RESEARCH | Egyptian Journal of Agricultural Research | FIELD CROPS

Response of sugarcane to water stress under applied of different potassium levels combined with silicate and chitosan

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ABSTRACT

Water stress in Egypt is expected to further increase in the future as a result of climate change and rapid population growth that impact of crop production and soil properties. To evaluate and reduce the impact of water stress, two field experiments were conducted at Shandaweel Agricultural Research Station, Sohag Governorate, Egypt in 2020/2021 and 2021/2022 seasons under normal irrigation and water stress and different rates of K-fertilization combined with silicate and chitosan addition. The sugarcane cultivar (Giza-4) *"Saccharum sp L."* was applied as a planting material. A randomized complete block design (RCBD) was used as a split-split plot arrangement with three replicated. The results explained that water stress had a significant effect on all studied traits of sugarcane. Normal irrigation improved height, diameter stalk, number of millable canes/fed, brix%, sucrose% and sugar recovery% as well as cane and sugar yields/fed in both seasons. Moreover, increasing K-level to 48 kg K_2O/fed resulted in a significant increase in all studied traits of sugarcane in both seasons. As well as the results indicated that the application of silicone + nano chitosan had positive effects on height and diameter stalk, number of millable canes/fed, brix%, sucrose% and sugar recovery% as well as cane and sugar yields/fed in both seasons reached to 90.2% under water stress compared with the production under normal irrigation. In addition, soil salinity (EC) and soil pH were generally decrease with treatments application meanwhile all other soil studied parameters (cations, anions and available NPK) were increase compared with control. Thus, it was found that, supplying sugarcane with a combination of both 48 kg K_2O/fed and (silicon + nano chitosan) application can be recommended to adapt and reduce the negative impact of water stress on soil and crop production and get the economical cane and sugar yields, as well as the best quality traits of sugarcane crop.

Keywords: Sugarcane, Normal irrigation, Water stress, K-fertilization, Silicone, Chitosan.

INTRODUCTION

Prolonged droughts are one of the many negative consequences of climate change, and they present a big problem in the twenty-first century. According to projections, greater droughts and problems with water scarcity would plague several countries in the upcoming years (Spinoni *et al.,* 2021). Water stress (WS) causes severe damage to agriculture, urban landscape, rangelands, and forests every year. Plant growth is inhibited by water stress, which also has negative effects on crop physiology, morphology, and yield (Bayat and Moghadam, 2019). Water deficiency affects the morphological characteristics and important physiological and biochemical processes of plant. Sugarcane is an annual crop of the tropics, as it goes during four definite phases of growth, namely germination, tillering, grand growth, and maturity (Van Dillewijn, 1952; Abdelrady *et al.,* 2023), tillering and early grand growth (together known as the formative phase) has been identified as the most critical water demand period, and stress during this phase affects the final yield (Naidu, 1976). Under Egypt conditions, this formative phase coincides with the hot summer period that highly impact water availability and plant trails. Water stress plays an important role in reducing the yields of many crops (Meher *et al.,* 2017), most production areas of sugarcane (*Saccharum* sp L.) in the world, including Egypt, are in rain-fed conditions; hence the crop has a chance of experiencing water deficits. Water stress can reduce sugarcane yield up to 80% (Singh and Gururaja, 1987), WSthe water stress, may affect cane at the stem elongation phase to the mature phase (Ramesh and Mahadevaswamy, 2000), some compounds had been studied to reduce the potential effect of water stress. Potassium is closely associated with the improvement of sugarcane quality, acting in the conversion of reducing sugar to recoverable sugars. Potassium is activator of several enzymes of generative growth and synthesis of sucrose in sugarcane.

Due to the deposit of suspended Nile silt rich in K-bearing minerals upstream of the created lake caused by the High Dam, potassium fertilization has become extremely significant in Egypt. Consequently, the consumption of potassium fertilization has been increased (Abd El-Hamd, 1989; Abd El-Hadi *et al.,* 1990), however, continuous crop removal without compensation is likely to cause an irreparable damage from the soil fertility of view, and therefore adding K- fertilizer may increase the growth and productivity of sugarcane. Many research indicated that increasing of k-fertilizer levels led to improving sugarcane yield and its components and quality characters (Abd-Elazez, 2021; Sasy and Abu-Ellail, 2021).

Chitosan is an eco-friendly biopolymer non-toxic, non-allergenic, cost-effective, and biodegradable, that serves various purposes in the agricultural, biomedical, and feed sectors (Asgari-Targhi *et al.,* 2018; Arif *et al.,* 2021), This organic compound encourages plant growth and non-biological and biological resistance. (Priyaadharshini *et al.,* 2019; Behboudi *et al.,* 2018). Chitosan nanoparticles (CNPs) are more efficient than conventional chitosan at the bulk scale. due to their small size (less than 100 nm), high aspect ratio, and surface area (Hassan *et al.,* 2021). CNPs enhance plant metabolic activity and transport active chemicals more efficiently across cell membranes (Bandara *et al.,* 2020). Although CNPs have been proven to have beneficial impacts on plant quality and productivity, there are limited reports about their ability to promote plant immune systems under a biotic stress such as water stress (Hassan *et al.,* 2021). Some studies showed that exogenous treatment of CNPs caused a significant improvement in the plant's innate immune response through induction of the defense enzyme activity, an increase in the total phenolic content (Chandra *et al.,* 2015), stimulating photosynthetic rate, enhanced content of chlorophylls and carotenoids and mineral uptake, stomata closure (ABA synthesis), and induction of proline, sugars and amino acids (osmotic adjustment and turgor pressure maintenance), and reduced transpiration (Ali *et al.,* 2021).

The soil contains silicon dioxide, which makes up between 50 and 70 percent of the soil mass. Silicon is the second most common mineral element in the soil. Silicon serves a variety of ecological purposes, playing intricate roles in plant activities and mediating connections with the outside world and other living things. Silicon is typically absorbed by plant roots below pH nine in the form of silicic acid [Si (OH)], an uncharged monomeric molecule that is principally dependent on two distinct Si influx transporters (Lsi1) and a distinct Si efflux transporter (Lsi2). Lsi6, a different influx transporter, controls how Si is discharged from the xylem into leaf tissues and helps root-to-shoot translocation. (Wang *et al.,* 2021). In addition, Si taken up by roots, Si fertilizer can also be efficiently supplied to leaves to increase plant dry matter production (Hussain *et al.,* 2021) and is absorbed mainly via circular pathways, stomata, and trichomes (Puppe *et al.,* 2018).

