Zagazig J. Agric. Res., Vol. 48 No. (1) 2021 1-18

Plant Production Science

Available online at http://zjar.journals.ekb.eg

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

ALLEVIATION OF WATER DEFICIENCY EFFECT BY APPLICATION OF POTASSIUM SILICATE TO FABA BEAN INTERCROPPED WITH SUGAR BEET IN SANDY SOIL

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Received: 21/12/2020 ; Accepted: 17/01/2021

ABSTRACT: Two field experiments were carried out at Ismailia Agricultural Research Station, Agricultural Research Center, Ismailia governorate (Lat. 30° 35' 30" N, Long. 32° 14' 50" E, 10 m a.s.l.), Egypt, during 2018/2019 and 2019/2020 growing seasons. The objective of this study was to determine the rate of potassium silicate that could mitigate the effect of water shortage on productivity of faba bean intercropped with sugar beet and its effects on water and land equivalent ratios, as well as farmer's net revenue. In split plot design with three replications, three irrigation treatments *i.e.*, 120, 100 and 85% Evapotranspiration (mm/d) (ETo) were assigned to the main plots, while three rates of sprayed potassium silicate (unsprayed (control), 200 ppm and 300 ppm) were arranged in sub-plots. The results showed that irrigation with 120% ETo and spraying with 200 ppm potassium silicate attained the highest yield and its components for both faba bean and sugar beet under their intercropping system in both growing seasons. For faba been and sugar beet, N, K and Si content were positively affected by irrigation levels at 100% ETo with foliar potassium silicate 200 ppm, but P content was positively affected by irrigation levels at 120% ETo with foliar 200 ppm potassium silicate. The available P and K in the soil were positively affected by irrigation with 120% ETo with foliar 300 ppm potassium silicate. N content was positive affected by irrigation with 100% ETo with foliar 200 ppm potassium silicate. The highest values of water and land equivalent ratios (WER and LER), as well as total and net return were obtained under irrigation with 120% ETo and spraying with 200 ppm potassium silicate. However, both WER and LER under application of 100% ETo and 200 potassium silicate were higher than irrigation with120% ETo and unsprayed plants in both growing seasons. The highest value of farmer net revenue was obtained when 120% ETo and spraying with 200 ppm potassium silicate were applied. Thus, to attain the highest faba bean with sugar beet in an intercropping system and highest water and land equivalent ratios, as well as farmer's net revenue, 120% ETo and spraying with 200 ppm potassium silicate should be applied. However, in case of water shortage, 100% ETo and spraying with 200 ppm potassium silicate could be applied to mitigate the effect of water deficiency.

Key words: water equivalent ratio, nutrients, land equivalent ratio, intercropped, faba bean, sugar beet and sandy soil.

INTRODUCTION

In sandy soil, silicon (Si) is considered a limiting factor for plant growth and yield. Si is continuously lost *via* leaching, thus fertilization with it could increase yield, soil productivity and improve nutrients content (**Meena *et al.*, 2014**). Long term of intensive crop cultivation

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sprayed with silicates compounds increase growth parameters, yield and yield components (**Henk, 2018**). Some studies reported that, in general, using of silicates compounds increased plant growth, yield and yield components, and yield quality as reported by **Abd El-Mageed *et al.* (2016)**. Silicon plays an important role in photosynthetic rate, plant growth and nutrients uptake as documented by **Wang *et al.* (2006**). It improves cell structural, plant architecture, strength and leaf, which affect plant growth parameters and tolerance to environmental stresses (**Rizwan *et al.*, 2015**). **Arkadiusz (2018)** reported that spraying with 100 ppm to 300 ppm of potassium silicate in the growing medium had high effect at 4-leaf stage and positively effect at other stages of plant. Application of foliar spraying of pea plants with K-silicate at the rate of 228 ppm enhanced growth parameters, yield and yield components and nutrients contents (**Ismail *et al.*, 2017)**. **Moustafa (2013)** found that single and combined application of K-silicate at 0.05 to 0.20% and royaljelly at 0.025 to 0.10%, greatly enhanced growth characters, pigments content and leaf content of N, P and K. Furthermore, **Abdul-Qadir *et al.* (2017)** showed that when plants were treated with K-silicate, marked improvement in each of shoot fresh weight, shoot length, leaf area and leaf length was observed under water stress. In addition, foliar application of 15 ppm Si increased N P K and Si content in plant, weight of shoot, number of panicles, number of grains per panicle and grain yield (**Soratto *et al.*, 2012**). **Abd El-hady and Bondok (2017) r**eported that, sugar beet plants sprayed with 16 cm^3/l K-silicate 150 and 180 days after sowing gave superiority in leaf and root fresh weights, root length and diameter and photosynthetic pigments (Chl "a", Chl"b" and carotenoids). Furthermore, this rate also produced the highest mean value for each of root yield (28.50 ton/fad.), top yield (5.140 ton/ fad.), biological yield (33.64 ton/fad.) and sugar yield (4.788 ton/fad.), compared to control treatment.

Intercropping is one of the techniques that can be used to increase land utilization and improve production (**Bhattanagar *et al.*, 2007**). Yield advantage is the most common motive to adopt intercropping systems, which lead to greater resource depletion by intercrops, compared to monocultures (**Hauggaard-Nielsen *et al.*, 2006**). When the co-crops in an intercropping system having different requirements of the available resources, namely quantity, quality, and time of demand, the advantages of intercropping system could be more apparent (**Alfa and Musa, 2015**). The efficiency of the intercropping is directly depends on proper management of the factors of production (**Porto *et al.*, 2011**), which bring ecological and economic benefits and consequently increase production, as compared to monoculture (**Batista *et al.*, 2016**).

Sugar beet is becoming one of the important cultivated crops in Egypt as it used to reduce sugar food gap in Egypt. It has lower growth season, and consequently lower water requirements, compared to sugarcane. Several researchers in Egypt reported reduction in sugar beet yield when exposing to water stress. **El-Darder *et al.* (2017)** indicated that reduction the applied water to sugar beet by 23% in sandy soil under sprinkler system resulted in 8% yield losses. Whereas, under drip system, reduction in the applied water by 22% resulted in reduction in sugar beet yield by 7%. **Mehanna *et al.* (2017)** applied water stress to sugar beet and found that 33% reduction in the applied irrigation water reduced yield by 18%. A reduction in the yield of sugar beet by 14% occurred when it exposed to 17% reduction in the applied irrigation water.

In the past 10 years, the cultivated area of legume crops, specifically faba bean has been steadily decreased as result of the expansion in the cultivation of sugar beet. One of the solutions that could be used to solve part of the problem of legumes deficiency is to intercrop it with sugar beet. Several researchers studied the effect of intercropping legumes, including faba bean on sugar beet in Egypt. **Azad and Alam (2004), Marey (2004) and Salama *et al.* (2016)** intercropped faba bean and chickpea with sugar beet, they reported that both crops are good nominees to be intercropped with sugar beet to maximize land productivity. **Zohry *et al.* (2020a)** intercropped faba bean and chickpea with sugar beet and they found that both land and water equivalent ratios were 1.32 and 1.31, respectively. Whereas, **El-Mehy *et al.* (2019)** found that land equivalent ratio was 1.35 and water equivalent ratio reached 1.50 under the intercropping system of faba bean with sugar beet.

