http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS

Pakistan Journal of Biological Sciences

ISSN 1028-8880
DOI: 10.3923/pjbs.2020.454.466

Research Article
Growth, Yield and Biochemical Impact of Anti-transpirants on Sunflower Plant Grown under Water Deficit

[1]Maha Mohamed Shater Abdallah, [2]Bakry Ahmad Bakry, [1]Hala Mohamed Safwat El-Bassiouny and [1,3]Amany Attia Abd El-Monem

[1]Department of Botany, Division of Agricultural and Biological Research, National Research Centre, 33 El-Buhouth Street, Dokki, Giza, Egypt
[2]Department of Field Crops Research, Division of Agricultural and Biological Research, National Research Centre, 33 El-Buhouth Street, Dokki, Giza, Egypt
[3]Department of Biology, University Collage of Tayma, University of Tabuk, Tabuk, Saudi Arabia

Abstract

Background and Objective: Climate change affecting on weather in many different ways especially drought and temperature rise. This will drastically down plant production, if not start looking for another source to increase water productivity to cope up with water stress conditions. In this study efforts were conducted to interpret the use of anti-transpirants to conserving irrigation water, aiding plant survival under dry conditions and protecting plant against drought stress. **Materials and Methods:** Two field experiments were carried out during 2017 and 2018 successive growing summer seasons at the experimental farm of National Research Centre, Nubaria, El-Beheira Governorate, Egypt. Anti-transparent ,i.e., chitosan (100 and 150 mg L^{-1}), calcium carbonate (5 and 10 g L^{-1}), salicylic acid (200 and 300 mg L^{-1}) were foliar sprayed on sunflower plants grown under two water levels (normal 100% and deficit 50%). **Results:** The results showed that water stress decreased growth criteria, photosynthetic pigments, osmoprotectants, yield components, oil and carbohydrate (%) as compared to 100% of irrigation requirements. Meanwhile, water deficit induced significant increases in (proline). Foliar treatments of sunflower plant with chitosan, calcium carbonate, salicylic acid increased growth criteria, yield components, photosynthetic pigments, total soluble sugars, proline and free amino acid as compared to control plant. Data also illustrated that, all used treatment improved seed yield, oil and carbohydrate% of sunflower plants. **Conclusion:** Generally, it could be concluded that 10 g L^{-1} $CaCO_3$ and 300 mg L^{-1} SA at 50% level of water irrigation could be recommended for sunflower plant grown under similar field conditions in order to get optimum yield and to save irrigation water.

Key words: Anti-transpirants, WP (water productivity), chitosan, calcium carbonate, salicylic acid and drought

Citation: Maha Mohamed Shater Abdallah, Bakry Ahmad Bakry, Hala Mohamed Safwat El-Bassiouny and Amany Attia Abd El-Monem, 2020. Growth, yield and biochemical impact of anti-transpirants on sunflower plant grown under water deficit. Pak. J. Biol. Sci., 23: 454-466.

Corresponding Author: Amany Attia Abd El-Monem, Department of Botany, Division of Agricultural and Biological Research, National Research Centre, 33 El-Buhouth Street, Dokki, Giza, Egypt

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Recently there is serious need to balance between water requirements, water availability and water consumption thus saving water is becoming a critical consideration for agriculture, particularly in arid and semi-arid regions where water is the main limiting factor for plant growth and development. Water stress betide whenever the privation of water in transpiration surpassed the level of absorption. It can be known by the decrease in water content occur with shortage of turgidity, stomata closure and consequently reduction in growth and photosynthesis process[1]. Also, plants are abundant in water consumption because only approximately 5% of water uptake is used for its growth and maturation while the 95% residual is lost for transpiration[2]. Ahmed[3] stated that, some chemical with satisfied biological actions could be utilized to decrease the rate of transpiration and alleviate plant water shortage by stimulate the leaf struggle to the transmission of water vapor. According to their mode of action, such anti-transpirants were classified into three groups first type is film-forming (in which superficial layer of leaf covered with films that are sealed to water vapor), second type reverberate materials (which reflect back a portion of the radiation falling on the upper surface of the leaves) and third type stomatal closing types (which affect the metabolic processes in leaf tissues)[4].

Chitosan is a natural, cheap and slight toxic compound that is eco- friendly and biodegradable with numerous uses in agriculture; it produced as the result of the de-acetylation of chitin. New *et al.*[5] stated that, it can be used as fertilizer and as determinant for agrochemical unleash, to stimulate plant growth and productivity, to protect plants against microorganisms and to improve plant growth[6,7] and opposed to oxidative trouble[8]. Sheikha and Al-Malki[9] show that, chitosan improved vegetative growth of faba bean or soybean as well as the level of leaf chlorophyll.

Moreover, chitosan encouraged ABA activity, which participates a crucial role in the regulation of stomatal opening and decreasing the rate of transpiration when the plant exposed to stress[10]. So, we recommend that chitosan may be the potential anti-transpirant that assists plants overcome water stress.

Many studies showed the efficiency of foliar Ca^{2+} sprays as nitrate and chloride, but there is less information on the effects of foliar sprays of Ca^{2+} as calcium carbonate ($CaCO_3$). Anti-transpirants products based on stomata close, such as calcium carbonate $CaCO_3$, are active in heavy water limited environments, where they may improve crop yield which acts on stomatal regulation by affecting stomatal guard cells, decreasing losses of water vapor in an ABA-dependent way[11], can be more effective in temperate regions, when occasional or episodic drought events occur compared with the film-forming material[12]. Furthermore, calcium signals elements are contributed in ABA-stimulate stomatal closure and plant acclimation to abiotic stresses[13]. Calcium channel proteins can regulate stomatal closure. The results point to that calcium ions are possibly sharing in the regulation of stomata behavior in wheat plants. Ramadan and Omar[14] found that, foliar spraying of $CaCO_3$, significantly increased all growth parameters, yield and water used efficiency in cabbage plant under drought stress.

Salicylic acid is a plant phenolic growth bio regulator reacts endogenously as non-enzymatic antioxidant of phenolic nature, it contributes in the regulation of physiological processes in plants. Ahmed[3] stated that, 5% salicylic acid increased photosynthetic pigment, fruits No., antioxidant enzymes which play a defense strategy against the drought stress condition and all other growth parameters. In previous study described by Misra *et al.*[15] foliar application of salicylates can mitigate the rate of transpiration and prevent water loss from stomata, salicylic acid act as signal molecule which activate ABA activity and responsible for plants stomatal closure. This activity of stomata can reflect on other physiological processes like stomatal movement, respiration, which may affect the photosynthetic process and most probably involved in regulation of photosynthetic reaction.

Sunflower is an essential oil seed crop worldwide and in Mediterranean regions and at drought rising problem[16]. To endurance under these stress conditions and confront different soil and climatic conditions depends up on, plant's capability to verify the stimulus, produces and transmits, signals and support biochemical alterations that regulate the metabolism[17,18].

This study aimed to study the effect of calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) or salicylic acid (200 and 300 mg L^{-1}) in alleviate oxidative damage, accelerate growth, photosynthesis in leaves and yield quantity and quality, of sunflower plants.

