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EFFECTS OF PROLONGED RESTRICTION IN WATER SUPPLY AND SPRAYING WITH POTASSIUM SILICATE ON GROWTH AND PRODUCTIVITY OF POTATO

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Abstract

The supply of water for agricultural use has become tight. High temperatures raise the evaporation rate from plant, thus increasing the amount of water needed by plants, particularly when grown in newly reclaimed sandy soil with limited water supply. Under subtropical environment such as Egypt, application of anti-stress materials might decrease transpiration. thus, a field experiment was carried out during the successive seasons of 2017 and 2018 at Experimental Farm of National Research Center, Nubaria, Behira Governorate to study the effect of potassium silicate at different concentration (0, 1.5 and 3cm^3/L) on growth, yield, tuber quality and biochemical constituents of potato under different irrigation intervals (2, 3 and 4 days). The results showed that the best values of potato vegetative growth parameters, photosynthetic pigments, yield, characteristics of tubers quality, in addition carbohydrates, starch and elements (nitrogen, phosphorus and potassium) and phytochemicals (phenols and flavonoids) was obtained with application the irrigation every three days compared to irrigation every 4 days and 2 days as control. Similarly the best results in these parameters was obtained with foliar application of potassium silicate at concentration of 3cm^3/L. In most cases, the lowest significant values of all previous parameters were achieved when potato plants were irrigated at four days and were not sprayed with potassium silicate. On the contrary, the highest content of proline recorded with irrigation every four days and potassium silicate at concentration 3cm^3/L.

It can be recommended that using the three days irrigation interval with foliar spray of potassium silicate at 3cm^3/L is the best for potato production under sandy soil conditions.

Key words : *Solanum tuberosum* - Irrigation - Potassium Silicate -Yield- Biochemical constituents.

Introduction

Potato (*Solanum tuberosum* L.) is one of the major essential crops grown in Egypt for local consumption, exporting and manufacturing in some food industries. Potatoes contain a large variety of nutrients, also have various bioactive compounds for example flavonoids, carotenoids and phenolics, whose several useful effects on health have been known (Mouille and Charrondiere, 2009; Wegner and Jansen, 2015; Hala *et al*., 2016). In order to optimize potato yield and quality to face the rising demand of population and the rising agriculture exports to save hard currency, various aspects of production chain should be considered in an integrated way. Theses aspects consist of potato tubers quality, soil value, irrigation management, fertilization, forecasting of pests and diseases, in addition determination of suitable sowing dates (Hegazy, 2009 and Omar *et al.,* 2015).

Water stress is a major challenge in arid and semi-arid areas. Where, water supply is limited for using in crop growing (Salvin *et al.,* 2000 and Ibrahim *et al*., 2012). Irrigation is vitally important for potato plants due to the short vegetative period and rapid growth under the Egyptian condition which requires the optimal level of water quantities. Irrigation hesitancy ranges from 2 to 14 days depending on climate, crop development and soil type (Abd El-Gawad *et al*., 2017). Water shortage affects most of plant physiological processes, for instance photosynthesis, cellular progress, coalescence and transmission of nutrients in the plants (Davis *et al*., 2007). Under Egypt's subtropical conditions, the use of anti-stress might decrease the plant transpiration rate. Thus, enhancing water use efficiency (WUE) (Nehad, 2015). Therefore, using anti-stress agents such as potassium silicate or aluminum silicate resulted in 20% decline in the recommended supplementary water. Using antitranspiration agents improving water use efficiency by decreasing leaf transpiration rate, reducing leaf water loss and improving assimilation area of plant in sandy soil (Nehad, 2015). In the same trend, Kamal (2013) found that potassium silicate enhanced the growth and improved pepper production under water stress condition. Hala *et al*., (2016) showed that the highest yield of potato, size and number of tubers were achieved with irrigation level 100% of crop evapotranspiration (Etc) under conventional agricultural. In the same context, Abd Elwahed (2018) who indicated that the plant growth, fruit quality, yield and total chlorophyll of tomato showed the greatest value with applying 100% Etc and foliar application with potassium silicate at 300 ppm. On the contrary, the maximum content of proline in tomato leaves was recorded with the irrigation level at 60% of Etc of untreated plants with potassium silicate.

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, 1995). 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 (Crusciol *et al*., 2009; Das *et al*., 2017).

So, the aim of this experiment is to study the effect of irrigation intervals and foliar application with anti-stress substances on growth and yield of potato, and to overcome the problems of lack of irrigation water and water stress in some potato cultivations in arid land.