Si has been widely reported to improve plant tolerance to various abiotic and biotic stresses, such as water stress, salt, freezing, nutrient imbalance, radiation damage, metal toxicity, pests, and pathogens. Foliar application of Si-containing solutions is a viable alternative Si fertilization method to increase Si accumulation. (Vandegeer, 2021). Despite the fact that Si is not considered an essential element for plants, it is well known to be beneficial for plant growth and development, especially under stress conditions (Coskun *et al.*, 2016). Silicon enhances seed germination in wheat, maize, lentil, and tomato under water stress (Biju *et al.,* 2017), the effects of which are attributed to the increased antioxidant defense and decreased oxidative stress induced by Si (Zia, 2017). During growth stages of plant, Si has been found to increase plant biomass and grain yields of several crop species under water stress (Chen *et al.,* 2011), which is attributed to increases in total root length, surface area, and volume as well as increases in plant height, dry matter, panicle length, and tiller number (Emam *et al.,* 2014). Another important feature due to the possible role of Si is reducing spikelet sterility and subsequently increasing the grain yields of rice supplied with Si.

Thus, the objective of the present study is to evaluate i) the effect of normal and water stress irrigation regime on sugarcane yield, technological quality of sugarcane and soil properties, and ii) the role of using silicon and nano chitosan combined with different levels of K-fertilizer in alleviating the negative effect of water stress.

MATERIAL AND METHODS

Two field experiments were designed at Shandaweel Agricultural Research Station (latitude of 26 33° N, longitude of 31 41°E and altitude of 69 m), Sohag Governorate, Egypt, in the 2020/2021 and 2021/2022 seasons to study the efficacy of normal irrigation and water stress under different rates of K-fertilization combined with silicate and chitosan addition on the yield and quality of sugarcane as well as soil properties. The field experiment has included 24 treatments, represents the combinations among three K-fertilization levels 24, 36 and 48 kg/fed. K_2O (50, 75 and 100% of K recommended rate) and four treatment factors 1- without "control" 2- silicone, as (potassium silicate) 3-chitosan as (nano chitosan) 4-"silicone + nano chitosan" under two irrigation regime were used to sugarcane, which are 1- Normal irrigation (11800 m^3) (22 irrigation/season = 100% of irrigation), 2- water stress irrigation (7080 m^3) (13 Irrigation/season = 60% of irrigation).

The sugarcane cultivar (Giza-4) was applied, and the experiments were designed as randomized complete block design (RCBD) as a split-split plot arrangement with three replicated. The primary plots were dedicated to irrigation regime (normal and water stress). Potassium fertilizer levels were randomly applied in the sub plots, while treatment compounds were distributed in the sub-sub plots, in both seasons. Each plot area was 35 m^2 with 5 rows of 7 meters in length and 1.0 meter apart. Sugarcane was cultivated in the 1st week of March and harvested after 12 months, in both seasons. P-fertilizer as calcium super phosphate (15% P_2O_5) was added once during seed bed preparation at the rate 30 kg P_2O_5/fed. N-fertilizer was applied as urea (46% N) at the rate of 210 kg N/fed, which was split into two equal doses; after the1st and 2nd hoeing, *i.e.* (60 and 90 days from planting). However, K-fertilizer was added once as potassium sulfate (48% K_2O) with the 2nd dose of N fertilizer. Chitosan was added to soil immediately before irrigated 2nd, and Silicon was sprayed on the leaves of sugarcane plant at age of plant 45 days. The Sugar Crops Research Institute's recommendations for the other farming practices were followed. Table (1) explained some chemical and physical properties of the experimental soil and meteorological data recorded at Shandaweel Agricultural Research Station represented in Table (2).

Table 1. Chemical and physical properties of the upper 40-cm of the experimental soil

Season			2020/2021	2021/2022
Mechanical analysis		**Sand%**	21.5	21.7
		Silt	29.3	28.8
		Clay	49.2	49.5
Soil texture			Clay loam	Clay loam
Chemical analysis	**Available macro nutrients**	**N (ppm)**	94	110
		P (ppm)	18	19
		K (ppm)	917	950
		$CaCO_3$%	1.20	1.47
	Anion (meq L^{-1})	**CO_3^-**	0	0
		HCO_3^-	0.69	0.73
		CL^-	0.52	0.89
		SO_4^{--}	1.57	1.18
	Cation (meq L^{-1})	**Ca^{++}**	0.55	0.56
		Mg^{++}	0.68	0.38
		Na^+	1.09	1.31
		K^+	0.47	0.55
	EC(ds/m) (1 ,5)		0.278	0.281
	pH (1 , 2.5)		7.55	7.6

The recorded data:

A: At harvest, the following information was gathered for each treatment from 20 randomly selected millable canes, From the soil's surface to the top of the visible dewlap, the stalk height (in cm) was measured. At the centre of the stalks, the diameter in centimeters (cm) was measured.

B: At harvest, a sample of 20 millable canes from each treatment was collected at random, cleaned and crushed to extract the juice, which was analyzed to determine the following quality traits, Brix% (total soluble solids of juice) was determined using "brix Hydrometer" referring to the method that described by "The Chemical Control Lab" of Sugar and Integrated Industries Company (Anonymous, 1981). Sucrose% was determined using "Sacharemeter" according to (A.O.A.C., 2005). Sugar recovery% was measured as described by Yadav and Sharma, (1980) as follows:

$$\text{Sugar recovery \%} = [\text{sucrose\%} - 0.4(\text{brix\%} - \text{sucrose \%}) \times 0.73].$$

C: Each experimental unit's middle three rows of harvested sugarcanes were cut off at the top, cleared of debris, weighed, and numbered to assess the following traits, The number of millable canes per feed was calculated in thousands per fed. The cane yield per fed tonne was calculated using the fresh weight in kilogrammes (kg) of the millable canes in each plot, which was then translated into tonnes per fed. The following equation was used to determine sugar yield/fed (tonne), Cane yield/fed (tonne) x sugar recovery% equals sugar yield/fed (tonne).

