2665.1**	**246.07**	**109.36**	**22.82**	**17.02**
10% Yeast	**60.88**	**102.33**	**4.21**	**24.33**	**3179.2**	**254.29**	**117.05**	**24.27**	**18.05**
0.3 % Algae	**62.16**	**101.11**	**3.44**	**24.99**	**3268.4**	**260.32**	**120.26**	**24.95**	**18.99**
0.6% Algae	**61.88**	**104.33**	**3.66**	**25.55**	**3408.6**	**278.28**	**124.09**	**26.02**	**20.07**
L.S.D. 5%	**0.92**	**1.66**	**0.14**	**2.76**	**145.3**	**3.45**	**2.64**	**2.40**	**0.54**

Improving growth and overall quality of horticultural plants by yeast application was reported by **Gomaa *et al.*, (2005), Hussain and Khalaf (2007), Ahmed *et al.*, (2011) and El-Desouky *et al.*, (2011) and Taha and Helal (2019).** As for benzyladenine (BA), it is regulating various processes i.e. plant growth and development including cell division and differentiation, leaf expansion and nutrient mobilization. It is also implicated in secondary metabolites synthesisand vascular development (**Duszka *et al.*, 2009)**. BA exogenously application result in an increasing plant height (**Letham, 1969)**, leaf area (**Abdullah *et al.*, 1986)** and branching (**Hrotko *et al.*, 1996)**. Data in Table (4) show that all the applied treatments significantly increased photosynthetic pigments content, *i.e,* chlorophyll a, b, a+b and carotenoids compared with the control at 75 DAP during the two growing seasons of 2017 and 2018. Results also showed that foliar spraying with 0.6% *Spirulina* extract showed a maximum increment in chlorophyll a, chlorophyll b and total chlorophyll by 16.7 & 36.0%, 53.2 & 86.0% and 28.2 & 52.7%, respectively over the corresponding untreated plants (control) in 1st and 2nd seasons, respectively followed by 0.3% *Spirulina* extract and 10% yeast extract, in descending order. On the other hand, low concentration (25 ppm) of benzyladenine extracts exhibited slightly decrease effects in chlorophyll a, chlorophyll b and total chlorophyll. On the contrary, low concentration (25 ppm) of benzyladenine extracts showed significant increment on carotenoid by 55.3 & 55.8% over the control followed by 5% yeast and 50 ppm benzyladenine in descend order at both seasons.

Table 4. Effect of foliar application treatments on photosynthetic pigments content of potato plant at 75 days after planting during 2017 and 2018 seasons.

Item		Control	Benzyladenine (BA)		Yeast extract		Alga extract		L.S.D.
			25 ppm	50 ppm	5%	10%	0.3 %	0.6%	5%
2017									
Chlorophyll ($mg\ g^{-1}$)	(a)	1.02	1.04	1.14	1.11	1.15	1.17	1.19	0.01
	(b)	0.47	0.53	0.62	0.57	0.66	0.71	0.72	0.04
	(a+b)	1.49	1.57	1.76	1.68	1.81	1.88	1.91	0.05
Carotenoids ($mg\ g^{-1}$)		0.47	0.73	0.68	0.7	0.64	0.66	0.59	0.04
2018									
Chlorophyll ($mg\ g^{-1}$)	(a)	0.86	0.91	1.09	1.13	1.15	1.15	1.17	0.03
	(b)	0.43	0.57	0.61	0.64	0.68	0.73	0.8	0.08
	(a+b)	1.29	1.48	1.7	1.77	1.83	1.88	1.97	0.11
Carotenoids ($mg\ g^{-1}$)		0.52	0.81	0.67	0.7	0.59	0.58	0.56	0.03

These results are of great interest, because they are lightly considered direct reason for the higher dry matter production and distribution in potato plants shoots as affected by different applied treatments. In this respect, total carbohydrate increase with different applied treatments consider as a direct result of increasing both photosynthesis rate and efficiency. Our results go on line with those reported that these treatments are implicated in the synthesis of secondary metabolites, influences chlorophyll biosynthesis and chloroplast differentiation (**Duszka *et al.*, 2009** for benzyiadenine**; Fathy and Farid, 1996** and **El-Desouky *et al.*, 2011** for yeast **and El-Sheekh** and **El-Saied, 1999**; **Abd El-Aal, 2012** and **Osman, 2015** for algae effectiveness)**.**

Endogenous phytohoromones

Data in Table 5 show endogenous phytohormones content changes *i.e.*, Gibberellic Acids (GA_3), Auxins , Cytokinins, Abscisic Acid (ABA), and Salicylic Acid of potato (*Solanum tuberosum* L.) plant at 75 days after planting during 2018 season sprayed with different used promoting treatments compared with the control which greatly improved morphological, metabolical and histological performances of potato plant as apparent from results obtained in the present study.