In spite of all the research work done on application of potassium silicate in Egypt, no work was done on its application to faba bean intercropped with sugar beet. Thus, the objective of this study was to determine the best rate of potassium silicate that could mitigate the effect of water shortage on productivity of both faba bean and sugar beet in an intercropping system and its effects on water and land equivalent ratios, as well as farmer's net revenue.

MATERIALS AND METHODS

A field experiment was carried out at Ismailia Agricultural Research Station, ARC, Ismailia Governorate (Lat. 30° 35' 30" N, Long. 32° 14' 50" E, 10 ma.s.l.), Egypt during 2018/ 2019 and 2019/2020 seasons. Average monthly weather data at the experimental site during the two growing seasons were obtained from https:// power. larc. nasa. gov/ data-access-viewer/ and presented in (Table 1. These data were used to calculate monthly reference evapotranspiration (ETo) values using Penman-Monteith equation, as presented in the United Nations FAO Irrigation and Drainage Paper by **Allen *et al.* (1998)**. This equation is included in Basic Irrigation Scheduling model (**BISm, Snyder *et al.*, 2004**).

Chemical and physical soil analyses of the experimental site before sowing were conducted by the standard method of **Tan (1996)** as shown in Tables 2 and 3**.**

The experiment was carried out in sandy soil. It was arranged in split plot design with three replications. Three irrigation water requirement rates (120, 100, 85%ETo) was assigned in the main plots while three rates of potassium silicate *i.e.*, unsprayed or control, spraying 200 ppm and spraying 300 ppm) was arranged in the sub plots. The area of the experimental plot was 14.4 m^2. The sub-plot consisted of 4 ridges (3m long and 1.2m width).

Peanut was the previous summer crop in both seasons. Sugar beet (c.v. Sauther) was sown on November 1st and 5th in 2018 and 2019 seasons, respectively and harvested on May 5th and 6th in 2019 and 2020 seasons, respectively in both solid and intercropping culture. Whereas, faba bean (cultivar 843) was sown on November 15th and 17th in 2019 and 2020 seasons, respectively and harvested on April10th and 13th in 2019 and 2020 seasons, respectively. Faba bean seeds were inoculated by *Rhizobium leguminosarum* before seeding, Arabic gum was used as a sticking agent in solid and intercropping culture.

In the intercropping culture, sugar beet seeds were sown on both sides of the ridge (1.20 m width) in hills spaced 30 cm apart (35000 plant/ fad., 100% of sole crop). Faba bean seeds were sown on one row on top of the ridge (1.20 m width) in hills 20 cm apart. It thinned to two plants hill^{-1} with 25% planting density of recommended faba bean sold culture. Sole sugar beet seeds were sown on both sides of the ridge (1.20 m width) in hills spaced 30 cm apart (35000 plant/fad., 100% of sole crop). Sole faba bean was planted in ridges (1.20 m width) and 20 cm apart between hills on the top of ridges at 4 rows, 2 plants per hill (140000 plant/fad., 100% of sole crop). The recommended solid culture of both crops was used to estimate competitive relationships.

Potassium silicate fertilizer (K_2SiO_3, 500 g K L^{-1} and 114 g Si L^{-1}) was produced by Technogene Company, China. It was used at 3 rates, 0,200 and 300 ppm (foliar spray). Fertilizer of K-silicate solution at rate 200 ppm Si prepared through mixed K-silicate equal 0.737 l with 419.4 l fad.$^{-1}$ irrigation water and 300 ppm equal 1.105 l with 419.1 l fad.$^{-1}$ of irrigation water. Four spray doses in 25, 40, 55 and 70 days after sowing were applied. EC of spray solution was from 400 to 450 ppm. Other fertilizers were applied during growing season as follows: two doses of ammonium sulfate (200 g N kg^{-1}) added to the soil at rate 8.4 Kg N fad.$^{-1}$ for faba been 20 and 35 days from sowing. For sugar beet, mono calcium superphosphate (67.39 g P kg^{-1}) added before sowing at rate 6.76 Kg P fad.$^{-1}$, 100 Kg N fad.$^{-1}$ at four doses was added to soil, and potassium sulfate (400 g K kg^{-1}) was added at rate 39.92 Kg K fad^{-1}.

Sprinkler system was used to irrigate the experiment. A solid-set sprinkler irrigation system with rotary RC 160 sprinklers of 0.40 to 1.12 an average 0.58 m^3/hour discharge rate at 2.80 bars nozzle pressure was used to irrigate the crops. The sprinkler system consists of main

Table 1. Monthly weather data and ETo in 2019 and 2020 growing seasons in Asmailia Agricultural Research Station

Month	2019					2020				
	SR	Tx	Tn	WS	ETo	SR	Tx	Tn	WS	ETo
Jan.	12.8	17.8	7.5	2.6	**2.4**	12.8	17.4	6.2	2.3	**2.3**
Feb.	16.0	19.7	8.5	2.5	**2.9**	16.0	19.4	6.8	2.3	**2.9**
Mar.	20.5	23.9	11.5	3.0	**4.5**	20.5	23.8	10.4	2.6	**4.4**
Apr.	24.1	27.4	13.5	3.1	**5.8**	24.1	27.9	12.7	2.9	**6.0**
May.	27.7	32.6	17.9	3.1	**7.5**	27.7	33.1	17.1	2.9	**7.7**
Jun.	30.0	35.1	20.6	3.0	**8.2**	30.0	35.8	19.6	3.0	**8.5**
Jul.	29.0	37.8	23.5	2.8	**8.5**	29.0	38.4	22.6	2.8	**8.8**
Aug.	26.8	36.7	23.8	2.7	**7.8**	26.8	37.2	22.8	2.7	**8.0**
Sep.	23.4	33.9	21.3	2.8	**6.6**	23.4	34.3	19.9	2.9	**6.8**
Oct.	18.9	29.2	18.1	2.7	**4.8**	18.9	29.3	16.7	2.6	**4.9**
Nov.	14.6	24.3	14.2	2.4	**3.3**	14.6	23.9	12.6	2.3	**3.2**
Dec.	11.2	21.5	12.3	2.5	**2.7**	11.2	21.2	10.8	2.2	**2.6**

SR = solar radiation (MJ/m^2 /day), TX and TN = maximum and minimum temperature, respectively (°C), WS = wind speed (m/s), ETo = reference evapotranspiration (mm/day).

