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RESPONSE OF YIELD AND QUALITY OF SWEET POTATO PLANTS TO IRRIGATION INTERVALS AND SOME SOIL AND FOLIAR APPLICATION TREATMENTS

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ABSTRACT

A field experiment was carried out during the two successive summer seasons of 2019 and 2020 in a Private Farm at Meet Faris Village, Dekarns, District Dakhlia Governorate, Egypt to study the effect of irrigation intervals (15 and 30 days) and some soil application treatments (humic acid at 20 kg /fad. and fulvic acid at 10 kg/fad.) and foliar application treatments (without, trehalose at 1 g/l, potassium silicate at 1ml/l and algae extract at 1g/l) on growth, plant water relationships, yield and its components as well as tuber roots quality of sweet potato plants cv. Beauregard grown under clay soil conditions using follow irrigation system .

The obtained results showed that, the interaction treatment between irrigation sweet potato plants cv Beauregard grown in clay soil during summer seasons conditions every 15 or 30 days and treated plants with fulvic acid at 10 kg /fad. as soil application + spraying with potassium silicate at 1 ml/l increased main vine length , both fresh and dry weight of shoots/ plant, average tuber root weight , total yield/fad. and K contents in tuber roots. In addition, the interaction between irrigation every 15 and treating with fulvic acid at 10 kg /fad. as soil application+ foliar spray with potassium silicate at 1 ml/l increased number of branches/plant, marketable yield and total carbohydrates in tuber roots. Also the plants grown under the same irrigation intervals (every 15 days) and treating with fulvic acid at 10 kg /fad.+ spraying with trehalose at 1 g/l significantly increased total , free water in leaf tissues , however , the interaction between irrigation every 15 days intervals and treating with fulvic acid at 10 kg /fad. as soil application+ spraying with algae extract at 1 g/l increased N and P in shoots and tuber roots as well as tuber root diameter. On the other hand, the interaction between irrigation every 30 days and treated plants with FA at 10 kg /fad.+ spraying with *potassium silicate at 1 ml/l increased K contents in shoots , tuber root length and dry matter contents in tuber roots. The interaction between irrigation every 30 days and treating with humic acid only at 20 kg /fad increased bound water (%) , osmotic pressure and proline amino acid in leaves of sweet potato in both growing seasons*

Conclusively, *it could be concluded that, irrigation sweet potato plants grown in clay soil during summer seasons every 15 or 30 days and treated plants with fulvic acid at 10 kg /fad. soil application + spraying with potassium silicate at 1 ml/l or with algae extract or trehalose at 1 g/l of each to obtain high productivity and best tuber root quality.*

Keywords: Sweet potato, irrigation intervals, humic & fulvic acid, trehalose, potassium silicate, growth, plant water.

INTRODUCTION

Sweet potato *(Ipomoea batatas* (L.) Lam.) is considered as one of the very important crops in tropical and subtropical regions as well as in developing countries. Its chief use is for human consumption and for starch manufacturing. Its roots and leaves have high nutritious value. So, the same plant produces two useful food types; namely, tuberous roots and green tops which can be used for human and animal feeding, respectively.

Agriculture in Egypt is almost entirely dependent on irrigation from River Nile, although there are minor contributions from groundwater. The average consumption of water for agriculture is about 58 billion $m^3 year^{-1}$. Agriculture has major disadvantages over other water-consumed activities (industry, domestic and tourism *etc.*) due to a large percentage of irrecoverable losses because of high rates of evaporation and evapotranspiration. In order to mitigate such this difficulty, agriculture has to come up with innovative ideas with respect to both cropping and irrigation water management to improve water productivity and to accomplish agriculture sustainability concepts. Excessive permeability and low water and nutrient holding capacities are the major problems in soils (Suganya and Sivasamy, 2006). Hence, managing irrigation water and plant nutrients are the major challenge of soil amelioration efforts. Since, insufficient irrigation water results of high soil moisture tension, which fall plant under stress and, in turn, reduce its yield. While, excess irrigation water may reduce crop yield due to leaching of applied nutrients, increased disease incidence and/or failure to stimulate growth of the commercially valuable parts of the plant (Solomon, 1993).

The shortest irrigation intervals or increasing water quantity gave the best results for enhancing growth, yield and quality than the longest irrigation intervals or reduced water qualities, in this regard (Thompson *et al.*, 1992, Abdel -Fattah *et al*., 2002, Ekanayake and Collins, 2004, Ayoub 2005, Abou El-Khair *et al*., 2011, Yooyongwech *et al.*, 2013 , Saqib *et al.* 2017 , Abu El-Fotoh *et al*., 2019 on sweet potato and Mahmoud *et al.*, 2019 on potato).

Fulvic acid is a bi-product of humic acid. Humic acid is extracted from any material containing well-decomposed organic matter - soil, coal, composts, etc. As humic material is decomposed by living microbes, these microbes create the most biologically complex organic compound, Fulvic acid. Fulvic acid is low molecular weight and is biologically very active. Because of its low molecular weight, it has the necessity and ability to readily bond minerals and elements into its molecular structure causing them to dissolve and become mobilized Fulvic complexes (Brady and Weil, 2008).

Several studies showed that application of fulvic and humic acids increased the growth and enhanced crop quality and quality for various cultivated crops, (Bryan and Stark, 2003 on potato, Shankle *et al*., 2004 on sweet potato, Verlinden *et al*., 2009, Selim *et al*., 2010 on potato , Saif El-Deen *et al*., 2011 and Abd- All *et al*., 2017 on sweet potato and Abd El-Baky *et al*. 2020 on okra).

Trehalose is one of organic solutes, a non-reducing disaccharide of glucose, that has a very useful effect as an osmoprotectant in many crops (Sadak *et al*., 2019).Trehalose is also, a very vital sugar which has been shown to be a potential mitigating agent against different abiotic stresses (Yang *et al*., 2014). It functions as a compatible solute and plays an important role in stabilizing of macromolecules under stress conditions (Shafiq *et al*. 2015). Also, it is imperative to improve drought tolerance of economic cash crops and vegetables under the changing environmental conditions. A range of mechanisms (physiological, biochemical and molecular) used by plants to tolerate water stress (Ashraf 2010).

Spraying plants with trehalose enhancing plant growth, yield and quality of some plants such as (Alam *et al*., 2014 on Brassica species, Shafiq *et al.*, 2015 and Akram *et al*., 2016 on radish, Khater *et al*., 2018 on cowpea and Wang *et al*., 2019 on sweet potato).

Algae are natural bio active materials rich in minerals, protein, lipids, carbohydrates, vitamins and microelements (B, Mo, Zn, Cu). In addition, seaweed fertilizer aunique combination of N, P, K, trace elements and simple sugar that are in dissolved forms that are easily absorbed through roots and leaves, besides releasing trace elements bound to the soil and it is safe to human, animals and the environment (Sathya *et al*., 2010).

The beneficial effect of algae extract spraying on plants was demonstrated in terms of increase in growth , yield and tuber quality (Blunden and Paul, 2006, Sarhan, 2011, Haider *et al*. 2012 on potato, Doss *et al.* ,2015 on sweet potato Prajapati, 2016 on potato, Mahmoud *et al*., 2018 on sweet potato, Abd-Elatif and Ismaiel, 2019 on cassava , Issa *et al*., 2019 and Dziugieł, Wadas, 2020 on potato).

The positive effect of potassium silicate might be due to the contained soluble potassium and silicon, potassium which plays a role in several of the essential regulatory functions in the plant (Abou-Baker *et al*., 2011). As well as, potassium plays an essential position in plant under biological and non-biological stresses (Marschner, 2012). As for silicon sources like potassium silicate K_2SiO_3 is considered as a crucial beneficial mineral serving growth and maturity of plants (Epstein, 1999). Also, it reduces the multiple stresses of plants by conserving water in the plant, photosynthetic activity, stomatal conductance and leaf erectness under high transpiration rates (Das *et al*., 2017).

Foliar spray with potassium silicate increased plant growth, N,P and K contents in leaves , yield and its components as well as quality (Salim *et al*., 2014, on potato Abd- All *et al*., 2017 on sweet potato , Abd El-Gawad *et al*., 2017, Mahmoud *et al*., 2019, Shaheen *et al*., 2019 on potato).

Therefore, the present study was planned to evaluate the suitable irrigation intervals, soil amendments materials and some foliar spray treatments on growth, plant water relationship and yield and its components as well as tuber roots nutritional status of sweet potato plants using flood irrigation system under clay soil conditions.

MATERIALS AND METHODS

Two field experiment was carried out during the two successive summer seasons of 2019 and 2020 in a Private Farm at Meet Faris Village, Dekarns, District Dakhlia Governorate, Egypt, to study the effect of irrigation intervals and some soil and foliar treatments on growth, plant water relationships, tuber roots yield and quality of sweet potato under clay soil conditions using flood irrigation system.

The physical and chemical analyses of the experimental soil are presented in Table A.

This experiment included 16 treatments, which were the combinations between two irrigation intervals and eight soil and foliar application treatments

Table A: The physical and chemical properties of the experimental soil

Soil properties	2019 season	2020 season
Physical properties		
Sand (%)	22.46	21.63
Silt (%)	23.50	23.78
Clay (%)	52.91	56.76
O.M (%)	1.89	1.92
Chemical properties		
pH	7.74	7.51
Total N (%)	0.17	0.16
Available P_2O_5 (%)	0.033	0.037
Available K_2O (%)	0.54	0.52

OM: Organic matter , Total N: Total nitrogen

as follows: Irrigation intervals: every 15 and 30 days. Soil and foliar application treatments**:** Humic acid (HA) as soil application at 20 kg /fad. only, HA as soil application at 20 kg /fad. and spraying with trehalose at 1g / l, HA as soil application at 20 kg /fad., and spraying with potassium silicate (KSi) at 1 ml/l, HA as soil application at 20 kg /fad. and spraying with algae at 1 g/l, Fulvic acid (FA) as soil application at 10 kg /fad. only, FA as soil application at 10 kg /fad. and spraying with trehalose at 1g / l, FA as soil application at 10 kg /fad. and spraying with KSi at 1 ml/l, FA as soil application at 10 kg /fad. and spraying with algae at 1 g/l.

These treatments were arranged in a split plot design with three replicates. The irrigation intervals were arranged in the main plots and soil and foliar application treatments were randomly distributed in the sub plots.

Trehalose (C_{12} H_{22} O_{11}) was obtained from Sigma chemical Co. USA. potassium silicate (10 % K_2O) was obtained by Technogene group, Soliman Gohar Square, Dokki, Giza, Egypt. Algae extract was produced at the Algae Production Station of the National Research Centre (NRC, Giza, Egypt) . Major components of algae extract is shown in Table, B.