Material and Methods

Experimental site

The field experiment was carried out during two successive seasons 2017 and 2018 at Experimental Farm of National Research Center, Nubaria, Behira Governorate (altitude of 27 m above sea level, latitude 30°72'66"N and longitude 30°20'18"E) under new reclaimed sandy soil conditions to investigate the effect of foliar application of potassium silicate on growth, yield, tuber quality and biochemical constituents of potato plants under different irrigation intervals. Physical and chemical properties of the experimental soil are shown in table 1. Soil was analyzed according to the methods described by Cottenie *et al*., (1982).

Table 1: Some physical and chemical properties of the used soil.

<table>
<tr><th colspan="8">Physical properties</th></tr>
<tr><td>Sand (%)</td><td>Silt (%)</td><td colspan="2">Clay (%)</td><td>Texture</td><td>F.C. %</td><td colspan="2">W.P. %</td></tr>
<tr><td>90.0</td><td>0.71</td><td colspan="2">9.29</td><td>Sandy</td><td>16.62</td><td colspan="2">5.20</td></tr>
<tr><th colspan="8">Chemical analysis</th></tr>
<tr><td>EC M/m</td><td>pH</td><td colspan="6">Meq/ L</td></tr>
<tr><td rowspan="2">1.7</td><td rowspan="2">8.2</td><td>Ca^{++}</td><td>Mg^{++}</td><td>Na^{++}</td><td>K^{+}</td><td>$Hco3^{-}$</td><td>Cl^{-}</td></tr>
<tr><td>7.00</td><td>0.55</td><td>1.0</td><td>0.31</td><td>1.4</td><td>0.70</td></tr>
</table>

Plant material

Potato tubers (cv. Cara) were used in this experiment. Tubers size 4 cm diameter was obtained from Union of Producers and Exporters of Horticultural Crops, Cairo, Egypt, were used in two seasons. The tubers were planted in the 25 of January month during the two seasons 2017 and 2018.

Treatments

This study involved three irrigation intervals which is 2, 3 and 4 days. The recommended irrigation of potato plant under drip irrigation system in sandy soil is 2 days, with spraying by potassium silicate (K_2SiO_3) [contained 10% K_2O and 25% SiO_2] at (0, 1.5 and 3 cm^3/L) after 40, 50 and 60 from planting. Chemical analysis of irrigation water as shown in table 2**.** Irrigation water was analyzed according to Cottenie *et al*., 1982. The total amounts of irrigation water requirement (m^3/fed.) were calculated in the different treatments during two successive seasons of 2017 and 2018 as shown in table 3.

Table 2: Chemical analysis of irrigation water during the experiment.

pH	7.0
EC (dS m^{-1})	3.88
Sodium Adsorption Ratio (SAR)	6.5
Soluble Anions (meq/1)	
HCO_3^-	1.89
Cl^-	22.20
SO_4^{--}	12.60
Soluble Cations (meq/1)	
Ca^{++}	10.53
Mg^{++}	6.85
Na^{++}	19.13
K^+	0.18

Cultivation

The experimental plot area was 7.2 m^2 involved three rows, each row was 3 × 0.8 meter. The plant distance was 30 cm apart on one side of the row.

As for fertilization, 30m^3 organic manure per feddan plus 75 units /feddan of calcium super-phosphate (15%

Table 3: Total amount of irrigation water requirements (m^3/fed.) for the different irrigation levels during two successive seasons of 2017 and 2018.

Water supply (days)	m^3/feddan	
	2017	2018
2	2435.3	2450.0
3	1950.0	1960.0
4	1475.7	1485.6

P_2O_5) at were added during the soil preparation. Nitrogen fertilizer was added in the form of ammonium sulphate (20.6 N /fed) at 150 units/ fed. in two equal portions (30 and 45 day old). Potassium sulphate (48% K_2O) was applied at a rate of 96 units per feddan at two times. The first dose (48 units) was added during preparation the soil for planting and the second dose (48 units) at the beginning of the formation of the tubers. Cultural practices, disease and pest control management were followed according to the recommendations of the Egyptian Ministry of Agriculture.

Data collection

Vegetative growth

A random sample of 5 plants was taken at 70 days after planting for the determination of the following characters:

- Plant height.
- Number of leaves and shoots/ plant.
- Fresh and dry weight of leaves shoots and whole plant.

Photosynthetic pigments content

Photosynthetic pigments in fresh leaf tissue of potato plants were determined calorimetrically according to Lichenthaler and Wellburn (1983).

