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Coping sugar beet plants (*Beta vulgaris* l.) To tolerate heat stress by using some chemical compounds

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THIS STUDY attempt to first, investigate the effects of heat stress on sugar beet plants; accordingly, the experiment was conducted in Upper Egypt, Kom Ombo, Aswan Governorate, which is situated between latitude of 24º 05' 20" N, longitude of 32º 53' 59" E and the altitude is 85 m above sea level, during 2019-2020 and 2020-2021 seasons. Secondly,–it's trying to alleviate high temperature stress by using some chemical compounds (salicylic acid, calcium chloride and potassium silicate) under three planting dates (20th September, 20th October and 20th November) on physiological traits, yield and quality of sugar beet plants. The results of this study indicated that: Planting dates significantly affected most of the studied traits. Planting in November was the best for physiological traits; it gave the minimum stomatal closure% and proline content and the highest relative water content. For chemical compounds, Foliar application of potassium silicate at high level 2000 mgl^{-1}had the first order, it recorded the highest top, root and sugar yield. Planting in October and spraying with K-silicate at level 2000 mgl^{-1} can be recommended to get the maximum values of root and sugar yields.

Keywords: heat stress, planting date, chemical compounds, sugar beet.

Introduction

One of the great limitations to production of crop and food security worldwide is Abiotic stress. It is caused huge crop loss and reduced yield more than 50% of some major crops **(Ahmad and Prasad, 2012).** The most important climate factors that affects development, yield and growth of crops is temperature. High temperatures led to heat stress to plants and making water loss from leaves to highest level accordingly forming water deficit conditions for plants. An increase in global warming has already started to impact crop production and yield negatively in many areas of different continents **(Schiermeier, 2014)**.

The main source of sugar in Egypt is Sugar beet which has a substantial role in gross domestic production. There are numerous reports about the importance of sugar beet as a vital crop to human, livestock feed and high energy of source **(Dawood *et al.,* 2019).** Recently Climate change conditions towards warming especially in Egypt are expected to prolong summer and compress the winter season. Thus, it was thought fascinating to change the planting date under these conditions to avert the high-temperature effect at the beginning of the full season. The importance of time of planting is variable in determining proper growth period required for proper photosynthetic activities of the crop. Active role was found for planting date on growth, yield and quality of sugar beet; **Singh *et al.,* (2019)** found 15th October was the best sowing date for sugar beet. It reported earlier root swelling, higher root and sugar yields and quality. While, **Hossain *et al.* (2021)** revealed that planting on 10th November produced the highest tuber yield of tropical sugar beet genotypes.

One alternative for reducing the damage caused by high temperatures is using attenuators such as some chemical materials as foliar application or enrichment to increase tolerant of plant to heat stress on sugar beet plants. In this respect, silicon considered a limiting factor for plant growth and yield and plays a role in intensify the tolerance of plants to various abiotic stresses, and its applicable to the world of agriculture has been widely recognized, **(Guo *et al.,* 2006).** Most of the assistance of silicon because it is deposited in the

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form of amorphous silica (SiO2-n H2O) in the cell wall beneath the leaf cuticle, forming a cuticle-silica double layer that acts as a defensive barrier, decreasing loss of water in the plant by evapotranspiration **(Rodrigues et al., 2019). Abd El-Hady and Bondok (2017)** reported that plants of sugar beet which sprayed with K-silicate at 150 and 180 days after sowing gave the highest root , top and sugar yields (28.5, 5.14 and 4.79 tons fed $^{-1}$) compared with control treatment. **Alkahtani *et al.* (2021)** found that under drought, Si application considerably increased sucrose %, root and sugar yields, relative water content (RWC) and chlorophyll concentration of sugar beet as compared with control. Calcium has a role in metabolic activities, like stabilization of membranes, signal transduction through second messenger, and control of enzyme activity, exogenous application of calcium in the form of $CaCl_2$ was the reasons for the induction of heat tolerance by stimulated the activities of peroxidase, SOD and catalase **(Arshi *et al.,* 2006)**. Salicylic acid, which is a phenolic-type compound, has long been known as a signal molecule in the induction of protective mechanisms against biotic or abiotic stressors in plants **(Horvath *et al.,* 2007).** Foliar application of salicylic acid at 2000 ppm increased the top fresh wight and root biomass**,** sucrose % and sugar yield of sugar beet plants **(El-Gamal *et al.,* 2021).**

This study aimed to define the relative response of yield and quality of sugar beet to:

1-Study the appropriate planting date under high temperature conditions in Upper Egypt (Kom Ombo, Aswan Governorate) to get the highest productivity of sugar beet plants.

2- Determine the potentiality of some chemical compounds at different levels which are safe on human health and environment to alleviate the heat stress implemented in sugar beet plants through investigating its growth and some metabolic activities.

Materials and Methods

During 2019-2020 and 2020-2021 seasons a field experiments were conducted at Kom Ombo Agricultural Research Station, Aswan Governorate, Egypt, which is situated between latitude of 24° 05' 20'' N, longitude of 32° 53' 59'' E and the altitude is 85 m atop sea level, The experiments were carried out to study trying alleviation of high temperature stress by using some chemical compounds under three sowing dates of sugar beet plants *(Beta Vulgaris L.)*, the first planting time on 20th September (P1), the second planting time on 20th October (P2) and the third one on 20th November (P3), while**,** the harvesting time was after 180 days from sowing for each planting date in both seasons.. The following materials and methods were applied.

Materials

Soil samples

At a depth (0-30 cm) from soil surface soil samples were taken before sowing and prepared for some chemical and physical analysis, as discussed by **Piper (1955)** as given in Table (1).

Meteorological data

Table (2), display the meteorological data at the experimental site in both growing seasons, source: Central Laboratory for Agriculture Climate (CLAC), Agriculture Research Center (ARC), Egypt.

Sugar beet variety

Magribal multi-germ sugar beet variety was sown in three sowing dates on 20th September, 20th October and 20th November.

Chemical compounds

Potassium silicate (K_2SiO_3) at levels 500, 1000 and 2000 mgl^{-1}, salicylic acid ($C_7H_6O_3$) at 25, 50 and 100 mgl^{-1}, Calcium chloride ($CaCl_2$) at 0.2, 0.4 and 0.8% and control treatment (tap water).