MATERIALS AND METHODS

Two field experiments were conducted at the experimental farm of national research center, (latitude 30°30'1.4"N, longitude 30°19'10.9"E and mean altitude 21 m a.s.l.) at (NRC), Al-Nubaria district, El-Beheira Governorate, Egypt during two summer of 2017 and 2018 seasons.

Experimental design was split-plot in randomized complete block arrangements with 3 replications. The main plots were devoted to water irrigation quantities (50 and 100% from recommended irrigation quantity 2000 and 1000 m^3/fed). The sub-plots were allocated to 3 foliar treatment of chemical compounds employed as anti-transpirants i.e., calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) and Salicylic acid (200 and 300 mg L^{-1}). The physical and chemical analysis of experimental soil was recorded at (Table 1).

The experiments were laid out under drip irrigation system, the experimental unit consisted of five ridges, each of 0.60 m in width and 5.0 m in length (15 m^2).

Seeds of Egyptian sunflower cultivar (Sakha-53) were sown in hills 30 cm apart on 15th June in both summer seasons of 2017 and 2018. Two weeks later, the seedlings were thinned to 1 plant/hill. Mono super phosphate fertilizer (15.5% P_2O_5) at rate of 75 kg ha^{-1} P_2O_5 (4200 m^2) was added during field preparation. Ammonium nitrate (33.5% N) at rate of 144 kg ha^{-1} N and potassium sulphate (48% K_2O) at rate of 115 kg ha^{-1} K_2O were added starting from 15 days after planting in 5 equal doses at 7 days interval.

Irrigation water requirements: Irrigation was carried out using the new sprinkler irrigation system, four irrigations water requirements was calculated using Penman Monteith equation and crop coefficient according to Allen *et al.*[19]. The average amount of irrigation water applied with drip irrigation system were 4760 and 2380 m^3 ha^{-1}/season represented (100 and 50%, respectively) for both two summer seasons.

The amounts of irrigation water were calculated according to the following equation:

$$IWR = \left(\frac{ETo \times Kc \times Kr \times I}{Ea} + LR \right) \times 4.2$$

Where:

IWR = Irrigation water requirement m^3 ha^{-1}
Kc = Crop coefficient
Kr = Reduction factor[20]
I = Irrigation interval (day)
Ea = Irrigation efficiency (90%)
LR = Leaching requirement = 10% of the total water amount delivered to the treatment

All the required cultural practices were adopted uniformly as necessary during the growing season.

Morphological characters of vegetative growth: After 60 days from planting, ten plants were randomly taken from each plot to record plant height (cm), number of leaves/plant, stem fresh weight (g), leaves fresh weight (g) shoot fresh weight/plant , stem dry weight (g), leaves dry weight (g) shoot dry weight/plant, root length (cm), root fresh weight (g) and root dry weight (g).

Yield and yield components: The heads were covered completely after pollination to prevent birds attack. At harvest, ten guarded plants were randomly taken from each experimental unit to record the following characters: Head diameter (cm), seed yield/plant (g), 1000-seed weight (g), seed yield t ha^{-1}, biological yield t ha^{-1} and straw yield t ha^{-1}. Also, seed yield per plot was weighed and converted into yield ha^{-1}.

Chemical analysis: Photosynthetic pigments were estimated using the method of Lichtenthaler and Buschmann[21] in fresh leaves. Total soluble sugars (TSS), were extracted by the method of Prud'homme *et al.*[22]. Proline was assayed according to the method described by Bates *et al.*[23]. Free amino acid content was extracted according to the method described by Vartanian *et al.*[24]. Free amino acid was determined with the ninhydrin reagent method[25]. Oil yield (kg ha^{-1} was calculated by seed yield (kg ha^{-1} × seed oil content (%). Seed oil (%) was determined by Soxhlet apparatus using petroleum ether (40-60°C bp) according to the Official Method[26].

Water productivity of sunflower seed "WP sunflower seed": The WP of sunflower seed is an indicator of effectiveness use of irrigation water for crop production. The $WP_{sunflower\ seed}$ was calculated according to James[27] as follows:

$$WP_{sunflower\ seed} = Ey/Ir$$

where, WP sunflower seed is the water productivity of sunflower seed (kg sunflower seed.m^{-3} irrigation water), Ey is the economical yield (t ha^{-1}) and Ir is the amount of applied irrigation water (m^{-3} irrigation water/ha/season).

Table 1: Mechanical and chemical analysis of experimental soil

Sand (%)	Clay (%)	Silt (%)	pH	Organic matter (%)	$CaCO_3$ (%)	EC (dS m^{-1})	Soluble N (ppm)	Available P (ppm)	Exchangeable K (ppm)
85.3	4.0	10.7	7.84	0.4	1.0	3.95	8.1	3.2	20

Statistical analysis: The data were subjected to statistical analysis of variance of split plot design according to procedures outlined by Steel and Torrie[28] using MSTAT-C computer package[29]. Since the trend was similar in both seasons the homogeneity test Bartlet's equation was applied and the combined analysis of the two seasons was done according to the method. Means were compared by using least significant difference (LSD) at 5%.

RESULTS

Growth parameters

Effect of irrigation quantity (%): Data presented in Table 2 showed significant differences between treatments in all studied characters. Treatment of 100% recommended irrigation quantity had superiority in all characters (shoot length, leaves number/plant, fresh weight of shoot and root). Reducing irrigation quantity to 50% of water requirements significantly reduced all studied characters.

Effect of calcium carbonate, chitosan and salicylic acid: The effect of spraying treatments with different concentrations of calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) or salicylic acid (200 and 300 mg L^{-1}) on morphological parameters (plant height, leaves number/plant, fresh and dry weight of shoot and root) of sunflower plant were illustrated in Table 3. These results demonstrated different treatments concentration significantly improved growth criteria of sunflower plant as compared with control plant. The maximum increase in the growth parameters can be arranged as $CaCO_3$>chitosan>SA> as compared with the untreated plants.

Interaction of calcium carbonate, chitosan, salicylic acid and irrigation quantity (%): Data existing in Table 4 represented the interaction effect between irrigation quantity percent and calcium carbonate, chitosan or salicylic acid at different concentrations on different growth parameters of sunflower plant. Plants grown at 50% of WIR led to a significant decrease in all growth characters (shoot length, leaves number/plant, shoot and root fresh and dry weight) as compared to plants grown under 100% water irrigation requirements. All used treatments enhanced significantly the growth criteria when compared with the corresponding control of sunflower plant. The maximum increase in the growth parameters was observed at (5.0 g L^{-1} $CaCO_3$) at 100% water level and (10.0 g L^{-1} $CaCO_3$ and 150 mg L^{-1} chitosan) at 50% water level.

Photosynthetic pigments

Effect of irrigation quantity (%): Plants subjected to the 50% of WIR in field conditions leads to significant decreases in photosynthetic pigments (chlorophyll a and b, carotenoids and total pigments) as compared to plants grown under the level of 100% WIR (Table 5).