Tuber yield and its components

Five plants of each experimental plot were taken randomly after 110 days from planting and their tubers were collected to evaluate;

- Average tuber weight.
- Average tubers weight per plant.
- Total tuber yield per ton/feddan.
- Marketable yield (Yield of good shapes and healthy) per ton/feddan.

Characteristics of tubers quality

Samples of tubers were taken randomizly for determination of physical properties of tubers, *i.e.* number per plant, diameter and length.

Biochemical constituents

Fresh tubers of potato were dried in oven at (70°C) to constant weight and dried sample was taken for chemical analysis. The following chemical analysis was determined:

- Total carbohydrates were determined spectrohotometrically according to Dubois *et al.,* (1956).
- Starch content was determined using the method of Somogi (1952).
- Total phenols were described by Danial and George (1972).
- Total flavonoids were determined by spectrophotometer according to Chang and Wen (2002).
- Proline was determined according to Bates *et al.,* (1973).
- Minerals: Nitrogen was determined on the basis of Kjeldal-N. Phosphorus was determined by spectrophotometer. As well as, potassium was determined by flame photometry according to the method described in the AOAC (2000).

Experimental design

The factorial experiment was consisting 12 treatments with three replicates. The experiment was arranged in split plot design. The four irrigation intervals treatments occupied the main plots and the three levels of potassium silicate treatments were allocated at random in the sub plots. The field data were statistically analyzed as a split plot design.

Statistical analysis

All data were analyzed for statistical significant differences using LSD test at 5% level. Data were subjected to statistical analysis according to the procedures reported by Snedecor and Cochran (1980).

Results and Discussion

Vegetative growth characters

The data shown in (Tables 4, 5) indicated that the effect of irrigation periods on vegetative growth of potato plants during 2017 and 2018 seasons. Vegetation characteristics of potato plants, which are plant height, number of leaves, fresh and dry weight of leaves, shoots and whole plant recorded significantly higher with irrigation every three days followed irrigation period every two days. 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). Abdel-Gawad (2010) who pointed before that the irrigation when depletion of 60% of the accessible soil water enhanced the area of leaves, the weight of common bean leaves fresh and dry weight. As well as, Kamal (2013) indicted that the irrigation treatment with deficit (1000 m^3/feddan) applied to the pepper plants recorded the lowest values of the vegetative growth characteristics compared with the highest level of irrigation water (2600 m^3/feddan).

Potassium silicate as foliar application showed a significant effect at the level of 5% on vegetative growth characteristics of potato plants *i.e.* plant height, number of leaves, fresh and dry weight of leaves, shoots and whole plant, during the two seasons of planting. Potassium silicate concentration had an impact on growth of the potato plants. The concentration 3cm^3/L of potassium silicate showed the best growth characteristics compared other concentrations (Tables 4, 5). 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 (Marschner, 2012; Crusciol *et al*., 2009; Das *et al*., 2017). In the same trend found by Abou-Baker *et al.,* (2011) mentioned that spraying potassium silicate on faba bean plants at 300 ppm concentration appeared the maximum values for plant height, root length and dry weight for shoot and root. In addition, Salim *et al.,* (2014) and Shaheen *et al*., (2019) they found that the best values for the growth characteristics of the potato plant are achieved with the use of potassium silicate spray on plants at a concentration of 2000 ppm or 3 cm^3/L. Similar results were obtained before by other investigators, Wand and Galletta, 1998 on strawberries; Kamal, 2013 on sweet pepper.

There was no significant between irrigation periods and concentrations of potassium silicate on vegetative growth characteristics of potato plants during two seasons (Tables 4, 5).

Photosynthetic pigments

It is obvious from Table 6 that, the content of photosynthetic pigments (chlorophyll a, b, total chlorophyll and carotenoids) of leaves of potato plants during two seasons of study. Chlorophyll a, b, total chlorophyll and carotenoids after 70 days from sowing appeared the highest content in plants supplied with irrigation every three days followed by two days. This result might be due to the use of the appropriate irrigation water level

Table 4: Effect of different water intervals, levels of potassium silicate and their interactions on vegetative growth characters of potato plant during 2017 season.

