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Effect of Zeolite, Potassium Fertilizer and Irrigation Interval on Yield and Quality of Sugar Beet in Sandy Soil

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ABSTRACT

Two field experiments were carried out at Al-Hussein Agricultural Society Farm, Giza Governorate**,** Egypt, during 2017/2018 and 2018/2019 growing seasons to study the effect of three irrigation intervals [every 3 days (the conventional practice), 5 and 7 days], two levels of zeolite (zero and 500 kg/fed) and four levels of potassium fertilizer the first one in the form of potassium sulphate as a control [100% of the recommended K-dose], which was applied to the soil and three foliar doses of nano- potassium (500, 1000 and 1500 mg /l) on yield and quality of sugar beet grown under drip irrigation system in a sandy soil. The treatments were arranged in a complete block design in a split-split plot with three replications. Results revealed that increasing irrigation interval from 3 up to 7 days significantly reduced biochemical and physiological traits and root and sugar yields/fed. Soil application of zeolite achieved the highest values of all the parameters studied as compared to the untreated soil. Spraying beets with 1500 mg /l of nano-K gave the same trend of the recommended K-dose. Water use efficiency (WUE) for sugar yield increased with decreasing the amounts of applied irrigation water. Under conditions of the present work, adding 500 kg of zeolite/fed to the sandy soil, spraying beets with 1500 mg l^{-1} as nano-K fertilizer and irrigating the crop every 5 days using drip irrigation can be recommended to get the highest root and sugar yields as well as to save water and increasing water use efficiency.

Keywords: Irrigation interval, K-nano fertilizer, sugar beet, quality, yield, zeolite

INTRODUCTION

Nowadays, land reclamation is on the major issues of the Egyptian Government agenda in order to overcome the overwhelmingly unfavorable population to land ratio (Bush, 2007),in addition to the limited water resources. Water resources currently available for use are 55.5 billion cubic meters per year (BCM/yr) from the Nile River, 1.3 BCM/yr effective rainfall and 2 BCM/yr non-renewable groundwater, *i.e.* a total of 58.8 BCM/yr, of which, the agriculture sector utilizes more than 85% of Egypt's share from the Nile. Thus, the gap between water supply and demand is about 20 BCM/yr (MWRI, 2014). To overcome this dilemma, modern systems as drip irrigation must be used instead of the traditional surface irrigation, using appropriate irrigation intervals especially in sandy soils. On the other hand, sugar beet is sensitive to water deficit at the time of crop emergence and for a period of about one month (Camposeo and Rubino, 2003), they added that severe water stress decreased leaf area and plant growth. Moreover, Neseim *et al.* (2014) reported that drought stress significantly reduced all root and leaves morphological growth characters, root yield and white sugar/fed of sugar beet. El-Kady *et al.* (2019) found that total applied irrigation water for sugar beet was 2546 m^3/season/fed under drip irrigation system in a sandy soil at Wady El-Notron.

Imran *et al*. (2019) found that increasing irrigation intervals for sugar beet from 5 to 10 days increased sucrose %. Irrigation every 5 days improved growth and biochemical traits, yield and quality. Mehanna *et al*. (2020) indicated that the highest values of root diameter, and root yield of sugar beet were given by 7 days irrigation intervals with significant differences as compared with using 14 days under drip irrigation system. Wang *et al.* (2013) explained that plant responses to drought stress depend on the duration and severity of the drought period and its impacts will extent to inevitably result in oxidative damage due to the over production of reactive oxygen species (ROS), which can oxidize multiple cellular components like proteins and lipids, DNA and RNA, unrestricted oxidation of the cellular components, which will cause the peroxidation of membrane lipids, thus reducing the selective permeability of the cell membrane and ultimately cause cell death. In the same context, Brien *et al.* (2012) mentioned that the majority of ROS produced in response to stress conditions is hydrogen peroxide (H_2O_2). Catalase (CAT) and superoxide dismutase (SOD) are well-known enzymes involved in the detoxification of H_2O_2 and super oxide radicals via conversion to water and oxygen. Therefore, the use of fast-acting and effective alternatives such as nano fertilizers, which have many benefits for plant compared with traditional fertilizers because they contribute to reducing environmental pollution, achieving sustainable agriculture, ensure favorable environment for microorganisms, in addition to its capability to increase crop yields, decreasing production costs per unit area and easy storage. Moreover, nano fertilizers have the ability to enhance growth parameters as plant height, leaf area, number of leaves per plant, dry matter, chlorophyll production and the rate of photosynthesis, which result in

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more production and translocation of photosynthesis to different parts of the plant (Manjunatha *et al*. 2016).

Potassium fertilizer plays a vital role in promoting vegetative growth, enhancing nutrient transport and increasing reactions and enzymatic activities as well as rates that are reflected positively in providing raw materials necessary for cell division, growth and development. Potassium has various profound effects on the plant physiological, biochemical and morphological characteristics, maintain the osmotic balance,*i.e.* osmoregulation, opening and closing of stomata, as cofactor enzymes because it is somatically, a major active solute of plant cell and stress resistance (Wang *et al*., 2013). Aysan *et al.* (2014) reported that spraying with nano-K at the rate of 600 mg/l achieved an increase in leaf area, grain yield, biological yield, and chlorophyll content of *Ocimum basilicum*. Zangeneh, Nayereh and Rasouli (2018) reported that the application of 1000 mg l^{-1} K-nano increased chlorophyll content but 2000 mg l^{-1} increased the potassium content and activity of the enzyme of grape fruit. Abdallah, Maha *et al*. (2019) showed that, under drought, foliar application of K_2SO_4 (200 mg l^{-1}) led to an increase in growth parameters, yield components, photosynthetic pigments, stomatal opening area in both upper and lower epidermis of wheat plant. Likewise, Jasim *et al.* (2020) stated that spraying leaves of maize with 500 mg l^{-1} of nano potassium + 150 kg ha^{-1} of potassium sulphate fertilizer was superior for yield.

Zeolite belongs to a group of natural minerals with physical and physicochemical properties that can be utilized in various fields such as construction and agriculture. Natural zeolites are inert and non-toxic spongy mineral substances, with a crystalline structure. Zeolite can be used as a slow-release fertilizer. It has carrier, which is hydrated aluminosilicates consisting of a stable three-dimensional framework of silica and aluminum tetrahedra, which have a molecular sieve action due to their open channel network, and are composed of TO4 tetrahedra linked with oxygen sharing the negative charge created by the presence of AlO_2^- which is balanced by cations that neutralize the charge deficiency (Gruener *et al.* 2003). It can improve the efficiency of water and nutrient use of plants and decrease runoff and sediments amount by increasing the soil water holding capacity, acting as slow/controlled-release fertilizer aspect of light sandy soils in particular, which is reflected in higher yield and better quality (Khodaei and Asilan, 2012). Zeolite decrease application rate of N and K fertilizers, as they are carriers of N and K fertilizers, thereby increasing efficacy. Also, zeolites are capable to absorb part of the excess nutrients and water, resulting in more balanced macronutrient cation ratios in the root environment and can keep water in root zone (Savvas *et al.*, 2004). Akbari *et al*. (2011) confirmed that zeolite (500 kg/ha), significantly increased leaf area, root length and root yield of sugar beet. Abdelwahab and Amira Soliman (2017) pointed out that soil amendment zeolite (497.7 kg fed^{-1}) significantly increased growth, stomatal conductance plant pigments and yield of Evening Primrose (*Oenothera biennis*,L.) under sandy soil. Tahereh *et al.*(2017) recorded significant increases in root and sugar yield of sugar beet by using zeolite under water deficient (75% of moisture evacuated from soil). Mahmoud (2019) found that irrigation treatment at 55% depletion of available soil moisture and soil application of zeolite (100 kg fed^{-1}) have highly significant effect on increasing of yield of wheat. Somayeh *et al*. (2020) found that the application of zeolite 10 ton ha^{-1} reduced the activity of catalase and superoxide dismutase enzymes and increased water use efficiency of amaranth plant under water-deficit stress conditions under sandy soil.