Methods

Treatments

The thirty treatments were applied including three planting dates (20th September, 20th October and 20th November) and ten foliar sprays with chemical compounds treatments as follows: Potassium silicate (K_2SiO_3) at levels 500, 1000 and 2000 mgl^{-1}, salicylic acid ($C_7H_6O_3$) at 25, 50 and 100 mgl^{-1}, Calcium chloride ($CaCl_2$) at 0.2, 0.4 and 0.8% and control treatment (tap water) as well as their interactions. First spray treatment was given at 60 days from sowing and repeated six times with 15 days interval, spraying solution volume was (400 l/fed).

Experimental design

The experiment was randomized complete block design (RCBD) in split-plot with four replicates in the two seasons, where, planting dates were allocated at random in the main plots, while, foliar spraying treatments were assigned to the sub-plots.

Application of minerals fertilizers

A recommended dose of nitrogen fertilizer was added in the form of ammonium nitrate (33.5% N) at the rate 90 Kg N/fed (fed= 0.42 ha), in two identical doses; the 1st dose was utilized after thinning (4 true- leaf stage) and the other dose was applied at one month later. Before sowing and at the time land preparation Phosphorus was applied in the form of calcium super-phosphate (15% P_2O_5) at rate 30 kg/fed. Potassium sulfate (48% K_2O) was added at the rate 48 kg/fed with the first nitrogen dose. Thinning process was done to one plant /hill (35000 plants / fed).

Plant measurements and analysis:

A sample of five guarded plants from each sub sub-plot was taken randomly after 90, 120 and 135 days after sowing to study the following characteristics:

Stomatal parameters (at 120 days from sowing):

At the Egyptian mineral resources ' authority, central laboratories sector and with the software program The Scanning Electron Microscope, using SEM Model Quanta 250 FEG (Field Emission Gun) closure of Stomatal % and area of pore (μm^2) for adaxial and abaxial side of completely expanded leaves from several application were measured, **Willey (1971)**. Image J software (http://image j.nih.gov/ij/docs/guide) was used to image analysis.

Free proline (μ mol g^{-1} FW) (at 90 and 135 days from sowing):

Fresh samples of leaf (100 mg) were homogenized in (sulfosalicylic acid ,3%) 10 mL and then filtered. Supernatant (2ml) was combined with acid ninhydrin (2 ml) and acetic acid (glacial) (2 ml) and incubated at 95 °C for 60 min, at that time, the reaction was cooled in an iced bath. Toluene, 4 mL was added and vortexed and read absorbance of chromophore at 520 nm by a spectrophotometer, proline was determined out of a standard curve as μ mol g^{-1} fresh wight (**Bates et al., 1973**).

Relative water content (RWC) (at 90 and 135 days from sowing):

Relative water content was calculated according to **Weatherly (1950)**:

Relative water content % = [(FW – DW) / (TW – DW)] × 100,

Whereas: FW, TW and DW were sampling fresh, turgid and dry weights, respectively.

Harvest measurements

At the harvesting date (180 days from the planting date) root yields and quality were estimated by randomly selecting ten plants from each plot.

Root quality

a-Sucrose % (pol %) was polarimaterically on a extract of lead acetate of fresh roots determined by Saccharometer apparatus aligns with the form stated by **Carruthers and Oldfield (1960).**

b- Sugar lost to molasses (SLM%) was evaluated by **Devillers (1988)** using the follows equation:

SLM = [0.14 (Na + K) + 0.25 (α–amino N) + 0.5]

c- Extractable Sugar percentage (ES%) was computed as described by **Dexter *et al.,* (1967).**

ES % =[Pol % - (SLM + 0.6)].

3.2.5.2. Top, root and sugar yields (ton fed^{-1}).

Roots and tops were separated and each was weighed in kg per each plot and used to determine Top and Root yield (ton fed^{-1}).

Sugar yield (ton fed^{-1}).was calculated by multiplying root yield by extractable sugar percentages:

Sugar yield (ton fed^{-1}) = root yield (ton fed^{-1}) x extractable sugar%

Statistical analysis:

Data were statistically analyzed according to the technique (MSTAT-C) computer software package. Using analysis of variance (ANOVA) for the split plot design as recorded by **Gomez and Gomez (1984).** least significant difference (L.S.D) at 5% level was used to compared between the mean values according to as evaluated Snedecor and Cochran (1980).

Table 1. Physical and chemical properties of the experimental soil site (0-30 cm, soil depth) during 2019/2020 and 2020/2021 seasons.

Physical ~~and chemical~~ properties	Particle size distribution			Soil texture		OM%	Available nutrients (mg kg^{-1} soil)		
	Clay %	Silt %	Sand %				N	P_2O_5	K_2O
2019/2020	15.22	27.44	57.34	Sandy loam		1.51	34.8	2.7	87
2020/2021	16.50	23.30	60.20	Sandy loam		2.00	36.4	3.1	99
Chemical properties	**PH**	**EC (ds m^{-1})**	**Soluble anions (meq L^{-1})**				**Soluble cations (meq L^{-1})**		
			CO_3^-	HCO_3^-	Cl^-	SO_4^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
2019/2020	7.5	0.36	-	0.30	0.89	1.02	0.53	0.27	1.25	0.16
2020/2021	7.3	0.39	**-**	0.33	0.82	1.13	0.54	0.35	1.31	0.15

Table 2. Means values of meteorological data recorded at Kom Ombo station Agricultural Research Station during 2019/2020 and 2020/2021 seasons.

Month	Temperature degrees (C°)		Sunshine hours/ Month	Relative humidity %	Rainy days
	Maximum temperature	Minimum temperature			
2019/2020					
September	39.5	24.4	296.3	23.7	0
October	35.7	20.6	313.3	27.0	0
November	29.3	14.8	299.6	38.9	0
December	24.1	10.6	289.1	43.7	0
January	23.0	8.9	298.2	40.8	0
February	25.2	10.6	281.1	35.4	0
March	30.0	13.9	321.6	24.3	0
April	37.2	19.3	316.1	20.6	0
May	38.4	23.0	346.8	18.8	0
2020/2021					
September	40.2	25.6	300.3	24.1	0
October	37.4	21.9	315.9	28.0	0
November	28.8	15.1	303.1	38.3	0
December	26.2	10.9	290.8	46.2	0
January	23.3	9.2	300.4	44.4	0
February	24.3	9.9	285.2	38.2	0
March	32.2	14.2	331.0	23.4	0
April	38.5	20.2	318.8	18.5	0
May	36.9	23.9	344.7	18.1	0

source: Central Laboratory for Agriculture Climate (CLAC), Agriculture Research Center (ARC), Egypt.