As for auxins level, it was extremely increased in potato shoots with different treatments compared with control plants. In this respect, the most superior treatments were the algae extract at 0.6 % for IAA followed by benzyladenine (BA) at 25 ppm and 10% yeast extract, whereas both 5% yeast extract and 50 ppm benzyladenine were the highest effective treatment on IBA followed by 0.3% algae extract, 25 ppm benzyladenine and 10% yeast extracts in descending order which highly increased total auxins compared with control and other treatments. With regard to gibberellins level, data in the same Table (5) also clearly illustrate that the level of gibberellin like-substances in potato (*Solanum tuberosum* L.) shoots was increased with algae extract at different used treatments as compared with the control plants but it mostly increased in cases of algae extract at 0.6, 0.3 % and low concentrates of benzyladenine and yeast extract treatments.

Furthermore, the level of cytokinins positively responded to the different assigned treatments. Since, the activity was the lowest in the control. Generally, these phytohormones those promote growth aspects (*i.e.*, growth promoters, auxins, gibberellin and cytokinin) were highly increment with different assigned treatments compared with the control.

Here the treatments of algae extract at 0.6, 0.3 %, yeast extract at 5% and benzyl adenine at 50 ppm, respectively gave the highest values activity of promoting phytohormones level. Also, endogenous hormones increase in potato plants obtained in the present study could be interpret the obtained modifications in different studied histological features (Table 6) and the improvement of growth (Table 3) and tubers yield characteristics (Table 7). For example, increasing cytokinins could be in favor of increasing the number of formed lateral stems and that could also increase transverse growth on the account of longitudinal one as well as increasing of sink organs (tubers) ability to accumulate and storage more assimilates. With regard to the growth inhibitor, abscisic acid level reduced with various assigned treatments compared with the control, but the reduction was more obvious with treatments of 25 ppm benzyladenine, 5% yeast extract, 50 ppm benzyladenine, 10% yeast extract, 0.6% and 0.3% algae extracts in descending order.

Table 5. Effect of foliar application treatments on endogenous phytohormones content (µg g^{-1} fwt.) of potato shoots at 75 days after planting during 2018 season.

Item			Control	Benzyladenine		Yeast extract		Algae extract	
				25 ppm	50 ppm	5%	10%	0.3%	0.6%
Promoters	Auxins	IAA	9.26	14.11	7.75	6.63	11.81	8.1	16.98
		IBA	60.59	94.34	212.66	212.91	79.02	187.79	-
		Total	69.85	108.45	220.41	219.54	90.83	195.89	16.98
	Gibberellic Acids		207.52	331.51	213.29	248.85	110.33	219.42	414.69
	Cytokinins		189.35	319.97	629.68	673.47	708.25	735.2	841.99
	Total promoters		486.72	759.93	1063.38	1141.86	909.41	1150.51	1273.66
	Increment (%)		0.0	56.13	118.48	134.6	86.84	136.56	161.68
Inhibitors	Abscisic acid		2.56	0.76	1.4	1.22	1.41	2.08	1.64
	Increment (%)		0.0	-70.3	-45.3	-52.3	-44.9	-18.8	-35.9
SA	Content		42	96.46	30.45	35.55	58.13	48.58	71.55
	Increment (%)		0.0	129.67	-27.5	-15.4	38.4	15.67	70.36

IAA: 3-Indole acetic acid IBA: Indole 3 butyric acid SA: Salicylic acid % Increment: % Relative to control

Moreover, salicylic acid level Table (5) was increased with the different assigned treatments compared with the control. In this respect, these results being of great interest for interpreting each of the obtained vigorous growth and the great tubers yield of potato plant attained in the present study.