The present research was carried out to assess the importance of zeolite and nano-potassium fertilizer in mitigating the negative impacts of drought stress resulting from prolonging irrigation intervals and improving yield and quality of sugar beet grown under drip irrigation system in a sandy soil.

MATERIALS AND METHODS

Two field experiments were carried out at Al-Hussein Agricultural Society Farm, Cairo-Alexandria Desert Road, Giza Governorate, Egypt**,** (latitude of 31.14^{o} N and longitude of 31.39^{o} E) in 2017/2018 and 2018/2019 seasons to study the effect of zeolite as a soil amendment, potassium fertilizer and irrigation intervals on sugar beet growth, physicochemical characteristics, yield and quality response under drip irrigation system in a sandy soil. This work included 24 treatments, represent the combinations of three irrigation intervals [every 3 days (the conventional practice), 5 and 7 days], two levels of zeolite (zero and 500 kg/fed) and four levels of potassium fertilizer, the first one in the form of potassium sulphate (48% K_2O) as a control and three levels of nano-K (3.2%K_2O). A complete block design in a split-split plot arrangement with three replications was used, where irrigation intervals were allocated at random in the main plots, levels of zeolite were distributed in the sub-plots, while the sub-sub plots were assigned to the levels of potassium fertilizer, where 100% of the recommended K-dose was applied to the soil and three foliar doses of nano potassium [500, 1000 and 1500 mg /l] were given to sugar beets as foliar application, after 50, 65 and 80 days from sowing. Water deficits treatments were carried out at period of about a month after sowing. The experimental unit area was 12 m^2 (4 terraces of 1 m apart and 3 m long) and 15 cm between hills. Multi-germ sugar beet variety *viz* "Magribel" was sown on both side of terraces in the 2nd week of October in the 1st and 2nd seasons, while harvesting took place at age of 180 days after sowing in both seasons. Phosphorus fertilizer was applied in the form of calcium super phosphate (15% P_2O_5) at the rate of 30 kg P_2O_5 /fed during seed bed preparation. Nitrogen fertilizer was applied at 120 kg N/fed as ammonium nitrate (33.5% N) in 4-equal doses; the 1st was applied after thinning (4- true-leaf stage) and another three ones were given at two-week intervals, after the first one. Natural zeolite at the rate of 500 kg/fed was mixed with experimental soil at seed bed preparation. Nano-K fertilizer was purchased from Physiology Department (Nano-technology project), Faculty of Agriculture, Cairo University. Zeolite was purchased from El-Ahram Company for Mining and Natural Fertilizers, Giza, Egypt and its analysis is presented in Table 1. Other field practices were done as recommended by Sugar Crop Research Institute. Transmission electronic microscope (TEM), Model JEOL (JEM-1400 TEM, Japan) was used to investigate and measure the size of the of K-nano particles (6.36 - 15.00 nm) exhibited in Fig. 1 at TEM lab, Faculty of Agriculture, Cairo University (FA-CURP) as shown by Elavazhagan and Arunachalam (2011).Soil samples (at 0-30 cm depth) were collected from the experimental site to determine its physical and chemical properties using the method described by (AOAC, 1990). as shown in Table 2-a. Metrological data of the experimental site at Southern Tahrir region, determined as reported by Chapman and Praft (1961) are illustrated in Table 2-b.

Table 1. Chemical composition of natural zeolite

Chemical composition	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	P_2O_5
(%)	62.22	0.34	11.10	1.50	0.60	2.71	0.78	1.08	0.36

Table 2-a. Some physical and chemical traits of the experimental soil site for 2017/2018 and 2018/2019 seasons.

Physical characteristics	Particle size distribution Sand%	Silt%	Clay%	Soil texture	Moisture content (%) F.C	W.P	A.W	Available nutrients (mg/kg soil) N	P	K
2017/2018	94.0	4.2	1.8	Sandy	15.19	6.11	9.08	25	1.7	80
2018/2019	93.5	4.6	1.9	Sandy	15.21	6..14	9.07	31	1.9	93

Chemical characteristics	p^H	EC (dS/m)	Soluble anions (meq/l) CO_3^-	HCO_3^-	Cl^-	SO_4^-	Soluble cations (meq/l) Ca++	Mg++	Na+	K+
2017/2018	8.00	0.41	-	0.52	2.81	0.83	1.34	0.47	2.21	0.14
2018/2019	7.95	0.76	-	0.75	3.25	1.58	1.61	1.51	2.26	0.20

Table2-b.Average agro-meteorological data of Southern Tahrir region

Month	Max. temp. (°C)	Min. temp. (°C)	Relative humidity (%)	Wind speed (km/hr)
October	30.0	14.2	57	8.4
November	25.4	10.4	69	7.4
December	21.3	6.9	69	6.2
January	19.8	5.6	67	6.1
February	21.2	7.3	65	7.0
March	23.8	10.9	63	7.8
April	28.2	11.4	56	8.7
Average/year	28.2	12.6	58	8.5

Source: Southern Tahrir agro-meteorological station,

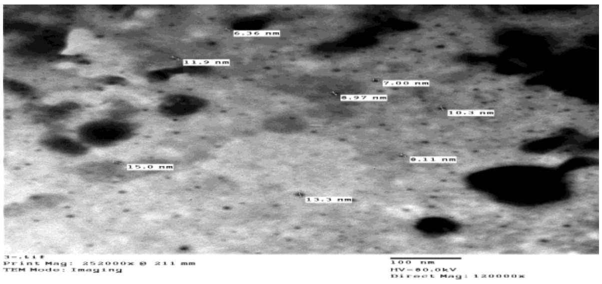

Fig. 1.Transmission Electron Microscopy (TEM) of potassium nano particle diameter (nm)

Studied traits:

Five plants were randomly collected from the middle ridge of each sub-sub plot at 120 days from sowing to determine the following:

1. Biochemical and physiological analysis:

Antioxidant enzymes activity in leaves: Catalase activity (CAT) was determined by the method of Aebi (1984).To estimate Superoxide Dismutase (SOD) activity, the method of Beyer and Fridovich (1987) was followed. Hydrogen peroxide (H_2O_2) concentration in leaves was determined as described by (AOAC, 1990). The Enzymes activity levels were expressed as units of enzymatic activity per g of protein content in the samples (U/g protein). Hydrogen peroxide (H_2O_2) content was expressed as m mol g^{-1} fresh weight.

Photosynthetic pigments *i.e.,* chlorophyll a, b and carotenoids (mg/g leaf fresh weight) were determined according to the method described by Wettstein (1957).

Measurement and analysis of stomatal parameters: The morphological changes of stomata in terms of stomatal pore area (µm^2) and stomatal closure% for adaxial (upper) and abaxial (lower) surface of fully expanded leaves from different treatments were measured as shown by Willey (1971) through the Scanning Electron Microscope, using SEM Model Quanta 250 FEG (Field Emission Gun) at the Egyptian mineral resources authority, central laboratories sector linked with the software program. Image analysis was performed using Image J Software (http://imagej.nih.gov/ij/docs/guide).