Results and Discussion

Biochemical and physiological analysis

1-Stomatal parameters

Effect of planting date

According to the results in Table (3), there were significant differences between three planting dates (20th September, 20th October and 20th November) for stomata closure% and stomatal pore area µm^2 at the age 120 days from sowing. Planting on 20th September (P1) had the highest percentage of stomata closure reached 26.65 and 49.19% for the two surfaces of the leaf, respectively. In the same time, it gave the smallest area of stomatal pore on upper and lower surfaces of leaf recorded 25.13 and 21.54 µm^2. While, late planting in November (P3) was favorite where, it produced the lowest stomata closure recorded 20.52 and 38.77% and the greatest area of stomatal pore 36.47 and 26.86 µm^2 for upper and lower leaf surface. The increase in stomata closure% with reduce stomatal pore area (µm^2) in early planting date in September may be attributed to high temperature in this period which cause plant leaves accumulation of abscisic acid (ABA), which set up imbalance ionic that coerce K^+ to leak out from guard cells and guard cell loss of turgor pressure thus, narrowing the aperture that would be due to decreased leaf relative water content and increased stomatal closure **(Abdel Fatah, Eman and Khalil, Soha, 2020)**. These results are in harmony with those obtained by **El-Kady *et al.*, (2019)** who found that the percentage of open stomata decreased by nearly half after 6 days of high temperature accumulation.

Effect of three chemical compounds

ata in Table (3) show that foliar spraying with salicylic acid, calcium chloride and K-silicate at all their concentrations significantly decreased stomata closure% and increased stomatal pore area (µm^2) in both directions of leaf at sample age 120 days from sowing. Application of K-silicate at maximum level caused the lowest stomata closure (20.42 and 40.34%) and the largest area of stomata pore with (35.96 and 28.57 µm^2) for upper and lower leaf, respectively. Meanwhile, K-silicate at middle level had the second order with (21.28 and 40.94%) and (33.74 and 28.23 µm^2) for stomata closure and stomatal pore area, respectively. Calcium chloride treatment at high level had the third order in its effect on both traits. These may be attributed to in stressed plants guard cell loss of turgor pressure by the enhanced accumulation of abscisic acid in leaves, which begin an imbalance of ionic that compels K+ to leak out from guard cells and thinning the aperture that might be due to lower relative water content of leaf content and loss of turgor pressure of guard cell then increase stomatal closed. Spraying with K-silicate led to an enhance in K+ content in the cells of guard and an increase in the water uptake by the adjoining cells, at that time the stomata opening. These results coincide with those found by Abdel Fatah, Eman and Khalil, Soha (2020) showed that increasing the foliar spray level of nano-K fertilizer from 500 to 1500 mgl-1 significantly increased stomata pore area and decreased stomata closure % on the two leaf surfaces of sugar beet in both seasons

Effect of interaction

With respect to interactions effect, the results in Table (3) manifest that planting sugar beet in November and sprayed with K-silicate at 2000 mgl^{-1} was the best interaction gave the lowest stomata closure% and the highest size of stomata pore area on both leaf surfaces. In contrast, planting date in September and sprayed with tap water (without chemical compounds) gave the highest stomata closure % and the lowest stomatal aperture on lower and upper leaf side.

Table 3. Some morphological changes of stomatal characteristics for upper (U) and lower (L) leaves surfaces as affected by planting date, some chemical compounds and their interactions (data are combined across 2019/2020 and 2020/2021).

Treatments (foliar spray)	Stomata closure % (sample at 120 days from sowing)							
	P1		P2		P3		Mean	
	U	L	U	L	U	L	U	L
Control (Water tap)	30.85	55.22	27.79	49.09	24.37	42.82	**27.67**	**49.04**
Salicylic acid (25 mgl^{-1})	28.78	51.01	24.89	45.35	20.85	42.33	**24.84**	**46.23**
Salicylic acid (50 mgl^{-1})	28.37	51.33	25.40	43.14	22.88	39.16	**25.55**	**44.54**
Salicylic acid (100 mgl^{-1})	28.09	46.36	24.96	41.87	21.94	37.52	**25.00**	**41.92**
Calcium chloride (0.2%,)	26.12	50.57	22.96	44.72	19.81	40.37	**22.96**	**45.22**
Calcium chloride (0.4%,)	26.07	49.64	22.98	44.17	20.58	39.58	**23.21**	**44.46**
Calcium chloride (0.8%,)	25.18	48.05	20.60	41.00	18.65	37.61	**21.48**	**42.22**
Potassium silicate (500 mgl^{-1})	25.22	47.71	20.70	42.64	18.95	37.17	**21.62**	**42.51**
Potassium silicate (1000 mgl^{-1})	23.62	55.96	21.14	40.39	19.08	36.02	**21.28**	**40.94**
Potassium silicate (2000 mgl^{-1})	23.86	44.76	19.64	40.39	17.77	34.87	**20.42**	**40.34**
Mean	**26.65**	**49.19**	**23.14**	**43.53**	**20.52**	**38.77**		
LSD at 0.05								
Planting date (P)							0.32	٠.28
Treatments (T)							0.53	0.36
Interaction (PXT)							0.91	0.45