Our results are in harmony with those reported by **Davies (1995)** and **Duszka *et al.* (2009).** They concluded that benzyladenine is an important plant hormone regulating various processes of plant growth and development including cell division and differentiation, enhancement of leaf expansion and nutrient mobilization. Many studies were conducted in Egypt (**Shady, 1978; Fathy and Farid, 1996; Gomaa *et al.*, 2005; Hussain and Khalaf, 2007; Ahmed *et al.*, 2011 and El-Desouky *et al.*, 2011)** and other countries **(Winkler *et al.*, 1962; Barnett *et al.*, 1990)** on yeast treatments. They suggested to participate a beneficial role due to its cytokinins, auxins and gibberellins content**,** improves carbohydrates accumulation and contents of protective agent, *i.e*., sugars, proteins and amino acids and also several vitamins in addition to its stimulatory effects on cell division and enlargement, protein and nucleic acid synthesis. As for Algae extract application for different crops, **Blunden (1991), Crouch and Van Staden (1994), Khan *et al.*, (2009)** and **Abd El-Aal (2012**) stated that it is a great importance due to it contains high levels of organic matter, micro elements (Fe, Cu, Zn, Co, Mo, Mn, and Ni), vitamins, amino acids and growth regulators such as auxins, cytokinin and gibberellins.

Anatomical studies:

Data in Table 6 and Figs. (1 and 2) show the effect of applied treatments on the mean counts and measurements in microns of certain histological features of the main stem and leaf of potato plant (*Solanum tuberosum* L.) at 75 days after planting during 2018 season.

Stem anatomy:

Table 6 and Fig. 1 show that different applied treatments increased the stem diameter compared with control. This increase reached its maximum values with algae extract at 0.6, 0.3 %, yeast extract at 10% and benzyladenine at 50 ppm, respectively compared with the stem diameter of the control. Also, it could be noticed that increase of the stem diameter was reversed upon different tissues comprising the whole section. Since, thickness of each cuticle layer, epidermis, cortex (collenchyma and parenchyma tissues) and pith parenchyma layers, as well as the dimensions of vascular bundles. Moreover, thickness of phloem tissue, cambial region and of xylem tissue, number of xylem vessels vascular cylinder and diameter of the widest xylem vessel were greatly increased compared with the control. In general, the stimulatory effects of applied treatments upon the anatomy features of treated plants could be attributed to the effect upon cambium activity. Increment of cambium activity could mainly attributed to the increase of endogenous hormones level especially cytokinins and auxins. These results are line with the findings of **Sotiropoulos *et al.*, (2002)** and **Abd El-Aal and Eid (2017)**. Of interest to note that these positive responses of different anatomical aspects to treatments were completely reversed upon vegetative and tubers growth of treated plants. So, present study revealed those increases of xylem tissue, *i.e*., the route of mineral nutrients and water translocation from roots to leaves and the phloem tissue i.e., the pathway of different assimilates from leaves to tuber plant sinks. Thereby, improvement of translocation events directly could be considered a direct reason for increment the final tubers yield.

Leaf anatomy:

Data in Table 6 and Fig. 2 clearly indicate the effect of applied treatments upon different anatomical features of potato leaves. In this respect, most of the studied features of leaf anatomy were enlarged with different applied treatments. Among these anatomical features were the most important ones, *i.e*., thickness of midrib, length & width of vascular bundle, thickness of phloem & xylem tissues and number of xylem vessels in vascular bundle as well as the leaf blade thickness. With regard to the blade thickness, it was increased with different used treatments to reach its maximum with algae extract at 0.6, 0.3%, yeast extract at 10% and benzyladenine at 50 ppm, respectively which were the most effective treatments in this order compared with the control and other treatments. Of interest, to note that mesophyll increasing belong to that increase of each of palisade and spongy tissue thickness. Since, the two components were increased with all applied treatments but reached their maximum as other traits with algae extract at 0.6% treatment. With regard to midrib anatomical features, increment in the midrib thickness in response to different applied treatments attributed to the increase in histological features such as thickness of both uppermost and lower most collenchyma tissues; lower most parenchyma tissue and dimensions of vascular bundle as well as thickness of phloem and xylem tissues as well as number and diameter of xylem vessels in the vascular bundle. These increases were further obvious with the algae extract at 0.6, 0.3% and yeast extract at 10% treatments. The mentioned results specially conductive tissues (xylem & phloem) increment are also of great importance because they could be involved in the understanding why vigorous growth and high yielded tubers existed with different applied treatments specially with algae extract at 0.6 % due to different promoters hormones (Table 5) of these studied extracts and that shoot branching from axillary buds is regulated by a network of inhibitory and promotive forces, which includes hormones (**Domagalska and Leyser, 2011**).

Table 6. Mean counts and measurements of histological features of potato (*Solanum tuberosum* L.) stem and leaf at 75 days after planting during 2018 season.