The experimental unit area was 21 m^2. (Three ridges, each 0.7 m width and 10 m long). One ridge was used for taking samples to measure the morphological and physiological traits and the other two ridges were used for yield determinations.

Beauregard cultivar stem cuttings about 20 cm lengths were transplanted at 25 cm apart, on April 25th and 29th in the 1st and the 2nd seasons, respectively. The source of stem cuttings was El-Baramon Hort. Res. Station, Dakhlyia Governorate, Egypt.

Table (B). Major constituents of the used algae extract

Constituents (D.W)	(%)	Macronutrients (%)		Micronutrients (ppm)	
Crude protein	50.56	N	8.09	Fe	2057
Ether extract	7.39	P	2.69	Zn	722
Crude fiber	9.83	K	0.65	Mn	747
Ash	9.18			Cu	93
Moisture	4.51				

Irrigation was started on 5th May, and ended 1st October (15 days before harvesting) in both seasons. Humic and fulvic acids were added as soil application, during planting of stem cuttings.

The transplants were sprayed with trehalose, potassium silicate and algae four times (45, 60, 75 and 90 days after transplanting) using spreading agent to improve adherence of the spray to the plant foliage for increasing absorption of solutions by the plants. The untreated plants (check) were sprayed with water and spreading agent. One ridge was left between each two experimental plots without spraying as a guard ridge to avoid the overlapping of spraying solutions. In addition, two ridges were left as a buffer zone between each two experimental units to avoid lateral seepage of irrigation water.

All treatments received equal amounts of ammonium sulphate (20.5 % N), calcium superphosphate (15.5% P_2O_5) and potassium sulphate (48.5 % K_2O) at a rate of 200, 150 and, 120 kg/fad., respectively. One third of N, K_2O and all amount of P_2O_5 were added with FYM at 20 m^3/fad. during soil preparation in the center of row and covered by clay. The rest of N and K_2O were added as soil application at three doses at 60, 75 and 90 days after transplanting in both growing seasons. The other conventional practices were applied.

Data recorded

A three-plant sample from each sub experimental unit was randomly taken at 110 days after transplanting to measure the plant growth traits and plant chemical constituents as follows:

Plant growth traits: Vine length (cm), number of branches/plant and total fresh weight were measured. Dry weight of shoot (leaves and branches) of each plant were dried at 70^oC till the constant weight and then weighed.

***Plant water relations*:** Total, free and bound water as well as osmotic pressure in the fourth upper leaf of sweet potato plants were determined for every experimental unit at 110 days after transplanting, in both seasons, according to the method described by **Gosev (1960).**

Proline amino acid content: It was determined in the shoots at 110 days after transplanting in both seasons of study according to **Bates (1973).** ***Nitrogen, phosphorus and potassium contents in shoots*****:** N, P and K (%) in the dried shoots (leaves and branches) were determined at 110 days after transplanting in both seasons according to **AOAC (1995**).

Yield and its components

At harvest time (150 days after planting), all tuber roots of each treatment were classified into two grades, *i.e.* marketable tuber roots (average tuber root were about 100 - 250 g) and non-marketable tuber roots (average tuber roots less than 100g or more than 250g), then weighed to determine the total yield which expressed as ton/fad. In addition, tuber root length, diameter and weight were determined.

Tuber root quality

Nitrogen, phosphorus and potassium percentages: in tuber roots were determined by using the same methods as described above in shoot chemical constituents**.**

Dry Matter (%): One hundred grams of the grated mixture were dried at 105^0C till the constant weight and DM (%) was recorded.

Total carbohydrate (%)*:* It was determined colorimetrically in dry tuber roots as (g glucose/ 100g) as outlined by **Michel *et al*. (1956**).

Statistical analysis

Collected data were subjected to proper statistical analysis of variance according to Snedecor and Cochran (1980) and the differences among treatments were compared using Duncans' multiple range test (Duncan, 1955), where means had the different letter were statistically significant, while those means followed by the same letter were statistically insignificant.

RESULTS AND DISCUSSION

1.Plant growth

1.1 Effect of irrigation intervals

Data in Table 1 indicate that, there were no significant differences between two irrigation intervals (15 or 30 days) regarding all plant growth parameters such as vine length, fresh weight of shoots and dry weight of

Table (1). Effect of irrigation intervals and some soil and foliar application treatments on plant growth at 110 days after planting of sweet potato during 2019 and 2020 seasons

	Vine length (cm)		Number of branches / plant		Fresh weight of shoot (g)		Dry weight of shoot (g)	
	2019 season	**2020 season**	**2019 season**	**2020 season**	**2019 season**	**2020 season**	**2019 season**	**2020 season**
	Effect of irrigation intervals							
15 days	153.12 a	157.25 a	12.75 a	13.25 a	614.08 a	610.00 a	112.71 a	113.46 a
30 days	152.44 a	154.22 b	12.33 a	13.00 a	600.79 a	593.41 b	112.75 a	111.71 b
	Effect of some soil and foliar application treatments							
HA	102.84 g	105.50 h	8.83 e	8.33 f	405.11 g	420.10 g	81.72 e	76.19 f
HA+ Trehalose	153.44 e	155.67 e	11.33 d	12.49 d	602.02 d	591.63 e	110.09 d	110.41 d
HA+ KSi	161.17 d	166.85 d	13.33 c	14.33 c	641.17 c	639.16 d	118.39 c	123.49 c
HA+ Algae	140.62 f	147.82 f	11.16 d	13.00 d	552.80 e	549.03 f	106.89 d	106.21 e
FA	99.57 g	110.55 g	11.16 d	10.49 e	419.08 f	412.03 g	84.40 e	78.45 f
FA + Trehalose	184.23 b	187.57 b	14.50 b	15.33 b	718.78 b	713.28 b	131.69 b	135.96 b
FA+ KSi	206.57 a	195.93 a	17.16 a	18.33 a	812.33 a	796.28 a	142.59 a	144.16 a
FA+ Algae	173.86 c	176.03 c	12.83 c	12.66 d	708.22 b	692.18 c	126.09 b	125.82 c

HA= Humic acid at 20 kg /fad. and FA= fulvic acid at 10 kg /fad. as soil application
Trehalose at 1 g/l, KSi= Potassium silicate at 1 ml/l, and algae extract at 1 g/l as foliar application
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

shoots at 110 days after transplanting in both seasons, except vine length and fresh weight of shoots in the 2nd season. This means that irrigation sweet potato plants after 15 days intervals gave the higher values of vine length and both fresh and dry weight of shoots in the 2nd season.

The longest irrigation intervals (stressed plants) reduced growth of sweet potato plant as: main stem length, number of branches, leaf area and shoot dry weight per plant comparing to unstressed plants (Abdel -Fattah *et al*., 2002). Also, Plants under drought alternate their performance to alleviate the changed environmental conditions.These changes include physiological and biochemical changes such as decreased leaf size, stem elongation, root proliferation and water use efficiency (Farooq *et al.*, 2009).

The increase in growth attributed to the function of water in the process of photosynthesis and therefore reflected on the increase in leaf area, dry weight and leaf chlorophyll fluorescence (Abd El-Gawad *et al*., 2017).

These results are harmony with those reported with Ayoub (2005), Abou El-Khair *et al.* (2011), Yooyongwech *et al.* (2014), Saqib *et al*. (2017) and Abu El-Fotoh *et al*. (2019) on sweet potato

1.2. *Effect of soil and foliar application treatments*

Treating sweet potato plants cv. Beauregard grown in clay soil during summer season with fulvic acid (FA) at 10 kg /fad. as soil application + spraying with potassium silicate (KSi) at 1 ml/l significantly increased vine length, number of branches/ plant, fresh weight of shoots and dry weight/ plant at 110 days after transplanting, followed by FA at 10 kg /fad. as soil application + spraying with algae extract at 1 g/l compared the other treatments in both seasons (Table 1). Whereas, treating with humic acid (HA) at 20 kg /fad. as soil application gave the lowest vine length number of branches/ plant, fresh weight of shoots and dry weight/ plant in both seasons.

The increases in dry weight of shoots / plant were about 74.48 and 89.21 % , 68.94 and 83.76 % for treating sweet potato plants with FA at 10 kg /fad. as soil application + spraying with KSi at 1 ml/l over treating with HA at 20 kg /fad. only or with treating with FA as soil application only in the 1st and 2nd seasons, respectively.

Fulvic acid is the most significant component of organic and natural substances in aquatic systems, it is highly beneficial to both plant and soil because: 1) it is important for increasing microbial activity. 2) It is considered as a plant growth bio-stimulant, and enhances vegetative characteristics. Fulvic acid is very effective due to: its low molecular weight which range from approximately 1.000 to 10.000 compared with humic acid, It includes important and ability to effectively bond minerals and elements into its molecular structure leading them dissolve and grow to be mobilized fulvic complexes, fulvic acid typically bears 70 or more mineral and trace factors as a part of its molecular complexes, also, it have an oxygen content twice that of humic acids and they have many carboxyl and hydroxyl groups much than humic acid. So, they are much more chemically reactive. This make FAs exchange capacity is more than double that of humic acids (Aiken *et al*., 1985).

As for fulvic acid, results are harmony with Abd El-Baky *et al.* (2020) showed that the highest values of vegetative growth (plant height, number of leaves and branches as well as fresh and dry weight of leaves and / or branches) were recorded with okra plant which received fulvic (3 g/L), but the lowest values were recorded with the control.

As for potassium silicate, this result might be due to the role of potassium silicate because it contains potassium, which helps in some of the physiological processes of plants, such as photosynthesis, protein synthesis and maintenance of water status in plant tissues. Also, potassium silicate contains silicon, which reduces biological and non-biological stresses in plants by preserving the potential of plant water, light activity, stomatal conductance and leaves under high rates of transpiration (Das *et al*., 2017). Also, the enhancement sweet potato plant growth characteristics due to algae extract spraying may be attributed to the auxins content of the algae extract which has an effective role in cell division and enlargement, this leads to increase the shoot growth, leaves number, and plant dry weight (Gollan and Wright 2006).

1.3. Effect of the interaction

The interaction between 15 or 30 days irrigation intervals and FA at 10 kg /fad. as soil application+ KSi at 1 ml/l as foliar application significantly increased vine length, number of branches/plant, fresh weight of shoots and dry weight of shoots at 110 days after transplanting in both seasons with no significant differences between them for vine length, fresh weight of shoots in both seasons and dry weight of shoots/ plant in the 1st season (Table 2).