Treatments (Foliar spray)	Stomatal pore area (μm^2) sample at 120 days from sowing							
	P1		P2		P3		Mean	
	U	L	U	L	U	L	U	L
Control (Water tap)	19.10	15.66	23.88	21.04	30.12	21.12	**24.36**	**19.27**
Salicylic acid (25 mgl^{-1})	25.98	17.56	29.13	24.03	35.17	24.28	**30.09**	**21.95**
Salicylic acid (50 mgl^{-1})	27.96	19.79	32.20	25.21	38.30	24.07	**32.82**	**23.02**
Salicylic acid (100 mgl^{-1})	23.28	21.29	27.22	27.77	34.13	30.57	**28.21**	**26.55**
Calcium chloride (0.2%,)	21.55	21.47	26.50	28.09	33.25	24.81	**27.10**	**24.79**
Calcium chloride (0.4%,)	25.05	22.72	31.95	25.29	36.13	24.80	**31.04**	**24.27**
Calcium chloride (0.8%,)	2٦.٩٦	23.90	٣١.٣1	29.25	3٧.٨٢	29.35	**32.03**	**27.50**
Potassium silicate (500 mgl^{-1})	2٤.٦٤	23.42	٢٩.٥1	28.03	3٦.٥٠	26.94	**30.22**	**26.13**
Potassium silicate (1000 mgl^{-1})	28.04	25.37	34.01	29.20	39.17	30.12	**33.74**	**28.23**
Potassium silicate (2000 mgl^{-1})	28.75	24.22	35.03	28.99	44.09	32.50	**35.96**	**28.57**
Mean	**25.13**	**21.54**	**30.07**	**26.69**	**36.47**	**26.86**		
LSD at 0.05								
Planting date (P)							0.19	0.17
Treatments (T)							0.27	0.25
Interaction (PXT)							0.48	0.39

P1= planting date on 20th September, P2 = planting date on 20th October, P3= planting date on 20th November.

Proline content

Effect of planting date

According to the results in Table (4), the different sowing dates significantly influenced proline content in leaves of sugar beet plants at samples age 90 and 135 days from sowing. Planting date on 20th September (P1) had the highest proline content (8.06 and 11.96 μ mol g^{-1}) in samples age 90 and

135 days from sowing, respectively. Per contra, the lowest content of proline (5.82 and 8.16 µ mol g^{-1}) was obtained on 20th November (P3). The increase of proline content may be due to the high temperature at the early planting in September Table (2). It is noted that accumulation of proline in beet plant with abiotic stress reveals a defence mechanism against the disagreeable effect of heat **(Ghaffaria el al., 2021).** This increase in proline very important as osmo-regulators, playing important role in osmo-regulation to mitigate the injurious impact of environmental stresses **(Abdelaal et al., 2020**). These results in consensus with the study of **Alkahtani *et al.,* (2021)** who found that sugar beet plants under drought stress revealed an increase in antioxidant enzymes and proline accumulation to mitigate drought stress.

Effect of three chemical compounds

Exogenous application of salicylic acid, calcium chloride and K-silicate at all their concentrations significantly decreased proline content as compared to control (tap water). The best results were sprayed with K-silicate at 2000 mgl^{-1} then calcium chloride at 0.8% without any significant difference between them recorded (5.42 and 5.51 µ mol g^{-1}) at sample age 90 days and (7.46 and 8.00 µ mol g^{-1}) at sample age 135 days from sowing, respectively as compared with control. While, the greatest values of proline (8.04 and 12.27 µ mol g^{-1}) produced by foliar spraying with salicylic acid at 25mgl^{-1} in the two samples, respectively. Under heat stress, free proline content was increased, it has a favorable role in reducing the harmful effect of stress on sugar beet, by the protective effect on phospholipids, plasmalemma, mitochondria and plastid membranes and proteins structure that help plants to tolerate stresses **(Ashraf and Foolad, 2007)** when spraying with K-silicate led to decrease it may be due to the helpful impact of Si on reducing MDA (lipid peroxidation) and oxidative stress and In this concern, **Alkahtani *et al.,* (2021)** found that under abiotic stress proline content elevated beet plants significantly comparison to control in the two seasons; treatment of Si causes a remarkable reduction in proline content when comparison to untreated stressed plants. **Ibrahim *et al.,* (2017)** fount that application of K-silicate at 8 gl^{-1} significantly decreased proline content of sugar beet from 7.22 to 5.32 µ mol g^{-1} under saline soil conditions.

Effect of interaction

Results of interactions between planting date and foliar spraying with three studied chemical compounds showed significant effect on proline content, it could be noticed that planting in November with sprayed K- silicate or calcium chloride at high level gave the lowest proline content. While, the highest values of proline content were recorded in beets sown in September and sprayed with water tap (without chemical compounds) followed by the spray with salicylic acid at lowest level.

Table 4. Free proline as affected by planting date, some chemical compounds and their interactions (data are combined across 2019/2020 and 2020/2021).

Treatments (foliar spray)	Proline (µ mol g^{-1} f.w.)							
	Sample at 90 days				Sample at 135 days			
	P1	P2	P3	Mean	P1	P2	P3	Mean
Control (tap water)	10.13	9.53	7.16	**8.94**	15.24	12.93	10.55	**12.91**
Salicylic acid (25 mgl^{-1})	9.34	7.91	6.86	**8.04**	14.75	12.24	9.83	**12.27**
Salicylic acid (50 mgl^{-1})	8.56	7.66	6.28	**7.50**	12.93	11.33	8.41	**10.89**
Salicylic acid (100 mgl^{-1})	8.10	7.48	5.98	**7.19**	11.66	9.85	8.06	**9.86**
Calcium chloride (0.2%)	9.06	8.00	6.65	**7.90**	12.57	11.41	10.10	**11.36**
Calcium chloride (0.4%)	8.42	6.87	5.78	**7.02**	11.84	10.53	7.46	**9.94**
Calcium chloride (0.8%)	6.64	5.34	4.56	**5.51**	9.17	8.63	6.19	**8.00**
Potassium silicate (500 mgl^{-1})	7.35	7.71	5.98	**7.01**	11.83	10.19	8.23	**10.08**
Potassium silicate (1000 mgl^{-1})	6.81	6.59	4.67	**6.02**	10.97	9.50	6.75	**9.07**
Potassium silicate (2000 mgl^{-1})	6.14	5.88	4.25	**5.42**	8.65	7.76	5.98	**7.46**
Mean	**8.06**	**7.29**	**5.82**		**11.96**	**10.44**	**8.16**	
LSD at 0.05								
Planting date (P)				0.38				0.42
Treatments (T)				0.44				0.61
Interaction (TXP)				0.73				NS

P1= planting date on 20th September, P2 = planting date on 20th October, P3= planting date on 20th November.