Table 2: Effect of irrigation quantity (%) on growth criteria of sunflower plant grown under sandy soil condition

	Water requirements (%)		
Treatments	50	100	LSD 0.05
Shoot length (cm)	97.24	112.48	0.920
Leaves number/plant	13.33	15.55	0.240
Fresh weight of stem (g)	48.45	71.40	7.335
Fresh weight of leaves (g)	17.04	27.68	0.855
Dry weight of stem (g)	11.58	16.41	1.140
Dry weight of leaves (g)	4.97	9.03	1.695
Root length (cm)	16.14	16.60	0.240
Fresh weight of root (g)	13.28	13.67	0.460
Dry weight of root (g)	5.33	5.65	0.240

Table 3: Effect of different concentrations of calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) and salicylic acid (200 and 300 mg L^{-1}) on growth criteria of sunflower plant grown under sandy soil condition

Treatments	Control	$CaCO_3$ (5 g L^{-1})	$CaCO_3$ (10 g L^{-1})	Chitosan (100 mg L^{-1})	Chitosan (150 mg L^{-1})	SA (200 mg L^{-1})	SA (300 mg L^{-1})	LSD 0.05
Shoot length (cm)	88.50	112.00	108.67	109.83	102.67	104.50	107.83	2.47
Leaves number/plant	12.33	15.58	15.67	14.00	14.00	13.83	15.67	1.52
Fresh weight of stem (g)	43.34	69.32	65.94	63.59	60.27	49.65	67.40	3.51
Fresh weight of leaves (g)	14.90	33.33	29.01	25.20	23.16	18.45	19.95	2.27
Dry weight of stem (g)	9.96	16.28	14.72	15.47	14.88	11.54	16.29	0.99
Dry weight of leaves (g)	5.07	8.40	8.15	7.91	7.28	5.99	6.33	1.58
Root length (cm)	15.25	17.00	15.83	17.83	17.50	16.33	14.83	0.91
Fresh weight of root (g)	10.78	13.73	12.74	13.95	13.16	13.81	12.63	1.05
Dry weight of root (g)	4.10	5.41	5.04	4.89	4.71	5.30	5.49	0.53

Table 4: Effect of interaction between irrigation quantity (%) and different concentrations of calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) and salicylic acid (200 and 300 mg L^{-1}) on growth criteria of sunflower plant grown under sandy soil condition

Water requirements (%)	Treatments	Concentration	Shoot length (cm)	Leaves number	Stem fresh weight (g)	Leaves fresh weight (g)	Stem dry weight (g)	Leaves dry weight (g)	Root length (cm)	Root fresh weight (g)	Root dry weight (g)
100	Control		90.70	13.33	54.21	20.91	11.82	6.96	15.17	11.95	4.55
	$CaCO_3$	5 g L^{-1}	135.00	17.50	87.53	43.17	19.55	13.34	17.67	14.87	5.91
		10 g L^{-1}	118.00	16.33	78.39	33.87	17.24	12.51	16.02	14.72	5.91
	Chitosan	100 mg L^{-1}	115.30	15.67	79.05	23.19	19.55	12.11	18.67	15.62	6.78
		150 mg L^{-1}	100.70	14.33	68.59	24.39	16.86	10.32	18.00	14.36	5.85
	SA	200 mg L^{-1}	112.00	14.67	54.03	22.65	19.91	7.92	17.00	13.99	5.89
		300 mg L^{-1}	115.70	17.00	78.05	25.50	18.87	8.10	13.67	13.20	5.62
50	Control		86.30	11.33	32.45	8.90	8.07	3.18	15.33	10.60	4.65
	$CaCO_3$	5 g L^{-1}	89.00	12.67	51.09	23.46	9.11	3.75	16.33	13.62	4.89
		10 g L^{-1}	99.30	15.00	53.49	24.15	12.18	8.28	15.67	14.77	5.75
	Chitosan	100 mg L^{-1}	104.30	12.33	48.12	12.20	11.37	3.68	17.00	14.34	5.01
		150 mg L^{-1}	104.70	13.67	51.93	21.92	15.89	7.22	17.00	12.97	5.56
	SA	200 mg L^{-1}	97.00	13.00	45.36	14.28	10.65	4.05	15.67	13.63	5.71
		300 mg L^{-1}	100.00	14.33	56.72	14.39	13.71	4.56	16.00	12.07	5.35
LSD 0.05			3.49	2.16	4.95	3.20	1.40	2.24	1.28	1.49	0.75

Table 5: Effect of irrigation quantity (%) on photosynthetic pigments (µg g^{-1} fresh weight) of sunflower plant grown under sandy soil condition

	Water requirements (%)		
Treatments	50	100	LSD 0.05
Chlorophyll a	12.16	17.01	0.52
Chlorophyll b	3.88	4.58	0.25
Carotenoids	1.94	2.82	0.09
Total pigments	17.98	24.41	1.11

Table 6: Effect different concentrations of calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) and salicylic acid (200 and 300 mg L^{-1}) on photosynthetic pigments (µg g^{-1} fresh weight) of sunflower plant grown under sandy soil condition

Treatments	Control	$CaCO_3$ (5 g L^{-1})	$CaCO_3$ (10 g L^{-1})	Chitosan 100 (mg L^{-1})	Chitosan (150 mg L^{-1})	SA (200 mg L^{-1})	SA (300 mg L^{-1})	LSD 0.05
Chlorophyll a	12.01	14.88	15.87	16.04	12.52	15.70	15.05	1.57
Chlorophyll b	4.03	4.00	4.64	4.92	2.98	4.77	4.31	0.09
Carotenoids	1.34	2.75	2.86	2.36	2.66	2.18	2.49	0.49
Total pigments	17.38	21.63	23.37	23.32	18.16	22.65	21.85	2.15

Effect of calcium carbonate, chitosan and salicylic acid: Table 6 showed the influence of different concentrations of calcium carbonate, chitosan or salicylic acid on photosynthetic pigments of sunflower leaves. Different treatments induced significant enhances in photosynthetic pigments (chlorophyll a and b, carotenoids and total pigments), compared with control plants. Data showed that, the maximum increase in the total chlorophyll was arranged as follow: $CaCO_3$ 10 g L^{-1}>100 mg L^{-1} chitosan>200 mg L^{-1} SA as compared with the untreated plants.

Interaction of calcium carbonate, chitosan, salicylic acid and irrigation quantity (%): Table 7 showed the influence of different concentrations of calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) or salicylic acid (200 and 300 mg L^{-1}) on photosynthetic pigments of sunflower plants subjected to different levels of water irrigation (%). Plants grown at 50% of WIR showed a significant decrease in photosynthetic pigments when compared to plants grown under the level of 100%. Treatment of sunflower plants with different concentrations of calcium carbonate, chitosan or salicylic acid promoted photosynthetic pigments under 100 and 50% WIR levels as compared with the corresponding WIR levels. The maximum raises in total pigments were found by using SA (200 mg L^{-1}) by 39.35 and 16.84% in response to 100% water irrigation when comparing with the same concentration at 50% and respectively as compared with the corresponding control.