Table 2. Physical analyses of the experimental soil before sowing

Soil depth (cm)	Particle size distribution			Texture class	Bulk density (mg m^{-3})	Field capacity (%)	Permanent wilting point (%)	Available water (%)
	Sand (%)	Silt (%)	Clay (%)					
0-20	94.30	3.70	2.00		1.65	12.75	3.60	9.15
20-40	95.80	3.00	1.20	Sandy	1.73	11.20	2.90	8.30
40-60	96.20	2.95	0.85		1.70	7.40	2.10	5.30

Table 3. Chemical analysis of the experimental soil before sowing

Soil depth (cm)	pH (1:2.5)	EC (dS m^{-1})	Soluble cations (meq l^{-1})				Soluble anions (meq l^{-1})			
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
0-20	7.66	0.56	1.22	0.53	1.54	0.18	-	1.10	1.72	0.65
20-40	7.59	0.50	1.20	0.50	1.58	0.15	-	1.06	1.74	0.63
40-60	7.40	0.48	1.25	0.48	1.62	0.16	-	1.08	1.75	0.68

Available nutrients (mg kg^{-1})

N	P	K	Si
12.15	4.50	57.18	40.23

EC soil saturation extract pH at 1 : 2.5 (soil : water suspension)

PVC pipe line (160 mm diameter), sub main PVC pipelines (110 mm diameter), and PVC lateral lines (50 mm diameter). The laterals were spaced at 10 X 10 meters apart. Application of the irrigation water treatments started after 30 and 15 days from sowing sugar beet and faba bean, respectively.

Other regular agronomic practices were done according to the technical recommendations .At harvest, ten individual plants of faba bean and sugar beet were taken from each experimental area. The recommended solid culture of both crops was cultivated and used to estimate competitive relationships. Parameters measured of faba been were plant height, number of branches/plant, number of pods/plant, number of seeds/plant, weight of 100-seeds and seed yield/fad.

At harvest of sugar beet, root of ten plants were taken from the plot to measure root length (cm), root diameter (cm), root weight and shoot yield per plant. While, plants of whole plot were harvested then separated into tops and roots and weighted, then converted to estimate roots and tops yield ton per fed. To determine quality traits of sugar beet, samples of 26 g fresh root weight were taken for each treatment to determine total soluble solids percentage (TSS%) measured by Refract meter according to **AOAC (1990)**. Sucrose (%) was estimated according to methods described by **Le-Doct (1927)**. Sugar yield per feddan was calculated according to the following equation:

Sugar yield per fad. (ton) = (root yield ton $fad.^{-1}$ × sucrose %).

Competitive Relationship

Land equivalent ratio (LER)

Land equivalent ratio is the ratio of area needed under sole cropping to produce the same production under intercropping at the same management level to produce an equivalent yield LER was calculated according to **Willey (1979)** as follows:

$$LER = (Yab/Yaa) + (Yba/Ybb)$$

Where: Yaa and Ybb are the sole crop yields of crops a (sugar beet) and b (faba bean), respectively; while Yab is the intercropped yield of crop a, and Yba is the intercropped yield of crop b.

Water equivalent ratio (WER)

Water equivalent ratio was used to quantify the efficiency of water use by an intercropping system (**Mao *et al.*, 2012**). The WER is defined as the total water needed in sole crops to produce the equivalent amount of the species yields on a unit area of intercrop as follows:

$$WER = \frac{\left(\frac{Y_{int,f}}{WU_{int}}\right)}{\left(\frac{Y_{mono,f}}{WU_{mono,f}}\right)} + \frac{\left(\frac{Y_{int,s}}{WU_{int}}\right)}{\left(\frac{Y_{mono,s}}{WU_{mono,s}}\right)}$$

Where: $Y_{int,f}$ and $Y_{int,s}$ are the yield of intercropped faba bean and sugar beet. WU_{int} is water consumptive use by the intercropped crops. $Y_{mono,f}$ and $Y_{mono,s}$ are the yield of mono faba bean and sugar beet. $WU_{mono,f}$ and $WU_{mono,s}$ are water consumptive use by mono faba bean and sugar beet, respectively.

Analyses of Soil and Plant Samples

Soil samples were air dried through 2 mm sieve and were used for the analysis. Plant samples were dried at 70°C for 72 hr., and digested using mixed chloric acid ($HClO_4$) and sulfuric (H_2SO_4) (1:1) according to the method of **Jackson (1973)**. Soil available N was determined used KCl extract (1:10), soil available P using extracted 0.5 N Na HCO_3, soil available K using extracted 1 N NH_4OAc at pH 7.0, soil available N and N in plant were estimated using distillation Kjeldahl, and available K and K in plant using the flame photometer (**Black, 1982**). Soil available P and P in plants was estimated using stance chloride ($Sn\ Cl_2$) by calorimetrically UV-Vis. Soil physical properties were estimated using Spectrophotometer **(Page *et al.*, 1982)**. Silicon was measured in plant using an atomic absorption spectrophotometer as described by **Page *et al.* (1982)**.

Economic performance

Farmer's benefit was calculated by determining each of total return, total cost and net return of intercropping cultures, as well as solid planting according to the following equation:

Total return (LE/fad.) = (yield A x price A + yield B x price B).

The prices used in analysis were farm price for faba bean seeds 2200 LE/Ardab and the price of sugar beet roots were 600 LE/ton. Net return for both crops in solid and intercropping system was calculated according to the following equation:

Net return (LE/fad.) = total return – total costs.

Statistical Analysis

Data were statistically analyzed using the MSTAT-C Statistical Software Package (**Freed, 1991**). The treatment means were compared using the Least Significant Differences (LSD) test with a significance level of 5% according to **Gomez and Gomez (1984)**.

RESULTS AND DISCUSSION

Faba Bean

Effect of irrigation and potassium silicate rates on faba bean yield and its components

Results in Table 4 indicate that all faba bean yield attributes and yield were significantly affected by irrigation and potassium silicate rates in both growing seasons. Different trends were observed for the interaction between irrigation and silicate potassium, where plant height, 100-seed weight and seed yield per fad., was found significant only in the first season. In the second season, only No. of branches/plant and 100-seed weight were found significant.

The results also showed that the highest faba bean yield was obtained under irrigation with 120% ETo and spraying with 200 ppm potassium silicate, which increased faba yield components, more than the unsprayed plants and plants sprayed with 300 ppm. **Mona *et al.* (2011)** observed the same effect of potassium silicate in faba bean. Potassium silicate, as a source of potassium, it is an activator for many enzymes involved in N-fixation and in protein synthesis, in addition to its role in maintaining water balance in the plants (**Divito and Sadras, 2014**). Furthermore, reducing the applied irrigation water from 120% ETo to 80% ETo and spraying faba bean with potassium silicate decreased faba bean yield losses, compared to the control treatment. This result implied that application of potassium silicate could increase faba bean yield under water deficiency. These results were true for both growing seasons. Similar trends were obtained by **Abou-Baker *et al.* (2010)** and in pea (**Ismail *et al.*, 2017**).