The increases in dry weight of shoots / plant were about 92.62 and 89.94 % for the interaction between irrigation after 30 days interval and treating with FA at 10 kg/fad.+ spraying with KSi at 1 ml/l over the interaction between irrigation after 15 days and treating with HA only at 20 kg /fad. in the 1st and 2nd seasons, respectively.

This may be due to the physiological function of silicon is based on relations between silicon deposition at certain points and enhanced resistance to

Table (2). Effect of the interaction between irrigation intervals and some soil and foliar application treatments on plant growth at 110 days after planting of sweet potato during 2019 and 2020 seasons

Treatments		Vine length (cm)		Number of branches / plant		Fresh weight of shoot (g)		Dry weight of shoot (g)	
Irrigation intervals	**Soil and foliar application treatments**	**2019 season**	**2020 season**	**2019 season**	**2020 season**	**2019 season**	**2020 season**	**2019 season**	**2020 season**
15 days	**HA**	101.33 h	107.00 h	9.00 fg	8.00 j	412.54 gh	429.86 i	74.33 h	73.00 i
	HA+ Trehalose	154.33 e	155.33 e	12.33 e	12.66 fg	607.36 e	596.26 f	111.67 ef	112.67 e
	HA+ KSi	157.67 de	168.33 d	14.00 cd	14.66 cd	650.00 d	657.98 d	121.00 cd	126.00 cd
	HA+ Algae	145.00 f	149.33 f	10.33 f	14.00 de	561.26 f	564.72 g	107.00 ef	106.33 f
	FA	100.33 h	114.67 g	10.33 f	9.66 i	428.82 g	417.38 ij	87.33 g	81.67 g
	FA + Trehalose	183.33 b	189.67 b	15.00 bc	15.33 c	724.88 b	716.56 b	132.00 b	135.67 b
	FA+ KSi	210.00 a	196.33 a	18.33 a	19.33 a	814.66 a	803.22 a	142.00 a	149.67 a
	FA+ Algae	173.00 c	177.33 c	12.66 de	12.33 fgh	713.10 bc	694.02 c	126.33 bc	122.67 d
30 days	**HA**	104.34 h	104.00 h	8.66 g	8.66 ij	397.67 h	410.33 j	89.10 g	79.38 gh
	HA+ Trehalose	152.54 e	156.00 e	10.33 f	12.33 fgh	596.67 e	587.00 f	108.50 ef	108.16 ef
	HA+ KSi	164.66 d	165.36 d	12.66 de	14.00 de	632.33 d	620.33 e	115.78 de	120.98 d
	HA+ Algae	136.24 g	146.30 f	12.00 e	12.00 gh	544.33 f	533.33 h	106.78 f	106.08 f
	FA	98.80 h	106.42 h	12.00 e	11.33 h	409.33 gh	406.67 j	81.46 gh	75.22 hi
	FA + Trehalose	185.12 b	185.46 b	14.00 cd	15.33 c	712.67 bc	710.00 b	131.38 b	136.24 b
	FA+ KSi	203.14 a	195.52 a	16.00 b	17.33 b	810.00 a	789.33 a	143.18 a	138.66 b
	FA+ Algae	174.72 c	174.72 c	13.00 de	13.00 ef	703.33 c	690.33 c	125.84 bc	128.96 c

HA= Humic acid at 20 kg /fad. and FA= fulvic acid at 10 kg /fad. as soil application
Trehalose at 1 g/l, KSi= Potassium silicate at 1 ml/l, and algae extract at 1 g/l as foliar application
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

various stresses (Shaaban and Abou El-Nour, 2014). In addition, silicon plays a role as a mechanical and a physiological barrier. It also alters the levels of osmolytes and antioxidant enzymes which are the first line of defense in drought stress, also reducing the levels of oxidative stress factors such as hydrogen peroxide (Sapre and Vakharia, 2016). These results are harmony with those obtained with Abd El-Gawad *et al*. (2017) on potato they showed that irrigation after the depletion of 55-60 % of available soil water and spraying with potassium silicate at 2000 ppm gave the highest values of leaf area, fresh and dry weight of shoots than other interaction treatments.

2. *Plant water relationship*

2.1. Effect of irrigation intervals

The obtained results in Table 3 illustrate that, total water and free water (%) in sweet potato leaves at 110 days after transplanting increased with shortest irrigation intervals (15 days), whereas bound water and osmotic pressure increased with increasing irrigation intervals (30 days).

The increase in bound water and the decrease in free water under water stress were mainly due to the increases in osmotic pressure resulted from the conversion of starch into soluble carbohydrates as indicated by Lancher (1993). These results are harmony with those reported with Mansour and Abu El-Fotoh (2018) on potato found that and Total and free water in leaf tissues were the highest significantly increased by increasing irrigation water levels up to 100 % from FC in both seasons. While, bound water (%) in leaf tissues were the superior with the lowest level of irrigation water in both seasons.

2.2.*Effect of soil and foliar application treatments*

Fulvic acid at 10 kg /fad. as soil application +foliar spray with trehalose at 1 g/l as foliar application significantly increased total water and free water at 110 days after transplanting and significantly decreased bound water and osmotic pressure in leaves at 110 days after transplanting (Table 3). In the other hand, HA at 20 kg /fad. as soil application significantly increased bound water and osmotic pressure in leaves and significantly decreased total water and free water in leaves in both seasons.

Spraying with trehalose is imperative to improve drought tolerance of economic cash crops and vegetables under the changing environmental

Table (3). Effect of irrigation intervals and some soil and foliar application treatments on plant water relationship at 110 days after planting of sweet potato during 2019 and 2020 seasons

Treatments	Total water (%)		Free water (%)		Bound water (%)		Osmotic pressure (%)	
	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
	Effect of irrigation intervals							
15 days	85.64 a	86.34 a	68.30 a	68.45 a	17.33 b	17.89 b	5.74 b	5.93 b
30 days	80.94 b	82.18 b	54.28 b	54.16 b	26.66 a	28.01 a	8.60 a	9.31 a
	Effect of some soil and foliar application treatments							
HA	79.26 f	80.10 g	51.60 g	53.42 f	27.65 a	26.68 a	8.42 a	8.79 a
HA+ Trehalose	84.06 c	85.85 c	62.79 d	63.21 b	21.27 c	22.64 bc	7.25 bc	7.54 c
HA+ KSi	81.63 e	81.60 e	57.81 e	57.66 d	23.82 b	23.94 b	7.44 b	7.98 b
HA+ Algae	79.24 f	80.86 f	54.77 f	55.04 e	24.46 b	25.81 a	8.12 a	8.51a
FA	83.03 d	84.31 d	62.19 d	61.81 c	20.84 c	22.50 c	6.85 c	7.50 c
FA + Trehalose	88.60 a	88.54 a	69.82 a	68.26 a	18.78 d	20.28 d	6.26 d	6.76 d
FA+ KSi	85.86 b	87.29 b	66.90 b	67.32a	18.96 d	19.97 d	6.32 d	6.65 d
FA+ Algae	84.65 c	85.53 c	64.43 c	63.75 b	20.22 c	21.77 c	6.74 cd	7.26 c

HA= Humic acid at 20 kg /fad. and FA= fulvic acid at 10 kg /fad. as soil application
Trehalose at 1 g/l, KSi= Potassium silicate at 1 ml/l, and algae extract at 1 g/l as foliar application
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

conditions. A range of mechanisms (physiological, biochemical and molecular) used by plants to tolerate water stress (Ashraf 2010).

2.3. ***Effect of the interaction***

The interaction between irrigation intervals at 15 days (higher water regime) and FA at 10 kg /fad. as soil application+ trehalose at 1 g/l significantly increased total water and free water in sweet potato leaves at 110 days after transplanting (Table 4).

The interaction between irrigation after 30 days (low water regime) and HA at 20 kg /fad. as soil application significantly increased bound water and osmotic pressure in leaves. This mean that, under water stress, bund water and osmotic pressure increased in leaves with HA at 20 kg /fad. as soil application.

Using trehalose enhancing water use efficiency, prolific deep root system, suppression in transpirational loss, maintenance of cell turgor potential, better photosynthetic rate at low leaf water potential, stomatal regulation, up regulation of antioxidants, synthesis of osmolytes, osmotic adjustment/osmoregulation, all together or independently they may show beneficial role in plants to resist drought stress (Shafiq *et al.*, 2015).

3.***Nitrogen, phosphorus, potassium and proline content in shoots***

3.1.***Effect of irrigation intervals***

Nitrogen, phosphorus and potassium contents in shoots increased with increasing irrigation water quality (15 days irrigation intervals), whereas proline amino acid contents in leaves increased with reducing irrigation water quality (30 days irrigation intervals) as shown in Table (5). This means that, proline content in leaves increased under water stress conditions.

In this regard, Barker *et al.* (1993) who found that leaf proline concentration averaged 20 times greater in the stressed plant compared to well watered plants. In this regard, Stewart (1977) reported that the conversion of proline to glutamic acid and hence to other soluble compounds proceeds readily in turgid leaves and it is stimulated by higher concentrations of proline. This suggests that proline oxidation could function as a control mechanism for maintaining low cellular levels of proline in turgid tissues. In water stressed, however, proline oxidation is reduced to negligible rates. It seems likely that inhibition of proline oxidation is necessary in maintaining high levels of proline found in stressed levels.