Treatments		Plant height (cm)	Number/plant		Fresh weight (g/plant)			Dry weight (g/plant)		
Water intervals (days)	Potassium silicate (cm^3/L)		Leaves	Shoots	Leaves	Shoots	Whole Plant	Leaves	Shoots	Whole Plant
2	0	57.67	49.33	4.67	301.38	115.13	416.51	26.60	15.78	42.38
	1.5	63.00	60.00	4.67	322.23	147.77	470.00	35.42	18.00	53.42
	3	68.67	65.33	5.67	349.37	157.00	506.37	37.55	20.84	58.39
Mean		63.11	58.22	5.00	324.33	139.97	464.29	33.19	18.21	51.40
3	0	58.00	51.33	5.00	295.08	118.40	413.48	27.60	16.78	44.38
	1.5	68.33	63.33	5.67	343.00	149.43	492.43	36.26	20.43	56.69
	3	70.33	67.33	6.00	356.13	161.67	517.80	39.00	21.67	60.67
Mean	65.56	60.67	5.56	331.41	143.17	474.57	34.29	19.63	53.92	
4	0	55.00	40.33	2.67	216.78	96.73	313.51	21.00	12.19	33.19
	1.5	62.67	49.33	4.33	282.03	123.33	405.37	24.00	15.33	39.33
	3	64.00	56.00	4.33	290.33	127.83	418.17	25.78	16.13	41.91
Mean		60.56	48.56	3.78	263.05	115.97	379.01	23.59	14.55	38.15
Potassium silicate average	0	56.89	47.00	4.11	271.08	110.09	381.17	25.07	14.92	39.99
	1.5	64.67	57.56	4.89	315.76	140.18	455.93	31.89	17.92	49.81
	3	67.67	62.89	5.33	331.94	148.83	480.78	34.11	19.55	53.66
L.S.D. at 5 %	Water intervals	2.24	7.70	1.16	37.70	9.32	35.13	6.30	1.52	7.71
	Potassium silicate	1.62	4.06	0.74	35.49	9.92	33.04	4.41	0.88	4.62
	Interactions	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

N.S = Not Significant ($p < 0.05$).

that inhibits chlorophyll enzymes (Abdel-Dayem *et al*., 2015). Also, the balanced moisture provided to the plant which resulted in an increase in the surface of photosynthesis is reflected on the increase in the surface of photosynthetic area and the content of photosynthetic pigments content (Abou El-Khair, 1999; Abd Elwahed, 2018).

On the other hand, results in Table 6 revealed that spraying potassium silicate with concentration 3 cm^3/L significantly increased the content of photosynthetic pigments *i.e.* chlorophyll a, b, total chlorophyll and carotenoids in potato leaves. This result was. This result probably due to the role of silica in the photosynthesis series and protection of chlorophyll degeneration with silica (Agarie *et al*., 1996). Silica plays an imperative function in the case of straight leaves, which is able to provide a greater leaf area towards the light, thereby increasing the efficiency of plant photosynthesis (Quanzhi and Erming, 1998). In addition, potassium has a vital role in the state of water in the plant, which promotes the transfer of recently synthesized photosynthetics and mobilization of metabolites (Kamal, 2013). The trends of these results are supported by Shinya and Yoshihiro (2000) found that application of potassium silicate enhanced the content of chlorophyll on sugar cane plant. Also, increased amount of chlorophyll b, soluble sugars and carotenoids was obtained with using 5mM potassium silicate on potato (Talebi *et al.,* 2015).

Irrigation intervals and potassium silicate enhanced photosynthetic pigments in potato leaves, on a fresh weight basis table 6. The potato plants that supplied with water irrigation every three days and potassium silicate at concentration 3 cm^3/L gave the best values for chlorophyll a, b, total chlorophyll and carotenoids in leaves. This result is attributable to silicon enhances the state of water in plant cells and therefore, making the plant easier to process photosynthesis (Crusciol *et al.,* 2009).

As well as, Gong *et al.,* (2005) found that silicon improved the chloroplast ultrastructure and enhanced the activities of antioxidant enzymes such a superoxide dismutase and catalase under water stress. This result was agreement with Abd Elwahed (2018) who showed that the tomtao plants are delivered for irrigation at 80% and 100% of crop evapotranspiration and spraying with potassium silicate 300 ppm concentration recorded the best of total chlorophyll in leaf.

Tuber yield and its components

In table 7 presented that the yield of potato plants expressed as average weight for tuber and tubers per plant, total tuber yield and marketable per ton/feddan enhanced by using water intervals every three days as

Table 5: Effect of different water intervals, levels of potassium silicate and their interactions on vegetative growth characters of potato plant during 2018 season.