Effect of irrigation and potassium silicate rates on faba bean, nutrients content and soil available NPK

Table 5 show that, in the first growing season, irrigation treatments and potassium silicate treatments had significant effects on P, K and Si contents in faba been shoots, whereas it had significant effects on P and K in faba bean seeds. Furthermore, irrigation treatments and potassium silicate were found to have significant effects on soil N and K. Potassium silicate treatments were found to have significant effect on N, P and K in faba bean seeds. Regarding the interaction between irrigation treatments and potassium silicate, it was found to have significant effects on Si content in the shoot. In addition, it had significant effects on soil N and K content.

In the second growing season, irrigation treatments and potassium silicate treatments have significant effects on P, K and Si contents in faba been shoots and seeds. Both treatments had significant effects on soil N and K. Whereas, the interaction between irrigation and potassium silicate treatments had significant effects on Si in the shoot, P in the seeds as well as N and K in the soil.

The highest N content in faba bean shoot was obtained from interaction between Irr_2 and Si_1in the first season, in the 2^{nd} season it was obtained from interaction between Irr_1 and Si_1, and valued as much as 1.48 and 1.47% in the 1^{st} and 2^{nd} season, respectively. The highest P content in the shoot was obtained from interaction between Irr_1 and Si_2 in both seasons, and valued as much as 0.37%. The highest K content in the shoot was obtained from interaction between Irr_2 and Si_1 in the 1^{st} season and 2^{nd} season, and amounted 1.38 and 1.40%, respectively. The highest Si content in the shoot was obtained from interaction between Irr_2 and Si_2 and recorded 94.63 and 111.10% in the 1^{st} and 2^{nd} season, respectively.

The highest N content in faba bean seeds was obtained from the interaction between Irr_2 and Si_1, and valued 3.58 and 3.52% in the 1^{st} and 2^{nd} seasons, respectively. The highest P content in the seeds was obtained from the interaction between

Table 4. Effect of irrigation water amounts (Irr), potassium silicate (Si) and their interactions on faba bean yield and its components in both seasons.

Irr	Si	Plant height (cm)	No. of branches/plant	No. of pods/plant	No. of seeds/plant	100-seed weight (g)	Seed yield (Ardab/fad)
2018/2019							
Irr_1	**Si_0**	82.5	4.36	13.63	49.03	82.06	3.69
	Si_1	92.2	4.76	14.66	52.76	84.76	4.32
	Si_2	89.8	4.53	14.36	51.63	83.96	4.04
Mean		88.2	4.55	14.22	51.14	83.60	4.01
	Si_0	78.7	4.07	13.23	47.63	80.26	3.28
Irr_2	**Si_1**	89.1	4.53	14.20	51.10	83.23	3.59
	Si_2	83.7	4.27	13.96	50.16	82.80	3.35
Mean		83.8	4.29	13.8	49.63	82.10	3.41
	Si_0	71.8	3.53	11.96	43.03	76.66	3.27
Irr_3	**Si_1**	72.3	3.86	12.56	45.23	78.86	3.35
	Si_2	79.3	3.73	12.43	44.66	77.96	3.29
Mean		74.5	3.71	12.32	44.31	77.83	3.30
LSD0.05 (Irr)		3.44	0.17	0.14	0.53	0.40	0.20
LSD0.05 (Si)		2.47	0.14	0.21	0.74	0.26	0.08
LSD0.05 (IrrxSi)		4.28	NS	NS	NS	0.46	0.14
Solid		99.20	2.70	11.03	39.66	82.60	10.73
2019/2020							
	Si_0	92.3	4.33	13.13	47.26	81.26	3.82
Irr_1	**Si_1**	96.8	4.46	14.23	51.30	85.06	4.17
	Si_2	93.6	4.03	13.73	49.40	82.26	4.01
Mean		94.2	4.27	13.70	49.32	82.86	4.00
	Si_0	87.0	3.77	12.86	46.26	78.56	3.75
Irr_2	**Si_1**	92.8	4.23	13.76	49.53	82.10	4.02
	Si_2	92.2	3.97	13.00	46.76	79.96	3.79
Mean		90.6	3.99	13.21	47.52	80.21	3.85
	Si_0	82.0	3.33	11.40	41.00	75.56	3.33
Irr_3	**Si_1**	87.5	3.70	12.40	44.60	78.70	3.62
	Si_2	87.7	3.50	12.00	43.16	77.66	3.51
Mean		85.7	3.51	11.93	42.92	77.31	3.48
LSD0.05 (Irr)		2.99	0.13	0.50	1.78	0.31	0.14
LSD0.05 (Si)		1.66	0.11	0.31	1.13	0.32	0.09
LSD0.05 (IrrxSi)		NS	0.20	NS	NS	0.55	NS
Solid		102.76	2.53	11.03	36.90	80.90	9.66

Irr1= 120% of ETo; Irr2=100% of ETo; Irr3= 85% of ETo; Potassium silicate (Si_0) = control (unsprayed); Potassium silicate (Si_1)= 200 ppm; Potassium silicate (Si_2)= 300 ppm.

Table 5. Effect of irrigation water amounts (Irr), potassium silicate (Si) and their interactions on nutrients percentage in faba bean shoots, seeds and soil available NPK in both seasons