Treatment / Histological Characteristics (micron)	Control	Benzyladenine 25 ppm	Benzyladenine 50 ppm	Yeast extract 5%	Yeast extract 10%	Alga extract 0.3%	Alga extract 0.6%
Stem							
Stem diameter	3482	3851	4252	4182	4595	5145	5138
Cuticle layer thickness	7	5	4	5	5	6	6
Epidermis thickness	15	14	15	14	14	16	15
Collenchyma thickness	183	175	212	176	231	209	217
Parenchyma thickness	207	293	316	260	358	339	382
Cambial region thickness	14	16	23	16	18	21	22
Phloem thickness	176	193	208	181	217	235	280
Xylem thickness	413	469	611	549	616	627	670
Xylem rows No. vascular cylinder	185	231	216	282	261	240	227
Xylem vessels NO. row	9	13	12	11	12	10	13
Widest xylem vessel diameter	34	35	32	34	30	31	32
Parenchymatous pith thickness	1452	1521	1474	1780	1677	2239	1954
Leaf							
Upper epidermis thickness	17	18	19	17	20	18	19
Lower epidermis thickness	14	14	15	13	14	13	15
Palisade tissue thickness	111	122	139	119	118	121	132
Spongy tissue thickness	226	243	312	235	258	287	294
Blade thickness	388	429	407	407	435	462	485
Upper collenchyma thickness	427	406	481	315	502	360	413
Lower collenchyma thickness	310	318	219	223	349	314	275
Phloem thickness	113	147	165	139	166	179	186
Xylem tissue thickness	394	415	461	421	570	456	477
Xylem rows number	11	13	15	14	15	16	16
Widest xylem vessel thickness	35	35	37	34	41	36	38
Midrib vascular bundle length	503	523	669	562	713	717	790
Midrib vascular bundle width	752	780	847	837	911	844	901
Leaf midrib thickness	2557	2644	2905	2552	3270	2832	3098

Also, developmental stages of bud outgrowth are likely associated with checkpoints for feedback regulation and hence enable the homeostasis of shoot number. These stages may also account for the observation that buds at different locations show different responses to signals such as auxin and cytokinin (**Dun *et al* 2006**). On the other hand, **Cline (1994)** stated that auxin inhibit axillary bud outgrowth whereas cytokinins promote it while, endogenous hormone levels has demonstrated powerful effects of auxin and cytokinin on axillary bud outgrowth. In general, these positive alterations in stem and leaf anatomy of potato plant treated with applied treatments led to vigorous growth and enhancement of tubers yield of treated plants.