Leaf area (cm^2) was measured using a Li-Cor area meter LI-3000 (Li-Cor., Inc., Lincoln, Nebraska, USA).

Leaf relative water content (LRWC) was estimated according to the method of Weatherly (1950) and calculated in leaves. Samples (0.5 g) were soaked up in 100 ml distilled water inside a closed Petri dish for 24 h and their turgid weights were recorded. Then, they were oven-dried at 65°C for 24 h and their dry weights were recorded. LRWC was calculated as follows:

$$\textbf{RWC \%} = [(FW - DW) / (TW - DW)] \times 100.$$

Whereas:

FW, TW and DW are sample fresh, turgid and dry weights, respectively.

At harvest, a random sample of ten guarded plants was taken from the middle ridges of each plot to determine the following traits:

1. Root characters:

Root length/plant (cm).

Root diameter/plant (cm).

2. Quality analysis:

Quality analysis was done on fresh samples of sugar beet roots at Laboratory of El-Nile Sugar Factory, Egypt.

Sucrose percentage (Pol %) was determined in fresh macerated root according to the method of Le-Docte (1927).

Impurities: sodium, potassium and α-amino-nitrogen concentrations were estimated as meq/100 g beet, where sodium and potassium were determined in the digested solution using "Flame-photomer". Alfa-amino-N (α-amino-N) was determined using Hydrogenation according to the method described by Cooke and Scott (1993).

Sugar lost to molasses percentage (SLM%) was calculated according to the equation of Devillers (1988)**,**

$$\textbf{SLM} = 0.14\,(Na + K) + 0.25\,(\alpha\text{–amino N}) + 0.5$$

Extractable sugar percentage (ES %) was calculated using the following equation of Dexter *et al.* (1967):

$$\textbf{ES\%} = \text{sucrose \%} - \text{SLM \%} - 0.6$$

Quality index (QI) was calculated using the equation of Cooke and Scott (1993) as follows:

$$\textbf{QI} = (\text{extracted sugar\%} / \text{sucrose \%}) \times 100$$

3. Yields:

Root yield/fed (ton).

Sugar yield/fed (ton) was calculated according to the following equation:

Sugar yield/fed (ton) = root yield/fed (ton) x extractable sugar%

4. Applied Irrigation Water:

In the present work, the inline emitters spacing was 30 cm (40 emitter/plot) *i.e.,* 14000 emitter/fed. The discharge rate of the emitter was 4 liters/hr *i.e.,* 42 m^3/fed/0.75hr. Ten overall irrigations (a total of 420 m^3 water/fed) were applied from sowing to the period of about a month after sowing. Thereafter, water stress treatments were carried out. The amount of given water, was 2520 m^3 /fed (60 irrigations) when beets were irrigated every 3 days and was 1260 m^3 /fed (30 irrigations) and 882 m^3 /fed (21 irrigations) plus 420 m^3 /fed, when beets were irrigated every 5 and 7 days, respectively. Hence, the total applied water was 2520, 1680 and 1302 (m^3/fed/season) for each of the studied irrigation interval, successively.

Water use efficiency (WUE) values as kg sugar/m^3 water applied was calculated for each treatment after harvest using the following equation according to Jensen (1983).

$WUE_{\text{sugar yield}}$ = sugar yield/fed (kg) / applied irrigation water /fed (m^3)

Statistical analysis: All obtained data were statistically analyzed according to the technique (MSTAT- c) computer software package. Using analysis of variance (ANOVA) for the split-split plot design as published by Gomez and Gomez (1984). Least significant of differences (LSD) method was used to test the differences between treatment means at 5% level of probability as described by Snedecor and Cochran (1980)

RESULTS AND DISCUSSION

Biochemical and physiological analysis:

Antioxidant enzymes activity and Hydrogen peroxide (H_2O_2) content:

Data in Table 3 indicate that activities of catalase (CAT) and superoxide dismutase (SOD) enzymes as well as hydrogen peroxide (H_2O_2) content significantly increased by prolonging irrigation interval from 3 (traditional, practice) up to 7 days in both seasons, with no significant differences among 3 and 5 irrigation intervals for CAT in the 1st season and SOD activities in the 2nd season. The increase in activity of scavenging enzymes with increasing drought stress, as the period between irrigations increased, might be due to the mechanisms of active oxygen species detoxification and enhanced levels of free radicals (ROS) in plant cells under stress conditions and correlate with production of H_2O_2 exist in all the plants and include activation of enzymatic defense. These results are in agree with those reported by Shahrokh *et al.* (2020), they found that deficient water increased the activities of CAT, SOD and H_2O_2 content in sugar beet leaves.

Data in the same Table showed that the addition zeolite as a soil amendment significantly decreased CAT activity and H_2O_2 content in both seasons, and SOD in the 1st one. These results may be due to that addition of zeolite improved soil particle aggregation, which increased water retention capacity and thus mitigated water shortage. In addition, zeolite has high cation exchange capacity, which allows the absorption of cations and holds them in plant-available form (Savvas *et al.*, 2004). This result coincides with those found by Somayeh *et al.* (2020).

The results showed that antioxidant enzymes activity and H_2O_2 content increased with foliar application with nano-K fertilizer at 500 and 1000 mg l^{-1} as compared to the soil application of the recommended K-dose (48 kg K_2O/fed) in both seasons. These increases were insignificant for CAT activities in the 1st season. On the other hand, increasing nano-K level up to 1500 mg l^{-1} resulted in a reduction in CAT activity and H_2O_2 content in the two seasons, with insignificant differences between the recommended K-level added to the soil and 1500 mg l^{-1} sprayed on beet tops for SOD activity in 1st season and H_2O_2 content in both seasons. These findings might be due to the beneficial role of nano-K fertilizer, which deliver the nutrients in the right place and right time and increase the nutrient use efficiency, which have been considered as smart delivery system (Manjunatha *et al.*, 2016). Enhanced effect of K via improved water retention in plant tissues and therefore reduces production of ROS (especially H_2O_2), which improve cell membrane stability and osmotic adjustment ability, and hence reduce antioxidant enzymes activity. These results are in harmony with those obtained by Zangeneh, Nayereh and Rasouli (2018).

Stomatal parameters:

Data in Table 3 show that increasing irrigation interval from 3 to 5 and 7 days significantly and gradually decreased stomatal pore area (SPE) on the upper and lower surfaces of leaves. However, the difference in this trait was insignificant for the upper (adaxial) leaf surface in the 1st season and lower (abaxial) surface in 2nd one, when beets were irrigated every 3 and/or 5 days, respectively. Stomatal closure% (SC %) on both leaf surfaces increased significantly with increased irrigation intervals in both seasons. These results may be due to, the stressed plants substantially enhanced accumulation of ABA in leaves, which sets up ionic imbalance that compels K+ to leak out from guard cells and loss of guard cell turgor pressure thus, narrowing the aperture that would be due to reduced leaf relative water content and increased stomatal closure. An increase in stomatal closer % and decrease in stomatal pore area under water stress (60% of irrigation water requirements) was found by El-Kady *et al.* (2019).

Significant differences in stomatal criteria were observed due to zeolite application (Table 3). Addition of 500 kg zeolite / fed enhanced (SPE) by 12.04 and 12.34% on the upper and lower leaf surfaces, respectively in the 1st season, corresponding to 11.69 and 11.65% in the 2nd one, as compared to the soil left without zeolite. However, zeolite caused a significant reduction of (4.01 and 4.10%) and (2.01 and 2.69%) in (SC %) of the upper and lower leaf surfaces, in the 1st and 2nd season, respectively. These results may be due to extraordinary sponginess of zeolite, which can absorb water up to 60% of their volume (Gruener *et al.* 2003); hence it can provide and ensure sufficient water in the root zone of plants for a longer time in sandy soils.