Table 2. Meteorological data recorded at Shandaweel Agricultural Research Station (average of 2020/2021 and 2021/2022seasons

Month					Relative humidity (%)		Wind speed(m/sec)	
2020/2021			2021/2022		Aver. 2020/21	Aver. 2021/22	Aver. 2020/21	Aver. 2021/22
	Max.	Min.	Max.	Min.				
Jan.	6.5	20.9	4.9	16.7	61	59	2.25	2.25
Feb.	6.5	21.5	6.9	19.8	59	53.1	2.66	2.30
Mar.	10.3	26.6	8.1	22.2	45.8	41.8	3.13	2.96
Apr.	14.5	32	16.6	34.1	36.6	29.1	2.84	2.54
May	21.4	37.7	18.5	34.5	30.5	27.3	2.96	2.96
Jun.	22.8	36.7	21	37.1	30.5	30.4	3.19	2.66
Jul.	25	38.9	22.4	37.4	29.1	31.5	2.42	2.66
Aug.	24.8	39.2	23.2	37.5	29.5	35.9	2.36	2.60
Sep.	21.9	35.1	21.4	36.4	40.9	37.7	3.01	2.54
Oct.	17	32.3	15.1	30.8	46.5	50	2.42	2.54
Nov.	13.9	28.3	11	25	52	53	1.71	2.01
Dec.	7.4	20	9.9	22.1	56.5	60	1.77	1.77

Soil analysis:

After harvesting, surface soil samples (0-30 cm) were taken separately from each experimental plot, air-dried, ground sieved through 2 mm sieve and analyzed for soil pH (suspension 1 ,2.5), EC (dSm^{-1} suspension 1 ,5), content of OM (%), available nitrogen, phosphorus, potassium and main anions and cations according to the methods described by **Cottenie, *et al.*, (**1982**) and Page *et al.*, (**1982**).**

Statistical analysis:

Using the computer "MSTAT-C" statistical analysis programme provided by **Freed et al.** (1989), the acquired data were statistically analysed in accordance with **Gomez and Gomez** (1984). According to **Snedecor and Cochran** (1981), the least significant differences (LSD) at the 0.05 level of probability were calculated to compare the variations in treatment averages.

RESULTS

I. Sugarcane growth traits

1. Stalk highest:

The statistical analysis in Table 3 indicated that the exposure of sugarcane plants to water stress led to a decrease in stalk highest compared to normal irrigation regime in both growing seasons. In addition, increasing the application of K-fertilizer level to 36 and 48 kg K_2O /fed caused a significant increase in stalk height to be (8.50 and 13.63 cm) and (6.00 and 16.42 cm), compared to those provided with 24 kg K_2O /fed, in the 1st and 2nd season, respectively (Table 3).

Furthermore, Data in Table 3 showed that the used treatment compounds, silicone (potassium silicate), nano chitosan, and (silicone+ nano chitosan) significantly affected stalk highest, in both seasons. As compared to the control treatment (without addition), applied silicone, nano chitosan, and (silicone+ nano chitosan) raised stalk height by 8.56, 8.78, and 12.73 cm, respectively, in the first season. The equivalent values for the second season were 9.16, 9.50, and 14.28 cm.

Table 3. Impact of water stress, k-fertilizer levels and (silicon and nano chitosan) on stalk height, stalk diameter and number of millable canes in 2020/2021 and 2021/2022 seasons

Treatments	**Stalk height (cm)**		**Stalk diameter (cm)**		**No. of millble cane (1000/fed)**	
	1st season	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
Irrigation treatments (A)						
Normal Irr.	313.11	305.33	2.50	2.55	44.160	44.544
Water Stress	284.81	276.69	2.38	2.39	40.471	40.816
LSD at 0.05	*	*	*	*	*	*
Potassium fertilization (B)						
24 kg K_2O/fed	291.58	283.13	2.41	2.43	42.007	42.263
36 kg K_2O/fed	300.08	289.75	2.44	2.45	42.383	42.733
48 kg K_2O/fed	305.21	300.17	2.48	2.52	42.488	43.044
LSD at 0.05	**1.44**	**3.19**	**0.02**	**0.01**	**0.091**	**0.154**
Silicone and nano chitosan treatments (C)						
Control	291.44	282.78	2.39	2.43	41.958	41.782
Si	300.00	291.94	2.45	2.47	42.297	42.887
nChi.	300.22	292.28	2.45	2.48	42.330	42.841
Si+ nChi.	304.17	297.06	2.48	2.51	42.679	43.211
LSD at 0.05	**1.31**	**1.42**	**0.01**	**0.02**	**0.106**	**0.145**

* , significant.

2. Stalk diameter:

Data in Table (3) showed that throughout both growth seasons, sugarcane plants exposed to water stress had smaller stalk diameters than those grown under regular irrigation. As well as by increasing K levels from 24 to 36 and 48 kg K2O/fed provided to cane plants in the first and second seasons, the diameter of the stalk greatly increased. Increased stalk diameter) showed that, in comparison to the control, the stalk diameter was gradually increased with the application of silicone, nano chitosan, and (silicone + nano chitosan) as investigated in Table 3. (Ramesh and Mahadevaswamy, 2000).

3. Number of millable canes/fed:

The number of millable canes/fed was highly effected and decreased by 3.689 and 3.728 thousand/fed, in the 1st and 2nd seasons, respectively under water stress compared to that normal irrigation. While the results showed that increasing the applied K-levels up to 48 kg K_2O/fed led to a significant increase the number of millable in both seasons. As well as number of millable canes/fed was increased with applied compounds, silicone, nano chitosan and (silicone+ nano chitosan), as compared to the control treatment under normal and water stress irrigation regime as represented in Table 3.

II. Juice quality traits

1. Brix %:

Data in Table 4 cleared that the exposure of sugarcane plants to water stress led to a decrease brix%, while increasing K-fertilizer application rate significantly improved in brix%, in both seasons. Additionally, Table 4's results showed that, in comparison to the control, brix% increased with the application of silicone, nano chitosan, and (silicone+ nano chitosan). The sugarcane plants' applied (silicone+ nano chitosan) significantly improved brix% in both seasons. Meanwhile, in the second season, there were negligible variations in this feature between silicone and nano chitosan (Masjedi *et al.,* 2017; Anggraeni *et al.,* 2022).

2. Sucrose %:

The results in Table 4, indicated that water stress led to a decrease sucrose%, in both seasons, but applied K-fertilizer by rate 48 kg K_2O/fed significantly increased sucrose % compared to that applied K-fertilizer by rate 24 and 36 kg K_2O/fed in the two seasons. Additionally, Sucrose% were significantly affected by used compounds, silicone, nano chitosan and (silicone+ nano chitosan) treatments as compared to the control while applied (silicone+ nano chitosan) for sugarcane plants significantly improved in sucrose%. However, insignificant variance in sucrose% was recorded among silicone and nano chitosan in this trait in the 2nd season.