3-Relative water content in leaves

Effect of planting date

It can be noticed in Table (5) that planting date had a significant effect on relative water content (RWC %) in both samples at 90 and 135 days from sowing. The highest percentage of RWC were achieved in November cultivation amounted 82.17 and 84.97%, followed by October planting date by

79.25 and 82.09% and fewer results 78.06 and 81.01% in September cultivation at samples age 90 and 135 days from sowing, respectively. Planting in September had high temperature which causes lowest RWC% because water is lost faster through transpiration than it can be replaced via plant root system (
% (**Ashraf et al., 2010).**

Effect of three chemical compounds

Data in Table (5) manifest that foliar spraying with studied three chemical compounds led to significant increases in relative water content (RWC) as compared to spraying with tap water (control). Spraying with K-silicate at high level 2000 mgl^{-1} gave the maximum values of RWC amounted to 85.66 and 88.34 % at samples age 90 and 135 days, respectively, than 83.53 and 86.14% when sprayed with calcium chloride at 0.8%. Whilst, the lowest increase 76.76 and 79.38% was obtained by spraying with salicylic acid at minimum level 25 mg^{-1} at both samples, respectively as compared to control (tap water). High value of RWC by K-silicate may be due to that Si is saved below the leaves cuticle layer, reducing the transpiration rate and maintaining great RWC in leaves, and minimizing consumption of water by the plant when it has a high osmotic potential under stress **(Sangster *et al.,* 2001).** As calcium chloride, can play a good role in the growth and activities of biochemical by plants grown under stress conditions, maybe through maintaining relative water content to stimulate the production of various metabolites **(Madany and ~~k~~Khalil, 2017)**. In this context, **Soudi, Amal (2013)** showed that foliar spraying with K- silicate at 2000 mgl^{-1} significantly increased water relative content% by 3.08 and 3.82% in both seasons, respectively compared with control.

Effect of interaction

Relative water content percentage (RWC %) was significant affected by the interaction between planting dates and foliar spraying with three chemical compounds at samples age 90 and 135 days from sowing. Sugar beet sown in the late sowing date in November and sprayed with K-silicate at high level 2000 mgl^{-1}produced the maximum values of RWC % in the tow samples. Whereas, the minimum values of RWC% were produced by early sown in September and spraying with water tap (control) followed by planting in the same date and sprayed with salicylic acid at level 25 mgl^{-1} in both samples.

Table 5. Relative water content % (RWC) as affected by planting date, some chemical compounds and their interactions (data are combined across 2019/2020 and 2020/2021).

Treatments (foliar spray)	Relative water content %							
	Sample at 90 days				Sample at 135 days			
	P1	P2	P3	Mean	P1	P2	P3	Mean
Control (tap water)	73.56	75.02	78.67	**75.75**	76.33	78.29	81.44	**78.68**
Salicylic acid (25 mgl^{-1})	74.22	76.47	79.59	**76.76**	76.74	79.04	82.36	**79.38**
Salicylic acid (50 mgl^{-1})	75.80	77.21	81.32	**78.11**	77.82	79.87	84.09	**80.59**
Salicylic acid (100 mgl^{-1})	76.46	78.91	81.62	**79.00**	79.23	81.38	84.44	**81.68**
Calcium chloride (0.2%)	76.59	76.55	80.91	**68.02**	80.86	80.82	83.64	**81.77**
Calcium chloride (0.4%)	78.07	78.81	81.95	**79.61**	81.84	81.58	84.72	**82.71**
Calcium chloride (0.8%)	81.99	83.87	84.74	**83.53**	85.26	85.64	87.53	**86.14**
Potassium silicate (500 mgl^{-1})	79.60	79.91	82.07	**80.53**	81.77	83.28	85.19	**83.41**
Potassium silicate (1000 mgl^{-1})	80.07	80.25	83.56	**81.29**	83.25	82.97	86.33	**84.18**
Potassium silicate (2000 mgl^{-1})	84.22	85.50	87.25	**85.66**	86.99	88.07	89.97	**88.34**
Mean	**78.06**	**79.25**	**82.17**		**81.01**	**82.09**	**84.97**	
LSD at 0.05								
Planting date (P)				0.75				0.70
Treatments (T)				0.83				1.04
Interaction (P xT)				1.43				1.80

P1= planting date on 20th September, P2 = planting date on 20th October, P3= planting date on 20th November.

Root quality

Effect of planting date

Tables (6) and (7) point out that the planting date significantly affected root quality characteristics, *i.e.* sucrose%, sugar lost to molasses (SLM) and sugar extractable%. Planting date on 20th October (P1) produced the highest values of sucrose and sugar extractable% reached 18.67% and 16.71%, respectively and on that the lowest sugar lost to molasses (1.352%). While, the minimum values of sucrose and sugar extractable% (17.43 and 15.24%) and the highest values of SLM% (1.593%) were obtained in view of planting beet seeds in September. The significant effect of sowing beet plant on 20th October on root quality might be due to the appropriate all environmental conditions at this sowing date of late winter especially temperature was described in sunny days and cool nights that gave the best production of sugar and retaining in roots of sugar beet. The predominance which resulted from the sowing date due to giving suitable temperature to best growth, formation of more photosynthetic yields, translocation and increase of sucrose accumulation in roots and reduced impurities to give high juice purity of roots **(Gobarah et al., 2019).**

Effect of three chemical compounds

Results in Tables (6) and (7), indicated that there were significant effects due to foliar spraying with all concentrations of salicylic acid, calcium chloride and K-silicate on root quality *i.e.* sucrose%, sugar lost to molasses (SLM%) and sugar extractable% compared to control (tap water). The greatest mean of sucrose% and sugar extractable% amounted to (19.01 and 17.13 %) were obtained under spraying with 0.8% calcium chloride, followed by (18.81 and 16.70%) by K-silicate at 2000 mg^{-1}, respectively. Contrarily, the lowest values of sucrose and sugar extractable% (17.16 and 15.07%) respectively, were found by salicylic acid at level 25 mgl^{-1} compared to control. For SLM%, the highest and lowest value (1.535 and 1.290 %) had been done by foliar spraying with tap water and calcium chloride at 0.8%, respectively. The increase in sucrose by $CaCl_2$ may be due to its role in regulating transcriptional the genes involved in sucrose transport (BʋSUC3 and BʋTST3). Subsequently, Ca^{2+} embellished the root biomass and synchronous led to induction of root (BʋSUC3 and BʋTST1) sucrose transporters which eventually supported the loading of more sucrose into beetroot under stress **(Hosseini *et al.,* 2019)**. Similar results reported that rising calcium dosses up to 288 ppm fed^{-1} showed higher values for sucrose and sugar recovery percentages **(Enan, 2015)**. **Alkahtani *et al.* (2021)** found that sucrose% reduced under drought; Si treatment gave the maximum results in sucrose% in sugar beet plants in both seasons compare with control.