Table 3 point out that increasing nano-K fertilizer levels from 500 to 1000 and 1500 mg /l sprayed on beet tops significantly increased (SPE) and decreased (SC%) on the upper and lower leaf surfaces in both seasons. Spraying of nano-K fertilizer at rate of 500 mg /l significantly decreased (SPE) and significantly increased (SC %) on the upper and lower leaf surfaces as compared to beets given 48 kg K_2O/fed added to the soil (K1), in both seasons. The same trend was obtained with spraying nano-K fertilizer at 1000 mg /l, but these increases were significant for (SPE) in both leaf surfaces, in the 1st season and the upper leaf surface, in the 2nd one. Spraying beets with nano-K at the highest level had similar effect of traditional K fertilizer (48 kg K_2O/fed), where it produced the highest (SPE) and the lowest (SC %) as compared with the other treatments, in both seasons, without significant differences between them. These results may be referred to that nano-particles have a diameter of less than 100 nm (6.36 - 15.00 nm) as shown in Fig.1, where can easily penetrate through the stomata of leaves and translocate from leaves through the phloem sieve, where elements are then redistributed to plant parts (Wang *et al.* 2013). Moreover, Abdallah *et al*. (2019) mentioned that, in most plant species, K^+ has the major act for turgor changes in the guard cells during stomatal movement. An increase in K^+ concentration in the guard cells results in the uptake of water from the adjacent cells then the stomata opining.

Table 3. Antioxidant enzymes activity, hydrogen peroxide (H_2O_2) and some stomatal parameters as affected by irrigation intervals, zeolite and potassium fertilizer levels in 2017/2018 and 2018/2019 seasons.

Treatments	Antioxidant enzymes activity (Ug^{-1} protein)				H_2O_2 ($\mu mol\ g^{-1}$ (fw))		Stomatal parameters							
							Stomatal pore area (μm^2)				Stomatal closure%			
	CAT		SOD				1st		2nd		1st		2nd	
	1st	2nd	1st	2nd	1st	2nd	U	L	U	L	U	L	U	L
Irrigation intervals (day)														
3	0.394	0.384	115.59	117.48	13.66	13.92	37.26	33.72	38.45	34.48	20.18	40.57	18.19	38.63
5	0.403	0.399	123.96	119.47	16.71	14.45	36.62	32.16	37.42	33.43	22.58	45.49	21.28	44.37
7	0.421	0.403	157.25	132.08	21.61	19.23	32.54	28.10	33.62	30.23	33.27	61.36	30.84	58.77
LSD at 5%	0.010	0.009	4.91	8.93	0.53	0.48	0.86	1.01	0.96	1.18	1.25	1.60	0.73	1.05
Zeolite/fed (kg)														
Without	0.414	0.403	140.14	123.30	18.32	16.72	33.46	29.50	34.48	30.91	27.35	51.19	24.44	48.60
500	0.397	0.388	124.39	122.72	16.33	15.02	37.49	33.14	38.51	34.51	23.34	47.09	22.43	45.91
LSD at 5%	0.007	0.008	4.01	NS	0.43	0.39	0.70	0.83	0.78	0.96	1.02	1.31	0.59	0.86
Potassium fertilizer levels														
K1	0.407	0.390	127.95	124.94	15.93	14.38	36.66	32.44	37.60	33.34	24.45	47.88	22.92	45.51
K2	0.411	0.402	137.25	127.17	19.77	18.72	33.67	29.51	34.47	31.01	27.22	51.74	25.43	49.72
K3	0.414	0.409	135.89	119.02	18.04	16.29	34.85	30.73	35.97	32.23	25.58	49.20	23.29	48.01
K4	0.391	0.377	127.97	120.91	15.56	14.10	36.73	32.62	37.96	34.27	24.13	47.72	22.10	45.78
LSD at 5%	0.011	0.010	5.67	NS	0.61	0.55	0.99	1.17	1.11	1.36	1.44	1.85	0.84	1.22

K1= 48 kg/fed potassium sulphate (48% K_2O); K2 = 500 mg l^{-1} nano-K; K3 = 1000 mg l^{-1} nano-K; K4 = 1500 mg l^{-1} nano-K, CAT = Catalase, SOD = Superoxide Dismutase, U = Upper leaf surface, L = Lower leaf surface, 1st = first season, 2nd= second season.

Photosynthetic pigments, leaf area, leaf relative water content (LRWC), root characters and yield:

Data in Table 4 show that chlorophyll a, chlorophyll b and carotenoid content in leaves, leaf area, leaf relative water content (LRWC), root diameter and root yield/fed significantly decreased by prolonging irrigation interval from 3 (check treatment) to 7 days, while root length increased in both seasons. However, the difference in this trait was insignificant for chlorophyll a, LRWC and root diameter in the 2nd season and root yield in both seasons, when irrigation was practiced every 3 and/or 5 days. The decrease in root yield per feddan with widening irrigation interval from 3 to 7 days amounted to 2.85 and 2.94 tons fed^{-1} in the 1st and 2nd season, respectively. These results may be ascribed to severe water stress, associated to longer irrigation intervals, increased H_2O_2 contents, which led to oxidation of proteins, damage to nucleic acids, programmed cell death cause of cellular damage (Brien *et al.* 2012). Also, reduction in light interception as leaf expansion is reduced as well as reductions in CO_2 fixation per unit leaf area as stomata close (Table 3) or photo-oxidation damages the photosynthetic mechanism. These results are in conformity with the findings of Neseim *et al.* (2014) and Imran *et al*. (2019).

The results in Table 4 clear that the addition of 500 kg zeolite/fed as a soil amendment significantly increased all mentioned traits as compared to untreated one in both seasons. The increment in root yield amounted to 2.27 and 1.95 ton/fed in the 1st and 2nd season, successively. The increases in all studied traits might be referred to the role of zeolite, which can act as a natural wetting agent. It is an excellent amendment for non-wetting sands and to assist water distribution through soils. In addition, zeolite can hold nutrients in the root zone of plants until required. (Khodaei and Asilan, 2012). These results are in agreed with those obtained by Akbari *et al*. (2011) and Tahereh *et al.* (2017).

Data in the same Table clear that increasing nano-K fertilizer levels from 500 to 1000 and 1500 mg /l sprayed on beet tops significantly increased all mentioned traits presented in Table 4 in both seasons. Spraying of nano-K fertilizer at the rate of 500 mg /l significantly decreased all the aforementioned traits, in both seasons. The same trend was obtained with spraying nano-K fertilizer at 1000 mg /l, with higher values of all traits over 500 mg /l in the 1st and 2nd seasons. Spraying beets with nano-K at the highest level had similar effect of soil application of the recommended K-dose (48 kg K_2O/fed), with significant increase in carotenoids, LRWC and root yield in the two seasons as well as root length and chlorophyll b in the 2nd season. The increase in root yield amounted to 2.01% and 1.74% in the 1st and 2nd season, respectively. These results might be due to the role of K, which has an important function in photosynthesis, translocation of assimilates osmo-regulation, stomata movement and area as show in Table 3, Also, nano particles have small size with physicochemical properties, *i.e.* wide specific surface area, high reactivity, tunable pore size, which may allow them access to a variety of plant surfaces and transport channels (Wang *et al.* 2013).These results reflected partial agreement with those obtained by Zangeneh, Nayereh and Rasouli (2018).