Table 4. Effect of water stress, k-fertilizer levels and (silicon and nano chitosan) on brix, sucrose and sugar recovery percentages in 2020/2021 and 2021/2022 seasons

Treatments	Brix %		Sucrose%		Sugar Recovery%	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation treatments (A)						
Normal Irr.	19.46	18.67	16.11	15.46	10.81	10.36
Water Stress	18.22	17.49	15.06	14.42	10.09	9.63
LSD at 0.05	*	*	*	*	*	*
Potassium fertilization (B)						
24 kg K_2O/fed	18.71	17.86	15.45	14.77	10.34	9.89
36 kg K_2O/fed	18.84	18.05	15.62	14.87	10.49	9.92
48 kg K_2O/fed	18.96	18.34	15.69	15.18	10.52	10.18
LSD at 0.05	**0.03**	**0.07**	**0.03**	**0.05**	**0.04**	**0.04**
Silicone and nano chitosan treatments (C)						
Control	18.59	17.79	15.35	14.68	10.27	9.81
Si	18.83	18.08	15.58	14.94	10.44	10.00
nChi	18.89	18.10	15.64	14.96	10.49	10.01
Si+ nChi	19.05	18.36	15.78	15.17	10.59	10.16
LSD at 0.05	**0.04**	**0.05**	**0.05**	**0.04**	**0.04**	**0.03**

* , significant.

3. Sugar recovery%:

In both seasons, water stress led to a reduced sugar recovery percentage than with regular irrigation (table 4). Increasing K-fertilizer from 24 to 36 and 48 kg K_2O/fed had a considerable positive impact on both seasons' sugar recovery percentage. Furthermore, it was discovered that the variation in this feature between 36 and 48 K_2O/fed was not significant in the first season.

Additionally, silicone, nano chitosan, and (silicone + nano chitosan) applications all had significant effects on the percentage of sugar recovery in both seasons. The application of silicon and nano chitosan to sugarcane plants greatly increased sugar recovery percent in both seasons, it was discovered. Meanwhile, in the second season, there were no appreciable differences in sugar recovery percent when silicone and nano chitosan were used (table 4).

III. Sugarcane yields:

1. Cane yield (ton/fed):

Data in Table 5 showed that cane yield was significantly affected by water stress in both seasons. The results pointed out that water stress a decrease in cane yield by 6.655 tons/fed (13.4%) in the 1st one, corresponding to 7.644 tons/fed (15.9%), in the 2nd one, compared to that obtained by normal irrigation. In addition, the cane yield significantly affected by K-fertilizer levels in the two seasons, increasing K-levels to 48 kg K_2O/fed enhanced cane yield by 2.688 and 1.046 tons/fed, compared with that got by adding 24 and 36 kg K_2O/fed, in the 1stone, respectively, corresponding to 1.886 and 0.580 tons/fed, in the 2nd one. These results are probably due to the increase in all of stalk height, diameter, and number of millable canes/fed (Tables 3).

On the other hand, the applied silicone, nano chitosan and (silicone+ nano chitosan) significantly increased cane yield by (1.583, 1.559 and 2.277 tons/fed) in the 1st season, respectively, corresponding to1.585, 1.638 and 2.561

tons/fed, in the 2nd one (Table 5), compared to the control treatment. Nevertheless, insignificant variance in cane yield was listed among silicone and nano chitosan in the 1st and 2nd seasons.

2. Sugars yield ton/fed:

Sugar yield was significantly affected by water stress in both seasons. The results pointed out that normal irrigation increased sugar yield by 1.079 and 1.154 tons/fed, compared to that obtained by water stress, in the 1st and 2nd seasons, respectively. The increase in sugar yield was associated with the increase in seasons, sucrose% and sugar recovery%, like cane yield, (Tables 4 and 5), which are the main components of sugar yield. Moreover, results pointed out that fertilizing sugarcane crop by 48 kg K_2O/fed increased sugar yield by 0.375 and 0.127 tons/fed in the 1st season, compared with that obtained by adding 24 and 36 kg K_2O/fed, in the 1st one, respectively, related to 0.341 and 0.191 tons/fed in the 2nd season. Furthermore, applied silicone, nano chitosan and (silicone+ nano chitosan) significantly increased cane yield /fed by (0.252, 0.278 and 0.409 tons/fed) in the 1st season, respectively, corresponding to 0.260, 0.267 and 0.440 tons/fed, in the 2nd one (Table 5), compared to the control treatment. However, insignificant variance was recorded among silicone and nano chitosan in this trait in the 2nd season.

Table 5. Effect of Water stress, k-fertilizer levels and (silicon and nano chitosan) on cane and sugar yields in 2020/2021 and 2021/2022 seasons

Treatments	Cane yield (tone/fed)		Sugar yield (tone/fed)	
	1st season	2nd season	1st season	2nd season
Irrigation treatments (A)				
Normal Irr.	56.390	56.411	6.096	5.850
Water Stress	49.735	48.767	5.017	4.696
LSD at 0.05	*	*	*	*
Potassium fertilization (B)				
24 kg K_2O/fed	51.625	51.525	5.349	5.109
36 kg K_2O/fed	53.249	52.831	5.597	5.259
48 kg K_2O/fed	54.313	53.411	5.724	5.450
LSD at 0.05	**0.231**	**0.147**	**0.025**	**0.029**
Silicone and Chest treatments (C)				
Control	51.719	51.143	5.322	5.031
Si	53.257	52.728	5.574	5.291
nChi.	53.278	52.781	5.600	5.298
Si+ nChi.	53.996	53.704	5.731	5.471
LSD at 0.05	**0.179**	**0.142**	**0.024**	**0.024**

* , significant.

IV. Significant interactions:

1. Interaction between Water stress x K-fertilizer levels (AxB):

The interaction between water stress x K-levels, had significant impacts on stalk height, diameter, and sucrose%, as well as cane yield/fed in the 1st and 2nd seasons. Likewise, sugar recovery% and sugar yield/fed were markedly affected by the interaction of A x B, in the 2nd season. However, number of millable cane had significant effect by the interaction between A x B in the 1st season (Table 6). The heights value of stalk height, diameter, number of millable cane, sucrose% and sugar recovery%, as well as cane and sugar yields/fed when cane fertilization by 48 kg K_2O/fed under normal irrigation in both seasons. Furthermore, data in Table 6 disclosed that insignificant differences in stalk diameter, number of millable cane/fed and sugar yield/fed, in the 1st one, and sucrose% in the 2nd one were obtained between add 24 and 36 kg K_2O/fed under water stress.