Effect of interaction

Sowing sugar beet on 20th October and sprayed with calcium chloride at 0.8% achieved the highest sucrose and sugar extractable %, followed by treatment with K-silicate at 2000 mgl^{-1}, while, the lowest means of these characters were recorded by sowing in September along with sprayed by tap water. Regarding, sugar lost to molasses%, planting on 20th October and gave the lowest value of SLM% followed by salicylic acid at level 100 mgl^{-1} in November cultivation.

Table 6. Root quality (sucrose% and sugar lost to molasses%) as affected by planting date, some chemical compounds and their interactions (data are combined across 2019/2020 and 2020/2021).

Treatments (foliar spray)	Root quality							
	Sucrose%				Sugar lost to molasses%			
	P1	P2	P3	Mean	P1	P2	P3	Mean
Control (tap water)	16.31	17.89	16.32	**16.84**	1.721	1.424	1.461	**1.535**
Salicylic acid (25 mgl^{-1})	16.66	1795	16.87	**17.16**	1.613	1.437	1.403	**1.484**
Salicylic acid (50 mgl^{-1})	16.98	18.87	17.31	**17.72**	1.574	1.346	1.326	**1.415**
Salicylic acid (100 mgl^{-1})	17.93	19.48	17.68	**18.36**	1.560	1.234	1.227	**1.340**
Calcium chloride (0.2%)	17.60	18.00	16.63	**17.41**	1.574	1.369	1.439	**1.461**
Calcium chloride (0.4%)	18.25	18.54	17.76	**18.18**	1.482	1.258	1.382	**1.374**
Calcium chloride (0.8%)	18.95	19.94	18.16	**19.01**	1.375	1.204	1.291	**1.290**
Potassium silicate (500 mgl^{-1})	16.37	17.97	17.45	**17.26**	1.692	1.421	1.427	**1.513**
Potassium silicate (1000 mgl^{-1})	17.18	18.45	17.82	**17.81**	1.677	1.449	1.428	**1.518**
Potassium silicate (2000 mgl^{-1})	18.10	19.60	18.75	**18.81**	1.674	1.393	1.496	**1.521**
Mean	**17.43**	**18.67**	**17.47**		**1.593**	**1.352**	**1.387**	
LSD at 0.05								
Planting date (P)				0.02				0.011
Treatments (T)				0.04				0.013
Interaction (PXT)				0.06				0.014

P1= planting date on 20th September, P2 = planting date on 20th October, P3= planting date on 20th November.

Top, root and sugar yields fed.$^{-1}$ (ton)

Effect of planting date

Planting date showed significant effect on top, root and sugar yields (Tables 7 and 8). Generally, 20th October was the optimum planting time, where it recorded the maximum values (35.21, 57.65 and 9.67) of top, root and sugar yields ton fed.$^{-1}$ respectively. On the contrast, the lowest values 32.74, 55.08 and 8.42 ton fed.$^{-1}$ were achieved when early planting date in September. The enticing effect of sowing sugar beet in October on yields might be attributed to the seasonable condition of environmental through this planting date, including relative humidity and temperature (Table 2), which enhancing germination, establishment, growth of vegetative, development, and ripening, accordingly increasing accumulation of dry matter, yield components, and, therefore, yield of root .This attainment in sugar yield may be due to the certain effect of planting in October on root fresh weight, yield of root and sucrose %, which affected sugar production. These results are in accord with those reported by **Tawfic *et al.*, (2014)** found that plants which sown in October were the best because a suitable condition for increasing root size and sucrose accumulation in root and thus gave the maximum root and sugar yields. **Singh *et al.*, (2019)** obtained that 15th October was the ideal planting date for sugar beet cultivation; it recorded earlier root swelling, higher root yield and higher sugar yield and quality. Contrariwise, **Nemeata Alla (2016)** indicated that sowing sugar beet at early planting date (on September) significantly increased top, root and sugar yields of sugar beet plants.

Effect of three chemical compounds

Data in the same Tables showed that foliar spray with three chemical compounds at all their concentrations significantly increased top, sugar and root yields (ton fed.$^{-1}$) as compared with control (tap water). The maximum values of top, root and sugar yields were 38.54, 64.37 and 10.78 ton fed.$^{-1}$, respectively achieved by spray with K- silicate at high level 2000 mg l^{-1} followed by calcium chloride at 0.8% for top and sugar yields and K- silicate at 1000 mg l^{-1} for root yield. From the results in this study observed that, Si has role effective in reducing heat stress by increasing water holding capacity, regulates stomatal conductance and photosynthesis process **(Koentjoro *et al.*, 2020)**. $CaCl_2$ play significant role in the growth under stress perhaps through maintaining RWC and other chemical compound inside plant tissues and it has the potential to stimulate the production of transpiration and more water became available to plants for better growth and productivity **(Madany and Khalil, 2017)**. In this context, **Alkahtani *et al.*, (2021)** showed that root and sugar yields were decreased in sugar beet plants under drought stress, Si treatment gave the maximum results in yields in both seasons compared with control. **Enan (2015)** indicated that increasing calcium application up to 288 ppm fed^{-1} resulted in higher values of yields of roots and sugar ton fed^{-1}.

Effect of interaction

Planting date in November and spraying with K-silicate at 2000 mg l^{-1} gave the highest value top yield, while, the highest sugar and root yields (ton fed.$^{-1}$) were achieved by plants sowing in October and received K- silicate at 2000 mg l^{-1}. On contrast, planting in September and sprayed with control recorded the minimum values of top, sugar and root yields followed by planting in September and spraying with salicylic acid at level 25 mgl^{-1}.

Table 7. Root quality (Sugar extractable %) and top yield as affected by planting date, some chemical compounds and their interactions (data are combined across 2019/2020 and 2020/2021).