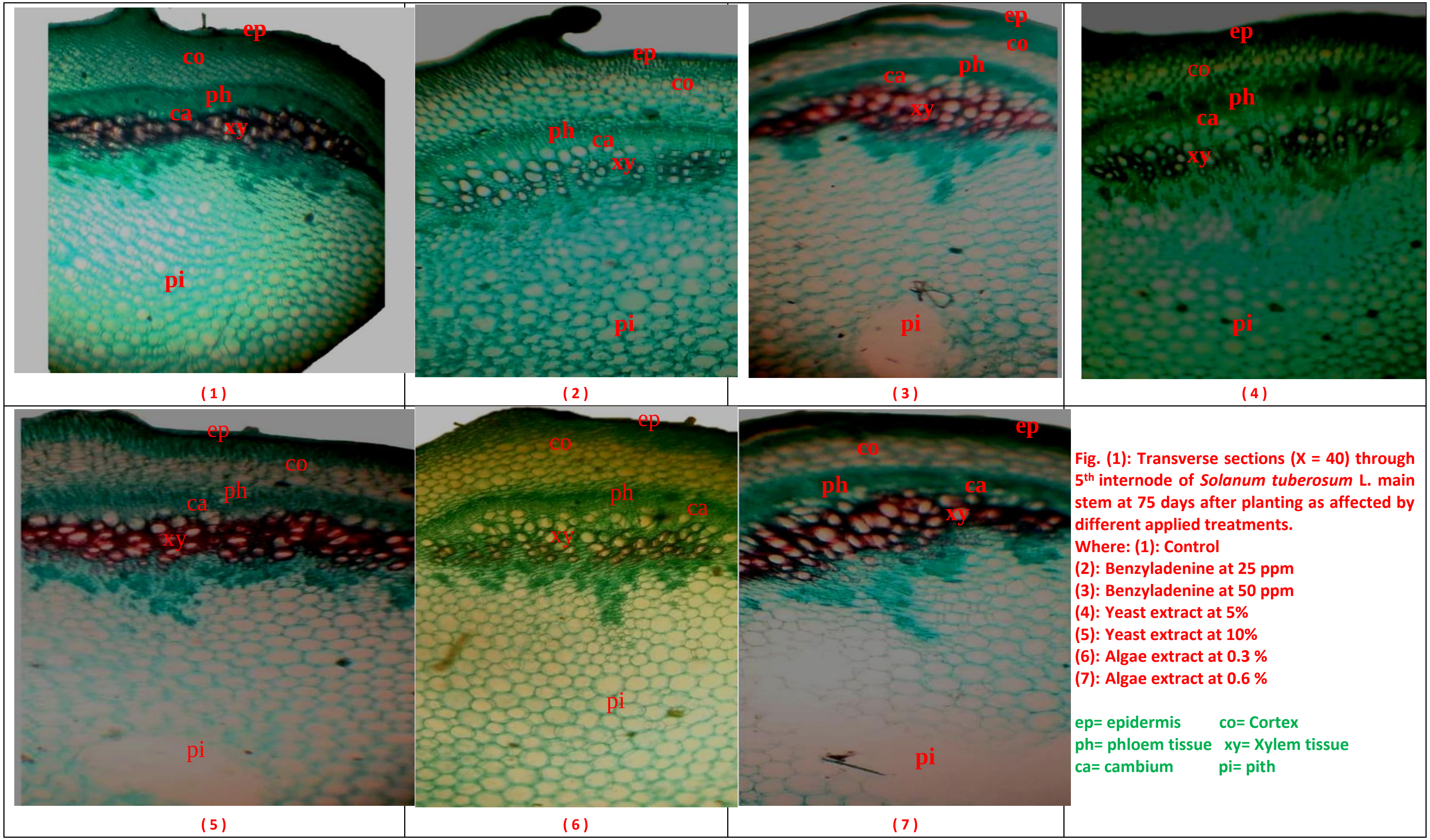

Fig. (1): Transverse sections (X = 40) through 5th internode of *Solanum tuberosum* L. main stem at 75 days after planting as affected by different applied treatments.
Where: (1): Control
(2): Benzyladenine at 25 ppm
(3): Benzyladenine at 50 ppm
(4): Yeast extract at 5%
(5): Yeast extract at 10%
(6): Algae extract at 0.3 %
(7): Algae extract at 0.6 %