Treatments		Plant height (cm)	Number/plant		Fresh weight (g/plant)			Dry weight (g/plant)		
Water intervals (days)	Potassium silicate (cm^3/L)		Leaves	Shoots	Leaves	Shoots	Whole Plant	Leaves	Shoots	Whole Plant
2	0	54.67	50.33	4.00	286.67	111.73	398.40	25.55	15.33	40.88
	1.5	62.33	57.33	4.33	318.33	142.33	460.67	35.00	19.33	54.33
	3	68.33	63.00	5.67	346.83	155.00	501.83	38.67	21.25	59.92
Mean		61.78	56.89	4.67	317.28	136.36	453.63	33.07	18.64	51.71
3	0	56.67	51.00	4.33	287.67	115.00	402.67	25.87	16.40	42.27
	1.5	66.67	64.33	5.33	343.66	153.40	497.06	35.83	20.35	56.19
	3	69.33	68.00	6.00	361.77	168.45	530.22	39.17	22.33	61.50
Mean		64.22	61.11	5.22	331.03	145.62	476.65	33.62	19.70	53.32
4	0	50.00	42.00	2.33	203.33	94.73	298.07	20.00	11.69	31.69
	1.5	60.00	50.00	4.00	268.83	125.67	394.50	24.00	15.33	39.33
	3	63.33	54.00	4.00	273.77	129.43	403.20	28.00	15.73	43.73
Mean		57.78	48.67	3.44	248.64	116.61	365.26	24.00	14.25	38.25
Potassium silicate average	0	53.78	47.78	3.56	259.22	107.16	366.38	23.81	14.48	38.28
	1.5	63.00	57.22	4.56	310.28	140.47	450.74	31.61	18.34	49.95
	3	67.00	61.67	5.22	327.46	150.96	478.42	35.28	19.77	55.05
L.S.D. at 5 %	Water intervals	1.06	4.02	0.62	9.11	11.68	7.36	2.03	1.99	1.50
	Potassium silicate	1.75	2.02	0.78	24.18	8.35	26.17	1.90	1.38	2.35
	Interactions	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

N.S = Not Significant ($p < 0.05$)

Table 6: Effect of different water intervals, levels of potassium silicate and their interactions on photosynthetic pigments during 2017 and 2018 seasons.

Treatments		2017				2018			
		Leaf pigments mg/g fresh weight							
Water intervals (days)	Potassium silicate (cm^3/L)	Chlor. "a"	Chlor. "b"	Chlor. a+b	Carot.	Chlor. "a"	Chlor. "b"	Chlor. a+b	Carot.
2	0	1.60	0.60	2.20	1.50	1.59	0.58	2.18	1.51
	1.5	1.61	0.70	2.31	1.59	1.62	0.71	2.33	1.62
	3	1.83	0.88	2.71	1.65	1.85	0.87	2.72	1.68
Mean		1.68	0.73	2.41	1.58	1.69	0.72	2.41	1.60
3	0	1.60	0.58	2.18	1.49	1.60	0.53	2.13	1.50
	1.5	1.71	0.83	2.54	1.65	1.75	0.82	2.57	1.67
	3	1.89	0.86	2.75	1.68	1.91	0.88	2.79	1.74
Mean		1.73	0.76	2.49	1.60	1.75	0.74	2.50	1.64
4	0	1.30	0.38	1.68	1.27	1.34	0.35	1.69	1.33
	1.5	1.53	0.56	2.09	1.56	1.52	0.57	2.08	1.53
	3	1.58	0.58	2.16	1.57	1.56	0.59	2.16	1.58
Mean		1.47	0.51	1.98	1.47	1.47	0.50	1.98	1.48
Potassium silicate average	0	1.50	0.52	2.02	1.42	1.51	0.49	2.00	1.45
	1.5	1.62	0.70	2.31	1.60	1.63	0.70	2.33	1.61
	3	1.76	0.77	2.54	1.63	1.77	0.78	2.56	1.66
L.S.D. at 5 %	Water intervals	0.07	0.05	0.09	0.09	0.01	0.06	0.06	0.04
	Potassium silicate	0.06	0.05	0.09	0.05	0.03	0.03	0.05	0.05
	Interactions	0.10	0.09	0.15	0.09	0.06	0.05	0.09	N.S.

Chlor = chlorophyll Carot = carotenoids N.S = Not Significant ($p < 0.05$)

compared to other treatments during two seasons of experiment. This result is return to motivate vegetative growth and process of photosynthesis with the application of the irrigation system every three days, as shown in the (Tables 4, 5 and 6). This result is in harmony with Ezzo *et al*., (2010) recorded that the greatest early yield, total yield and mean fruit weight of pepper were improved after irrigating plants with 110% of the required water supply. In addition, Kamal (2013) found that the increment in the amount of water reaching to 2,600 m^3/feddan resulted in the maximum increases in the early and total yield per feddan of sweet pepper compared with 1000 and 1800 m^3/feddan.