Table (4). Effect of the interaction between irrigation intervals and some soil and application treatments on plant water relationship at 110 days after planting of sweet potato during 2019 and 2020 seasons

Treatments		Total water (%)		Free water (%)		Bound water (%)		Osmotic pressure (%)	
Irrigation intervals	Soil and foliar application treatments	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
15 days	HA	80.79 g	82.14 ij	57.73 h	60.00 ef	23.06 e	22.14 e	7.09 ef	7.18 f
	HA+ Trehalose	88.92 b	90.34 a	70.13 d	70.87 b	18.79 g	19.47 f	6.59 f	6.49 g
	HA+ KSi	84.70 e	83.70 gh	64.40 e	63.40 d	20.30 fg	20.30 ef	6.77 f	6.77 fg
	HA+ Algae	81.25 g	82.93 hi	59.92 g	61.39 e	21.33 f	21.54 e	7.11 ef	7.18 f
	FA	84.71 e	85.07 ef	69.78 d	69.38 c	14.93 h	15.69 g	4.98 g	5.23 h
	FA + Trehalose	90.97 a	90.91 a	77.70 a	76.08 a	13.27 i	14.83 g	4.42 g	4.94 hi
	FA+ KSi	87.40 c	88.93 b	74.67 b	75.10 a	12.73 i	13.83 g	4.24 g	4.61 i
	FA+ Algae	86.38 d	86.72 c	72.10 c	71.40 b	14.28 hi	15.32 g	4.76 g	5.11 h
30 days	HA	77.73 ij	78.06 l	45.48 l	46.84 k	32.25 a	31.22 a	9.75 a	10.41 a
	HA+ Trehalose	79.20 h	81.37 j	55.45 i	55.56 gh	23.75 de	25.81 d	7.92 de	8.60 e
	HA+ KSi	78.57 hi	79.50 k	51.23 j	51.92 i	27.34 b	27.58 cd	8.11 cd	9.19 cd
	HA+ Algae	77.23 j	78.79 kl	49.63 k	48.70 j	27.60 b	30.09 ab	9.14 ab	9.85 b
	FA	81.36 g	83.55 gh	54.61 i	54.24 h	26.75 bc	29.31 a-c	8.72 bc	9.77 b
	FA + Trehalose	86.23 d	86.18 cd	61.94 f	60.44 ef	24.29 de	25.74 d	8.10 cd	8.58 e
	FA+ KSi	84.33 e	85.65 de	59.14 g	59.54 f	25.19 cd	26.11 d	8.40 b-d	8.70 de
	FA+ Algae	82.93 f	84.34 fg	56.76 h	56.11 g	26.17 bc	28.23 bc	8.72 bc	9.41 bc

HA= Humic acid at 20 kg /fad. and FA= fulvic acid at 10 kg /fad. as soil application
Trehalose at 1 g/l, KSi= Potassium silicate at 1 ml/l, and algae extract at 1 g/l as foliar application
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table (5). Effect of irrigation intervals and some soil and foliar application treatments on N,P and K contents in shoots as well as proline amino acid in leaves at 110 days after planting of sweet potato during 2019 and 2020 seasons

Treatments	N (%)		P (%)		K (%)		Proline amino acid (m/100 gm DW)	
	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
	Effect of irrigation intervals							
15 days	2.49 a	2.53 a	0.360 a	0.348 a	2.31 a	2.34 a	146.07 b	149.83 b
30 days	2.42 b	2.46 b	0.353 b	0.343 b	2.27 b	2.32 b	177.31 a	185.93 a
	Effect of some soil and foliar application treatments							
HA	2.10 h	2.23 f	0.323 h	0.312 f	2.10 g	2.12 g	198.52 a	207.82 a
HA+ Trehalose	2.47 e	2.49 d	0.349 e	0.347 d	2.24 d	2.26 e	151.81 e	163.08 d
HA+ KSi	2.37 f	2.36 e	0.347 f	0.339 e	2.18 e	2.20 f	156.26 d	171.15 c
HA+ Algae	2.54 d	2.60 c	0.353 d	0.352 c	2.34 c	2.35 d	182.93 b	189.35 b
FA	2.15 g	2.24 f	0.337 g	0.335 e	2.16 f	2.11 g	171.23 c	173.35 c
FA + Trehalose	2.69 b	2.71 b	0.379 b	0.361 b	2.43 b	2.55 b	134.02 g	126.24 f
FA+ KSi	2.60 c	2.59 c	0.369 c	0.351 cd	2.54 a	2.60 a	139.27 f	150.14 e
FA+ Algae	2.73 a	2.76 a	0.397 a	0.368 a	2.34 c	2.46 c	159.48 d	161.89 d

HA= Humic acid at 20 kg /fad. and FA= fulvic acid at 10 kg /fad. as soil application
Trehalose at 1 g/l, KSi= Potassium silicate at 1 ml/l, and algae extract at 1 g/l as foliar application
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

The present results indicating that soil water statutes with irrigation at 15 days intervals was the proper for uptakeing N, P and K into sweet potato shoots compared to 30 days irrigation intervals.

Similar results were observed by Saif El-Deen *et al*. (2011) and Abd- All *et al*. (2017) on sweet potato. They indicated that shortest irrigation intervals gave the highest mineral contents in shoots of sweet potato. In this regard, Rodríguez-Delfín *et al*. (2011) reported increase in free proline content of sweet potato cultivars when plants were subjected to water deficit conditions. Also, Saqib, *et al*. (2017) showed that leaf proline content in sweet potato shoots was the maximum in plants irrigated after 21 days interval, followed by 14 days interval.

3.2. *Effect of soil and foliar application treatments*

Data in Table 5 show that FA at 10 kg /fad. as soil application + foliar spray with algae at 1 g/l significantly increased N and P and K contents in shoots, whereas FA at 10 kg /fad. as soil application + foliar spray with KSi at 1 ml/l significantly increased K contents in shoots, while HA at 20 kg /fad. as soil application significantly increased proline content in leaves at 110 days after transplanting in both seasons.

This result may be due to the role of fulvic or humic acids which are harmony with those reported by many investigators. Humic acid application to soils boost up biological processes in soil and hold the nutrients in easily exchangeable form to minimize their leaching from soil profile with peculating water (Brady and Weil 2008). Addition of humic acid increases the uptake of both micro and macro nutrients and led to hormonal activities and improving nutritional status, it shows anti-stress affect in plant body when soil pH and temperature are unfavorable for plant growth (Kulikova *et al*., 2005).

Results are agreement with Abd- All *et al.* (2017). They indicated that application of humic acid to the soil significantly increased total nitrogen, potassium and phosphorous content of sweet potato tubers than untreated .

This increase in N, P and K contents in shoots may be due to that the high protein content (50.56 %) on dry basis of the algae extract which split natural plant amino acids involved directly in the metabolism (Table A). Also, algae extract is a rich source of potassium and contains considerable amounts of Ca, Cu, Fe, Mg, Mn, P and Zn. These results may explain the great benefits of algae extract on supplementing pea plants with their requirements from organic and mineral nutrients (Marrez *et al*., 2014).

These results are harmony with Abd-Elatif and Ismaiel (2019) on cassava. They showed that spraying plants with algae extract at 1 g/l recorded the highest percentages of N, and K contents in shoots than unsprayed plants.

3.3.*Effect of the interaction*

The interaction between 15 days irrigation intervals and FA at 10 kg/ fad. as soil application + spraying with algae at 1 g/l increased N and P contents , whereas the interaction between 30 days irrigation intervals +FA at 10 kg /fad.+ spraying with algae at 1 g/l increased K content in shoots (Table 6). The interaction between 30 days irrigation intervals and HA at 20 kg /fad. as soil application only increased proline content in leaves at 110 days after transplanting.

This means that, under water stress proline content increased with HA at 20 kg /fad. as soil application only.

4. Yield and its components

4.1.Effect of irrigation intervals

Irrigation sweet potato plants every 15 days significantly increased tuber root diameter, tuber root weight, marketable yield and total yield /fad., with no significant differences with irrigation every 30 days with respect to tuber root weight, total tuber root yield in both seasons and unmarketable yield in 2nd season whereas, irrigation every 30 days intervals significantly increased tuber root length in both seasons and unmarketable yield in the 1st season (Tables 7 and 8).

Irrigation every 15 days intervals increased total yield about 0.447 and 0.525 ton/fad. over irrigation every 30 days intervals (water stress) in the 1st and 2nd seasons, respectively. Marketable yield percentages from total yield were about 87.96 and 85.76 % for 15 days irrigation intervals and 85.77 and 85.56 % for 30 days irrigation intervals.

The shortest irrigation intervals (irrigation every 15 days) to sweet potato plants, led to keep higher water content in the plant tissues and this in turn produced heavier tuber roots than those under water stress (longest irrigation interval, every 30 days). Water stress causes an increase in ABA/CYT ratio, which in turn decreased plant growth (Marschner, 1995). Also, he added that under sufficient water conditions there was a decrease in ABA and increase in CYT, GA and IAA reflecting good growth, dry matter content and yield. Moreover, under water stress (irrigation every 30 days) the synthesis of ABA from carotenoids in roots occurs and then transport to different parts of plant especially leaves and this in turn affect the dry matter accumulation in leaves and different organs (Lancher, 1993).

Table (6).Effect of the interaction between irrigation intervals and some soil and foliar treatments on N,P and K contents in shoots as well as proline amino acid in leaves after 110 days from planting of sweet potato during 2019 and 2020 seasons

Treatments		N (%)		P (%)		K (%)		Proline amino acid (m/100 gm DW)	
Irrigation intervals	Soil and foliar treatments	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
15 days	HA only	2.22 i	2.25 j	0.331 j	0.316 i	2.14 k	2.13 kl	193.43 b	192.24 d
	HA+ Trehalose	2.47 g	2.54 f	0.352 ef	0.349 de	2.27 g	2.29 h	133.30 h	148.39 i
	HA+ KSi	2.38 h	2.38 h	0.350 fg	0.340 fg	2.20 hi	2.22 i	152.25 fg	160.15 h
	HA+ Algae	2.54 f	2.60 e	0.354 e	0.354 cd	2.38 e	2.40 f	167.98 d	169.11 g
	FA only	2.16 j	2.30 i	0.342 i	0.338 fgh	2.19 ij	2.14 k	147.86 g	149.42 i
	FA + Trehalose	2.75 b	2.75 b	0.381 b	0.361 b	2.45 c	2.54 c	119.95 i	105.88 l
	FA+ KSi	2.62 d	2.62 e	0.377 c	0.352 cde	2.49 b	2.58 b	121.09 i	132.19 k
	FA+ Algae	2.77 a	2.82 a	0.398 a	0.380 a	2.38 e	2.47 d	132.69 h	141.27 j
30 days	HA only	1.97 l	2.21 k	0.315 k	0.309 i	2.07 l	2.12 l	203.61 a	223.41 a
	HA+ Trehalose	2.47 g	2.44 g	0.347 gh	0.345 ef	2.22 h	2.24 i	170.32 d	177.78 f
	HA+ KSi	2.37 h	2.35 h	0.344 hi	0.338 gh	2.17 j	2.19 j	160.26 e	182.16 e
	HA+ Algae	2.55 f	2.61 e	0.352 ef	0.350 de	2.31 f	2.31 g	197.87 b	209.59 b
	FA only	2.13 k	2.17 l	0.332 j	0.332 h	2.13 k	2.08 m	194.59 b	197.28 c
	FA + Trehalose	2.64 d	2.67 d	0.377 c	0.362 b	2.42 d	2.56 b	148.09 g	146.60 i
	FA+ KSi	2.59 e	2.57 f	0.361 d	0.351 cde	2.59 a	2.62 a	157.46 ef	168.09 g
	FA+ Algae	2.68 c	2.71 c	0.396 a	0.357 bc	2.30 f	2.45 e	186.26 c	182.51 e