Treatments (foliar spray)	Sugar extractable%				Top yield (ton fed.$^{-1}$)			
	P1	P2	P3	Mean	P1	P2	P3	Mean
Control (tap water)	14.00	15.87	14.27	**14.71**	11.47	12.49	12.10	**12.02**
Salicylic acid (25 mgl^{-1})	14.44	15.91	14.86	**15.07**	12.37	13.00	12.82	**12.17**
Salicylic acid (50 mgl^{-1})	14.81	16.92	15.39	**15.70**	13.20	13.94	13.44	**13.52**
Salicylic acid (100 mgl^{-1})	15.77	17.65	15.85	**16.42**	13.89	14.67	14.47	**14.34**
Calcium chloride (0.2%)	15.43	16.03	14.59	**15.35**	12.87	13.99	13.40	**13.42**
Calcium chloride (0.4%)	16.17	16.68	15.78	**16.21**	13.80	15.13	14.43	**14.45**
Calcium chloride (0.8%)	16.98	18.14	16.27	**17.13**	14.87	16.36	16.22	**15.82**
Potassium silicate (500 mgl^{-1})	14.08	15.95	15.42	**15.15**	14.18	15.22	15.25	**14.88**
Potassium silicate (1000 mgl^{-1})	14.90	16.40	15.79	**15.69**	14.66	15.65	16.03	**15.45**
Potassium silicate (2000 mgl^{-1})	15.83	17.61	16.65	**16.70**	15.12	16.22	16.85	**16.06**
Mean	**15.24**	**16.71**	**15.49**		**13.64**	**14.67**	**14.50**	
LSD at 0.05								
Planting date (P)				0.02				0.02
Treatments (T)				0.04				0.04
Interaction (PXT)				0.04				0.07

P1= planting date on 20th September, P2 = planting date on 20th October, P3= planting date on 20th November.

Table 8. Root and sugar yields (ton fed.$^{-1}$) as affected by planting date, some chemical compounds and their interactions (data are combined across 2019/2020 and 2020/2021).

Treatments (foliar spray)	Root yield(ton fed.$^{-1}$)				Sugar yield (ton fed.$^{-1}$)			
	P1	P2	P3	Mean	P1	P2	P3	Mean
Control (tap water)	20.16	21.35	21.45	**20.99**	2.82	3.39	3.06	**3.09**
Salicylic acid (25 mgl^{-1})	21.01	21.62	21.81	**21.48**	3.04	3.44	3.24	**3.24**
Salicylic acid (50 mgl^{-1})	22.13	22.65	22.02	**22.27**	3.28	3.83	3.39	**3.50**
Salicylic acid (100 mgl^{-1})	22.80	23.75	23.09	**23.21**	3.60	4.19	3.66	**3.82**
Calcium chloride (0.2%)	21.97	22.41	21.90	**22.09**	3.39	3.59	3.20	**3.39**
Calcium chloride (0.4%)	23.46	24.49	23.97	**23.97**	3.79	4.08	3.78	**3.88**
Calcium chloride (0.8%)	24.33	25.92	24.65	**24.97**	4.13	4.70	4.01	**4.28**
Potassium silicate (500 mgl^{-1})	23.67	23.79	23.97	**23.81**	3.33	3.79	3.70	**3.61**
Potassium silicate (1000 mgl^{-1})	24.64	26.12	25.41	**25.39**	3.67	4.28	4.01	**3.99**
Potassium silicate (2000 mgl^{-1})	25.34	28.10	27.01	**26.82**	4.01	4.95	4.50	**4.49**
Mean	**22.95**	**24.02**	**23.53**		**3.51**	**4.03**	**3.66**	
LSD at 0.05								
Planting date (P)				0.04				0.01
Treatments (T)				0.05				0.01
Interaction (PXT)				0.09				0.02

P1= planting date on 20th September, P2 = planting date on 20th October, P3= planting date on 20th November

References

Abd El-Hady M.A. and Bondok A.M. (2017) Impact of potassium silicate on growth, productivity and powdery mildew disease of sugar beet under newly reclaimed soil conditions. *Mid. East J. Agric. Res.*, 6 (4):1232-1242.

Abdel-Fatah Eman M. and Khalil Soha R. A. (2020) Effect of zeolite, potassium fertilizer and irrigation interval on yield and quality of sugar beet in sandy soil. *J. of plant production, Mansoura Univ.*, 11(12): 1569-1579.

Abdelaal K. A.A., Rashed S. H., Ragab A., Hossain A. and El-Sabagh A. (2020) Yield and quality of two sugar beet (*Beta vulgaris* L. ssp. Vulgaris var. *altissima* Döll) cultivars are influenced by foliar application of salicylic acid, irrigation timing, and planting density. *Acta Agric. Slovenica*, 115(2): 273-282.

Ahmad P. and Prasad M.N.V. (2012) Abiotic Stress Responses in plants: Metabolism, Productivity and Sustainability. https://www.Researchgate.net /10.1007/97814 61406341

Alkahtani M. D. F., Hafez Y.M., Attia K., Rashwan E., Al-Husnain L., Al-Gwaiz H.I.M. and Abdelaal K.A.A. (2021) Evaluation of silicon and proline application on the oxidative machinery in drought-stressed sugar beet. *Antioxidants*, 10: 1-19.

Ashraf M. and Foolad M.R. (2007) Roles of glycinebetaine and proline in improving plant abiotic stress tolerance. *Environ. Exp. Bot*., 59, 206–216.

Ashraf M., Afzal M., Ahmad R., Maqsood M.A., Shahzad S.M., Aziz A. and Akhtar N. (2010) Silicon management for mitigating abiotic stress effects in plants. *Global Science Books, plant stress*, 4: 104-114.

Arshi A., Abdin M.Z. and Iqbal M. (2006) Sennoside content and yield attributes of *Cassia Angustifolia Vahl*. as affected by NaCl and $CaCl_2$. *Soil Hortic*. 111, 84-90.

Bates L.S., Waldren R.P. and Teare I.D. (1973) Rapid determination of free proline for water stress studies. *Plant soil*, 39: 205-207. http://dx.doi.org/10.1007/BF0001806048.

Carruthers A., Oldfield J.E.T. (1960) Methods for the assessment of beet quality. *Int. Sugar J.* **63** (1), 103-105.