Average weight for tuber and tubers per plant and the yield for total tuber and marketable per ton/feddan significantly increased by using potassium silicate as foliar with concentration 3cm^3/L, during 2017 and 2018 seasons Table 7. This increment of the yield can be discussed with the stimulation of potassium silicate for the vegetative growth of the potato, as shown in (Tables 4, 5) and the process of photosynthesis, as shown in table 6. The same trend found before by Tarabih *et al*., (2014) indicated that the 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. In the same trend, Abd El-Gawad *et al*., (2017) showed that the potato plants are sprayed with potassium silicate at 2000 ppm. The yield of tubers is amplified for per plant and per feddan.

The interaction between water intervals and potassium silicate showed significant effect on average weight for tubers per plant, total tuber yield and marketable per ton/feddan of potato Table 7. On the contrary, in average tuber weight the interaction was not significant

In general, the maximum tuber yield and its components was recorded by water intervals every three days and potassium silicate at concentration 3 cm^3/L. Results may be attributed to the use of anti-stress which leads to a lower rate of transpiration of the plant, thus the amount of water used is improved for their efficient use (Makus, 1997; Singh *et al.,* 1999). Also, it has been proven with Egilla *et al.,* (2001) that the increase the application of K + enhances the rate of photosynthesis, plant growth and yield, furthermore drought resistant water stress.

Characteristics of tubers quality

The results of the characteristics of tubers quality of potato plant during two successive seasons 2017 and 2018 are summarized in Table 8. The physical tubers quality of potato (number of tubers per plant, tuber length and tuber diameter) presented obvious increases with

Table 7: Effect of different water intervals, levels of potassium silicate and their interactions on tubers yield parameters of potato plant during 2017 and 2018 seasons.

Treatments		2017				2018			
		Average weight				Average weight			
Water intervals (days)	Potassium silicate (cm^3/L)	(g)		(Ton/fed)		(g)		(Ton/fed)	
		Tuber	Tubers /plant	Total yield	Marketable yield	Tuber	Tubers /plant	Total yield	Marketable yield
2	0	137.50	1283.33	10.27	6.44	130.50	1270.00	10.16	8.56
	1.5	146.67	1533.33	12.27	8.67	140.67	1553.33	12.43	10.43
	3	166.11	1716.67	13.73	10.27	160.24	1700.00	13.60	11.76
Mean		150.09	1511.11	12.09	11.97	145.13	1507.78	12.06	10.25
3	0	140.00	1293.33	10.35	8.75	136.67	1276.67	10.21	8.61
	1.5	149.06	1671.67	13.37	11.37	148.44	1680.00	13.44	11.44
	3	178.89	1733.33	13.87	12.12	176.51	1740.00	13.92	12.08
Mean		155.31	1566.11	12.53	10.74	150.54	1565.56	12.52	10.71
4	0	117.33	952.00	7.62	6.02	114.00	942.00	7.54	5.94
	2.5	125.33	1050.00	8.40	6.56	127.17	1053.33	8.43	6.59
	5	135.00	1093.33	8.75	6.75	135.67	1096.67	8.77	6.85
Mean		132.56	1031.78	8.25	6.44	131.94	1030.67	8.25	6.46
Potassium silicate average	0	131.61	1176.22	9.41	7.81	128.39	1162.89	9.30	7.70
	1.5	149.69	1418.33	11.35	9.40	141.76	1428.89	11.43	9.48
	3	156.67	1514.44	12.12	10.28	157.47	1512.22	12.10	10.23
L.S.D. at 5 %	Water intervals	11.36	55.84	0.45	0.45	11.17	47.25	0.38	0.38
	Potassium silicate	12.04	63.16	0.51	0.51	12.01	59.67	0.48	0.48
	Interactions	N.S.	109.39	0.87	0.87	N.S.	103.36	0.83	0.83

N.S = Not Significant ($p < 0.05$).

Table 8: Effect of different water intervals, levels of potassium silicate and their interactions on some characteristics of tubers quality of potato plant during 2017and 2018 seasons.