Free amino acids, TSS and proline

Effect of irrigation quantity (%): Table 8 showed the effect of irrigation quantity (%) on free amino acids, total soluble sugars and proline contents. Decreasing the irrigation quantity to 50% significantly decreased either FAA, TSS content when compared with 100% irrigation requirements of sunflower plants under field conditions. In contrast proline increased with decreasing irrigation quantity (%) up to 50% of irrigation requirements of sunflower plants under field conditions.

Table 7: Effect of interaction between irrigation quantity (%) and different concentrations of calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) or salicylic acid (200 and 300 mg L^{-1}) on photosynthetic pigments (μg g^{-1} fresh weight) of sunflower plant grown under sandy soil condition

Water requirements (%)	Treatments	Concentration	Chlorophyll a	Chlorophyll b	Carotenoids	Total pigments
100	Control		14.71	4.49	1.66	20.86
	$CaCO_3$	5 g L^{-1}	17.43	4.65	3.04	25.12
		10 g L^{-1}	19.29	5.80	3.29	28.38
	Chitosan	100 mg L^{-1}	16.49	4.99	2.34	23.82
		150 mg L^{-1}	13.91	2.45	3.17	19.53
	Salicylic acid	200 mg L^{-1}	20.65	5.10	3.32	29.07
		300 mg L^{-1}	16.56	4.65	2.91	24.12
50	Control		9.32	3.55	1.02	13.89
	$CaCO_3$	5 g L^{-1}	12.33	3.35	2.46	18.14
		10 g L^{-1}	12.45	3.49	2.43	18.37
	Chitosan	100 mg L^{-1}	15.59	4.86	2.37	22.82
		150 mg L^{-1}	11.12	3.52	2.16	16.80
	Salicylic acid	200 mg L^{-1}	10.75	4.50	1.03	16.23
		300 mg L^{-1}	13.55	3.96	2.07	19.58
LSD 0.05			2.22	0.34	0.69	3.05

Table 8: Effect of irrigation quantity (%) on free amino acid (FAA), total soluble sugar (TSS) and proline (mg/100 g dry weight) of sunflower plant grown under sandy soil condition

	Water requirements (%)		
Parameters mg/100 g dry weight	50	100	LSD 0.05
FAA	445.70	492.88	8.14
TSS	4055.14	4482.93	9.76
Proline	159.36	143.93	7.15

Table 9: Effect of different concentrations of calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) and salicylic acid (200 and 300 mg L^{-1}) on total soluble sugar (TSS), proline and free amino acid (FAA) (mg/100 g dry weight) of sunflower plant grown under sandy soil condition

Treatments	Control	$CaCO_3$ (5 g L^{-1})	$CaCO_3$ (10 g L^{-1})	Chitosan (100 mg L^{-1})	Chitosan (150 mg L^{-1})	SA (200 mg L^{-1})	SA (300 mg L^{-1})	LSD 0.05
FAA	317.63	530.63	413.53	620.25	540.38	456.93	405.70	8.29
TSS	2888.00	4228.25	3118.25	5434.00	4555.75	5243.00	4416.00	19.80
Proline	91.25	174.00	141.50	191.25	160.25	160.75	142.50	3.19

Effect of calcium carbonate, chitosan and salicylic acid: Data presented in Table 9 illustrated the effected by calcium carbonate, chitosan or salicylic acid at different concentrations. Different treatments induced accumulation of osmoprotectants (total soluble sugar proline and free amino acid) in plant as compared with the control. The maximum increases in proline, TSS and free amino acids were obtained by chitosan at 100 mg L^{-1}.

Interaction between calcium carbonate, chitosan, salicylic acid and irrigation quantity (%): Data recorded in Table 10 showed that decreasing the irrigation quantity (%) induced accumulation of osmoprotectants (total soluble sugar and proline) in sunflower plant. Foliar application of calcium carbonate, chitosan or salicylic acid induced an additive accumulation of osmoprotectants content as compared with the corresponding control at irrigation quantity (%). The maximum increase in proline was obtained by chitosan at 100 mg L^{-1}, followed by $CaCO_3$ at 5 g L^{-1} at 100 and 50% WIR of irrigation requirement compared with 100% of field capacity and with the corresponding control. In contrast plants grown at 50% of WIR led to a significant decrease in FAA contents as compared to 100% of irrigation requirement. The maximum increases in TSS and free amino acids obtained by chitosan at 100 mg L^{-1}, followed by $CaCO_3$ at 5 g L^{-1} at 100% of irrigation requirement when compared with control.

Table 10: Effect of interaction between irrigation quantity (%) and different concentrations of calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) or salicylic acid (200 and 300 mg L^{-1}) on total soluble sugar (TSS), proline and free amino acid (FAA) (mg/100 g dry weight) of sunflower plant grown under sandy soil condition

Water requirements (%)	Materials	Concentration	FAA	TSS	Proline
100	Control		325.60	2801.50	81.50
	$CaCo_3$	5 g L^{-1}	579.40	4522.50	167.00
		10 g L^{-1}	417.60	3177.50	142.50
	Chitosan	100 mg L^{-1}	649.00	5875.00	179.50
		150 mg L^{-1}	576.00	4677.50	159.00
	Salicylic acid	200 mg L^{-1}	483.95	5727.50	149.00
		300 mg L^{-1}	418.60	4599.00	129.00
50	Control		309.65	2974.50	101.00
	$CaCo_3$	5 g L^{-1}	481.85	3934.00	181.00
		10 g L^{-1}	409.45	3059.00	140.50
	Chitosan	100 mg L^{-1}	591.50	4993.00	203.00
		150 mg L^{-1}	504.75	4434.00	161.50
	Salicylic acid	200 mg L^{-1}	429.90	4758.50	172.50
		300 mg L^{-1}	392.80	4233.00	156.00
LSD 0.05			11.72	28.01	4.51

Table 11: Effect of irrigation quantity (%) on yield components oil yield of sunflower plant grown under sandy soil condition

	Water requirements (%)		
Treatments	50	100	LSD 0.05
Head diameter	13.38	14.62	0.65
Seed yield/plant (g)	55.11	65.19	1.51
Seed yield (t ha^{-1})	1.75	2.54	0.05
Seeds weight g-1000	62.27	72.29	0.28
Biological yield (t ha^{-1})	4.25	5.98	0.07
Straw yield (t ha^{-1})	2.50	3.44	0.04
Oil yield (kg ha^{-1})	0.67	0.91	0.02
Oil (%)	38.06	35.63	0.17
Carbohydrates (%)	14.07	14.62	0.24
Water productivity (kg m^{-3})	0.73	0.53	0.01

Table 12: Effect of different concentrations of calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) and salicylic acid (200 and 300 mg L^{-1}) on yield characters and oil yield of sunflower plant grown under sandy soil conditions