Irr	Si	Shoot				Seeds			Soil available nutrients (mg Kg^{-1})		
		N%	P%	K%	Si%	N%	P%	K%	N	P	K
						2018/2019					
Irr$_1$	**Si$_0$**	1.38	0.31	1.25	50.60	2.94	0.35	1.45	9.51	4.12	52.16
	Si$_1$	1.48	0.31	1.34	74.86	3.19	0.43	1.60	9.80	4.15	60.15
	Si$_2$	1.36	0.37	1.34	86.33	2.98	0.46	1.68	11.2	4.85	65.37
Mean		1.41	0.35	1.31	70.60	3.04	0.41	1.57	10.17	4.37	59.23
	Si$_0$	1.49	0.28	1.29	56.36	2.94	0.33	1.41	10.01	4.05	51.25
Irr$_2$	**Si$_1$**	1.49	0.33	1.38	79.36	3.58	0.41	1.66	11.05	4.09	58.26
	Si$_2$	1.42	0.35	1.38	94.63	3.21	0.42	1.62	12.04	4.60	62.39
Mean		1.47	0.32	1.35	76.78	3.24	0.39	1.57	11.03	4.25	57.3
	Si$_0$	1.35	0.23	1.22	45.10	2.81	0.27	1.34	9.06	4.00	41.29
Irr$_3$	**Si$_1$**	1.43	0.27	1.30	51.96	2.93	0.32	1.44	9.40	4.01	45.22
	Si$_2$	1.39	0.29	1.28	54.76	2.98	0.35	1.42	9.25	4.21	46.62
Mean		1.39	0.26	1.27	50.61	2.91	0.31	1.40	9.24	4.07	44.38
LSD0.05 (Irr)		N.S	0.04	0.05	9.17	N.S	0.06	0.04	1.05	N.S	6.21
LSD0.05 (Si)		N.S	0.02	0.02	3.64	0.15	0.04	0.07	1.18	N.S	8.15
LSD0.05 (Irr X Si)		N.S	N.S	N.S	6.31	N.S	N.S	N.S	1.32	N.S	8.64
						2019/2020					
	Si$_0$	1.38	0.27	1.26	50.7	2.91	0.36	1.42	10.42	4.25	54.30
Irr$_1$	**Si$_1$**	1.47	0.35	1.36	85.26	3.20	0.49	1.57	11.30	4.83	62.14
	Si$_2$	1.35	0.37	1.33	102.9	2.96	0.49	1.62	12.70	5.12	70.12
Mean		1.40	0.33	1.31	79.61	3.02	0.44	1.54	11.47	4.73	62.19
	Si$_0$	1.39	0.29	1.27	56.13	2.98	0.36	1.50	10.80	4.23	52.71
Irr$_2$	**Si$_1$**	1.46	0.32	1.40	90.63	3.52	0.48	1.66	13.51	4.60	59.28
	Si$_2$	1.43	0.37	1.36	111.1	3.24	0.50	1.60	12.91	4.93	70.10
Mean		1.46	0.32	1.34	85.96	3.25	0.44	1.59	12.41	4.59	60.70
	Si$_0$	1.42	0.22	1.20	48.40	2.86	0.32	1.35	9.17	4.24	43.12
Irr$_3$	**Si$_1$**	1.41	0.26	1.29	64.33	3.02	0.37	1.41	12.20	4.20	47.05
	Si$_2$	1.36	0.28	1.26	66.86	2.93	0.42	1.41	12.42	4.31	53.20
Mean		1.40	0.25	1.25	59.86	2.94	0.37	1.39	11.26	4.25	47.49
LSD0.05(Irr)		0.03	0.05	0.06	7.57	0.19	0.03	0.03	0.34	N.S	7.15
LSD0.05 (Si)		0.5	0.03	0.03	5.88	0.14	0.01	0.05	1.01	N.S	7.81
LSD0.05(Irr X Si)		NS	NS	NS	10.19	NS	0.02	NS	1.20	NS	8.25

Irr1= 120% ETo; Irr2=100% ETo; Irr3= 85% ETo; Potassium silicate (Si_0) = control (unsprayed); $Si_{1=}$ 200 ppm Potassium silicate; $Si_{1=}$ 300 ppm Potassium silicate.

Irr_1 and Si_2 in the 1st season while, in the 2nd season it was obtained from interaction between Irr_2 and Si_2, and amounted 0.46 and 0.50% in the 1st and 2nd season, respectively. The highest K content in faba bean seed was obtained from the interaction between Irr_1 and Si_2 in the 1st season while, in the 2nd season it was obtained from the interaction between Irr_2 and Si_1, and valued 1.68 and 1.66% in the 1st and 2nd season, respectively (Table 5).

The highest N content in the soil was obtained from the interaction between Irr_2 and Si_2 in the 1stseason while, in the 2nd season it was obtained from the interaction between Irr_2 and Si_1, and valued 12.04 and 13.51% in the 1st and 2nd season, respectively. The highest P and K content in the soil were obtained from the interaction between Irr_1 and Si_2 in both seasons (Table 5). These results are in harmony with those obtained by **Abd El-Mageed *et al.* (2016), Ismail *et al.* (2017) and Arkadiusz (2018).**

It could be also noticed from the table that irrigation with 100% ETo and spraying with 200 ppm potassium silicate increased most of the nutrients in faba bean shoots, roots and soil, compared to irrigation with 120% ETo and unsprayed treatment in both growing seasons. This result implied the role of potassium silicate in mitigating the effect of water deficiency (Table 5).

Sugar Beet

Effect of irrigation and potassium silicate rates on sugar beet yield and its components

Results in Table 6 indicate that there were significant effects due to irrigation and potassium silicate rates and their interaction on all sugar beet traits in both growing seasons, except root length in the second growing season. Furthermore, the highest sugar beet yield was obtained under irrigation with 120% ETo and spraying with 200 ppm of potassium silicate, compared to plants received 100 and 80% ETo and unsprayed plants or sprayed with 300 ppm of potassium silicate. This result could be explained by the suggestions of some studies that silicon could be used as a growth regulator (**Eneji *et al.*, 2008**). **Artyszak *et al.* (2016)** reported that foliar nutrition with silicon resulted in increase in fresh root mass, and increase in root yield, which determines the yield of sugar. **Ali *et al.* (2019)** indicated that spraying sugar beet with potassium silicate mitigated water stress resulted from delayed irrigation and increased sugar beet yield, compared to unsprayed plants. The table also showed that sugar beet yield losses were reduced under spraying with potassium silicate when the applied irrigation water was reduced from 120% ETo to 80% ETo, compared to the unsprayed plants.

Effect of irrigation and potassium silicate rates on sugar beet, nutrients content and soil available NPK

The results in Table 7 show that, in the first growing season, irrigation and potassium silicate treatments had significant effects on all nutrients contents in the shoots, roots, and soil, except P in the soil. Regarding the interaction between irrigation treatments and potassium silicate, it was found to have significant effects on K and Si content in the shoot only. Furthermore, it had significant effects on soil N and K content.

In the second growing season, irrigation treatments and potassium silicate treatments had significant effects on all nutrients contents in the shoots, roots, and soil, except N in roots. Both treatments have significant effects on soil N and K. The interaction between irrigation treatments and potassium silicate was found to have insignificant effects on all nutrients contents in the shoots, roots, and soil, except Si in the shoot and N and K in the soil. These results are in harmony with those obtained by **Meena *et al.* (2014), Abd El-Mageed *et al.* (2016), Zyada and Bardisi (2018) and Qasim *et al.* (2018)**.

The highest nutrient content in each of shoot, root and soil were obtained from interaction between Irr_1 and Si_1in the 1stseason, except P and K in the soil, where it was obtained from interaction between Irr_1 and Si_2. In the 2nd season, the highest nutrient content in the shoot, root and soil were obtained from the interaction between Irr_1 and Si_1, except N in the soil.

These results are in harmony with those obtained by **Wang *et al.* (2006), Ismail *et al.* (2017), Henk (2018)**. Similar results were obtained by **Rizwan (2015) and Qasem *et al.* (2018)**.