Treatments		2017			2018		
Water intervals (days)	Potassium silicate (cm^3/L)	No. tuber plant	Diameter (cm)	Length (cm)	No. tuber plant	Diameter (cm)	Length (cm)
2	0	4.67	5.17	5.27	4.67	5.00	5.43
	1.5	5.00	6.50	6.33	5.00	6.00	6.33
	3	6.00	7.33	8.00	6.33	7.00	7.83
Mean		5.22	6.33	6.53	5.33	6.00	6.53
3	0	4.67	5.33	5.27	4.67	5.00	5.43
	1.5	5.33	7.00	7.67	5.33	6.33	8.17
	3	6.00	7.67	8.33	6.33	7.00	8.33
Mean		5.33	6.67	7.09	5.44	6.11	7.31
4	0	3.00	4.33	4.33	3.00	4.33	4.00
	1.5	4.33	5.33	5.00	4.33	5.00	5.00
	3	4.33	6.00	5.33	4.33	6.00	5.50
Mean		3.89	5.22	4.89	3.89	5.11	4.83
Potassium silicate average	0	4.11	4.94	4.96	4.11	4.78	4.96
	1.5	4.89	6.28	6.33	4.89	5.78	6.50
	3	5.44	7.00	7.22	5.67	6.67	7.22
L.S.D. at 5 %	Water intervals	0.25	0.57	0.34	0.31	0.40	0.48
	Potassium silicate	0.53	0.59	0.40	0.59	0.90	0.39
	Interactions	N.S.	N.S.	0.69	N.S.	N.S.	0.67

N.S = Not Significant ($p < 0.05$).

Table 9: Effect of different water intervals, levels of potassium silicate and their interactions on nutritional values content of potato tubers during 2017 season.

Treatments		%		mg/g			%		
Water intervals (days)	Potassium silicate (cm^3/L)	Carbohydrates	Starch	Phenols	Flavonoids	Proline	N	P	K
2	0	52.45	43.75	34.00	11.80	33.70	1.52	0.54	2.51
	1.5	60.10	52.53	42.67	13.17	35.47	1.65	0.61	3.53
	3	62.73	53.43	43.77	14.73	37.20	1.84	0.65	3.77
Mean		58.43	49.91	40.14	13.23	35.46	1.67	0.60	3.27
3	0	54.08	44.40	38.67	12.12	43.15	1.54	0.54	2.52
	1.5	65.31	55.00	44.50	16.07	45.49	1.82	0.66	3.77
	3	67.78	58.85	47.43	17.51	49.06	1.89	0.68	3.84
Mean		62.39	52.75	43.53	15.23	45.90	1.75	0.63	3.38
4	0	47.45	41.15	31.17	10.40	51.83	1.30	0.51	2.36
	1.5	52.03	48.00	38.33	13.20	51.90	1.59	0.57	3.17
	3	54.66	50.00	40.85	14.17	53.40	1.59	0.58	3.25
Mean		51.38	46.38	36.78	12.59	52.38	1.49	0.55	2.93
Potassium silicate average	0	51.33	43.10	34.61	11.44	42.90	1.45	0.53	2.46
	1.5	59.15	51.84	41.83	14.15	44.29	1.69	0.61	3.49
	3	61.72	54.09	44.02	15.47	46.55	1.77	0.64	3.62
L.S.D. at 5 %	Water intervals	4.35	1.88	1.79	1.51	0.94	0.06	0.05	0.26
	Potassium silicate	4.40	3.15	2.08	0.74	1.06	0.09	0.02	0.21
	Interactions	N.S.	N.S.	N.S.	N.S.	1.84	N.S.	N.S.	N.S.

N.S = Not Significant ($p< 0.05$).

Table 10: Effect of different water intervals, levels of potassium silicate and their interactions on nutritional values content of potato tubers during 2018 season.

Treatments		%		mg/g			%		
Water intervals (days)	Potassium silicate (cm^3/L)	Carbohydrates	Starch	Phenols	Flavonoids	Proline	N	P	K
2	0	51.63	40.08	36.33	12.87	32.93	1.53	0.53	2.43
	1.5	61.22	50.62	41.00	14.50	34.40	1.62	0.62	3.50
	3	64.53	52.67	45.00	15.10	35.60	1.79	0.64	3.70
Mean		59.12	47.79	40.78	14.16	34.31	1.65	0.59	3.21
3	0	53.55	42.67	39.67	13.44	43.77	1.55	0.53	2.48
	1.5	64.53	52.67	44.83	15.24	46.07	1.80	0.65	3.70
	3	67.33	55.78	48.00	16.84	49.97	1.85	0.66	3.83
Mean		61.80	50.37	44.17	15.17	46.60	1.73	0.61	3.33
4	0	50.63	38.75	30.73	10.00	52.09	1.33	0.49	2.40
	1.5	54.98	43.00	37.33	13.17	52.17	1.57	0.57	3.13
	3	56.19	46.33	40.67	14.29	53.59	1.59	0.57	3.43
Mean		53.93	42.69	36.24	12.49	52.62	1.50	0.54	2.99
Potassium silicate average	0	51.94	40.50	35.58	12.10	42.93	1.47	0.52	2.44
	1.5	60.24	48.76	41.06	14.30	44.21	1.66	0.61	3.44
	3	62.68	51.59	44.56	15.41	46.39	1.75	0.62	3.65
L.S.D. at 5 %	Water intervals	2.77	2.12	3.32	1.69	0.54	0.10	0.10	0.21
	Potassium silicate	2.68	2.97	2.19	0.95	0.69	0.08	0.03	0.21
	Interactions	N.S.	N.S.	N.S.	N.S.	1.19	N.S.	N.S.	N.S.