HA= Humic acid at 20 kg /fad. and FA= fulvic acid at 10 kg /fad. as soil application
Trehalose at 1 g/l, KSi= Potassium silicate at 1 ml/l, and algae extract at 1 g/l as foliar application
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table (7). Effect of irrigation intervals and some soil and foliar application treatments on tuber root characteristics of sweet potato during 2019 and 2020 seasons

Treatments	Tuber root diameter (cm)		Tuber root length (cm)		Tuber root weight (g)	
	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
	Effect of irrigation intervals					
15 days	5.95 a	5.82 a	19.33 b	19.49 b	165.38 a	167.36 a
30 days	5.74 b	5.65 b	20.45 a	19.78 a	162.73 a	164.33 a
	effect of some soil and foliar application treatments					
HA	4.86 e	4.91 f	15.66 g	16.16 f	96.98 f	102.07 g
HA+ Trehalose	5.58 d	5.60 d	20.00 d	20.33 c	158.11 d	155.39 e
HA+ KSi	5.44 d	5.40 e	19.33 e	17.99 e	170.32 c	174.25 d
HA+ Algae	5.88 c	5.78 d	21.00 c	21.66 b	168.42 c	171.93 d
FA	5.03 e	4.85 f	18.33 f	18.66 d	112.73 e	114.23 f
FA + Trehalose	6.63 b	6.31 b	21.49 b	18.33 de	182.80 b	183.79 c
FA+ KSi	6.11 c	6.08 c	23.83 a	23.50 a	211.71 a	218.43 a
FA+ Algae	7.23 a	6.93 a	19.49 e	20.50 c	211.38 a	206.67 b

HA= Humic acid at 20 kg /fad. and FA= fulvic acid at 10 kg /fad. as soil application
Trehalose at 1 g/l, KSi= Potassium silicate at 1 ml/l, and algae extract at 1 g/l as foliar application
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan’s multiple range test.

Results are agreed with Abdel -Fattah *et al.* (2002), Ekanayake and Collins, (2004), Ayoub (2005), Abou El-Khair *et al.* (2011), Yooyongwech *et al.* (2014) and Abu El-Fotoh *et al*. (2017) on sweet potato and Mahmoud *et al.* (2019) on potato.

4.2. *Effect of soil and foliar application treatments*

Treating sweet potato plants with FA at 10 kg /fad. as soil application + foliar spray with algae at 1 g/l gave the highest tuber root diameter, whereas FA at 10 kg /fad.+ foliar spray with KSi at 1 ml/l gave the highest tuber root length , tuber root weight, marketable yield and total yield/fad. (Tables 7 and 8). The increases in total yield were about 48.53 and 49.42 % for FA at 10 kg /fad.+ spraying with KSi at 1 ml/l and 40.58 and 44.08 % for FA at 10 kg /fad.+ spraying with algae extract at 1 g/l over the HA only

Table (8). Effect of irrigation intervals and some soil and foliar treatments on yield and its components of sweet potato during 2019 and 2020 seasons

Treatments	Unmarketable tuber roots yield (ton/fad.)		Marketable tuber roots yield (ton/fad.)		Total tuber roots yield (ton/fad.)		Marketable tuber roots (%) to total yield tuber roots	
	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
	Effect of irrigation intervals							
15 days	1.850 b	2.214 a	13.520 a	13.331 a	15.371 a	15.545 a	87.96	85.76
30 days	2.124 a	2.168 a	12.800 b	12.851 b	14.924 a	15.020 a	85.77	85.56
	Effect of some soil and foliar treatments							
HA	2.931 a	2.840 a	9.225 f	9.099 f	12.156 e	11.939 f	75.89	76.21
HA+ Trehalose	2.316 c	2.034 c	11.870 d	12.517 c	14.186 d	14.552 d	83.67	86.02
HA+ KSi	1.654 e	2.394 b	13.775 c	13.342 b	15.430 c	15.737 c	89.27	84.78
HA+ Algae	1.956 d	2.459 b	12.281 d	12.093 d	14.237 d	14.553 d	86.26	83.10
FA	2.680 b	2.832 a	10.126 e	10.548 e	12.806 e	13.381 e	79.07	78.83
FA + Trehalose	1.521 e	1.354 e	15.702 b	15.703 a	17.224 b	17.057 b	91.16	92.06
FA+ KSi	1.840 d	1.970 c	16.216 a	15.869 a	18.056 a	17.840 a	89.81	88.95
FA+ Algae	1.002 f	1.644 d	16.087 ab	15.558 a	17.089 b	17.202 b	94.14	90.44

HA= Humic acid at 20 kg/fad. and FA= fulvic acid at 10 kg/fad. as soil application
Trehalose at 1 g/l, KSi= Potassium silicate at 1 ml/l, and algae extract at 1 g/l as foliar application
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.
Marketable tuber roots (average tuber roots was about 100-250 g), Unmarketable tuber roots (average tuber roots less than 100 g or more than 250 g)

at 20 kg /fad. in the 1st and 2nd seasons, respectively. This means that spraying plants with KSi at 1 ml/l , algae at 1 g/l and trehalose at 1 g/l with FA at 10 kg /fad. as soil application increased total yield compared to FA at 10 kg /fad. only.

The marketable yield percentage from total yield were about 91.16 and 92.06% for FA at 10 kg /fad.+ trehalose at 1 g/ l , 94.14 and 90.44 % for FA at 10 kg /fad. +algae extract at 1g/l in the 1st and 2nd seasons, respectively. HA at 20 kg /fad. as soil application gave the highest unmarketable yield /fad.

Fulvic acid is a bi-product of humic acid. Humic acid is extracted from any material containing well-decomposed organic matter - soil, coal, composts, etc. As humic material is decomposed by living microbes, these microbes create the most biologically complex organic compound, Fulvic acid. (Mikkelsen, 2005).

These results are in accordance with those reported by Shankle *et al*. (2004), Saif El-Deen *et al*. (2011) and Abd- All *et al*. (2017). They found that treated sweet potato plants with fulvic acid were the best for increasing yield and its components. As for algae extract, Doss *et al*. (2015), Abd- All *et al*. (2017), Mahmoud *et al*. (2018) on sweet potato, Abd-Elatif and Ismaiel (2019) on cassava. They showed that spraying plants with algae extract recorded the best yield and its components than unsprayed plants.

Potassium silicate is origin of high solubility of potassium and silicon is used in the provision of decrease amounts of potassium to facilitate get better the value of the yield (Tarabih *et al*., 2014). In this regard, Abd El-Gawad *et al*. (2017) showed that the potato plants are sprayed with potassium silicate at 2000 ppm significantly increased yield and its components per plant and per faddan.

4.3. *Effect of the interaction*

Yield and its components of sweet potato plants had significant affected by the interaction treatments in both seasons (Tables 9 and 10).

The interaction between irrigation every 15 days and fertilizing with FA at 10 kg /fad. as soil application+ algae extract at 1 g/l as foliar application increased tuber root diameter , whereas the interaction between irrigation every 15 days and FA at 10 kg /fad. as soil application+ KSi at 1 ml/ as foliar application significantly increased tuber root weight, marketable yield and total yield /fad in both seasons, with no significant differences with the interaction between irrigation every 30 days and FA at 10 kg /fad. as soil application + KSi at 1 ml/ as foliar application, regarding total yield /fad. or

Table (9). Effect of the interaction between irrigation intervals and some soil and foliar application treatments on tuber root characteristics of sweet potato at harvest time during 2019 and 2020 seasons

Treatments		Tuber root diameter (cm)		Tuber root length (cm)		Tuber root weight (g)	
Irrigation intervals	Soil and foliar application treatments	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
15 days	HA	4.90 ij	4.90 h	14.00 h	15.00 j	99.26 h	105.37 hi
	HA+ Trehalose	5.53 gh	5.50 fg	20.00 d	20.00 e	159.26 ef	157.15 f
	HA+ KSi	5.53 gh	5.40 g	19.66 de	18.33 g	175.56 c	179.07 cd
	HA+ Algae	5.96 ef	5.80 de	21.00 c	21.33 c	168.52 d	173.22 de
	FA	5.06 ij	4.96 h	17.66 g	18.33 g	114.07 g	112.59 gh
	FA + Trehalose	6.80 bc	6.46 b	20.66 c	21.00 cd	179.26 bc	184.82 c
	FA+ KSi	6.26 de	6.16 c	22.33 b	22.00 b	212.59 a	219.44 a
	FA+ Algae	7.56 a	7.36 a	19.33 ef	20.00 e	214.48 a	207.18 b
30 days	HA	4.83 j	4.93 h	17.33 g	17.33 h	94.69 h	98.77 i
	HA+ Trehalose	5.63 fgh	5.70 ef	20.00 d	20.66 d	156.95 f	153.64 f
	HA+ KSi	5.36 hi	5.40 g	19.00 f	17.66 h	165.08 de	169.42 e
	HA+ Algae	5.80 efg	5.76 def	21.00 c	22.00 b	168.31 d	170.64 de
	FA	5.00 ij	4.73 h	19.00 f	19.00 f	111.40 g	115.87 g
	FA + Trehalose	6.46 cd	6.16 c	22.33 b	15.66 i	186.33 b	182.75 c
	FA+ KSi	5.96 efg	6.00 cd	25.33 a	25.00 a	210.82 a	217.42 a
	FA+ Algae	6.90 b	6.50 b	19.66 de	21.00 cd	208.28 a	206.15 b

HA= Humic acid at 20 kg/fad. and FA= fulvic acid at 10 kg/fad. as soil application
Trehalose at 1 g/l, KSi= Potassium silicate at 1 ml/l, and algae extract at 1 g/l as foliar application
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table (10). Effect of the interaction between irrigation intervals and some soil and foliar application treatments on yield and its components of sweet potato during 2019 and 2020 seasons