Table 4. Photosynthetic pigments, leaf area (LA), leaf relative water content (LRWC), root characters and root yield as affected by irrigation intervals, zeolite and potassium fertilizer levels in 2017/2018 and 2018/2019 seasons.

Treatments	Photosynthetic pigments (mg/g f.w.)						LA (cm^2)		LRWC%		RL(cm)		RD(cm)		RY/fed(ton)	
	Chl. a		Chl. b		Carot.											
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation intervals (day)																
3	5.30	6.63	2.81	3.19	1.19	1.26	172.68	175.73	82.86	80.29	29.44	30.78	10.52	11. 73	23.24	24.29
5	5.03	6.44	2.33	2.75	0.74	1.08	169.12	174.98	75.94	79.40	30.14	32.87	9.88	11. 69	23.32	24.22
7	4.65	5.99	1.62	2.02	0.63	0.93	155.17	163.91	71.05	74.67	32.11	33.57	9.14	10.78	20.39	21.35
LSD at 5%	0.05	0.20	0.04	0.07	0.03	0.08	3.83	4.59	0.35	0.91	0.55	0.15	0.44	0.12	0.26	0.28
Zeolite/fed (kg)																
Without	4.88	6.15	2.16	2.58	0.79	1.02	162.02	168.27	74.42	76.82	29.74	31.58	9.03	10.67	21.18	22.31
500	5.11	6.57	2.35	2.73	0.92	1.16	169.29	174.81	78.82	79.42	31.39	33.23	10.69	12.13	23.45	24.26
LSD at 5%	0.04	0.17	0.04	0.07	0.03	0.05	2.74	2.48	0.12	0.60	0.59	0.13	0.38	0.14	0.22	0.18
Potassium fertilizer levels																
K1	5.12	6.47	2.38	2.61	0.95	1.18	168.20	174.40	76.94	78.53	30.95	32.73	10.42	11.92	23.40	24.08
K2	4.72	6.11	1.95	2.59	0.70	0.94	160.05	166.08	72.54	75.35	29.30	30.92	8.86	10.52	20.10	21.72
K3	4.97	6.33	2.27	2.64	0.80	1.02	166.12	170.90	77.12	77.86	30.55	32.15	9.60	11.14	21.90	22.84
K4	5.15	6.53	2.40	2.77	0.97	1.22	168.26	174.77	79.88	80.74	31.45	33.82	10.50	12.01	23.87	24.50
LSD at 5%	0.06	0.10	0.04	0.08	0.02	0.03	3.54	3.38	0.18	0.39	0.53	0.20	0.29	0.10	0.22	0.20

K1= 48 kg/fed potassium sulphate (48% K_2O); K2 = 500 mg l^{-1} nano-K; K3 = 1000 mg l^{-1} nano-K; K4 = 1500 mg l^{-1} nano-K, LA=Leaf area, LRWC = Leaf relative water content, RL=Root length, RD=Root diameter, RY=Root yield, 1st = first season, 2nd= second season.

2.Quality parameters:

Data in Table 5 indicate that sucrose%, potassium, alpha amino nitrogen, sucrose lost to molasses%, and sugar yield/fed of sugar beet were significantly affected by irrigation intervals in both seasons as well as extracted sugar% in the 1st one and quality index in the 2nd one. Significant increases in sucrose%, juice impurities and sucrose lost to molasses with increasing irrigation intervals from 3 up to 7days, while the highest increment in SY/fed was produced, when beets were irrigated every 5 days in both seasons as compared to those irrigated every 7 and/or 3 days. However, the difference was insignificant between 3 and 5 days irrigation intervals for sucrose% in the 1st and 2nd seasons as well as root K content in the 1st one, ES% in 2nd one and between 5 and 7 days irrigation intervals for QI% in the 1st season. In this connection, Bloch and Marlander (2006) stated that under drought conditions, sugar beet accumulates high concentrations of compatible solutes, such as potassium, sodium, amino acids, glucose and fructose which are the most important osmotically active compounds.

Table 5. Some technological parameters as affected by irrigation intervals, zeolite and potassium fertilizer levels in 2017/2018 and 2018/2019 seasons.

Treatments	Sucrose %		Impurities (meq/100 g beet)						SLM %		E.S %		QI %		SY/fed (ton)	
			K		Na		α-amino N									
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation intervals/days																
3	18.58	18.23	4.61	4.59	1.98	2.00	0.97	0.98	1.67	1.67	16.31	15.97	87.74	87.73	3.81	3.89
5	19.02	19.66	5.09	4.90	1.92	1.96	1.45	1.36	1.84	1.82	16.58	17.28	87.08	87.51	3.88	4.19
7	19.45	19.84	5.28	5.07	1.94	1.92	1.88	1.92	1.98	1.96	16.87	17.26	86.67	87.03	3.46	3.70
LSD at 5%	0.58	0.64	0.32	0.31	NS	NS	0.33	0.35	0.11	0.14	NS	0.68	0.71	NS	0.07	0.20
Zeolite/fed (kg)																
Without	18.37	18.66	5.24	5.06	2.28	2.33	1.78	1.66	2.00	1.95	15.78	16.11	85.86	86.31	3.34	3.59
500	19.65	19.83	4.74	4.64	1.62	1.59	1.09	1.18	1.66	1.67	17.39	17.56	88.47	88.54	4.08	4.26
LSD at 5%	0.37	0.42	0.29	0.20	0.13	0.07	0.23	0.21	0.06	0.08	0.39	0.42	0.44	0.42	0.08	0.10
Potassium fertilizer levels																
K1	18.80	18.66	5.29	4.97	2.13	2.15	1.61	1.62	1.94	1.90	16.26	16.16	86.45	86.56	3.81	3.89
K2	18.17	18.50	4.87	4.67	1.89	1.91	1.46	1.50	1.81	1.80	15.75	16.10	86.69	87.00	3.17	3.50
K3	19.22	19.89	4.88	4.84	1.90	1.92	1.33	1.29	1.78	1.77	16.84	17.52	87.55	88.05	3.69	4.00
K4	19.88	19.92	4.93	4.88	1.86	1.85	1.33	1.26	1.78	1.76	17.49	17.56	87.98	88.10	4.18	4.30
LSD at 5%	0.28	0.31	0.13	0.17	0.09	0.09	0.09	0.11	0.03	0.04	0.28	0.31	0.24	0.30	0.08	0.09

K1= 48 kg/fed potassium sulphate (48% K_2O); K2 = 500 mg l^{-1} nano-K; K3 = 1000 mg l^{-1} nano-K; K4 = 1500 mg l^{-1} nano-K, K= Potassium, Na= Sodium, α-amino N= Alpha amino nitrogen, SLM= Sugar loss in molasses, E.S= Extracted sugar, QI= Quality index, SY= Sugar yield, 1st = first season, 2nd= second season.

Moreover, Wang *et al.*, 2013) explained that the accumulation of compatible solutes is a strategy of many plants which might contribute to sustain physiological processes such as stomata opening, enzymes activity of the antioxidant, photosynthesis pigment, leaf area, leaf relative water content, which corresponds with the presented results in the Table 3 and 4.