N.S = Not Significant ($p< 0.05$).

water intervals after three days followed two days and 4 days compared control. Result may be due to develop the yield with irrigation water every three days, as shown in Table 7.

Application of potassium silicate as foliar on potato plants with concentration 3 cm^3/L was better to get the best characteristics of tubers quality of potato, which represent the number of tubers per plant, tuber length and tuber diameter Table 8. The same trend was obtained during the two seasons of planting of potato plants. This result is due to get the best yield and the highest rate of chlorophyll as well as the absorption of nitrogen, phosphorus and potassium with the use of potassium silicate at a rate of $3cm^3/L$. Similar result found by Kamal (2013) on sweet paper and Abd Elwahed (2018) on tomato.

Interactions caused no significant result on number of tubers per plant and tuber diameter with different levels of water intervals and potassium silicate**.** On the other hand, tuber length recorded significant response at 5% with irrigation every three days by adding potassium silicate as spraying on potato plants at a concentration of $3cm^3/L$ Table 8. This result is due to the role of potassium silicate ($3cm^3/L$ concentration) with irrigation level (every three days).

Biochemical constituents

Data recorded in (Tables 9, 10) showed clearly that irrigation periods had significant on biochemical constituents in tubers of potato plant. Application the water irrigation every three days increased carbohydrates, starch, phenols, flavonoids, nitrogen, phosphorus and potassium, on a dry weight basis. This result is likely due to the irrigation water every three 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 (Ezzo *et al.,* 2010; Abd Elwahed, 2018). As for total phenols, it can be discussed through the results of Kays (1997); Nakamura *et al*., (2003) they found that the phenolic compounds have free radical scavenging capabilities, which rely on stress exposure such temperature and water. As for, the content of flavonoids in plants is robustly affected by external factors as differences in growth and degree of maturity (Aherne and O´Brien, 2002). In the same respect, Gharibi *et al*., (2016) found that the maximum activity of antioxidants such as phenols and flavonoids achieved with the state of extreme stress (field capacity 25%). On the other hand, the highest content of proline was obtained with irrigation of potato plants every four days, during two seasonal sowing. This result may be due to proline is an essential binding acid that accumulates under pressure and is considered to have a primary function in osmotic adjustment (Nayyar and Walia, 2003).

It is clear from (Tables 9,10) that the different concentrations of potassium silicate resulted in a significant increment in biochemical constituents of potato tubers. The highest concentration of potassium silicate up to $3cm^3/L$ achieved the best content of carbohydrates, starch, phenols, flavonoids, proline, nitrogen, phosphorus and potassium. This result is probably due to the role of potassium and silicon in the physiological processes of plants. The same trend was found with Salim *et al*., (2014) found that the potassium silicate improved the content of elements like nitrogen, phosphorus and potassium in tuber of potato.

Concerning to the interaction between different levels of water intervals and potassium silicate on biochemical constituents of potato tubers *i.e.* carbohydrates, starch, phenols, flavonoids, nitrogen, phosphorus and potassium was no significant difference among all interactions plants (Tables 9,10). On the contrary, the content of proline showed significantly increase with irrigation every four days by addition potassium silicate at concentration $3cm^3/L$.

Conclusion

The results of this study can be summarized that the application of the irrigation system every three days with the use of potassium silicate at concentration $3cm^3/L$ to spray on potato plants, it has achieved the best growth, qualities of yield and process of photosynthesis. Furthermore, potato plants, which are irrigated every three days in new reclaimed sandy soil with supplementary spray anti-stress as potassium silicate ($3cm^3/L$) concentration have saved irrigation water at a rate 490 and 485.3 m^3 per feddan, respectively in 2017 and 2018 seasons as compared to recommended irrigation.

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