Treatments		Unmarketable tuber roots yield (ton/fad.)		Marketable tuber roots yield (ton/fad.)		Total tuber roots yield (ton/fad.)		Marketable tuber roots (%) to total yield tuber roots	
Irrigation intervals	Soil and foliar application treatments	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
15 days	HA	2.600 b	2.803 bc	9.600 i	9.094 i	12.200 i	11.897 i	78.69	76.44
	HA+ Trehalose	2.592 b	2.685 cd	11.675 fg	11.835 f	14.267 ef	14.520 fg	81.83	81.51
	HA+ KSi	1.352 e	2.558 d	14.511 d	13.735 d	15.863 cd	16.293 cd	91.48	84.30
	HA+ Algae	1.465 e	2.594 d	13.478 e	12.926 e	14.943 de	15.520 de	90.20	83.29
	FA	2.075 c	2.312 e	10.838 h	11.075 g	12.913 ghi	13.387 h	83.93	82.73
	FA + Trehalose	1.829 cd	1.665 i	15.104 d	15.468 bc	16.933 b	17.133 bc	89.20	90.28
	FA+ KSi	1.911 cd	1.836 h	16.682 a	16.447 a	18.593 a	18.283 a	89.72	89.96
	FA+ Algae	0.982 f	1.262 j	16.275 ab	16.068 a	17.257 b	17.330 b	94.31	92.72
30 days	HA	3.262 a	2.878 b	8.850 i	9.103 i	12.112 i	11.981 i	73.07	75.98
	HA+ Trehalose	2.041 c	1.384 j	12.064 f	13.199 e	14.105 efg	14.583 ef	85.53	90.51
	HA+ KSi	1.957 cd	2.231 ef	13.039 e	12.949 e	14.996 de	15.180 ef	86.95	85.30
	HA+ Algae	2.447 b	2.325 e	11.083 gh	11.260 g	13.530 fgh	13.585 gh	81.91	82.89
	FA	3.285 a	3.353 a	9.414 i	10.022 h	12.699 hi	13.375 h	74.13	74.93
	FA + Trehalose	1.214 ef	1.044 k	16.301 ab	15.938 ab	17.515 ab	16.982 bc	93.07	93.85
	FA+ KSi	1.769 d	2.104 fg	15.749 bc	15.292 c	17.518 ab	17.396 ab	89.90	87.91
	FA+ Algae	1.022 f	2.026 g	15.898 b	15.048 c	16.920 bc	17.074 bc	93.96	88.13

HA= Humic acid at 20 kg /fad. and FA= fulvic acid at 10 kg /fad. as soil application
Trehalose at 1 g/l, KSi= Potassium silicate at 1 ml/l, and algae extract at 1 g/l as foliar application
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.
Marketable tuber roots (average tuber roots was about 100-250 g), Unmarketable tuber roots (average tuber roots less than 100 g or more than 250 g)

with the interaction between irrigation every 30 days and FA at 10 kg /fad. as soil application + trehalose at 1 g/ as foliar application as for marketable yield in both seasons.

This mean that irrigation sweet potato cv. Beauregard grown in clay soil condition every 15 or 30 days and treated with FA at 10 kg /fad. as soil application +spraying with algae extract at 1 g/l or with KSi at 1 ml/l gave the highest values of marketable yield and total yield /fad.

Water stress conditions, plants treated with HA at 20 kg /fad. as soil application gave the highest values of unmarketable yield /fad., whereas plants treated with FA at 10 kg /fad.+ spraying with algae extract at 1 g/l gave the highest tuber root length in both seasons (Tables 9 and 10).

The marketable yield percentage from total yield were about 94.31 and 92.72% for the interaction between irrigation every 15 days and treated with FA at 10 kg /fad. as soil application + algae extract as foliar application 93.07 and 93.85 % for the interaction between irrigation every 15 days and treated with FA at 10 kg /fad. as soil application+ trehalose at 1 g/l as foliar spray in the 1^{st} and 2^{nd} seasons, respectively.

In this concern, Mahmoud *et al*. (2019) on potato plants under sandy soil. They found that the interaction between shortest irrigation intervals (every three days) and spraying with potassium silicate at 3ml/l showed significant effect on average weight for tubers per plant and the yield for total tuber and marketable yield as compared to the longest irrigation intervals and unsprayed plants.

5. *Tuber root quality*

5.1. Effect of irrigation intervals

There were no significant differences between both irrigation intervals on tuber root quality at harvesting time in both seasons, except nitrogen, and DM% in the 1^{st} season and P contents in both seasons (Table 11). The maximum N and P in tuber roots were observed in 15 days irrigation intervals, while DM (%) was reduced. There were no significant differences between two irrigation intervals (15 or 30 days) regarding K and total carbohydrates in both seasons, N and DM (%) in the tuber roots in 2^{nd} season.

This result is likely due to the irrigation water every 15 days preserved of the moisture in the root zone and this ensured adequate soil water, air and nutrients during the plant growth periods. Thus, the accessibility of moisture in the soil leads to increase nutrients movement in the soil, which reflected in increasing absorption of minerals through plant and carbohydrates assimilation (Abd Elwahed, 2018).

Table (11). Effect of irrigation intervals and some soil and foliar application treatments on tuber root quality of sweet potato at harvest time, during 2019 and 2020 seasons

Treatments	N (%)		P (%)		K (%)		Total carbohydrates (%)		DM (%)	
	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
	Effect of irrigation intervals									
15 days	1.59 a	1.57 a	0.247 a	0.243 a	2.01 a	2.01 a	57.00 a	57.00 a	22.79 b	23.50 a
30 days	1.55 b	1.56 a	0.239 b	0.234 b	2.01 a	2.00 a	56.50 a	56.33 a	23.91 a	24.41 a
	Effect of some soil and foliar application treatments									
HA	1.22 h	1.24 g	0.142 h	0.140 h	1.69 g	1.71 g	52.83 e	52.83 d	19.33 e	19.33 f
HA+ Trehalose	1.57 e	1.55 e	0.244 e	0.238 e	1.89 e	1.86 e	56.50 c	55.16 c	22.83 d	24.50 d
HA+ KSi	1.52 f	1.54 e	0.227 f	0.216 f	1.79 f	1.79 f	55.00 d	53.50 d	22.00 d	22.00 e
HA+ Algae	1.64 d	1.65 d	0.257 d	0.263 d	2.22 c	2.22 c	57.50 c	58.00 b	24.50 bc	25.83 c
FA	1.29 g	1.29 f	0.149 g	0.147 g	1.66 h	1.69 g	53.50 e	52.83 d	19.83 e	19.66 f
FA + Trehalose	1.76 b	1.75 b	0.310 b	0.299 b	2.24 b	2.27 b	59.00 b	59.00 b	25.50 b	27.00 b
FA+ KSi	1.69 c	1.68 c	0.287 c	0.282 c	2.36 a	2.32 a	62.50 a	63.16 a	28.50 a	29.50 a
FA+ Algae	1.84 a	1.84 a	0.326 a	0.324 a	2.20 d	2.19 d	57.16 c	58.83 b	24.33 c	23.83 d

HA= Humic acid at 20 kg /fad. and FA= fulvic acid at 10 kg /fad. as soil application
Trehalose at 1 g/l, KSi= Potassium silicate at 1 ml/l, and algae extract at 1 g/l as foliar application
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

The present results are in accordance with those reported by Ayoub (2005) who found that increasing irrigation water quantity up to the highest rate increased the tuber roots contents of N, P, K, total carbohydrate, starch, sugar, total soluble solids (TSS) and carotene in tuber roots.

5.2. *Effect of soil and foliar application treatments*

Treating sweet potato plants with FA at 10 kg /fad. as soil application + spraying with algae extract at 1 g/l increased N and P , whereas FA at 10 kg /fad. as soil application + KSi at 1 ml/l as foliar application increased K, total carbohydrates and DM% in tuber roots in both seasons (Table 11). In this regard, fulvic acid application to the soil significantly increased total nitrogen, potassium and phosphorous content of sweet potato tubers than untreated (Abd-All *et al*., 2017). Also, Doss *et al.* (2015) spraying of sweet potato plants with seaweed extract at the concentration of 0.75% led to positive response on total sugars, starch, carbohydrates and carotene contents, in both seasons than unsprayed.

5.3. *Effect of the interaction*

The interaction between irrigation every 15 days intervals and treating plants with FA at 10 kg /fad. as soil application + spraying with algae extract at 1 g/l significantly increased N and P contents in tuber roots, whereas the interaction between 15 days irrigation intervals and FA at 10 kg /fad. as soil application + spraying with KSi at 1 ml/l increased total carbohydrates % in tuber roots in both seasons (Table 12). On the other side, K (%) and DM(%) in tuber roots were significantly affected by the interaction between irrigation every 30 days intervals and treating plants with FA at 10 kg /fad. as soil application + spraying with KSi at 1 ml/l in both season .

Conclusively, it could be concluded that, irrigation sweet potato plants cv Beauregard grown in clay soil during summer seasons conditions, the interaction between irrigation every 15 or 30 days and treated plants with fulvic acid at 10 kg /fad. soil application + spraying with KSi at 1 ml/l or with spraying with algae extract at 1 g /l or trehalose at 1 g/l as foliar spray were the best treatments for increasing the growth , productivity and gave the best tuber root quality.

Table (12). Effect of the interaction between irrigation intervals and some soil and foliar application treatments on tuber root quality of sweet potato at harvest time during 2019 and 2020 seasons

Treatments		N (%)		P (%)		K (%)		Total carbohydrates (%)		DM (%)	
Irrigation intervals	Soil and foliar application treatments	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
15 days	HA	1.23 i	1.24 j	0.144 m	0.147 l	1.70 j	1.66 i	52.66 hi	52.33 g	18.33 h	18.33 j
	HA+ Trehalose	1.58 f	1.55 g	0.244 i	0.233 i	1.92 f	1.91 d	55.66 e-g	54.00 f	22.00 f	24.00 f
	HA+ KSi	1.53 g	1.53 g	0.230 j	0.215 j	1.82 h	1.86 e	54.33 g-i	53.33 fg	22.00 f	22.00 gh
	HA+ Algae	1.66 d	1.67 e	0.264 g	0.264 g	2.21 de	2.19 c	57.00 de	57.33 de	23.66 e	25.66 c-e
	FA	1.30 h	1.27 i	0.153 l	0.151 k	1.56 k	1.68 i	54.66 f-h	52.66 fg	19.33 gh	19.00 ij
	FA + Trehalose	1.80 b	1.77 c	0.314 c	0.314 c	2.27 b	2.27 b	60.00 bc	60.00 bc	25.00 c-e	27.00 c
	FA+ KSi	1.72 c	1.71 d	0.291 e	0.291 d	2.37 a	2.32 a	64.00 a	65.00 a	27.66 b	28.66 ab
	FA+ Algae	1.88 a	1.87 a	0.333 a	0.328 a	2.21 cd	2.19 c	57.66 de	61.33 b	24.33 de	23.33 fg
30 days	HA	1.21 i	1.24 j	0.141 m	0.133 n	1.68 j	1.76 g	53.00 hi	53.33 fg	20.33 g	20.33 hi
	HA+ Trehalose	1.57 f	1.55 g	0.244 i	0.244 h	1.87 g	1.81 f	57.33 de	56.33 e	23.66 e	25.00 d-f
	HA+ KSi	1.51 g	1.56 g	0.224 k	0.218 j	1.76 i	1.71 h	55.66 e-g	53.66 fg	22.00 f	22.00 g
	HA+ Algae	1.63 e	1.64 f	0.250 h	0.263 g	2.23 c	2.26 b	58.00 cd	58.66 cd	25.33 cd	26.00 cd
	FA	1.29 h	1.32 h	0.144 m	0.142 m	1.77 i	1.71 h	52.33 i	53.00 fg	20.33 g	20.33 hi
	FA + Trehalose	1.73 c	1.74 d	0.306 d	0.283 e	2.22 cd	2.27 b	58.00 cd	58.00 d	26.00 c	27.00 bc
	FA+ KSi	1.66 d	1.66 e	0.282 f	0.273 f	2.35 a	2.32 a	61.00 b	61.33 b	29.33 a	30.33 a
	FA+ Algae	1.79 b	1.81 b	0.320 b	0.320 b	2.19 e	2.20 c	56.66 d-f	56.33 e	24.33 de	24.33 ef