Table 6. Significant interaction effect between water stress and K-fertilizer levels on some traits of sugarcane in 2020/2021 and 2021/2022 seasons

A	B	Stalk height (cm)		Stalk diameter (cm)		N. of mill. Cane (1000/fed)		Sucrose%		Sugar recovery%		Cane yield (ton/fed)		Sugar yield (ton/fed)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Normal Irr.	24 kg K_2O	307	298.6	2.46	2.52	43.9	44.13	16	15.2	10.68	10.21	55.04	55.16	5.88	5.631
	36 kg K_2O	314.3	305.3	2.5	2.53	44.3	44.66	16.2	15.5	10.87	10.4	56.38	56.82	6.13	5.911
	48 kg K_2O	318	312.1	2.55	2.58	44.3	44.84	16.2	15.7	10.87	10.49	57.75	57.25	6.279	6.007
Water Stress	24 kg K_2O	276.2	267.7	2.37	2.34	40.3	40.4	15	14.3	9.99	9.58	48.21	47.89	4.818	4.587
	36 kg K_2O	285.8	274.2	2.37	2.38	40.3	40.8	15.1	14.3	10.1	9.43	50.12	48.84	5.064	4.608
	48 kg K_2O	292.5	288.3	2.4	2.46	40.7	41.25	15.2	14.7	10.16	9.87	50.87	49.57	5.17	4.892
LSD at 0.05		**2.04**	**4.51**	**0.01**	**0.02**	**0.13**	**NS**	**0.04**	**0.07**	**NS**	**0.05**	**0.326**	**0.208**	**NS**	**0.041**

A , Water stress, and B , K-fertilizer levels, , NS , non-significant.

2. Interaction between water stress x silicon & nano chitosan (AxC):

The interaction between water stress x silicon & chitosan (AxC) had a significant impact on stalk height, brix%, sucrose%, and cane yield in the 1st and 2nd seasons. Likewise, stalk diameter and sugar yield were markedly affected by this interaction in the 1st season. However, number of millable cane and sugar recovery% had a significant effect by this interaction in the 2nd season (Table 7). The heights values of these traits were obtained with silicone+ nano chitosan treatment under normal irrigation in both seasons as well as under water stress.

Table 7. The interaction effect between water stress and silicon & nano chitosan on some traits of sugarcane in 2020/2021 and 2021/2022 seasons

B	C	Stalk height (cm)		Stalk diameter (cm)		Brix%		Sucrose %		Sugar recovery%		Cane yield (ton/fed)		Sugar yield (ton/fed)	
		season													
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
24 kg K_2O	Cont.	283	272	2.37	2.38	18.5	17.5	15.2	14.5	10.1	9.66	50.4	50.2	5.12	4.86
	Si	292	284	2.42	2.43	18.7	17.9	15.45	14.8	10.3	9.92	51.7	51.7	5.35	5.14
	nChi.	294	285	2.42	2.44	18.8	17.9	15.5	14.8	10.4	9.93	51.9	51.7	5.40	5.14
	S+nChi	298	291	2.44	2.47	18.9	18.1	15.66	15.0	10.5	10.1	52.5	52.5	5.53	5.29
36 kg K_2O	Cont.	294	284	2.39	2.42	18.6	17.8	15.38	14.6	10.3	9.75	51.7	51.1	5.34	4.99
	Si	302	292	2.45	2.45	18.8	18.0	15.63	14.9	10.5	9.92	53.6	53.1	5.65	5.29
	nChi.	301	290	2.43	2.45	18.9	18.0	15.69	14.8	10.6	9.89	53.3	53.1	5.65	5.27
	S+nChi	304	293	2.47	2.49	19.1	18.4	15.77	15.1	10.6	10.1	54.3	54.1	5.75	5.49
48 kg K_2O	Cont.	298	293	2.42	2.48	18.7	18.1	15.48	15.0	10.4	10.0	53.1	52.1	5.51	5.24
	Si	306	300	2.48	2.52	18.9	18.3	15.66	15.2	10.5	10.2	54.4	53.4	5.72	5.44
	nChi.	307	301	2.5	2.54	19.0	18.4	15.72	15.2	10.5	10.2	54.6	53.6	5.76	5.48
	S+nChi	311	307	2.51	2.56	19.2	18.6	15.9	15.4	10.7	10.3	55.2	54.5	5.91	5.64
LSD at 0.05		**2.28**	**2.46**	**0.01**	**NS**	**NS**	**0.09**	**NS**	**0.07**	**0.07**	**0.05**	**0.311**	**0.25**	**0.04**	**0.04**

B , K-fertilizer levels, C , silicon & nano chitosan, NS , non-significant.

3. Interaction between K-levels x silicon & nano chitosan (BxC):

Data in Table 8, clarified that stalk height and sugar recovery % as, well as, cane and sugar yields/fed in both seasons, and stalk diameter in the 1st one, as well as, brix% and sucrose% in the 2nd one, were significantly impacted by the interaction between K-levels x silicon & chitosan (BxC). Fertilization cane plants by 48 kg K_2O/fed with added (silicon+ nano chitosan) give the best values of this traits in both seasons. However, in same Data 7, disclosed that insignificant differences in stalk diameter between Si, and nano chitosan, as well as between chitosan and (Si+chitosan) in the 1st season.

Table 8. The interaction effect between K-fertilizer levels and (silicon & nano chitosan) on some traits of sugarcane in 2020/2021 and 2021/2022 seasons

A	C	Stalk height (cm)		Stalk diameter (cm)		N. of mill. Cane 1000/fed		Brix%		Sucrose%		Sugar recovery%		Cane yield (ton/fed)		Sugar yield ton/fed	
		Season															
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Normal Irr.	Cont.	308	299	2.43	2.5	43.8	44.2	19.2	18.3	15.8	15.1	10.6	10.1	54.7	55.2	5.81	5.59
	Si	313	306	2.52	2.55	44.2	44.6	19.5	18.7	16.1	15.5	10.8	10.4	56.7	56.5	6.13	5.88
	nChi.	314	306	2.51	2.56	44.2	44.5	19.5	18.7	16.2	15.5	10.9	10.4	56.6	56.6	6.15	5.87
	Si+nChi	317	311	2.55	2.58	44.5	44.9	19.7	19.0	16.3	15.7	11.0	10.6	57.6	57.3	6.30	6.05
Water Stress	Cont.	275	267	2.36	2.36	40.1	39.4	18.0	17.3	14.9	14.2	9.92	9.50	48.8	47.1	4.84	4.47
	Si	287	278	2.38	2.38	40.4	41.2	18.2	17.5	15.1	14.4	10.1	9.60	49.8	48.9	5.02	4.70
	nChi.	286	279	2.39	2.39	40.5	41.2	18.2	17.5	15.1	14.4	10.1	9.64	50.0	49.0	5.05	4.72
	Si+nChi.	291	283	2.4	2.43	40.9	41.5	18.4	17.7	15.2	14.6	10.2	9.77	50.4	50.1	5.16	4.89
LSD at 0.05		1.86	2.01	0.01	NS	NS	0.201	0.06	0.07	0.06	0.06	NS	0.04	0.254	0.201	0.034	NS

A , Water stress, C , silicon & nano chitosan, NS , non-significant.