The results manifested that soil application of zeolite appreciably affected all of the above mentioned traits in the 1st and 2nd seasons as compared to the untreated soil. These results pointed to a positive effect of zeolite in reducing juice impurities (K, Na and α-amino N), SLM% and improved SY /fed. These results may be ascribed to relatively better conditions in the rhizospheric zone as a result of zeolite application, which can preserve the moisture of the soil for long-term and increase availability of nutrients to sugar beet plants (Khodaei and Asilan, 2012).

Data in Table 5 show that soil application of potassium sulphate and three levels of foliar nano -K had a significant effect on sucrose %, impurities (K, Na and α-amino N meq/100g beet), SLM%, ES%, QI% and SY /fed in both seasons. Foliar spray with K2 (nano-K) significantly decreased impurities, SLM and SY fed^{-1} seasons as well as sucrose% and ES% in the 1st season one as compared to (100% soil K at recommended dose). The same trend was obtained with spraying nano-K fertilizer at 1000 and/or 1500 mg /l for impurities and SLM in both seasons, except K in the 2nd season. Sucrose % and ES% increased significantly as compared to the soil application of the recommended K-dose in both seasons. Application of K4 increased sucrose% and ES% in the 1st season substantially and over passed K3, in the 1st season. Foliar spray with K4 increased SY/fed by 9.71 and 10.54%, in the 1st and 2nd season, respectively as compared to that given 100% traditional K fertilizer. These results cleared that the highest values of impurities (K, Na and α-amino N), sugar lost to molasses was recorded with (100% soil K at the recommended dose) in both seasons. Significant decreases in impurities values were recorded with increasing the level of nano-K reflecting the benefits of using nano-materials to feed sugar beet and to eliminate the negative impact of impurities on sugar beet quality. Despite the vital role of potassium in supporting phloem loading at high concentrations of sucrose, it led to s increasing impurities in roots (Brien *et al.,* 2012).

3. Significant interaction effects:

The first order interaction

Data in Table 6 manifest that the addition of zeolite to the sandy soil under the studied irrigation intervals led to significant increases in chlorophyll a, b and sucrose % as compared to untreated one. The increments in the previously mentioned traits tend to decrease as the irrigation interval was prolonged from 3 up to 7 days except sucrose %. On the contrary, higher values of activity of superoxide dismutase (SOD) and sugar lost to molasses (SLM %) were recorded in beets grown in soil left without zeolite, with ascending increase in SOD and SLM as irrigation interval was widened. These results point to the role played by zeolite in alleviating drought, accompanying the increase in irrigation intervals, by absorbing a portion of the excess nutrients and keeping water in root zone (Khodaei and Asilan, 2012). Concerning sucrose%, Brien *et al*. (2012) noted a positive correlation between sucrose concentration and the number of cambium rings and the distance between rings, which decreased under severe drought, therefore the storage capacity of the root is affected by long watering duration.

Data in Table 7 indicate that the difference between the recommended K-level added to the soil (K1) and 1500 mg l^{-1} sprayed on beet tops (K4) was insignificant in their effect on root yield/fed (in both seasons) and SOD (in the 1st one), when sugar beet was irrigated at 3-day intervals.

However, the variance between K1 and K4 was significant under 7-day intervals. There was insignificant difference between K1 and K3 in their influence on sugar yield/fed and sucrose% (in the 1st season) when beets were irrigated every 3 days, with a significant variance between K1 and K3 under wider irrigation intervals *i.e.,* 5-and 7-days intervals. However, sugar yield showed opposite results concerning irrigation intervals, in the 2nd season (Table 7)

Table 6. Significant interaction between irrigation intervals and zeolite affected on some biochemical traits, sucrose% and sugar loss to molasses% of sugar beet.

Irrigation intervals (day)	Zeolite/fed (kg)	SOD(Ug^{-1} pro.) 1st	Chl. a (mg/g fw) 1st	Chl. b(mg/g fw) 1st	Sucrose% 1st	Sucrose% 2nd	SLM% 1st
3	Without	117.86	5.13	2.66	17.89	17.59	1.76
	500	113.31	5.46	2.96	19.26	18.88	1.57
5	Without	131.09	4.94	2.23	18.32	19.06	2.00
	500	116.83	5.11	2.42	19.72	20.26	1.68
7	Without	171.46	4.56	1.58	18.91	19.32	2.23
	500	143.04	4.75	1.66	19.98	20.35	1.73
LSD at 5%		6.95	0.06	0.08	0.65	0.72	0.09

SOD= Superoxide dismutase, chl. a =Chlorophyll a, chl.b= Chlorophyll b, SLM= Sugar loss to molasses

Table 7. Significant interaction between irrigation intervals and potassium fertilizer levels affected on some biochemical, physiological, quality traits, root and sugar yields/fed of sugar beet.

Irrigation intervals(day)	K fertilizer levels	SOD(Ug^{-1} pro.) 1st	H_2O_2(μmol g^{-1} fw) 2nd	SC%(L) 2nd	RY/fed(ton) 1st	RY/fed(ton) 2nd	Suc.% 1st	K (meq/100g beet) 1st	K (meq/100g beet) 2nd	QI% 2nd	SY/fed(ton) 1st	SY/fed(ton) 2nd
3	K1	115.24	12.62	37.34	24.24	24.94	18.52	5.17	4.70	86.68	3.90	3.84
	K2	105.45	16.00	39.80	21.05	22.91	18.03	4.41	4.16	87.50	3.34	3.55
	K3	123.06	14.01	38.94	23.21	24.23	18.35	4.48	4.66	87.99	3.77	4.01
	K4	118.61	13.07	38.43	24.48	25.09	19.40	4.37	4.83	87.89	4.22	4.16
5	K1	123.86	13.40	43.83	24.38	24.92	18.71	5.22	4.96	86.97	3.95	4.17
	K2	115.42	16.48	46.69	20.77	22.49	18.00	5.02	4.80	87.16	3.24	3.70
	K3	125.76	15.05	44.45	23.22	24.13	19.43	5.01	4.95	88.33	3.97	4.35
	K4	130.79	12.90	42.52	24.87	25.31	19.94	5.11	4.87	88.48	4.37	4.55
7	K1	162.81	16.66	55.36	21.58	22.36	19.16	5.49	5.25	86.03	3.57	3.67
	K2	123.99	23.67	62.67	18.47	19.76	18.47	5.17	5.05	86.34	2.95	3.26
	K3	161.86	19.82	60.66	19.25	20.15	19.87	5.15	4.92	87.82	3.35	3.65
	K4	180.35	16.78	56.40	22.27	23.11	20.28	5.31	5.05	87.94	3.96	4.21
LSD at 5%		9.82	0.96	2.11	0.38	0.35	0.49	0.19	0.25	0.42	0.14	0.15

SOD= Superoxide dismutase, H_2O_2= Hydrogen peroxide, SC (L) %= Stomatal closure% of leaf lower surface, RY=Root yield, Suc.%= Sucrose, QI= Quality index and SY= Sugar yield

Root potassium content was insignificantly affected in case of fertilizing beets with (K1 and K4), in the 1st season or (K2 and K4), in the 2nd one, when beets were irrigated at wider intervals *i.e.,* 5 and 7 days, with a marked difference between the K-fertilizer levels under closer intervals *i.e.,* irrigation every 3 days (Table 7). Insignificant variance was detected in both SC% (L) and H_2O_2 as affected by (K2 and K3) and (K3 and K4), respectively, when irrigation was applied every 3 days interval, with a significant variance between the concerned K levels, when it was given every 5 days (Table 7).