HA= Humic acid at 20 kg /fad. and FA= fulvic acid at 10 kg /fad. as soil application
Trehalose at 1 g/l, KSi= Potassium silicate at 1 ml/l, and algae extract at 1 g/l as foliar application
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

REFERENCES

A.O.A.C.(1990). Association of Official Agricultural Chemists. Official Methods of Analysis. 10th. Ed. A.O.A.C., Washington, D.C

Abd- All, A. E., A. E. El-Namas and E. M. EL-Naggar (2017). Effect of Humic Acid and Foliar Application of Different Potassium Sources on Yield, Quality and Water Use Efficiency of Sweet Potato Grown under Drip Irrigation in Sandy Soil. *Alex. Sci. Exch. J.,* 38(3): 543-552.

Abd El-Baky, M.M.H., M. EL-Desuki , S.R. Salman, Abd El-Wanis Mona M., S.D. Abou-Hussein and M.O. Bakry (2020). Effect of Humic and Fulvic Acid on Growth and Yield of two Okra cultivars grown in Wadi El-Tor, south Sinai. Middle East J. Appl. Sci., 10(1): 101-109.

Abd El-Fattah, M.A. M. E. Sorial and I.M. Ghnim (2002). Physiological response of sweet potato (*Ipomoe batatas* (L.) Lam.) plants to water stress a different growth stages in relation to nitrogen fertilization at varying levels. *J. Agric. Sci., Mansoura Univ*., 27 (11): 7547-7571.

Abd El-Gawad, H.G., N.A.I. Abu El-Azm and M.S. Hikal (2017). Effect of potassium silicate on tuber yield and biochemical constituents of potato plants grown under drought stress conditions. *Middle East J. Agric. Res*., 6(3): 718-731

Abd Elwahed, A.H.M. (2018). Application of potassium silicate under different irrigation water levels. J. Biol. Chem. Environ. Sci., **13(1):** 59-78.

Abd-Elatif A. A. and Sh.A.Ismaiel (2019). Impact of some foliar application treatments on yield and quality of cassava in newly reclaimed soils. *Fayoum J. Agric. Res,& Dev*.,33(1B):370-383**.**

Abou El-Khair, E. E. , Dalia A.S. Nawar and R.S.E. Anwar. (2011). Effect of drip irrigation systems and water quantity on growth, yield and water use efficiency of sweet potato plant grown under sandy soil conditions. *Zagazig J. Agric. Res.,* 38 (1): **23-52.**

Abou-Baker, A. H. ; M. Abd-Eladl and M. M. Abbas (2011). Use of silicate and different cultivation practices in alleviating salt stress effect on bean plants. *Australian J. Basic and Applied Sci*., 5(9):769-781.

Abu El-Fotoh H.M., A.S. Abd-El-Kader and F.Y.O. Manssur (2019). Effect of irrigation intervals, antitranspirants, compost and humic acid on growth and yield of sweet potato. *Zagazig J. Agric. Res*., 46 (3):649-664.

Aiken, G. R.; D. M. McKnight and P. Mac Carthy (1985). *Humic Substances of Soil, Sediment and Wate*r. New York, Wildy- Inter Science.

Akram N. A., M.Waseem, R. Ameen and M. Ashraf (2016). Trehalose pretreatment induces drought tolerance in radish (*Raphanus sativus* L.) plants: some key physio-biochemical traits. *Acta Physiol. Plant*, 38(3):1-10.

Alam M.M., Nahar K., Hasanuzzaman M. and M. Fujita (2014). Trehalose induced drought stress tolerance: a comparative study among different Brassica species. *Plant Omics Journal*, 7:271–283.

Ashraf, M. (2010). Inducing drought tolerance in plants: some recent advances. *Biotechnol Adv.*, 28:169–183.

Ayoub, I.I. (2005). Effect of fertigation and plant population on growth, yield and storability of sweet potato grown under sandy soil conditions. Ph.D. Thesis, Fac. Agric., Zagazig Univ., Egypt.

Barker, D.J., C.Y. Sullivan and L.E. Moser (1993). Water deficit effect on osmotic potential, cell wall elasticity and proline in five forage grasses. *Agron. Journal*, 85:270-275.

Bates, L. S. (1973). Rapid determination of proline for water stress studies. *Plant and Soil*, 39: 205-207.

Blunden, G. and P.B. Paul (2006). The effect of aqueous seaweed extracts and kinetin on potato yields. *J. Sci. Food Agric*., 28 (2):535-543.

Brady, N.C. and R.R. Weil (2008). The nature and properties of soils. *European J. Soil Biol*., 42(1): 65- 69**.**

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

Das, K.K., G.S. Swamy, D. Biswas and K.K. Chnaniya (2017). Response of soil application of diatomaceous earth as a source of silicon on leaf nutrient status of guava. *Int. Journal Curr. Microbiol. App. Science*, 6(4):1394-1399.

Doss, M. M., S. M. El-Araby, M. A. Abd El-Fattah and A. A. Helal. (2015). The impact of spraying with different concentrations of seaweed extract under different levels of mineral NPK fertilizers on sweet potato (*Ipomoea batatas* L.) plants . *Alex. J. Agric. Res*., 60(3): 163-172.

Duncan, D.B. (1955). Multiple rang and multiple F test. *Biometrics*, 11: 1- 42.

Dziugieł T. and W. Wadas (2020). Possibility of increasing early crop potato yield with foliar application of seaweed extracts and humic acids. *J. Central European Agric.*, 21(2):300-310.

Ekanayake I. J. and W. Collins (2004). Effect of irrigation on sweet potato root carbohydrates and nitrogenous compounds. *Food, Agric. Environ*., 2 (1): 243-248.

Epstein, E.(1999). Silicon. Annul. Rev. Plant. Physiol. *Plant Mol. Biol.*, **50:** 641-664.

Farooq M.; A. Wahid; N. Kobayashi; D. Fujita and S.M.R. Basra (2009). Plant drought stress: effects, mechanisms and management. *Agron. Sustain. Dev.*, 29 185–212.

Gollan, J.R. and J.T. Wright (2006). Limited grazing by native herbivores on the invasive seaweed caulerpa. Taxifolia in a temperate. *Aus. Estuary Marine and Fresh Water Res*., 57(7): 685-694.

Gosev, N. A. (1960). Some methods in studying plant water relations. Leningrad Acad. of Science, U.S.S.R. (C.F. Hussein, M.H., Ph.D. Thesis, Fac. Agric., Ain Shams Univ., Cairo, Egypt, 1973).

Haider, M. W.; C. M. Ayyub; M. A. Pervez and H. U. Asad (2012). Impact of foliar application of seaweed extract on growth, yield and quality of potato (*Solanum tuberosum* L .). *Soi. Envi*. 31(2):157–162.

Issa R., M. Boras and R. Zidan (2019). Effect of Seaweed Extract on the Growth and Productivity of Potato Plants. *SSRG – IJAES*, 6 (2):83-89.

Kamal, A. M. (2013). Influence of irrigation levels, antitranspirants and potassium silicate on growth, fruit yield and quality of sweet pepper plants (*Capsicum annuum* L.) grown under drip irrigation. *J. Plant Production, Mansoura Univ*., 4 (11):1581 – 1597.

Khater M.A., Mona G. Dawood, Mervat Sh. Sadak, Magda A. F. Shalaby, M.E. El-Awadi and K. G. El-Din (2018). Enhancement the performance of cowpea plants grown under drought conditions via trehalose application. *Middle East J. Agric. Res*., 7(3): 782-800**.**

Kulikova, N.A., E.V. Stepanova and O.V. Koroleva (2005). Use of humic substances to remediate polluted environments: from Theory to practice. springer, Netherlands pp. 285310.

Lancher, L. (1993). Physiological plant ecology. Ecophysiology and stress physiology of functional groups. Third edition springier press. Berlin, New York, London, Paris, Tokyo.

Mahmoud S. H., Dina M. Salama, A.M.M. El-Tanahy and A. M. El-Bassiony (2019). Effects of prolonged restriction in water supply and spraying with potassium silicate on growth and productivity of potato. *Plant Archives*, 9 (2):2585-2595.

Mahmoud S.H., Neama M. Marzouk, A.M.M. EL-Tanahy and S.D. Abou-Hussein (2018). Humic acid as soil drench and Effective seaweed enhanced growth and productivity of sweet potato plants. *Middle East J. Appl. Sci*., 8(4): 1355-1363.

Mansour F. Y. O. and H. M. Abu El-Fotoh (2018). Effect of planting date , irrigation level and foliar spraying with calcium and boron treatments on potato 1. Plant growth , plant water relationship and plant chemical constituents. *J. Product. & Dev*., 23(3): 755 – 788.

Marrez, D. A., M. M. Naguib,Y. Y. Sultan, Z. Y. Daw and A. M. Higazy (2014). Evaluation of chemical composition for *Spirulina platensis* in different culture media. *Res. J. Pharmaceutical, Biol. and Chem. Sci.,* 5(4): 1161-1171.

Marschner, H. (1995). *Mineral Nutrition of Higher Plants*. 2nd ed. Acad. Press Limited, Text Book, Pp. 864.

Marschner, P. (2012). *Mineral Nutrition of Higher Plants*, 3rd ed.; Academic Press:London, UK. pp: 178-189.