4. Interaction among water stress x K-levels x silicon & nano chitosan (AxBxC):

As for the 2nd order interaction effect, the collected data demonstrated that the interactions among water stress x K-levels x silicon & chitosan AxBxC had a marked influence in sucrose%, sugar recovery% and sugar yield in the 1st and 2nd seasons, and stalk diameter in the 1st one, as well as stalk height and brix% in the 2nd one (Table 9 and 10). The results confirmed that the increases in stalk height, stalk diameter, brix, sucrose and sugar recovery, as well as cane and sugar yields, were found as a result of raising of K-level from 24 to 48 kg K_2O/fed + applying (silicon+ nano chitosan) under normal irrigation. Although, no significant difference between adding 36 and/or 48 kg K_2O/fed, combined with (silicon+ nano chitosan) under normal irrigation in the 1st season.

Tables 9. Significant interaction effect between irrigation system (normal & water), K-fertilizer levels and (silicon and chitosan) on some traits of sugarcane in 2020/2021 and 2021/2022 seasons.

A	B	Stalk height								Stalk diameter								Cane yield								Sugar yield							
		C																															
		1st season				2nd season				1st season				2nd season				1st season				2nd season				1st season				2nd season			
		Cont.	Si.	Chi.	Si+C	Cont.	Si.	Chi.	Si+C	Cont.	Si	Chi.	Si+C	Cont.	Si.	Chi.	Si+C	Cont.	Si	Chi.	S+C	Cont.	Si	Chi.	S+C	Cont.	Si	Chi.	S+C	Cont.	Si	Chi.	S+C
Normal Irr.	24 kg K_2O	302	306	308	312	293	299	299	303	2.39	2.48	2.46	2.49	2.47	2.53	2.54	2.56	53.4	55.3	55.4	56	54.2	55.3	55.4	55.8	5.59	5.90	5.94	6.10	5.36	5.68	5.69	5.80
	36 kg K_2O	309	316	315	317	300	306	306	309	2.43	2.52	2.49	2.55	2.49	2.53	2.54	2.56	54.7	56.9	56.3	57.7	55.3	57.1	57	57.8	5.87	6.20	6.18	6.28	5.61	5.87	5.91	6.16
	48 kg K_2O	313	318	319	322	304	312	312	320	2.46	2.56	2.58	2.6	2.54	2.58	2.59	2.62	56	57.9	56.1	59	56.2	57.1	57.3	58.4	5.96	6.30	6.32	6.53	5.81	6.00	6.03	6.19
Water Stress	24 kg K_2O	264	278	279	284	250	269	271	280	2.34	2.37	2.37	2.39	2.29	2.34	2.34	2.38	47.4	48.1	48.5	48.9	47.3	48	48	49.3	4.64	4.80	4.85	4.97	4.37	4.59	4.60	4.78
	36 kg K_2O	279	288	286	290	268	277	274	277	2.35	2.38	2.37	2.39	2.35	2.37	2.37	2.41	48.7	50.4	50.1	50.9	46.8	49.1	49.1	50.3	4.82	5.10	5.11	5.22	4.38	4.62	4.63	4.81
	48 kg K_2O	282	294	295	299	281	288	290	293	2.38	2.39	2.41	2.42	2.42	2.45	2.48	2.49	50.1	50.9	57	51.4	48.1	49.7	49.9	50.7	5.05	5.15	5.19	5.29	4.66	4.89	4.94	5.08
LSD at 0.05		NS				3.48				0.02					NS			NS				0.349				0.02				0.021			

A , Water stress, B , K-fertilizer levels, and C , silicon & nano chitosan, NS , non-significant.

Table 10. Significant interaction effect between irrigation system (normal & water), K-fertilizer levels and (silicon and chitosan) on some traits of sugarcane in 2020/2021 and 2021/2022 seasons

A	B	Brix%								Sucrose%								Sugar recovery%							
		C																							
		1st season				2nd season				1st season				2nd season				1st season				2nd season			
		Cont.	Si.	nChi.	Si+nChi	Cont.	Si.	nChi.	Si+nChi	Cont.	Si.	nChi.	Si+nChi	Cont.	Si.	nChi.	Si+nChi	Cont.	Si.	nChi.	Si+nChi	Cont.	Si.	nChi.	Si+nChi
Normal Irr.	24 kg K_2O	19	19.3	19.4	19.5	17.91	18.53	18.53	18.76	15.7	15.9	16	16.2	14.8	15.33	15.3	15.5	10.5	10.7	10.72	10.9	9.89	10.3	10.27	10.4
	36 kg K_2O	19.2	19.4	19.6	19.7	18.32	18.67	18.59	19.02	15.9	16.2	16.3	16.3	15.1	15.51	15.4	15.8	10.7	10.9	10.99	10.9	10.14	10.5	10.36	10.7
	48 kg K_2O	19.3	19.6	19.7	19.9	18.67	18.92	18.95	19.16	15.9	16.2	16.3	16.5	15.4	15.66	15.7	15.8	10.7	10.9	10.89	11.1	10.35	10.5	10.52	10.6
Water Stress	24 kg	17.9	18.1	18.1	18.3	17.09	17.26	17.31	17.47	14.7	15	15	15.1	14.1	14.27	14.3	14.5	9.8	9.99	10.01	10.2	9.43	9.56	9.59	9.71
	36 kg K_2O	18	18.2	18.2	18.4	17.29	17.39	17.44	17.7	14.8	15.1	15.1	15.3	14.1	14.21	14.2	14.5	9.89	10.1	10.13	10.3	9.35	9.4	9.42	9.56
	48 kg K_2O	18.17	18.29	18.34	18.51	17.46	17.7	17.79	18.03	15	15.1	15.2	15.3	14.5	14.66	14.7	14.9	10.1	10.1	10.18	10.3	9.7	9.84	9.9	10
LSD at 0.05		NS				0.13				0.11				0.1				0.1				0.07			

A , Water stress, B , K-fertilizer levels, and C , silicon & chitosan, NS , non-significant.