The results in Table 8 indicate that the difference between the recommended K-level added to the soil (K1) and foliar application with nano-K fertilizer at 1500 mg l^{-1} (K4) in their effect on chlorophyll a, without addition of zeolite, in the 2nd season were insignificant. However, the difference between K1 and K4 reached the level of significance when 500 kg zeolite/fed was applied, due to higher values of these trait produced by K4 over that obtained by K1.

Table 8. Significant interaction between zeolite and potassium fertilizer levels affected on chlorophyll a, yield and quality of sugar beet.

Zeolite/fed (kg)	K fertilizer levels	Chl. a	RY fed (ton)	Suc. %	QI %	SY Yield/ fed (ton)	
		2nd	2nd	1st	2nd	1st	2nd
Without	K1	6.31	23.33	18.28	85.46	3.47	3.63
	K2	5.91	20.36	17.65	85.59	2.86	3.10
	K3	6.12	21.89	18.26	87.04	3.26	3.67
	K4	6.25	23.63	19.30	87.16	3.79	3.97
500	K1	6.63	24.82	19.31	87.66	4.15	4.15
	K2	6.30	23.07	18.68	88.41	3.49	3.91
	K3	6.54	23.78	20.17	89.06	4.12	4.33
	K4	6.82	25.37	20.45	89.04	4.58	4.64
LSDat 5%		0.14	0.28	0.40	0.43	0.12	0.13

Chl.a= Chlorophyll a, RY=Root yield, Suc.= Sucrose% , QI= Quality index, SY= Sugar yield

Data in the same Table showed insignificant difference in sucrose% (in the 1st season) and sugar yield/fed (in the 2nd one) as affected by K1 and K3, when sandy soil was left without zeolite application. However, beets fertilized with K3 surpassed those given K1, when 500 kg zeolite/fed was mixed with the soil, which disclose the beneficial role of zeolite in ensuring nutrients for sugar beet crop in sandy soils.

The second order interaction

The second order interaction among the studied factors had a significant effect on the traits presented in Table 9. The widest stomatal pore area, either on the upper or the lower surface of leaves of sugar beet was found in plants fertilized with K4 and irrigated every 5 days with the addition of zeolite, in the 2nd season, pointing to the role of potassium, especially as nano particles and zeolite, which may contribute in water conservation in the sandy soil.

The highest value of stomatal closure % on the upper surface of leaves of sugar beet was recorded in sugar beet fertilized with K2 and irrigated at the least frequent irrigation interval *i.e.*, every 7 days, without addition of zeolite, in the 2nd season, showing the negative influence of water stress as irrigation intervals were prolonged, in addition of the absence of zeolite on the closure of leaf stomatal.

Data in Table 9 exhibited a significant difference in root yield/fed in response to fertilizing beets with K1 and/or K4, as the period between irrigation was widened up to 7 days, while the difference between K1 and K4 in this trait was insignificant under 3 and 5-day irrigation intervals, without zeolite application, in both seasons. On the other hand, the variance in root yield/fed was insignificant in case of applying K1 and/or K3, irrigating sugar beet at 3-and 5-day intervals, with the addition of zeolite, with a significant variance between these two K-fertilizer levels in this trait at the longest irrigation intervals *i.e.*, 7 days. These results cleared the distinguished role of zeolite addition in saving K-fertilizer under higher water stress in sandy soil, compared to that left without zeolite application.

Table 9. Significant interaction between irrigation intervals, zeolite and potassium fertilizer levels affected on some physiological traits yield and quality of sugar beet.

Irrigation intervals (day)	Zeolite /fed (kg)	K fertilizer levels	Stomatal pore area (μm²) (U)	Stomatal pore area (μm²) (L)	Stomatal closure% (U)	RY/ fed (ton)		K (meq/ 100 g beet)	QI %	SY/ fed (ton)	
			2nd		2nd	1st	2nd	1st	1st	1st	2nd
3	Without	K1	38.22	33.18	18.18	23.55	24.45	5.57	85.63	3.64	3.61
		K2	34.25	31.25	19.73	19.38	21.30	4.20	86.70	2.91	3.11
		K3	35.89	32.78	17.98	21.83	23.20	4.63	86.81	3.27	3.66
		K4	36.57	34.00	18.76	23.53	24.32	4.67	87.98	3.93	3.85
	500	K1	42.11	35.98	17.55	24.92	25.43	4.77	88.02	4.17	4.06
		K2	38.36	35.43	18.61	22.71	24.51	4.62	88.19	3.76	3.99
		K3	39.44	35.37	17.74	24.58	25.26	4.33	89.13	4.26	4.37
		K4	41.87	37.86	16.93	25.43	25.85	4.06	89.49	4.51	4.47
5	Without	K1	37.58	33.50	21.43	23.31	24.52	5.46	85.20	3.61	3.90
		K2	33.00	29.14	24.69	20.01	20.84	5.43	85.28	3.01	3.22
		K3	35.21	30.25	22.83	22.23	23.13	5.34	86.01	3.50	4.01
		K4	35.89	32.33	20.41	23.48	24.62	5.46	86.64	3.90	4.25
	500	K1	40.33	36.40	20.00	25.45	25.33	4.97	87.67	4.29	4.43
		K2	37.41	32.38	22.46	21.52	24.14	4.62	87.64	3.46	4.19
		K3	37.83	35.29	19.88	24.20	25.12	4.67	89.04	4.43	4.68
		K4	43.00	38.12	18.50	26.25	26.00	4.76	89.14	4.85	4.81
7	Without	K1	33.20	28.46	30.57	20.11	21.02	5.66	84.66	3.17	3.38
		K2	30.53	26.61	35.31	17.48	18.95	5.59	84.22	2.65	2.96
		K3	31.32	29.00	32.40	18.40	19.35	5.48	85.32	3.02	3.34
		K4	32.14	30.45	31.00	20.80	21.95	5.42	85.87	3.53	3.81
	500	K1	35.45	32.53	29.76	23.06	23.71	5.32	87.53	3.98	3.96
		K2	33.25	31.24	31.80	19.46	20.57	4.76	88.07	3.24	3.57
		K3	36.12	30.71	28.91	20.11	20.96	4.82	88.97	3.67	3.95
		K4	37.00	32.87	27.00	23.73	24.27	5.19	88.73	4.38	4.60
LSD at 5% level			0.89	1.05	1.12	0.53	0.49	0.43	0.59	0.20	0.24

U= Upper leaf surface, L= Lower leaf surface. RY=Root yield, ,QI= Quality index, SY= Sugar yield

Data in Table 9 manifest that the highest value of potassium content in roots was obtained in beets fertilized with K1 without soil addition of zeolite and irrigated at the longest irrigation intervals *i.e.*, every 7 days, while the lowest value was recorded in beets sprayed with K4 with soil application of zeolite, and irrigated every 3 days in the 1st season, showing that root-K, as one of the harmful impurities decreasing the extractability of sugar from beets, is actually increased under water stress soil conditions.

The results point to a significant difference in QI % as affected by K1 and K2, without addition of zeolite to the soil, under the most frequent irrigation *i.e.*, every 3 days. However, as irrigation intervals were prolonged to 5 and 7 days, insignificant variance was found between K1 and K2 in their influence on this trait, when zeolite was not applied (Table 9).

The results pointed to insignificant variance in sugar yield, when beets were fertilized with K1 or K3, irrigated every 3 and/or 5 days. However, the difference in SY/fed, as affected by K1 or K3, was significant in case of irrigating beets every 7 days, when zeolite was added to the sandy soil in both cases in the 1st season. The highest root and sugar yields/fed were produced by spraying sugar beet with 1500 mg l^{-1},(K4) adding 500 kg zeolite/fed and irrigating it every 5 days.