Table 6. Effect of irrigation water amounts (Irr), potassium silicate (Si) and their interactions on sugar beet yield and its components of in both seasons

Irr	Si	Root length (cm)	Root diameter (cm)	Root weight/plant (g)	Top fresh weight (g)	Root yield/fad. (ton)
			2018/2019			
Irr_1	**Si_1**	17.8	11.1	818.3	464.3	24.55
	Si_2	18.2	11.4	861.6	480.0	25.85
	Si_3	17.7	11.0	838.3	468.3	25.15
Mean		17.9	11.2	839.4	470.8	25.18
	Si_0	16.1	10.3	745.0	390.0	22.35
Irr_2	**Si_1**	18.0	11.2	831.6	457.3	24.95
	Si_2	17.3	10.7	801.6	448.6	24.05
Mean		17.1	10.7	792.7	432.0	23.78
	Si_0	14.8	9.1	710.0	324.3	21.3
Irr_3	**Si_1**	17.6	10.4	805.0	419.3	24.15
	Si_2	17.1	9.5	756.6	405.6	22.70
Mean		16.5	9.7	757.2	383.1	22.71
LSD 0.05 (Irr)		0.15	0.38	11.08	2.65	0.33
LSD 0.05 (Si)		0.20	0.23	11.29	7.30	0.33
LSD 0.05 (Irr x Si)		0.35	0.41	19.55	12.65	0.58
Solid		19.03	11.66	913.0	525.0	27.4
			2019/2020			
	Si_0	16.8	10.6	808.3	455.6	24.04
Irr_1	**Si_1**	17.9	11.0	846.6	475.6	25.28
	Si_2	17.3	10.8	821.6	466.6	24.4
Mean		17.3	10.8	825.5	466.0	24.58
	Si_0	15.9	10.4	746.6	387.3	22.21
Irr_2	**Si_1**	18.0	11.3	836.6	463.3	24.87
	Si_2	17.6	11.1	808.3	453.3	24.04
Mean		17.2	10.9	797.2	434.6	23.70
	Si_0	15.4	8.7	681.6	313.3	20.38
Irr_3	**Si_1**	18.1	11.0	795.0	409.6	23.76
	Si_2	17.2	10.7	746.6	394.0	22.29
Mean		16.9	10.1	741.1	372.3	22.14
LSD 0.05 (Irr)		NS	0.16	9.34	8.98	0.35
LSD 0.05 (Si)		0.23	0.17	6.84	6.60	0.26
LSD 0.05 (Irr x Si)		0.41	0.30	11.85	11.43	0.45
Solid		8.5	11.50	881.6	495.0	26.76

Irr_1= 120% ETo; Irr_2=100% ETo; Irr_3= 85% ETo; Potassium silicate (Si_0) = control (unsprayed); $Si_{1=}$ 200 ppm Potassium silicate; $Si_{1=}$ 300 ppm Potassium silicate.

Table 7. Effect of irrigation water amounts (Irr), potassium silicate (Si) and their interactions on nutrients percentage in sugar beet shoots, roots and soil available NPK in both seasons

Irr	Si	Shoot				Root			Soil available nutrients (mg Kg^{-1})		
		N%	P%	K%	Si%	N%	P%	K%	N	P	K
					2018/2019						
Irr$_1$	**Si$_0$**	1.33	0.19	1.72	55.23	1.63	0.20	3.21	13.82	4.25	61.41
	Si$_1$	1.70	0.24	2.25	99.56	2.12	0.30	3.58	13.82	5.12	65.32
	Si$_2$	1.60	0.24	2.09	85.10	1.86	0.26	3.51	11.95	5.92	65.30
Mean		1.54	0.22	2.02	79.96	1.87	0.26	3.50	11.72	5.10	64.01
Irr$_2$	**Si$_0$**	1.37	0.19	1.81	60.56	1.63	0.23	3.13	10.24	3.96	52.36
	Si$_1$	1.69	0.24	2.17	95.56	1.90	0.29	3.50	13.61	4.97	59.76
	Si$_2$	1.56	0.22	1.90	81.36	1.69	0.25	3.37	11.30	5.83	60.24
Mean		1.54	0.21	1.96	79.16	1.74	0.26	3.33	13.20	4.86	56.45
Irr$_3$	**Si$_0$**	1.28	0.15	2.67	48.06	1.24	0.22	3.05	10.21	5.81	42.70
	Si$_1$	1.48	0.17	1.77	61.56	1.62	0.21	3.21	10.14	4.00	51.30
	Si$_2$	1.38	0.18	1.89	69.13	1.30	0.24	3.36	10.25	4.30	55.21
Mean		1.38	0.17	1.77	59.58	1.38	0.22	3.21	10.20	4.70	49.74
LSD 0.05 (Irr)		0.04	0.01	0.10	6.77	0.21	0.25	0.03	0.90	N.S	5.12
LSD 0.05 (Si)		0.08	0.01	0.06	2.87	0.15	0.02	0.11	1.30	N.S	6.38
LSD 0.05 (IrrxSi)		N.S	N.S	0.10	4.97	N.S	N.S	N.S	1.46	N.S	6.94
					2019/2020						
Irr$_1$	**Si$_0$**	1.44	0.20	1.87	63.56	1.73	0.21	3.61	9.38	5.35	56.14
	Si$_1$	1.73	0.27	2.07	112.8	1.95	0.30	3.79	12.36	5.50	64.27
	Si$_2$	1.63	0.23	2.06	99.53	1.92	0.24	3.71	12.10	5.51	71.13
Mean		1.60	0.23	2.00	91.96	1.81	0.25	3.70	11.28	5.45	63.85
Irr$_2$	**Si$_0$**	1.39	0.18	1.77	60.66	1.72	0.21	3.35	10.24	4.13	58.25
	Si$_1$	1.65	0.23	2.05	108.9	1.76	0.28	3.57	12.40	5.38	60.89
	Si$_2$	1.55	0.22	1.88	94.63	1.71	0.22	2.69	12.61	5.49	63.50
Mean		1.53	0.21	1.89	88.06	1.79	0.23	3.53	11.75	5.00	60.88
Irr$_3$	**Si$_0$**	1.28	0.16	1.73	51.6	1.28	0.19	3.20	8.75	4.05	60.01
	Si$_1$	1.48	0.16	1.80	70.6	1.53	0.21	3.35	9.52	4.60	57.18
	Si$_2$	1.40	0.19	1.90	79.0	1.36	0.21	3.41	8.64	4.87	49.86
Mean		1.38	0.17	1.81	67.06	1.39	0.20	3.32	8.97	4.51	55.68
LSD 0.05 (Irr)		0.10	0.02	0.09	8.69	N.S	0.3	0.16	2.16	0.46	1.87
LSD 0.05 (Si)		0.05	0.01	0.06	6.14	N.S	0.02	0.13	2.26	0.52	2.29
LSD 0.05 (IrrxSi)		NS	NS	NS	10.64	NS	NS	NS	2.51	NS	3.14

Irr$_1$= 120% ETo; Irr$_2$=100% ETo; Irr$_3$= 85% ETo; Potassium silicate (Si$_0$) = control (unsprayed); Si$_{1=}$ 200 ppm Potassium silicate; Si$_{1=}$ 300 ppm Potassium silicate.