V. Soil properties:

Data in Table (11) stated that the effective of water stress on soil properties as well as the silicon and nano chitosan treatment as individual or combined application under normal and water stress irrigation regime. As compared to control treatments the mean values of soil pH and EC after cane harvested were slightly decreased under all treatments applied, the maximum reduction was observed in (Si + nChi) under both irrigation regimes. On the other hand, soil organic matter (OM) and available macro-nutrients (NPK) were generally increased with all treatments applied as compared to control under different irrigation regimes. Also, the results explored that the macro-nutrients content was increased more under normal irrigation than water stress.

With respect to different treatments that applied, many soluble cations and anions were affected as investigated in Table 11. The collected data show that typically K^+, Ca^{+2} and Mg^{+2} as cations decreased slightly under all treatments as compared to control. The same direction was observed with HCO_3^- as anions under normal irrigation while all values were increased as compared to control under water stress. In addition, SO_4^{-2} was increased under all treatments applied with normal irrigation and water stress regimes. Furthermore, Cl^- under all examined treatments did not show an identifiable trend.

Table 11. Interaction effect of soil conditioners applied with water stress on soil chemical properties

water stress	Conditioners	OM %	pH	EC	Anions meq L^{-1}				Cations meq L^{-1}				Available macro-nutrients		
					CO_3^-	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+	N	P	K
1st season															
Normal irrigation	Cont.	0.95	7.56	0.43	-	1.84	1.04	1.99	1.03	1.44	0.96	0.87	88	21	410
	Si	1.04	7.52	0.415	-	1.15	1.04	2.49	1.1	1.22	1.14	0.7	89	21	365
	nChi	1.22	7.57	0.423	-	1.15	1.04	2.63	1.1	1.22	1.28	0.64	92	23	248
	Si+nChi	1.32	7.53	0.301	-	0.92	1.04	1.21	0.73	0.71	1.02	0.54	101	30	380
Water stress	Cont.	0.41	7.57	0.578	-	0.69	1.52	3.79	1.55	1.68	1.09	0.47	89	18	505
	Si	0.80	7.54	0.497	-	1.61	1.04	3.02	1.28	1.22	1.95	0.52	102	21	420
	nChi	0.90	7.53	0.532	-	3.45	1.04	1.54	1.71	1.61	1.1	0.9	112	21	390
	Si+nChi	1.19	7.56	0.462	-	2.3	1.04	1.83	1.1	1.22	1.63	0.68	115	38	490
2nd season															
		OM %	pH	EC	CO_3^-	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+	N	P	K
Normal irrigation	Cont.	1.07	7.63	0.50	-	2.00	1.16	2.06	1.06	1.52	1.12	1.3	92	22	450
	Si	1.16	7.59	0.49	-	1.31	1.14	3.04	1.13	1.6	1.16	0.95	95	23	390
	nChi	1.34	7.64	0.49	-	1.31	1.14	3.08	1.13	1.6	1.2	0.98	95	25	315
	Si+nChi	1.44	7.5	0.37	-	1.08	1.14	1.34	0.8	0.79	1.18	0.9	102	32	430
Water stress	Cont.	0.53	7.64	0.65	-	0.85	1.62	3.93	1.58	1.76	1.3	1.83	94	20	525
	Si	0.70	7.51	0.57	-	1.77	1.14	2.97	1.31	1.3	1.97	1.1	96	24	460
	nChi	0.90	7.60	0.60	-	3.61	1.14	1.89	1.74	1.6	1.7	0.96	108	24	440
	Si+nChi	2.01	7.63	0.53	-	2.46	1.14	2.14	1.23	1.43	1.65	0.98	112	41	515

DISCUSSION

1. Effect of water stress on sugarcane traits:

Water stress irrigation (7080 m^3) (13 Irrigation/season = 60% of irrigation) recorded the decrease values of stalk length, stalk diameter, number of millable canes/fed, brix, sucrose, and sugar recovery percentages as well as cane and sugar yields/fed (Tables 3, 4 and 5). Regarding stalk length and diameter, these findings may be explained by the necessity of water for the photosynthetic process, the lengthening of stalk cells, and the turgidity of leaf cells. as reported by Van Dillewijn (1952). Furthermore, water stress may affect cane at the stem elongation phase to the mature phase (Ramesh and Mahadevaswamy, 2000). As for, number of millable canes/fed Its outcomes are most likely a result of water's critical influence on sugarcane growth phases, particularly during germination and emergence, and most critically on tillering, and in turn the productivity of harvestable canes, as indicated by Humbert (1968), who stated that light frequent irrigations are preferable for young aged canes in the formative phase (the 1st four months of cane plant age) (Rahman et *al.,* 2008). As well as the Juice quality was affected by water stress as observed by Gadallah and Mehareb (2020). The increase in cane yield was associated with the increase in both stalk length, stalk diameter and number of millable canes/fed. These results are in harmony with those mentioned by El-Shafai (1996), Bekheet (2006). Moreover, the two components of sugar yield, cane yield and sugar recovery percent, both increased along with sugar yield.

2. Effect of potassium levels on sugarcane traits:

Potassium fertilizer addition has an important role in increasing length and diameter stalk, as well as number of millable canes. It is possible that the rise in these cane features is due to potassium's crucial involvement in the development and expansion of plant organs. Additionally, during the transportation process, the ripening stalk rose at harvest, which had an impact on the prices of millable cane at harvest (El-Geddawy *et al.,* 2015; Fahmy *et al.,* 2017; Hemeid *et al.,* 2017; Abu-Ellail *et al.,* 2019; Kadarwati, 2020; Taha *et al.,* 2020; Abd-Elazez, 2021; Sasy and Abu-Ellail, 2021). On the other hand, increasing the k-levels application rate to 48 kg k/fed resulted increase in quality juice characters (brix, sucrose and sugar recovery%) (Table 4). This result is mainly due to the pronounced influence of potassium element due to its importance in transportation process in the storied crops (Taha *et al.,* 2020; Abd-Elazez, 2021; Sasy and Abu-Ellail, 2021). In addition, the results of increasing the cane yield with increasing fertilizing k-level to 48 kg K_2O/fed refers to the increase the stalk height, diameter and number of millable canes/fed (Tables 5). As well as, increasing the sugar yield was also associated with the increase in sugar recovery% and cane yield, which consider the main components of sugar yield. This result coincided with that reported by El-Geddawy et al., (2015), Fahmy *et al.,* (2017), Hemeid *et al.,* (2017), Abu-Ellail *et al.,* (2019), Kadarwati, (2020), Taha *et al.,* (2020), Abd-Elazez (2021) and Sasy and Abu-Ellail, (2021).