ep= epidermis co= Cortex
ph= phloem tissue xy= Xylem tissue
ca= cambium pi= pith

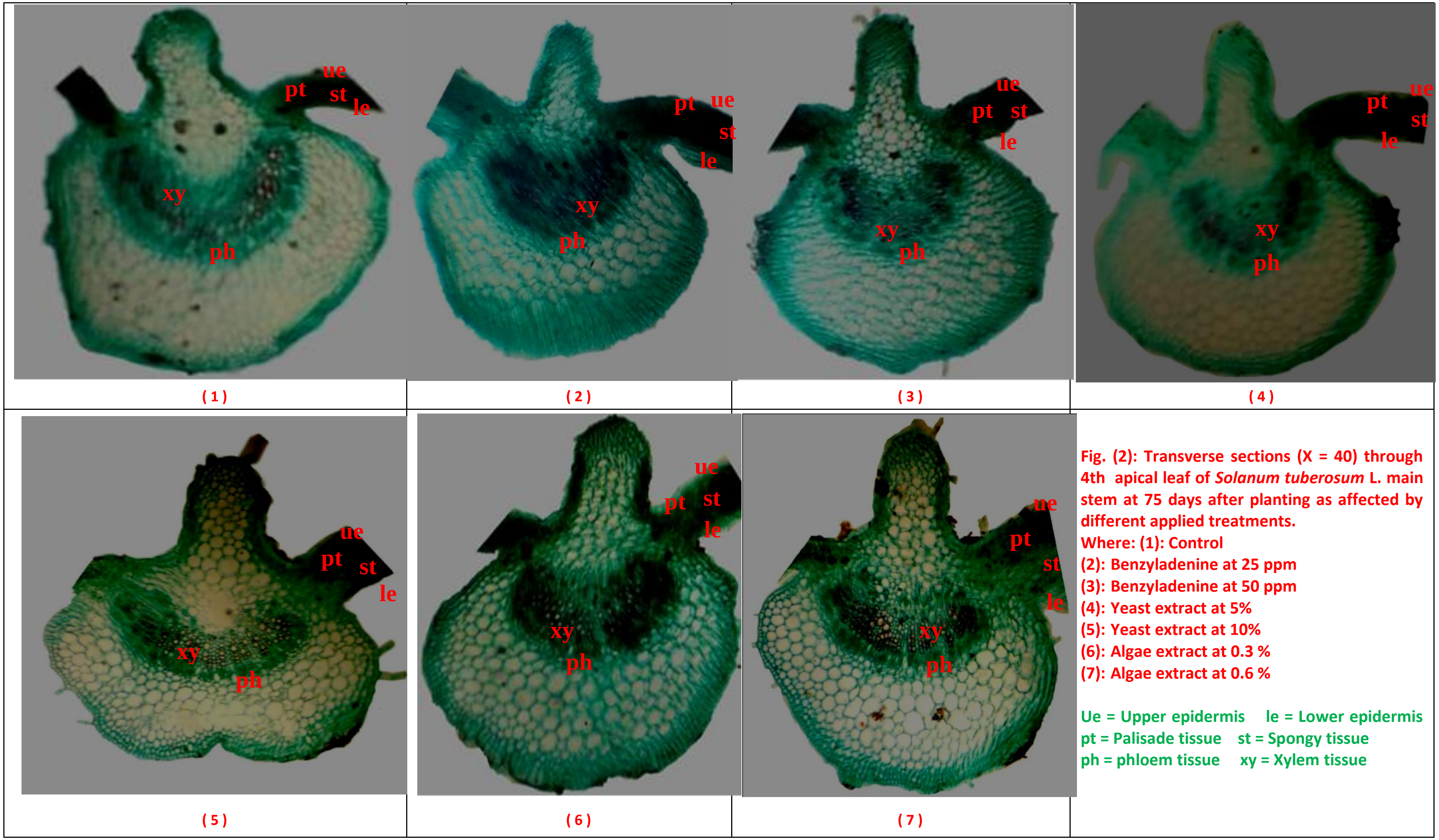

Fig. (2): Transverse sections (X = 40) through 4th apical leaf of *Solanum tuberosum* L. main stem at 75 days after planting as affected by different applied treatments.
Where: (1): Control
(2): Benzyladenine at 25 ppm
(3): Benzyladenine at 50 ppm
(4): Yeast extract at 5%
(5): Yeast extract at 10%
(6): Algae extract at 0.3 %
(7): Algae extract at 0.6 %

Ue = Upper epidermis le = Lower epidermis
pt = Palisade tissue st = Spongy tissue
ph = phloem tissue xy = Xylem tissue

That as well mentioned afterwards reversed upon high increases in the final tubers yield. Also, the previously mentioned and discussed results of potato leaf anatomy of treated plants, reveal that increasing of leaf anatomy features compared with control confirmed by vigorous growth of potato was positively along with minerals content (N, P and K), photosynthesis pigments and carbohydrates content (**Abd El-Aal and Eid, 2017**).

Tubers yield and chemical constituents:

Data in Table (7) obviously show that tubers yield and its components of potato were highly increased as affected by different applied treatments. All applied treatments significantly increased tubers number/plant, tubers fresh weight/plant and tubers total yield/feddan as well as tubers dry matter compared with the control during the two growing seasons. Same data revealed that the highest total tubers yield were obtained with algae extract at 0.6, 0.3 %, yeast extract at 10 % and benzyladenine at 50 ppm, respectively which were the most effective treatments in this order compared with the control and other treatments. These results are of great interest because they mean that used treatments increased dry matter accumulation in tubers yield. However, the stimulation of dry matter production considered as a direct result of that vigorous growth including the photosynthetic area and photosynthetic pigments in leaves of potato plants during different stages of growth. Our results are in agreement with those of **Rama Rao (1991), Awad *et al.*, (2006), Ahmed *et al.*, (2011), Fawzy *et al.*, (2012 a, b), Mansowr (2012)** and **Osman (2015) and Taha and Helal (2019).**

Table 7. Effect of foliar application treatments on tuber yield components of potato plant during 2017 and 2018 seasons.