Water use efficiency (WUE):

Data in Table 10 show that decreasing irrigation frequency from the traditional practice *i.e*, every 3 days (2520 m^3water/fed/growing season) to 5 days (1680) m^3water/fed/growing season) and 7 days (1302) m^3 water/fed/growing season) significantly increased water use efficiency (WUE), calculated as sugar yield (kg/fed) /m^3 of the seasonal applied water. The same trend was found in the 2nd season. These results were probably due to lower amount of water applied per growing season as irrigation interval was increased. These finding are in agreement with that mentioned by Somayeh *et al.* (2020).

Application of zeolite to the sandy soil caused significant improvement in WUE calculated on sugar basis, with increments amounted to 21.54 and 18.57% over untreated soil in the 1st and 2nd season, respectively. These finding could be referred to that using zeolite to decreases water leaching and ensures its availability, which improved plant growth and increased sugar yield (Table 5) and ultimately increased WUE.

The results show that the highest value of WUE resulted from spraying beets with1500 mg l^{-1} as nano-K-fertilizer (K1), followed by the recommended K-dose in the 1st season, while the lowest value of WUE was recorded from beets given 500 mg l^{-1} as nano K-fertilizer (K2), in both seasons. These results can be attributed to the same trend of sugar yield (Table 5). In addition, the difference in WUE as affected by K1 and K3 was insignificant, in the 2nd season. These results are in accordance with those obtained by Neseim *et al*. (2014).

Concerning the significant effect of the interaction between irrigation intervals and zeolite levels on WUE in both seasons, it was found that the difference between zeolite levels was ascendingly increased as the irrigation intervals was prolonged. These results point to the role played by zeolite as water stress increased.

Table 10. Water use efficiency (kg sugar/m^3 water) under the studied treatments

Irrigation intervals (day) (A)	Potassium fertilizer levels (C)	WUEsugar: Zeolite/fed (kg) (B)					
		1st Season			2nd Season		
		Without	500	Mean	Without	500	Mean
3	K1	1.45	1.65	1.55	1.43	1.61	1.52
	K2	1.15	1.49	1.32	1.23	1.58	1.41
	K3	1.30	1.69	1.50	1.45	1.73	1.59
	K4	1.56	1.79	1.67	1.53	1.77	1.65
Mean		1.36	1.66	1.51	1.41	1.67	1.54
5	K1	2.15	2.55	2.35	2.32	2.63	2.48
	K2	1.79	2.06	1.93	1.92	2.49	2.21
	K3	2.08	2.64	2.36	2.39	2.79	2.59
	K4	2.32	2.87	2.60	2.53	2.88	2.71
Mean		2.09	2.53	2.31	2.29	2.70	2.49
7	K1	2.43	3.06	2.75	2.60	3.04	2.82
	K2	2.04	2.49	2.27	2.27	2.74	2.51
	K3	2.32	2.82	2.57	2.57	3.03	2.80
	K4	2.71	3.36	3.04	2.93	3.53	3.23
Mean		2.38	2.93	2.63	2.59	3.09	2.84
Mean of zeolite		1.95	2.37	2.16	2.10	2.49	2.29
Mean of K-fertilizer levels	K1	2.01	2.42	2.22	2.12	2.43	2.27
	K2	1.66	2.02	1.84	1.81	2.27	2.04
	K3	1.90	2.38	2.14	2.14	2.52	2.33
	K4	2.20	2.68	2.44	2.33	2.73	2.53
L.S.D at 5%							
A				0.04			0.12
B				0.05			0.06
C				0.05			0.07
A x B				0.06			0.06
A x C				0.13			NS
B x C				0.06			NS
A x B x C				0.11			NS

As for the significant interaction of irrigation intervals and K levels in the 1st season, insignificant difference in WUE was recorded, when beets were fertilized with K1 and/or K3, under 3 and 5-day irrigation intervals, with a significant variance between these K levels under the widest period between irrigations *i.e.*, 7 days.

In respect to the significant interaction of zeolite and K levels in the 1st season, insignificant difference between K1 and K3 in their influence on WUE, with the addition of 500 kg zeolite/fed, while the difference between these K-fertilizer levels were appreciable without application of zeolite.

The 2nd order interaction among the studied factors had a significant effect on WUE in the 1st season. The difference in WUE as affected by K3 and K4 was insignificant under the shortest period between irrigation intervals (3 days), while the difference in this trait was substantial under longer periods of irrigation intervals (5 and 7 days), with the addition of 500 kg zeolite/fed. Adding 500 kg of zeolite/fed, spraying beets with 1500 mg l^{-1} nano-K fertilizer and irrigating the crop every 7 days save water and achieve the highest water use efficiency followed by irrigating every 5 days as compared to traditional practice (irrigating every 3 days).

CONCLUSIONS

Under conditions of the present work, adding 500 kg of zeolite/fed to the sandy soil as a soil amendment to maintain its water and nutrients content, spraying beets with 1500 mg l^{-1} as nano-K fertilizer and irrigating the crop every

5 days using drip irrigation can be recommended to get the highest root and sugar yields as well as to save water and to raise water use efficiency.

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تأثير الزيوليت وسماد البوتاسيوم وفترة الرى على إنتاج وجودة بنجر السكر في الاراضى الرملية

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أُقيمت تجربتان حقليتان بمزرعة جمعية الحسين الزراعية محافظة الجيزة ، مصر ، خلال موسمي 2018/2017 و 2019/2018 لدراسة تأثير ثلاث فترات ري [كل 3 أيام (الممارسة التقليدية-كمقارنة) ، 5 و 7 أيام] ، وإضافة الزيوليت للتربة بمستويين (بدون و 500 كجم/فدان) ، وأربعة مستويات لسماد البوتاسيوم [100 % من المعدّل الموصى به (48 كجم بو2أ) فى صورة كبريتات بوتاسيوم أضيف للتربة، وثلاثة مستويات للرش الورقى بسماد نانو البوتاسيوم بمعدل[500 و 1000 و 1500 ملليجرام /لتر] على حاصل وجودة بنجر السكر تحت نظام الري بالتنقيط في تربة رملية.. استُخدِم تصميم القطاعات كاملة العشوائية فى ترتيب القطع المنشقة مرتين فى ثلاث مكررات. أوضحت النتائج التالى: أدت زيادة فترة الري من 3 إلى 7 أيام إلى إنخفاض الخصائص الفسيولوجية والمكونات الكيميائية و حاصلى جذور وسكر/فدان في كلا الموسمين . سجَّلت إضافة الزيوليت كمحسِّن للتربة أعلى القيم بفروق معنوية لجميع الصفات المدروسة وحاصلى الجذور, والسكر مقارنة بالمُتحصَّل عليه من التربة غير المعاملة بالزيوليت. سجَّل الرش الورقي لنباتات بنجر السكر بمعدل 1500 ملجم /لتر فى صورة نانومترية نفس إتجاه سماد سلفات البوتاسيوم التقليدي . إزدادت قيمة "كفاة إستخدام المياه لحاصل السُكَّر بنقص كمية المياه المضافة فى الموسمين.تحت ظروف هذا البحث ، يمكن التوصية بإضافة الزيوليت للتربة الرملية بمعدل 500 كجم/فدان + الرش الورقى بمعدل 1500 مليجرام /لتر فى صورة البوتاسيوم النانونى وإجراء الرى كل 5 أيام للحصول على أعلى حاصل من الجذور والسكر للفدان، وقيم عالية لكفاءة إستخدم المياه.