3. Impact of silicon and chitosan on sugarcane traits:

Silicon and nano chitosan played an important role in increasing yield, its components and juice quality of sugarcane. These results refer to the influence of nano chitosan in maintaining dry matter production under water stress that could be attributed partly to a reduction in transpiration by induction of stomatal closure (Emami Bistgani *et al.,* 2017). In addition, Emam, and Deraz, (2014) concluded that chitosan is deposited in the cell wall of plants helped to show how it is used as an antiperspirant in agriculture. In addition, chitosan encourages a decline in stomata conductance, raising the leaves' resistance to water vapour loss. This enhances the efficiency with which plants utilize water to assimilate carbon, leading to the formation of biomass. Moreover, Si is responsible for strengthening of cell wall and is also responsible for mechanical support in improving lignification (Hajiboland *et al.,* 2015; Guerriero *et al.,* 2016). As well as, it's impact in minimum water loss and increase the shoot and root growth. Under water deficit condition, treatment of rice plant with Si caused increase in grain yield due to enhancement of dry matter production. Recently, a study reported that Si application improved the carbon metabolism which compensates the losses of water stress (El-sayed *et al.,* 2018; Hussain, *et al.,* 2021).These results due to that silicate addition increased the soluble Si concentration, which increased Si uptake, dry biomass, and sugar and stalk yield of sugarcane grown under continuous irrigation and water deficit imposed in both phenological (stages Camargo *et al.,* 2017). Ali *et al.,* (2021) and Hassan *et al.,* (2021) explained that the several physiochemical methods used by plants to reduce the negative impacts of water stress. For instance, the accumulation of suitable solutes such as proline, carbohydrates, and amino acids was linked to osmotic adjustment and cell turgidity. Other strategies for ROS scavenging and water stress mitigation in plants include decreased stomata and increased antioxidant enzyme activity.

4. Effect of silicon and chitosan on soil properties:

Applied of organic soil conditioner changes and improves some soil chemical properties under water stress and shortage and can be used to alleviate stresses. As any other biopolymer, chitosan interacts with soil components in a variety of ways, including by attaching polymer molecules to their surfaces, coating soil particles with a thin polymer film, forming a polymer bond between adjacent particles, adhesion, hydrogen bonding, and bridging soil particles with polyvalent counterions. (Chang, et al., 2015). Likewise, nano chitosan can be used as organic nanoparticles to improve water resistance and water demand characteristics in plants seems to be a promising eco-friendly strategy for water resource management in arid and semi-arid areas.

The declining soil pH relates to the acidity of chitosan (pH = 4.0), which at first causes an increase in H+ in the soil solution and, as a result, lowers soil pH. The zeta potential was closed to 0 for pH in all soils when the clay fraction was treated with chitosan, indicating that the soil charges were partially neutralized. Such results are harmony with Ribeiro *et al.* (2012) study on applied organic amendment to soil. On the other hand, OM and available NPK were increased under water stress, such increase may be due to the presence of available water in low amount as a result to water stress which led to accumulate of nutrients around root zone and the plant cannot absorb it normally. The behavior of chitosan still needs more investigation and examination.

Applied of chitosan have different mechanism of action in soil, with low pH soil can increase in electrostatic bonds of chitosan positively charged with negatively charged of soil particles and this interaction is responsible for lowering soil pH (Adamczuk *et al.,* 2021). While in case of alkaline soils, chitosan can acquire either a little amount of positive charge or a small amount of negative charge on a tiny surface area, and the electrostatic forces that are generated with negatively charged soil components can range from weakly attractive to weakly repulsive. Additionally, different dissolution/jellification patterns of both studied types of chitosan may exert a significant effect on their interactions with soil components because chitosan gel of highly extended surface can form much more electrostatic bonds than chitosan particles of much smaller surface area. In addition, type of chitosan plays an important role in soil because chitosan of lower molecular mass dissolves better and faster in soil organic acids (fulvic and humic acids) than chitosan having a higher molecular mass. Moreover, chitosan can glue soil particles together by adhesive forces or by the formation of polymer ties connecting neighboring soil particles which are not in direct contact.

Danghui *et al.* (2020) reported that Si addition has been shown to considerably increase soil total organic carbon and phytolith C sequestration. In certain experiments, it was discovered that Si has a significant impact on controlling the overall C balance and turnover, whether the experiment is short-term or long-term. Protection of soil organic C by amorphous Si is one of the Si-enhanced soil organic C stability processes that control the C balance and C turnover on a decade scale. Additionally, by competing with other elements for binding sites at organic matter and mineral surfaces, dissolved silicon addition significantly boosted concentrations of nitrogen. (Reithmaier *et al.,* 2017). The different findings may be attributed to (1) different soil texture and (2) different Si fertilizer addition processes.

On the other hand, silicon absorption by plant could be enhances the water stress tolerance via enhancing root hydraulic conductance and water uptake in plants. Si-mediated decrease in membrane oxidative damage may have contributed to the enhanced root hydraulic conductance. In addition, Si controls a number of plant water relations under water stress conditions, including (1) antioxidant system activation, (2) gene expression stimulation and defence responses, (3) osmotic process adjustment and homeostasis maintenance, (4) increased nutrient uptake and mineral balance maintenance, (5) photosynthesis and gas exchange regulation, and (6) enhanced plant growth and water uptake.

CONCLUSION

The effect of water stress on sugarcane characteristics and some soil parameters was assessed in this study. As a result of reducing all plant growth qualities, the results demonstrated that water stress had a considerable or extremely significant impact on sugarcane attributes studied in both seasons. Additionally, water stress considerably influenced the chemical properties of soil while having little impact on its physical characteristics, except for its significant impact on OC concentration. To reduce the effects of water stress, silicon and chitosan were added to the soil and applied as foliar and soil additions, respectively. The findings demonstrate that treatment with silicon and nano chitosan in addition to a high dose of K-fertilizer had a much greater impact on all the examined attributes in both seasons than control treatment under normal and water stress conditions as well as soil properties. Thus, supplying sugarcane with a combination of both 48 kg K_2O/fed + applying (silicon+ nano chitosan) under normal and water stress irrigation regime can be recommended to get the economical cane and sugar yields, as well as the best quality traits of sugarcane crop and can be applied to safe about 40% from irrigation water.

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