Item	Tubers number plant	Tubers fresh weight (g plant)	Tubers dry matter %	Tubers specific gravity	Tubers total yield (ton feddan)
			Season 2017		
Control	7.66	482.85	18.41	1.061	11.986
25 ppm Benzyl-Ad	5.55	539.33	18.62	1.061	13.013
50 ppm Benzyl-Ad	8.55	564.77	19.71	1.073	15.016
5% Yeast	8.33	539.55	19.82	1.072	13.012
10% Yeast	9.22	597.16	18.72	1.074	15.765
0.3 % Algae	10.00	621.58	19.93	1.081	15.958
0.6% Algae	10.11	652.83	20.58	1.083	16.873
L.S.D. 5%	1.28	18.56	0.97	N.S.	0.218
			Season 2018		
Control	8.56	476.18	17.07	1.060	11.693
25 ppm Benzyl-Ad	9.77	544.66	19.09	1.067	12.259
50 ppm Benzyl-Ad	9.52	601.19	19. 59	1.067	14.648
5% Yeast	9.22	499.57	18.41	1.060	13.652
10% Yeast	10.10	632.19	19.75	1.071	14.865
0.3 % Algae	10.52	655.67	20.05	1.074	15.576
0.6% Algae	11.04	664.12	20.15	1.081	16.459
L.S.D. 5%	1.10	11.94	0.81	N.S.	0.612

Regarding to tubers chemical constituents, data presented in Table (8) show that most of applied treatments highly increased determined bio-constituents content *i.e*., N, P, K, crude protein and starch (%) in the marketable potato tubers. In this respect, the most effective treatment algae extract at 0.6, 0.3 % and yeast extract at 10 %. The above mentioned results evidently indicated that the applied treatments were greatly increased the ability of potato tubers as sink organs having high nutritive value, *i.e*., it increased their validity for human consumption.

Also, the same data clearly indicate that increasing the minerals content in potato tubers was positively and greatly in line with minerals and bioconstituents composition of vegetative organs (*i.e*., leaves), which induce the most active metabolical cases. Such results indicate the stimulative effect of the applied treatments to enhance internal metabolical mechanism of potato plant towards maximizing its growth and productivity. The obtained positive bio-constituents responses are the result of increasing leaf area and its reversion upon increasing the net photosynthesis per unit of leaf area. Our results were in line with those reported by **Davies (1995)** and **Duszka *et al.*, (2009).** They concluded that benzyladenine is regulating various processes of plant *i.e*., enhancement of nutrient mobilization, increases field crops yield and improves crop quality in addition to implicate in the synthesis of secondary metabolites. For yeast treatment suggested to participate a beneficial role during yield due to its cytokinins content**,** improves carbohydrates accumulation**.** Add to its contents of protective agent, *i.e*., sugars, proteins and amino acids and also several vitamins (**Shady, 1978)**. Improving yield and overall quality of horticultural plants by yeast application was reported by **Winkler *et al.*, (1962), Barnett *et al.*, (1990), Gomaa *et al.*, (2005), Hussain and Khalaf (2007), Ahmed *et al.*, (2011) and El-Desouky *et al.*, (2011).** As for Algae extract, application for different crops is a great importance due to it contains high levels of organic matter, micro elements (Fe, Cu, Zn, Co, Mo, Mn, and Ni), vitamins, amino acids and also, growth regulators such as auxins, cytokinin and gibberellins

(**Blunden, 1991; Crouch and Van Staden, 1994 and Khan *et al.*, 2009).** The beneficial effects of algae extract is a result of many components that may work synergistically at different concentrations **Fornes *et al.*, (2002).** Foliar application with algae extract has already been shown to enhance plant yield and its quality were stated by **Featonby and Van Staden (1983), Sivasankari *et al.*, (2006), Abdel Mawgoud *et al.*, (2010), Shehata *et al.*, (2011)**, **Abd El-Aal (2012)** and **Osman (2015)**.

Table 8. Effect of foliar application treatments on tuber chemical constituents % of potato plant during 2017 and 2018 seasons.

Item	N	P	K	Crude protein	Starch
Season 2017					
Control	2.48	0.32	3.52	15.50	10.01
25 ppm Benzyladenine	2.68	0.35	3.55	16.75	10.90
50 ppm Benzyladenine	2.93	0.36	3.71	18.31	11.12
5% Yeast extract	2.98	0.37	3.82	18.62	11.70
10% Yeast extract	2.61	0.38	3.54	16.31	11.03
0.3 % Algae extract	2.80	0.33	3.58	17.50	10.04
0.6% Algae extract	2.06	0.25	3.17	12.87	8.94
L.S.D. 5%	0.11	0.01	0.06	0.68	1.53
Season 2018					
Control	2.44	0.29	3.41	15.25	9.77
25 ppm Benzyladenine	2.58	0.32	3.51	16.12	10.34
50 ppm Benzyladenine	2.73	0.33	3.56	17.06	11.23
5% Yeast extract	2.85	0.34	3.57	17.81	11.31
10% Yeast extract	2.50	0.35	3.47	15.62	11.15
0.3 % Algae extract	2.60	0.32	3.54	16.25	10.06
0.6% Algae extract	2.01	0.26	3.17	12.56	8.57
L.S.D. 5%	0.03	N.S.	N.S.	0.47	0.59