Effect of irrigation and potassium silicate rates on sugar beet chemical traits

Results in Table 8 indicate that the effect of irrigation treatments and potassium silicate were found significant on sucrose percentage and TSS in both seasons. However, the interaction between irrigation treatments and potassium silicate was insignificant in both seasons. The table also showed that there were clear reduction in sucrose percentage and TSS as a result of reduction in the applied irrigation amounts from 120 ETo to 80% ETo. It can be also noticed from the table that, in general, spraying with 200 ppm of potassium silicate attained the highest value of sucrose percentage in both growing seasons under the three irrigation amounts. On the contrary, TSS values were the highest under no spraying with potassium silicate under the three irrigation amounts. **Artyszak *et al.* (2016)** reported that foliar application of silicon had no significant effect on sugar beet roots quality parameters. Similar results were obtained by **Ali *et al.* (2019)**.

Land equivalent ratio (LER)

The values of LER were estimated using data of recommended solid cultures of both crops. Intercropping faba bean with sugar beet increased LER to be higher than 1.0 as compared to solid cultures of both crops. The results in Table 9 showed that irrigation water amounts, potassium silicate and their interactions significantly affecting LER in both growing season. In general, the highest values of LER were found under application of 120% ETo and spraying with 200 ppm potassium silicate, and valued 1.34 and 1.37 in the first and second season respectively. Whereas the lowest values of LER was found under application of 80% ETo and unsprayed treatment. This result implied that irrigation with 120% ETo and spraying with 200 ppm potassium silicate can attain maximize land usage by 34 and 37% (Table 9). Similar results were obtained by **Abd-Allah *et al.* (2019)** for faba bean intercropped with sugar beet.

It can be also noticed from the table that LER under 100 ETo and 200 potassium silicate was higher than 120% ETo and unsprayed plants in both growing seasons, which showed the role of potassium silicate in mitigating water deficiency.

Water equivalent ratio

The results in Table 10 indicate that higher values of WER for faba bean, WER for sugar beet and total WER were obtained under application of the three irrigation treatments and 200 ppm silicate potassium in both growing seasons. However, the highest total WER was obtained when irrigation with 120% ETo and 200 ppm of silicate potassium were applied in both growing seasons. The lowest value of total WER was obtained under 80% ETo in both growing season. Similar results were obtained by **Zohry *et al.* (2020a and b)**.

It can be also noticed from the table that WER under 100% ETo and spraying with 200 potassium silicate was higher than its value under 120% ETo and unsprayed plants in both growing seasons.

Economic Performance

The results in Table 11 showed that, in both growing seasons, the highest total and net return were obtained when irrigation with 120% ETo was applied and 200 ppm potassium silicate was sprayed, recorded 14629 and 13957 LE in the first season and second season, respectively. The application of 120% ETo and 300 ppm potassium silicate gave the second best total and net returns, where the net return were 13593 and 13077 LE in the first season and second season, respectively.

Conclusion

The results of this investigation clearly showed that irrigation with 120% ETo and spraying with 200 ppm potassium silicate attained the highest yield from both faba bean and sugar beet in an intercropping system, water and land equivalent ratios, as well as farmer's net revenue. For faba been and sugar beet, N, K and Si content were positively affected by irrigation levels at 100% ETo with foliar potassium silicate 200 ppm, but P content was positively affected by irrigation levels at 120% ETo with foliar 200 ppm potassium silicate. The soil available P and K were positively affected by irrigation levels at 120% ETo with foliar 300 ppm potassium silicate, but N content was positive affected by irrigation levels at 100% ETo with foliar 200 ppm potassium silicate.

Table 8. Effect of irrigation water amounts (Irr), potassium silicate (Si) and their interactions on sugar beet chemical traits in both seasons

Irr	Si	Sucrose (%)		TSS	
		First season	Second season	First season	Second season
	Si_0	18.2	18.1	20.6	20.6
Irr_1	Si_1	18.6	18.6	20.3	20.1
	Si_2	18.6	18.4	20.4	20.4
Mean		18.5	18.4	20.4	20.4
	Si_0	17.7	17.8	20.0	19.8
Irr_2	Si_1	18.2	18.4	19.5	19.4
	Si_2	18.0	18.2	19.7	19.5
Mean		17.9	18.1	19.7	19.6
	Si_0	17.2	17.3	19.4	19.2
Irr_3	Si_1	17.7	17.8	19.0	18.5
	Si_2	17.7	17.7	19.2	18.8
Mean		17.6	17.6	19.2	18.8
LSD 0.05 (Irr)		0.22	0.26	0.13	0.14
LSD 0.05 (Si)		0.16	0.08	0.11	0.15
LSD 0.05 (Irr x Si)		NS	NS	NS	NS
Solid		18.1	18.4	20.7	20.5

Irr_1= 120% ETo; Irr_2=100% ETo; Irr_3= 85% ETo; Potassium silicate (Si_0) = control (unsprayed); $Si_{1=}$ 200 ppm Potassium silicate; $Si_{1=}$ 300 ppm Potassium silicate.

Table 9. Land equivalent ratio for faba bean intercropped with sugar beet under irrigation treatments and spraying with potassium silicate in both seasons.

		First season			Second season		
Irr	Si	$RY_{Faba\ bean}$	$RY_{Sugar\ beet}$	LER	$RY_{Faba\ bean}$	$RY_{Sugar\ beet}$	LER
Irr_1	Si_0	0.34	0.89	1.23	0.39	0.89	1.28
	Si_1	0.40	0.94	1.34	0.43	0.94	1.37
	Si_2	0.37	0.91	1.28	0.41	0.91	1.32
Mean		0.37	0.91	1.28	0.41	0.91	1.32
	Si_0	0.30	0.81	1.11	0.38	0.82	1.20
Irr_2	Si_1	0.33	0.91	1.24	0.41	0.92	1.33
	Si_2	0.31	0.87	1.18	0.39	0.89	1.28
Mean		0.31	0.86	1.17	0.39	0.88	1.27
	Si_0	0.30	0.77	1.07	0.34	0.76	1.10
Irr_3	Si_1	0.31	0.88	1.19	0.37	0.88	1.25
	Si_2	0.30	0.82	1.12	0.36	0.83	1.19
Mean		0.30	0.82	1.12	0.36	0.82	1.18
LSD 0.05 (Irr)		0.04		0.12	0.06		0.07
LSD 0.05 (Si)		0.11		0.08	0.07		0.09
LSD 0.05 (Irr x Si)		0.09		0.11	0.21		0.16
Solid							

Irr_1= 120% ETo; Irr_2=100% ETo; Irr_3= 85% ETo; Potassium silicate (Si_0) = control (unsprayed); $Si_{1=}$ 200 ppm Potassium silicate; $Si_{1=}$ 300 ppm Potassium silicate.