Dawood M.G., Abdel-Baky Y. R.,El-Awadi M.E.S. and Bakhoum G.S.(2019) Enhancement quality and quantity of faba bean plants grown under sandy soil conditions by nicotinamide and /or humic acid application. *Front.plant Sci.*, 28-36.

Devillers P., (1988) Prevision du sucre melasse. *Sucrerie Francases,* **129**, 190-200.

Dexter S.T., Frankes M.G. and Snyder F.W. (1967) A rapid of determining extractable white sugar as may be applied to the evaluation of agronomic practices and grower deliveries in the sugar beet industry. *J. Am., Soc., Sugar Beet Technol.* **14**: 433-454.

El-Gamal I.S.H., El-Safy Nadia K. and Abo-Marzoka E.A. (2021) Growth of some sugar beet varieties under different locations as affected by foliar application with salicylic acid on yield and quality. *Egyptian Academic J. of Biol. Sci.,* 12 (1): 161-173.

El-Kady M.S., Abdel Fatah Eman M. and Laboudy E.H.S. (2019) Growth, some physiological traits and productivity of sugar beet under different irrigation levels and mulch types in new reclaimed area. *Egyptian j. Agric. Sci.*, 70 (4) 393-408.

Enan S.A.A.M. (2015) Effect of seed soaking in gibberellic acid and foliar application of calcium on yield and quality of sugar beet under saline soil conditions, *Fayoum J. Agric. Res. And Dev*., 31(2):90-107.

Ghaffaria H., **Tadayona M.R., Bahadora M. and Razmjoo J. (2021)** Investigation of proline role in controlling traits related to sugar and root yield of sugar beet under water deficit conditions. *Agric. water Manag.*243: 106448.

Gobarah Mirvat E., Hussein M.M., Tawfik M.M., Ahmed Amal G. and Mohamed Manal F. (2019) Effect of different sowing dates on quantity and quality of some promising sugar beet (*Beta vulgaris* L.) varieties under north delta, condition. *Egypt. J. Agron*. 41(3): 343-354.

Gomez K.N. and Gomez A.A. (1984). Statistical procedures for agricultural research. A Wiley-Inter-Sci. Publication, John Wiley and Sons, New York 2th ed.68p.

Guo Z.G., Liu H.X., Tian F.P., Zhang Z.H. and Wang S.M. (2006) Effect of silicon on the morphology of shoots and roots of alfalfa (*Medicago Sativa*). *Australian J. of Experimental Agric*., 46: 1161-1166.

Hossain M.M., Kader M.A. and Kashem M.A. (2021) Optimum planting date for the maximum tuber yield of tropical sugar beet (*Beta vulgaris* L.) genotypes in the old Brahmaputra floodplain. *Journal of Scientific Agric.,* 5:44-48.

Horvath E., Szalai G. and Ganda T. (2007) Induction of abiotic tolerance by salicylic acid signaling. *J. of plant growth regulation,* 26 (3): 290-300. DOI: 10.1007/s 00344-007-9017-4.

Hosseini S. A., Rethore E., Pluchon S., Ali N., Billiot B. and Yvin J.C. (2019) Calcium application enhances drought stress tolerance in sugar beet and promotes plant biomass and beetroot sucrose concentration. *Int. J. Mol. Sci.,* 20 (3777): 2-22.

Ibrahim A.M., Khafaga H.S., Abd El-Nabi A.S., Eisa S.S. and Shehata A. (2017) Transplanting of sugar beet with soil drench by potassium humate or potassium silicate enhanced plant growth and productivity under saline soil conditions. *Current Science International*, 6 (2): 303-313.

Koentjoro Y., Puewanto E. and Purnomo D. (2020) Stomatal behavior of soybean under drought stress with silicon application. *Ann. Agri. Bio. Res*. 25 (1):103-109.

Madany M.Y. and Khalil R.R. (2017) Seed priming with ascorbic acid or calcium chloride mitigates the adverse effects of drought stress in sunflower (*Helianthus annuus* L.) seedlings. *Egypt J. Exp. Biol.(Bot.),* 13 (1): 119-133.

Nemeata Alla H.E.A. (2016) Yield and quality of sugar beet as affected by sowing date, nitrogen level and foliar spraying with calcium. *J. Agric. Res. Kafr El-Sheikh Univ*., 42(1): 170-188.

Piper C.S. (1955) soil and plant analysis. *Univ. of Adelaide, Australia*, P.178.

Rodrigues L.A., De Oliveira I.C., Nogueira G.A., Da Silva T.R.B., Candido C.S. and Alves C.z. (2019). Coating seeds with silicon enhances the corn yield of the second crop. *Revista Caatinga*, v. 32, n. 4, p. 897-903.

Sangster A.G., Hodson M.j. and Tubb H.J. (2001) Silicon deposition in higher plants. *In Studies in Plant Science, Silicon in Agriculture*, Datnoff, L.E.; Snyder, G.H.; Korndorfer, G.H., Eds; Elsevier: Amsterdam, the Netherlands, pp. 85-113.

Schiermeier, Q. (2014) Water risk as world warms. First comprehensive global- impact project show that water scarcity is a major worry. *Nature*, (505), 10-11.

Singh N.S., Thind K. and Singh Sanghera G. (2019) Interactive outcome of dates of sowing and genotypes over environments on root yield and quality attributes in sugarbeet (*Beta vulgaris* L.). *Acta Scientific Agriculture*, 3(10), 164–172. https://doi.org/10.31080/ asag.2019.03.0663

Snedecor G.W. and Cochran W.G. (1980) *"Statistical Methods*".7th Ed. The Iowa State 3Univ. Press Amer. Iowa, USA.

Soudi Amal K.M. (2013) Effect of two antitranspirants on growth and quality of sugar beet under different levels of soil moisture deficit. *Egypt. J. of Appl. Sci.*, 28 (5):305-318.

Tawfic Sahar F., Ranya M.A. and Eanar A.K. (2014) Effect of planting date and sulphur fertilizer on yield and quality of sugar beet under newly reclaimed soils. *J. Plant Production Mansoura Univ*., 5 (9): 1547-1556.

Weatherley P.E. (1950). Studies in the water relations of the cotton plant. 1- the field measurement of water deficits in leaves. New phytologist, 49:81-87.

Willey R.L.(1971) Microtechnique. In:"*A Laboratory Guide*" McMillan Publishing Inc., NY, P.99.