Conclusion

We recommend through this study that it is possible to spray with algae extract at 0.6 or 0.3 % as well as yeast extract at 10 % to increase the number of lateral stems which increasing the transverse growth on the account of longitudinal one as well as, increasing of sink organs (tubers) ability to accumulate and storage more assimilations, stimulate and improve of vegetative growth characteristics consequently, increasing both of yield and quality of potato tubers.

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دراسات على تحسين النمو والإنتاجية والجودة في نبات البطاطس

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[1] قسم بحوث البطاطس والخضر خضرية التكاثر– معهد بحوث البساتين– مركز البحوث الزراعية – مصر.

[2] قسم النبات الزراعى – كلية الزراعة – جامعة بنها – مصر.

أجريت تجربتان حقليتان بمحطة بحوث الخضـر ، قها ، محافظة القليوبية خلال موسـمى النمو 2017 ، 2018م لدراسـة التأثير المنفرد للرش الورقى بمعاملات البنزيل أدنين بتركيز 25 و 50 جزء فى المليون ومسـتخلص الطحالب بتركيز 0.3 و 0.6% ومسـتخلص الخميرة بتركيز 5 و 10 % بالإضـافة إلي معاملة الكنترول (ماء الصـنبور) على تنشـيط نمو البراعم الجانبية وتحسـين صـفات النمو الخضـرى والصـفات التشريحية والمكونات الكيميائية ومحصول الدرنات وجودته في نباتات البطاطس صنف بيكاسو حيث تم رش النباتات بالمعاملات المستخدمة ثلاث مرات عند 30 و 45 و 60 يوم من الزراعة خلال موسمي الدراسة.

وتتخلص أهم النتائج المتحصـل عليها في هذه الدراسـة كالتالي: أعطت كل المعاملات زيادة معنوية فى صـفات النمو الخضـرى مثل طول وعدد الأفرع الرئيسـية والجانبية للنبات وعدد ومسـاحة الأوراق/النبات والأوزان الطازجة والجافة عند عمر 75 يوم من الزراعة وذلك مقارنة بالكنترول في كلا موسمي النمو وكانت أفضل المعاملات في هذا الصدد معاملات مستخلص الطحالب بتركيز 0.6 ، 0.3 % ومستخلص الخميرة بتركيز 10% متبوعاً بمعاملة البنزيل أدنين بتركيز 50 جزء فى المليون على الترتيب مقارنة بالكنترول.

أوضـــحت النتائج المتحصــل عليها أن جميع المعاملات المســتخدمة أدت إلي زيادة محتوى الأوراق من صــبغات البناء الضــوئى والمحتوى الهرموني الداخلى للسـتيوكينيات والجبريلينات والأوكسـينات مما ادى الى كسـر السـيادة القمية للسـاق بينما أدت إلي نقص واضــح في المثبطات الداخلية مثل حمض الأبســيســك ، كما أدت المعاملات المختلفة إلى تغيرات واضــحة فى الصــفات التشــريحية لأوراق وســيقان نباتات البطاطس وخاصة الجانبية وزيادة المحصول الناتج من الدرنات/النبات والفدان وتحسين صفات الجودة للدرنات وزيادة محتوى الدرنات من المكونات الكيميائة (النيتروجين والفوسـفور والبوتاسـيوم والبروتين) وكانت أفضـل المعاملات هى مسـتخلص الطحالب بتركيز 0.6% ، 0.3% ومسـتخلص الخميرة بتركيز 10% ومعاملة البنزيل أدنين بتركيز 50 جزء فى المليون مقارنة بالنباتات الغير معاملة.

وبناءاً على النتائج المتحصــل عليها من الدراســة نوصـــي باســتخدام معاملات الرش الورقي بمســتخلص الطحالب بتركيز 0.6 أو 0.3% ومستخلص الخميرة بتركيز 10 % ثلاثة مرات لتحسين صفات النمو و المحصول وجودة الدرنات.