Treatments	Control	$CaCO_3$ (5 g L^{-1})	$CaCO_3$ (10 g L^{-1})	Chitosan (100 mg L^{-1})	Chitosan (150 mg L^{-1})	SA (200 mg L^{-1})	SA (300 mg L^{-1})	LSD 0.05
Head diameter (cm)	13.17	14.17	14.17	14.00	14.33	13.83	14.33	0.66
Seed yield (g/plant)	55.20	61.16	61.22	60.02	60.53	61.24	61.67	2.08
Seed yield (t ha^{-1})	1.99	2.18	2.18	2.14	2.16	2.18	2.19	0.07
1000-seeds weight (g)	63.40	64.23	66.67	69.85	65.98	70.02	70.78	1.29
Biological yield (t ha^{-1})	4.63	5.25	5.30	5.16	5.17	5.09	5.21	0.10
Straw yield (t ha^{-1})	2.64	3.07	3.12	3.02	3.01	2.91	3.02	0.07
Oil yield (kg ha^{-1})	0.68	0.78	0.79	0.82	0.77	0.82	0.85	0.02
Oil (%)	34.24	36.02	36.86	38.65	35.64	37.81	38.70	0.23
Carbohydrates (%)	13.29	14.22	14.77	14.77	14.77	14.28	14.34	0.27
Water productivity (kg m^{-3})	0.58	0.64	0.65	0.64	0.65	0.63	0.66	0.02

Yield components

Effect of irrigation quantity (%): Data presented in Table 11 showed significant differences between treatments in all studied characters. Treatment of 100% recommended irrigation quantity had superiority in all yield components (head diameter, seed yield/plant (g), seed yield (t ha^{-1}), 1000 seeds weight, biological yield (t ha^{-1}), straw yield (t ha^{-1}), oil yield (kg ha^{-1}), oil (%) and carbohydrate (%). Reducing irrigation quantity to 50% from recommended significantly reduced all studied characters. Results trend was logic because water stress causes reduction of yield.

Effect of calcium carbonate, chitosan and salicylic acid: Yield and its characters of sunflower plant as a result of calcium carbonate application (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) or salicylic acid (200 and 300 mg L^{-1}) were presented in Table 12. Data revealed that, all treatments increased significantly yield components (head diameter, seed yield/plant (g), seed yield (t ha^{-1}), 1000 seeds weight, biological yield (t ha^{-1}), straw yield (t ha^{-1}), oil yield (kg ha^{-1}), oil (%) and carbohydrate (%) as compared to the control. In general SA (300 mg L^{-1}) gave the highest values of head diameter, seed yield/plant, seed yield ha^{-1}, 1000 seeds weight, oil (%) and oil yield ha^{-1} (kg).

Interaction between calcium carbonate, chitosan, salicylic acid and irrigation quantity (%): Table 13 showed the influence of different concentrations of calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) or salicylic acid (200 and 300 mg L^{-1}) on yield components, oil and carbohydrate (%) of sunflower plants subjected to water deficit. Plants exposed to the 50% of water irrigation resulted in a significant decrease in all yield parameters and carbohydrate (%) when compared to plants grown under the level of 100% water irrigation except the oil (%). Treatment of sunflower plants with different concentrations of calcium carbonate, chitosan or salicylic acid promoted all yield parameter under water deficit as compared with the comparable level of water irrigation. The SA (200 mg L^{-1}) gave the highest values of oil yield ha^{-1} at the level 100% water irrigation and 10 g L^{-1} $CaCO_3$, 100 mg L^{-1} chitosan and 300 mg L^{-1} SA at 50% level of water irrigation. Concerning water productivity chitosan (150 mg L^{-1}) and SA (300 mg L^{-1}) gave the highest value at 50% of water irrigation requirements.

Table 13: Effect of interaction between irrigation quantity (%) and different concentrations of calcium carbonate (5 and 10 g L^{-1}), chitosan (100 and 150 mg L^{-1}) and salicylic acid (200 and 300 mg L^{-1}) on yield components oil yield of sunflower plant grown under sandy soil condition

Water requirements (%)	Treatment	Concentration	Head diameter (cm)	Seed (yield ga^{-1})	Seed yield (t ha^{-1})	1000-seeds weight (g)	Biological yield (t ha^{-1})	Straw yield (t ha^{-1})	Oil yield (kg ha^{-1})	Oil (%)	Carbohydrates (%)	Water productivity (m^3 ha^{-1}/season)
100	Control		14.00	60.33	2.39	69.77	5.52	3.13	0.79	33.14	15.37	0.50
	$CaCO_3$	5 g L^{-1}	15.00	67.24	2.61	69.90	6.22	3.61	0.89	34.00	13.45	0.55
		10 g L^{-1}	14.67	65.65	2.56	71.13	6.02	3.46	0.88	34.42	13.99	0.54
	Chitosan	100 mg L^{-1}	14.67	64.42	2.52	71.67	6.06	3.54	0.94	37.48	14.82	0.53
		150 mg L^{-1}	14.67	62.41	2.46	70.27	5.81	3.36	0.85	34.69	14.69	0.52
	Salicylic acid	200 mg L^{-1}	15.67	71.39	2.74	75.67	6.28	3.54	0.99	36.24	15.01	0.58
		300 mg L^{-1}	13.67	64.85	2.53	77.60	5.95	3.41	1.00	39.47	15.01	0.53
50	Control		12.33	50.07	1.59	57.03	3.73	2.14	0.56	35.34	14.17	0.67
	$CaCO_3$	5 g L^{-1}	13.33	55.08	1.75	58.57	4.28	2.53	0.67	38.05	13.12	0.73
		10 g L^{-1}	13.67	56.80	1.80	62.20	4.58	2.78	0.71	39.30	14.44	0.76
	Chitosan	100 mg L^{-1}	13.33	55.62	1.77	68.03	4.26	2.50	0.70	39.83	14.72	0.74
		150 mg L^{-1}	14.00	58.65	1.86	61.70	4.52	2.66	0.68	36.59	14.85	0.78
	Salicylic acid	200 mg L^{-1}	13.00	51.09	1.62	64.37	3.90	2.27	0.64	39.37	13.54	0.68
		300 mg L^{-1}	14.00	58.49	1.86	63.97	4.48	2.63	0.70	37.94	13.67	0.78
LSD 0.05			0.93	2.94	0.09	1.82	0.15	0.10	0.03	0.32	0.38	0.03

DISCUSSION

Commonly, serious reductions in plant growth, exhibited by smaller, limped chlorotic and furled leaves, were established indicating drought stress. All studied plant growth parameters significantly decreased due to water stress (50% of field capacity) in both growing seasons (Table 2). Water stress decreased growth and productivity of sunflower (*Heliantus annuus* L.) may be due to the less availability of water that reduced nutrient availability. Also, water shortage resulted in more production of ROS which led to breakdown of vital material in cells such as DNA, RNA, protein and phospholipids which reflexed to decline of cells division, elongation and development in different plant tissues[30]. The decline in growth parameters possibly due to the diminution in the activity of meristematic tissues which are responsible for cell elongation[4,31]. Moreover, plant fresh and dry weight lowered due to water shortage that resulted a decrease in chlorophyll contents that parallel to photosynthetic efficiency[32].