Michel, K.G., P.A. Gilees, J.K. Hamilton, and F. Smith (1956). Colorimetric method for determination of sugars and related substances. *Anal. Chem*., 28 (3) 350.

Mikkelsen, R. (2005). Humic Materials for Agriculture. *Better Crops*, 89(3): 6-8.

Prajapati , A., Patel C. K. Singh N., Jain S. K. Chongtham S. K. Maheshwari M. N. Patel C. R and Pate R. N. (2016). Evaluation of seaweed extract on growth and yield of potato. *Environ. & Ecology*, 34 (2): 605-608.

Rodríguez-Delfín, A., A.Posadas, C. León-Velarde, V. Mares, and R. Quiroz (2011). Effect of salt and water stress on the proline and total chlorophyll content and nutrients uptake on two sweet potato cultivars grown on soilless culture. II *Inter. Symp. Soilless Culture and Hydroponics held on 15–19 May*, 2011, *Puebla, Mexico*, pp. 55–62.

Sadak, M.S., H.M.S. El-Bassiouny and M.G.Dawood (2019). Role of trehalose on antioxidant defense system and some osmolytes of quinoa plants under water deficit. *Bull. National Res. Centre*, 43: 5.

Saif El-Deen,U.M., A.S.Ezzat and A.H.A. El-Morsy (2011). Effect of phosphorus fertilizer rates and application methods of humic acid on productivity and quality of sweet potato. *J. Plant Production, Mansoura Univ*., 2 (1):53.66.

Salim, B.B.M., H.G. Abd El-Gawad and A. Abou El-Yazied (2014). Effect of foliar spray of different potassium sources on growth, yield and mineral composition of potato (*Solanum tuberosum* L.). *Middle East J. Appl. Sci*., 4(4): 1197-1204.

Sapre S. S. and D. N. Vakharia (2016). Role of silicon under water deficit stress in wheat: (Biochemical perspective): *A review .Agric. Rev.,* (37):109-116**.**

Saqib M., M.F. Khalid, S. Hussain , M. A. Anjum (2017). Effect of water stress and planting system on growth, yield and quality of sweet potato. *Acta Sci. Pol. Hortorum Cultus*., 16(6): 201–210.

Sarhan, T. Z. (2011). Effect of humic acid and seaweed extracts on growth and yield of potato plant (*Solanum tubersum* L) Desiree *cv*. *Mesopotamia J. Agric*., 39(2):19–27**.**

Sathya, B., H. Indu, R. Seenivasan and S. Geetha (2010). Influence of seaweed liquid fertilizer on the growth and biochemical composition of legume crop, *Cajanus cajan* (L.) Mill sp. *J. Phytology*., 2 (5): 50–63.

Selim, E. M., A. S. El-Neklawy and S. M. El-Ashry (2010). Beneficial effects of humic substances on soil fertility to fertigated potato grown on sandy soil. *Libyan Agric. Res. Center Journal Inter*., 1 (4): 255-262.

Shaaban, M.M. and E.A. Abou El- Nour (2014). Macro and micro-nutrients concentrations and uptake by maize seedlings irrigated with fresh or saline water as affected by k-silicate foliar fertilization. *Amer. Journal. Plant Physiol*., 9: 95-102.

Shafiq S., N.A. Akram and M.Ashraf (2015). Does exogenously-applied trehalose alter oxidative defense system in the edible part of radish (*Raphanus sativus* L.) under water-deficit conditions?. *Sci. Hort*., 185: 68–75.

Shaheen, A.M., M.E. Rageb, F. A. Rizk, S.H. Mahmoud, M.M. Soliman and N.M. Omar (2019). Effect of some active stimulants on plant growth, tubers yield and nutritional values of potato plants grown in newly reclaimed soil. *Journal Anim. Plant Sci*., 29(1): 215-225.

Shankle MW, T.F. Garrett and J.L. Main .2004. Humic acid nutrient trial. *Mississippi Agric. Forestry Exp. Station Inform. Bull*., 405. 218 219.

Snedecor, G.W. and W.G. Cochran.(1980). *Statistical Methods*.7th ed., Iowa State Univ., Press, Ames., Iowa, U.S.A.

Solomon, K. (1993). Subsurface drip irrigation: product selection and performance. In: Jorsengen, G.S., Norum, K.N. (Eds.), Subsurface Drip Irrigation: *Theory, Practices and Applications*. CATI Publication No. 9211001.

Stewart, C.R. (1977). Inhibition of proline oxidation by water stress. *Plant Physiol*., 59: 930-932.

Suganya, S. and R. Sivasamy (2006). Moisture retention and cation exchange capacity of sandy soil as influenced by soil additives. *J. Appl. Sci. Res*., 2: 949–951.

Tarabih, M.E., E.E. El-Eryan and M.A. El-Metwally (2014). Physiological and pathological impacts of potassium silicate on storability of Anna apple fruits. *Amer. J .of Plant Physiological*, 9(2): 52-67.

Thompson, P.G., D.A. Smittle and M.R. Hall (1992). Relationship of sweet potato yield and quality to amount of irrigation. Hort. Sci., 27(1): 23 -26

Verlinden G., B. Pycke, J. Mertens, F. Debersaques, K. Verheyen G. Baert, J. Brif and G. Haesaert (2009). Application of humic substances results in consistent increases in crop yield and nutrient uptake. *J. Plant Nutri.,* 32: 1407-1426.

Wang W., H. Yu , H.S. Kim, Y. Yang , X. Qiu and S.S. Kwak (2019). Molecular characterization of a sweet potato stress tolerance-associated trehalose6-phosphate synthase 1 gene (IbTPS1) in response to abiotic stress. *Plant Biotech. Reports*, 13, 235–243.

Yang L.; X. Zhao; H. Zhu; M. Paul; Y. Zu and Z. Tang (2014). Exogenous trehalose largely alleviates ionic unbalance, ROS burst, and PCD occurrence induced by high salinity in Arabidopsis seedlings. *Front Plant Sci*., 5:570.

Yooyongwech S.; C. Theerawitaya; T. Samphumphuang and S. Cha-umb (2013) . Water-deficit tolerant identification in sweet potato genotypes (*Ipomoea batatas* (L.) Lam.) in vegetative developmental stage using multivariate physiological indices. *Scientia Horticulturae*, 162:242-251.

إستجابه محصول وجودة جذور البطاطا لفترات الرى وبعض الإضافات الأرضية و معاملات الرش

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قسم بحوث البطاطس والتكاثر الخضرى - معهد بحوث البساتين – مركز البحوث الزراعية- مصر

أجريت تجربة حقلية خلال موسمى صيف 2019، 2020 بمزرعة خاصة - بقرية ميت فارس – منطقه دكرنس - محافظة الدقهلية ، وذلك لدراسة تأثير فترات الرى (كل 15 ، 30 يوم) وبعض الإضافات للتربة (حمض الهيومك بمعدل 20 كجم / فدان ، وحمض الفولفيك بمعدل 10 كجم / فدان)، و بعض معاملات الرش (بدون ، تريهالوز بمعدل 1 جم/ لتر ، سليكات البوتاسيوم بمعدل 1 مل /لتر، مستخلص الطحالب بمعدل 1 جم/لتر) على النمو ، العلاقات المائيه فى النبات ، المحصول ومكوناته وجوده الجذور المتدرنه للبطاطا صنف بيوروجارد تحت ظروف الأرض الطينية و نظام الرى بالغمر.

أظهرت النتائج أن معاملة التفاعل بين ري نباتات البطاطا صنف بيروجارد النامية في الأرض الطينية خلال الموسم الصيفي كل 15 أو 30 يوم ومعاملة النباتات بحمض الفولفيك بمعدل 10 كجم / فدان كإضافة أرضية + الرش بسليكات البوتاسيوم بمعدل 1 مل / لتر أدى الى زيادة طول الفرع الرئيسي، الوزن الطازج والجاف للعرش / النبات ، متوسط وزن الجذر المتدرن ، المحصول الكلى للفدان ومحتوى الجذور من البوتاسيوم . بالإضافه الى ذلك فقد سجلت معاملة التفاعل بين رى نباتات البطاطا كل 15 يوم ومعاملة النباتات بحمض الفولفيك بمعدل 10 كجم / فدان كإضافة أرضية + الرش بسليكات البوتاسيوم بمعدل 1 مل / لترالى زيادة كل من عدد الأفرع / نبات ، المحصول القابل للتسويق ، محتوى الجذور المتدرنه من الكربوهيدرات الكلية . كما سجلت النباتات تحت نفس فتره الرى (كل 15 يوم) والمعاملة بحمض الفولفيك بمعدل 10 كجم / فدان كإضافة أرضية + الرش بالتريهالوز بمعدل 1 مل / لترالى زيادة معنوية في محتوى الورقة من الماء الكلى والماء الحر.علاوه على ذلك فقد سجلت معامله التفاعل بين الرى (كل 15 يوم) والمعاملة بحمض الفولفيك بمعدل 10 كجم / فدان كإضافة أرضية + الرش بمستخلص الطحالب بمعدل 1 جم / لترالى زيادة محتوى العرش والجذور المتدرنة من النيتروجين والفوسفور وكذلك قطر الجذر المتدرن. وعلى الجانب الأخر فقد سجلت معاملة التفاعل بين الرى (كل 30 يوم) والمعاملة بحمض الفولفيك بمعدل 10 كجم / فدان كإضافة أرضية + الرش بسليكات البوتاسيوم بمعدل 1 مل / لترالى زيادة محتوى العرش من البوتاسيوم ، طول الجذر المتدرن ، ونسبه المادة الجافة فى الجذور المتدرنة . أدت معامله التفاعل بين فتره الرى (كل 30 يوم) والمعاملة بحمض الهيومك فقط بمعدل 20 كجم / فدان كإضافة أرضية لزيادة محتوى أنسجة الورقة في البطاطا من الماء المرتبط (%) والضغط الأسموزى وكذلك محتوى الأوراق من الحمض الأمينى البرولين فى كلا موسمى النمو.

التوصية: يمكن أن نوصى برى نباتات البطاطا النامية في الأرض الطينية أثناء الموسم الصيفى كل 15 أو 30 يوم مع معاملة النباتات بحمض الفولفيك بمعدل 10 كجم / فدان كإضافة أرضية + الرش باى من سليكات البوتاسيوم بمعدل 1 مل /لتر ، أو الطحالب أوالتريهالوز بمعدل 1 جم لكل منهما وذلك للحصول على أعلى إنتاجية وأفضل جودة للجذور المتدرنة.

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