Table 10. Water equivalent ratio for faba bean intercropped with sugar beet under irrigation treatments and spraying with potassium silicate in both seasons

Irr	Si	First season			Second season		
		$WER_{faba\ bean}$	$WER_{sugar\ beet}$	WER_{total}	$WER_{faba\ bean}$	$WER_{sugar\ beet}$	WER_{total}
	Si_0	0.34	0.75	1.09	0.40	0.75	1.14
Irr_1	Si_1	0.40	0.79	1.19	0.43	0.79	1.22
	Si_2	0.38	0.77	1.14	0.42	0.76	1.17
	Si_0	0.37	0.82	1.18	0.47	0.83	1.30
Irr_2	Si_1	0.40	0.91	1.31	0.50	0.93	1.43
	Si_2	0.37	0.88	1.25	0.47	0.90	1.37
	Si_0	0.43	0.91	1.34	0.49	0.90	1.38
Irr_3	Si_1	0.44	1.04	1.48	0.53	1.04	1.57
	Si_2	0.43	0.97	1.41	0.51	0.98	1.49

Irr_1= 120% ETo; Irr_2=100% ETo; Irr_3= 85% ETo; Potassium silicate (Si_0) = control (unsprayed); $Si_{1=}$ 200 ppm Potassium silicate; $Si_{1=}$ 300 ppm Potassium silicate.

Table 11. Total return, total costs and net return for faba bean intercropped with sugar beet under irrigation treatments and spraying with potassium silicate in both seasons.

Irr	Si	Total return (LE)			Total costs (LE)			Net return (LE)
		Faba bean	Sugar beet	Total	Faba bean	Sugar beet	Total	
				2018/2019				
Irr_1	Si_0	8118	14730	22848	765	9620	10385	12463
	Si_1	9504	15510	25014	765	9620	10385	14629
	Si_2	8888	15090	23978	765	9620	10385	13593
Mean		8837	15110	23947	765	9620	10385	13562
Irr_2	Si_0	7216	13410	20626	765	9620	10385	10241
	Si_1	7898	14970	22868	765	9620	10385	12483
	Si_2	7370	14430	21800	765	9620	10385	11415
Mean		7495	14270	21765	765	9620	10385	11380
Irr_3	Si_0	7194	12780	19974	765	9620	10385	9589
	Si_1	7370	14490	21860	765	9620	10385	11475
	Si_2	7238	13620	20858	765	9620	10385	10473
Mean		7267	13630	20897	765	9620	10385	10512
				2019/2020				
Irr_1	Si_0	**8404**	14424	22828	765	9620	10385	12443
	Si_1	**9174**	15168	24342	765	9620	10385	13957
	Si_2	**8822**	14640	23462	765	9620	10385	13077
Mean		**8800**	14744	23544	765	9620	10385	13159
Irr_2	Si_0	**8250**	13326	21576	765	9620	10385	11191
	Si_1	**8844**	14922	23766	765	9620	10385	13381
	Si_2	**8338**	14424	22762	765	9620	10385	12377
Mean		**8477**	14224	22701	765	9620	10385	12316
Irr_3	Si_0	**7326**	12228	19554	765	9620	10385	9169
	Si_1	**7964**	14256	22220	765	9620	10385	11835
	Si_2	**7722**	13374	21096	765	9620	10385	10711
Mean		**7671**	13286	20957	765	9620	10385	10572

Irr_1= 120% ETo; Irr_2=100% ETo; Irr_3= 85% ETo; Potassium silicate (Si_0) = control (unsprayed); $Si_{1=}$ 200 ppm Potassium silicate; $Si_{1=}$ 300 ppm Potassium silicate.

Additionally, both WER and LER under 100% ETo and 200 ppm potassium silicate was higher than 120% ETo and unsprayed plants in both growing seasons. Thus, it could be concluded that spraying with 200 ppm potassium under water deficiency (100% ETo) could mitigating the effect of water deficiency.

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تقليل تأثير نقص المياه باستخدام سيليكات البوتاسيوم على الفول البلدى المحمل مع بنجر السكر في الأراضى الرملية

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تم إجراء تجربتين حقليتن بمحطة البحوث الزراعية بالإسماعيلية ، مركز البحوث الزراعية ، محافظة الإسماعيلية (خط الطول 30 درجة 35 '30 شمالاً ، خط الطول 32 درجة 14' 50 بوصة شرقاً ، 10 م فوق سطح البحر)، مصر خلال 2019/2018 و2020/2019، الهدف من هذه الدراسة هو تحديد أفضل معدل لسيليكات البوتاسيوم التي يمكن أن تخفف من تأثير نقص المياه على إنتاجية الفول البلدى المحمل مع بنجر السكر وتأثيره على معدل المكافئ الأرضى والمائى، وكذلك صافي إيرادات المزارع، في تصميم القطع المنشقة بثلاث مكررات، تم تخصيص ثلاث معاملات ري (120 ، 100 و80% ETo) للقطع الرئيسية، بينما تم توزيع ثلاث معدلات لرش سيليكات البوتاسيوم (بدون رش (كنترول)، 200 جزء في المليون و300 جزء في المليون) في القطع المنشقه، أوضحت النتائج أن الري باستخدام 120% ETo والرش بـ 200 جزء في المليون من سيليكات البوتاسيوم حقق أعلى محصول ومكوناته لكل من الفول وبنجر السكر تحت نظام التحميل في كلا موسمي النمو، بالنسبة للفول البلدى وبنجر السكر تأثر محتوى النيتروجين والبوتاسيوم والسيليكون إيجابياً بمستويات الري عند 100% ETo مع سيليكات البوتاسيوم 200 جزء في المليون، بينما تأثر محتوى الفسفور إيجابياً بمستويات الري عند 120% ETo مع 200 جزء في المليون من سيليكات البوتاسيوم، وقد تأثرت معدلات الفوسفور والبوتاسيوم فى التربه إيجابياً بمستويات الري عند 120% ETo مع 300 جزء في المليون من سيليكات البوتاسيوم ، لكن محتوى النيتروجين تأثر إيجابياً بمستويات الري عند 100% ETo مع 200 جزء في المليون من سيليكات البوتاسيوم، تم الحصول على أعلى قيم لمعدل المكافئ الأرضى والمائى (WER و LER)، وكذلك العائد الإجمالي والصافي تحت الري باستخدام 120% ETo والرش بـ 200 جزء في المليون من سيليكات البوتاسيوم، ومع ذلك، كان كل من WER و LER تحت الرى 100% ETo و200 سيليكات البوتاسيوم أعلى من الري مع 120% ETo وبدون رش بسيليكات البوتاسيوم في كلا موسمي النمو، تم الحصول على أعلى قيمة لصافي عائد المزارع عند الرى 120% ETo والرش بـ 200 جزء في المليون من سيليكات البوتاسيوم، وبالتالي، لتحقيق أعلى الفول المحمل على بنجر السكر وأعلى قيم لمعدل المكافئ الأرضى والمائى، وكذلك صافي دخل المزارع ، يجب الرى 120% ETo والرش بـ 200 جزء في المليون من سيليكات البوتاسيوم. بينما، في حالة نقص المياه، يمكن الرى 100% ETo والرش بـ 200 جزء في المليون من سيليكات البوتاسيوم للتخفيف من تأثير نقص المياه.

الكلمات الإسترشادية: معدل المكافئ المائى، العناصر، معدل المكافئ الأرضى، الدخل الكلى، التحميل، الفول البلدى، بنجر السكر، الأراضى الرملية.

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