These results revealed that foliar application of $CaCO_3$ led to reduction in plant net transpiration and this in turn may persist higher water quantity in the plant tissues, consequently support plant metabolism, photosynthetic rate, carbohydrate metabolism and several other essential functions that affect plant growth instantly and to produce higher yield[33]. In this respect, the present results are in general accordance with those previously found by Frommer and Sonnewald[34], who observed that $CaCO_3$ spraying affected leaf photosynthesis, leading to less accumulation of TSS. Moreover, the beneficial of these anti-transpirants on increasing plant water potential and stimulating cell division and growth characters could result in enhancing fruits. These results are in accordance with those obtained by Aly *et al.*[35] and Glenn *et al.*[36].

The stimulatory effects of chitosan (CHT) on plant growth can be attributed to fertilizing characteristic of CHT that provide plants with important nutrients. This result is almost identical to Katiyar *et al.*[37] they found that both 0.1 and 0.5% chitosan enhanced dry weights of land rice and sweet pepper plants. This stimulatory effect of chitosan may be due to an accessibility and intake of water and important nutrients particularly phosphorous, which act as key nutrient that playing an essential role in the metabolism of carbohydrates, cell division and formation of DNA and RNA[8]. Chitosan induced ABA activity, which plays a crucial role in reduced the rate of transpiration when the plant subjected to stress phase[10]. It also, regulate cell osmotic pressure and decreasing the buildup of free radicals by increasing oxidative enzyme pursuit. In both pot and field conditions, maize plants treated with Cu-CHT enhanced plant height, stem diameter, root length and number[38].

The SA exogenously applied can significantly increase plant growth under water stress conditions[39]. Salicylic acid prevents the high activity of ROS, improve cell division and elongation of plants tissues, activate translocation of soluble carbohydrates, ion uptake and membrane permeability which reflected on more growth and development[40,41].

Photosynthetic pigments (Table 5-7) significantly decreased under water stress in both growing seasons as compared with the control plants. The reduction in photosynthetic pigments in response to water stress might be due to decrease in leaf fresh and dry weight Table 2 which accompanied with reduction in exposed area to light energy responsible on photosynthesis. This mainly due to the closing of stomata, which limits CO_2 diffusion into the leaf[42]. Water deficit also, reduced the uptake of essential elements and photosynthetic capacity[43] imprudent cumulation of reactive oxygen species[44] which cause oxidative damage to DNA, lipid and proteins concomitant with decrease in plant photosynthetic pigments.

Foliar application of antitranspirants were tested to improve metabolism and production of plants and counteract the inhibitory effects of water deficit on photosynthetic synthesis. Similar results were recorded by El-Said[45] found that foliar application of $CaCO_3$ significantly enhanced total chlorophyll values in eggplant compared to untreated plants. In this connection, calcium regulates the phosphatase enzyme activities in the carbon reduction cycle and adjusts chloroplast NAD^+ kinase activity by a calmodulin-like protein[46]. Dolatabadian *et al.*[47] postulated that, calcium involved in regulating leaf senescence.

Chitosan may mitigate water stress actuate on photosynthetic pigments by promoting endogenous quantity of cytokinins and greater accessibility of amino compounds disseminate from chitosan[48]. Treatment with chitosan promoted the ultimate photosynthetic rates of soybean and maize, consequently enhances stomatal conductance and transpiration rate[49].

Exogenous application of SA markedly improved the growth, photosynthesis, antioxidant enzyme activity, stoma and chloroplast development of *D. superbus*[50]. Salicylic acid and chitosan are conceived covering materials inhibit water loss and they permit gases to pervade but not liquids which enable normal plant respiration but decrease 20% of transpiration rate. Also, they accountable to decrease leaf temperature and stimulate leaf reflectance[51,52]. Daneshmand *et al.*[53] postulate that, SA treatments increase photosynthetic pigments values, under osmotic stress conditions, via its role in protects photosynthetic apparatus through enhancing the capability of cell antioxidation and induction of new proteins.

Total soluble sugars increased under drought stress, that's played a critical role in, osmotic regulation, carbon storage and radical scavenging[32]. The reduction in total sugar values influenced by water deficit treatments may be attributed to its repressive action on photosynthetic pigment formation (Table 5) or to the bustle of ribulose diphosphate carboxylase leading to lowering in all sugar fractions[54]. Additionally, it is concluded that, proline reservation in plant tissues through various abiotic stresses might act as bio vital role against oxidative damages caused by (ROS) via its action as a single oxygen quencher[55-57].

Present results revealed that all tested foliar applications increased all free amino acids, TSS and proline. Dolatabadian *et al.*[47] reported that, the foliar applications of calcium increased proline accumulation in wheat leaves. Similar results were confirmed by El-Said[45] found that foliar application of $CaCO_3$ significantly enhanced TSS and proline contents in eggplant as compared with the untreated plants. Furthermore, SA improved the proline content which activates the enzymes of proline metabolism[58].

Carbohydrates may act as ROS scavengers and contribute to increase in membrane stabilization according to Bohnert and Jensen[59]. Also, El-Miniawy *et al.*[60] reported that total carbohydrates of strawberry increased as a result of chitosan spraying. Chitosan foliar application increased the concentration of simple organic molecules such as, sugar and free amino acids which playing a role in regulation of plant osmosis and consequently better plant growth and yield under un-favorable environmental conditions[61].

The substantial increase in carbohydrate percent by SA may be due to the activation of photosynthetic machinery, as a result of the stimulatory effects of the used plant growth bio stimulators on photosynthetic process. The SA treatment might also be assumed to inhibit polysaccharide-hydrolyzing enzyme system on one hand and/or accelerate the incorporation of soluble sugars into polysaccharides[62]. Moreover, El-Mageed[63] concluded that the SA enhanced the TSS which contributed as a solute for the osmotic regulation and /or a substrate for the protein and carbohydrates synthesis in roots and thus for growth of plants.

The suppression in sunflower yield as a result of water stress has been documented[64] There are numerous theories about the impact of water deficit on yield, via decreases the number of leaves and branches/plant (Table 2) as well as leaf number, resulting in a reduction in the carbon assimilation accompanied with photosynthetic rate (Table 5) and lowered radiation interception by plants reflected in less biomass and photoassimilate towards the developing organs[65]. In this connection, Liu *et al.*[66] describe another possibility that, water stress increased the rate of flower and pod deformation and abortion. Recent suggestion accomplished by Andersen *et al.*[67] in maize, low water potential interrupted metabolism of carbohydrate by inhibit the activity essential enzyme responsible on the breakdown of sucrose through stages of fruit maturation and seed establishment.

Using anti-transpirants can decrease transpiration rate in consequences persist additional water in plant tissues that would indicate favorably on plant assimilation, photosynthetic rate and enhanced photosynthate translocation from the green parts toward wheat grain, which is important for better quality and quantity of yield[4].

Bahawireth[68] suggested that, $CaCO_3$ increased water quantity applied to plant to persist higher moisture values in the soil and this in turn might prefer to the plant assimilation that leads to increase the plant growth characters and to produce higher yield on eggplant. Calcium carbonate promoted significantly the oil yield of olive[69]. Moreover, Abd-Alhamid *et al.*[70] concluded that the highest yield (kg/tree) and fruit oil (%) of Kalamata oil tree were recorded at treatment with 7% $CaCo_3$ at different dates.

Chitosan application increase in cowpea yield due to its role in promoting physiological approach, vegetative proliferation, photoassimilates translocation from source to sink, leaf-blade depth and the dimensions of the xylem and phloem vessels[49]. Some of these promoting effects of CHT exhibited on ear length and weight/plot, grain yield/plot and weight[38]. In addition, treatment with chitosan surpassed to lesser extent production of dry matter and oil yield reduction of plants grown under water deficit. This stimulatory effect of chitosan was accompanied by osmoregulation via proline, which increased in thyme leaves[71,72]. Salicylic acid as phenolic phytohormone is found in plants with vital roles in plant development, photosynthetic capacity, ion translocation[73]. It also stimulates specific modifications in leaf and chloroplast structure. In addition, it is promoting plant growth regulator of phenolic nature and classified as improvement promoter and enhances plant force under biotic and abiotic stresses). Moreover, Hayat *et al.*[74] proved that salicylic acid was responsible for protecting the plants from all stresses and retarding reactive oxygen forms that destroyed the plant cells. Under the water deficit, treatment with salicylic acid stimulated the oil accumulation up to 49.27% via stimulation of plant growth and the activation of enzymes responsible on photosynthate metabolism[32]. In this regard, Sohrabi *et al.*[75] recorded that, the oil yield of evening primrose plants treated with salicylic acid increased significantly as compared to the control. The effect of SA in seed oil accumulation might be correlated to the several factors: Species, growth behavior as well as developmental stage of application.

The 50% irrigation treatment recorded the highest water productivity value with anti-transpirant treatments expressed by highest produced yield as compared to untreated plants grown under the such level of water deficit. In this connection, the water productivity increased under water stress and further increased by SA and $CaCO_3$ applications. However, under water stress conditions, the produced yield showed progressive reduction following the considerable losses of water contents[14,63].

This study explores the stimulatory effects of anti-transpirants on sunflower plants grown under water stress. It also, explain some physiological aspects of these compounds in increasing capability of plants to facing water deficit. However, further studies must be done to evaluate the physiological effects of antitranspirants (chitosan, $CaCO_3$ and salicylic) on sunflower and other several plants grown under water deficit levels at molecular levels (i.e., enzyme, protein picture etc).

CONCLUSION

Foliar application of antitranspirants could effectively improve water stress conditions of sunflower plants under sandy soil conditions. Such mechanism can enhance resistance to drought stress through enhancing and activation the defense system of plant and protecting the photosynthetic assimilates and thereby increasing the carbohydrate, oil contents and the growth rate. The results also found that, the optimum combinations (100% of field capacity with 150 mg L^{-1} chitosan concentration as foliar application) for maximum seed yield accompanied by high water productivity. Foliar application of anti-transpirants is recommended for crop production under water scarcity.

SIGNIFICANCE STATEMENT

This study discovers the possible effect of anti-transpirants that can be beneficial for plants grown under water deficit. This study will help the researcher to understand the possible effect of these compounds. Thus, a new theory on these micronutrients' combination and possibly other combinations, may be arrived at.

REFERENCES

1. Tambussi, E.A., J. Bort and J.L. Araus, 2007. Water use efficiency in C_3 cereals under Mediterranean conditions: A review of physiological aspects. Ann. Applied Biol., 150: 307-321.
2. Prakash, M. and K. Ramachandran, 2000. Effects of moisture stress and anti transpirants on leaf chlorophyll. J. Agron. Crop Sci., 184: 153-156.
3. Ahmed, A.Y.M., 2014. Impact of spraying some antitranspirants on fruiting of williams bananas grown under Aswan region conditions. Stem Cell, 5: 34-39.
4. Abdallah, M.M.S., H.M.S. El-Bassiouny and M.A. AbouSeeda, 2019. Potential role of kaolin or potassium sulfate as anti-transpirant on improving physiological, biochemical aspects and yield of wheat plants under different watering regimes. Bull. Natl. Res. Centre, Vol. 43, No. 1. 10.1186/s42269-019-0177-8.
5. New, N., S. Chandrkrachang and W.F. Stevens, 2004. Application of chitosan in myanmar's agriculture sector. Proceedings of the 6th Asia Pacific Chitin and Chitosan Symposium, May 23-26, 2004, The National University of Singapore, Singapore.
6. Farouk, S., K.M. Ghoneem and A.A. Ali, 2008. Induction and expression of systematic resistance to downy mildew disease in cucumber plant by elicitors. Egypt. J. Phytopathol., 36: 95-111.
7. Farouk, S., A.A. Mosa, A.A. Taha, H.M. Ibrahim and A.M. El-Gahmery, 2011. Protective effect of humic acid and chitosan on radish (*Raphanus sativus*, L. var. sativus) plants subjected to cadmium stress. J. Stress Physiol. Biochem., 7: 99-116.
8. Guan, Y.J., J. Hu, X.J. Wang and C.X. Shao, 2009. Seed priming with chitosan improves maize germination and seedling growth in relation to physiological changes under low temperature stress. J. Zhejiang Univ. Sci. B, 10: 427-433.
9. Sheikha, S.A.A.K. and F.M. Al-Malki, 2011. Growth and chlorophyll responses of bean plants to the chitosan applications. Eur. J. Sci. Res., 50: 124-134.
10. Lim, C.W., W. Baek, J. Jung, J.H. Kim and S.C. Lee, 2015. Function of ABA in stomatal defense against biotic and drought stresses. Int. J. Mol. Sci., 16: 15251-15270.
11. Nasraoui, B., C. Baltus and P. Lepoivre, 1999. Effect of the antitranspirant film folicote on the *in vitro* release of esterase activity and on the infection of bean leaves with *Botrytis cinerea*. Arab J. Plant Prot., 17: 121-124.
12. Iriti, M., V. Picchi, M. Rossoni, S. Gomarasca, N. Ludwig, M. Gargano and F. Faoro, 2009. Chitosan antitranspirant activity is due to abscisic acid-dependent stomatal closure. Environ. Exp. Bot., 66: 493-500.
13. Song, W.Y., Z.B. Zhang, H.B. Shao, X.L. Guo and H.X. Cao *et al*., 2008. Relationship between calcium decoding elements and plant abiotic-stress resistance. Int. J. Biol. Sci., 4: 116-125.
14. Ramadan, A.E.Y. and M.M. Omar, 2017. Effect of water regime and antitranspirants foliar on production and yield of cabbage in summer season. Egypt. J. Soil Sci., 57: 467-476.
15. Misra, B.B., B.R. Acharya, D. Granot, S.M. Assmann and S. Chen, 2015. The guard cell metabolome: Functions in stomatal movement and global food security. Front. Plant Sci., Vol. 6. 10.3389/fpls.2015.00334.
16. Caterina, R.D., M.M. Giulian, T. Rotunno, A.D. Caro and Z. Flagella, 2007. Influence of salt stress on seed yield and oil quality of two sunflower hybrids. Ann. Applied Biol., 151: 145-154.
17. Dolatabadian, A. and R.S. Jouneghani, 2009. Impact of exogenous ascorbic acid on antioxidant activity and some physiological traits of common bean subjected to salinity stress. Not. Bot. Hort. Agrobot. Cluj, 37: 165-172.
18. Abdallah, M., A.A. Abd El-Monem, R.A. Hassanein and H.M.S. El-Bassiouny, 2013. Response of sunflower plant to the application of certain vitamins and arbuscular mycorrhiza under different water regimes. Aust. J. Basic Applied Sci., 7: 915-932.
19. Allen, R.G., L.S. Pereira, D.R. Raes and M. Smith, 1998. Crop evapotranspiration: Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56, Food and Agricultural Organization of the United Nations, Rome.
20. Martins, P.E.S., E.R. da Silva, J.G.C. Ruiz, G.R. Barbosa, J.R. Zanini and M.V.M. Filho, 2014. Uniformity of precipitation and radial profile of the super 10 sprinkler at different operating pressures. J. Water Resour. Prot., 6: 951-960.
21. Lichtenthaler, H.K. and C. Buschmann, 2001. Chlorophylls and Carotenoids: Measurement and Characterization by UV-VIS Spectroscopy. In: Current Protocols in Food Analytical Chemistry, Wrolstad, R.E., T.E. Acree, H. An, E.A. Decker and M.H. Penner *et al*. (Eds.). John Wiley and Sons, New York, USA., pp: F4.3.1-F4.3.8.
22. Prud'homme, M.P., B. Gonzalez, J.P. Billard and J. Boucaud, 1992. Carbohydrate content, fructan and sucrose enzyme activities in roots, stubble and leaves of ryegrass (*Lolium perenne* L.) as affected by source/sink modification after cutting. J. Plant Phys., 140: 282-291.
23. Bates, L.S., R.P. Waldren and I.D. Teare, 1973. Rapid determination of free proline for water-stress studies. Plant Soil, 39: 205-207.
24. Vartanian, N., P. Hervochon, L. Marcotte and F. Larher, 1992. Proline accumulation during drought rhizogenesis in *Brassica napus* var. *oleifera*. J. Plant Physiol., 140: 623-628.
25. Yemm, E.W., E.C. Cocking and R.E. Ricketts, 1955. The determination of amino-acids with ninhydrin. Analyst, 80: 209-214.

26. AOAC., 1990. Official Methods of Analysis of the AOAC. Methods 932.06, 925.09, 985.29, 923.03. 15th Edn., Association of Official Analytical Association of Official Analytical Chemists, Arlington, VA., USA.
27. James, L.G., 1988. Principles of Farm Irrigation System Design. John Wiley and Sons Inc., New York, pp: 85-99.
28. Steel, R.G.D. and J.H. Torrie, 1998. Principles and Procedures of Statistics: A Biometric Approach. McGrawHill Press, New York, USA.
29. Freed, R.D., S.P. Eisensmith, E.H. Everson, M. Weber, E. Paul and D. Islcib, 1988. MSTATC: Version 2.10. Michigan State University, USA.
30. Sahin, U., M. Ekinci, F.M. Kiziloglu, E. Yildirim, M. Turan, R. Kotan and S. Ors, 2015. Ameliorative effects of plant growth promoting bacteria on water-yield relationships, growth and nutrient uptake of lettuce plants under different irrigation levels. Hortscience, 50: 1379-1386.
31. El Sebai, T.N., M.M.S. Abdallah, H.M.S. El-Bassiouny and F.M. Ibrahim, 2016. Amelioration of the adverse effects of salinity stress by using compost, *Nigella sativa* extract or ascorbic acid in quinoa plants. Int. J. PharmTech Res., 9: 127-144.
32. Bakry, B.A., D.M. El-Hariri, M.S. Sadak and H.M.S. El-Bassiouny, 2012. Drought stress mitigation by Foliar application of salicylic acid in two linseed varieties grown under newly reclaimed sandy soil. J. Applied Sci. Res., 8: 3503-3514.
33. El-Gioushy, S.F., M.H.M. Baiea, M.A. Abdel Gawad-Nehad and O.A. Amin, 2017. Influence of $CaCO_3$ and green miracle foliar application on preventing sunburn injury and quality improvement of Keitt mango fruits. Middle East J. Agric. Res., 6: 1098-1110.
34. Frommer, W.B. and U. Sonnewald, 1995. Molecular analysis of carbon portioning in solanaceous species. J. Exp. Bot., 46: 587-607.
35. Aly, M., N.A. El-Megeed and R.M. Awad, 2010. Reflective particle films affected on, sunburn, yield, mineral composition and fruit maturity of 'Anna' apple (*Malus domestica*) trees. Res. J. Agric. Biol. Sci., 6: 84-92.
36. Glenn, D.M., A. Erez, G.J. Puterka and P. Gundrum, 2003. Particle films affect carbon assimilation and yield in Empire' apple. J. Am. Soc. Hortic. Sci., 128: 356-362.
37. Katiyar, D., A. Hemantaranjan, B. Singh and A.B. Nishant, 2014. A future perspective in crop protection: Chitosan and its oligosaccharides. Adv. Plants Agric. Res., Vol. 1, No. 1. 10.15406/apar.2014.01.00006.
38. Choudhary, R.C., R.V. Kumaraswamy, S. Kumari, S.S. Sharma and A. Pal *et al*., 2017. Cu-chitosan nanoparticle boost defense responses and plant growth in maize (*Zea mays* L.). Scient. Rep., 7: 9754-9765.
39. Kováčik, J., J. Grúz, M. Bačkor, M. Strnad and M. Repčák, 2009. Salicylic acid-induced changes to growth and phenolic metabolism in *Matricaria chamomilla* plants. Plant Cell Rep., Vol. 28, No. 1. 10.1007/s00299-008-0627-5.
40. Simaei, M., R.A. Khavari-Nejad and F. Bernard, 2012. Exogenous application of salicylic acid and nitric oxide on the ionic contents and enzymatic activities in NaCl-stressed soybean plants. Am. J. Plant Sci., 3: 1495-1503.
41. Nada, M.M. and M.A.M. Abd El-Hady, 2019. Influence of salicylic acid on cucumber plants under different irrigation levels. J. Plant Prod., 10: 165-171.
42. Lawlor, D.W. and G. Cornic, 2002. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. Plant Cell Environ., 25: 275-294.
43. Abou El-Kheir, M.S.A., S.A. Kandil and H.A. El-Zeiny, 2001. Response of some wheat cultivars to water stress imposed at certain growth stages. Egypt. J. Applied. Sci., 16: 82-98.
44. Yazdanpanah, S., A. Baghizadeh and F. Abbassi, 2011. The interaction between drought stress and salicylic and ascorbic acids on some biochemical characteristics of *Satureja hortensis*. Afr. J. Agric. Res., 6: 798-807.
45. El-Said, E.M., 2015. Effect of irrigation intervals and some antitranspirants on growth, yield and fruit quality of eggplant. J. Plant Prod., 6: 2079-2091.
46. Wang, Q., S. Yang, S. Wan and X. Li, 2019. The significance of calcium in photosynthesis. Int. J. Mol. Sci., Vol. 20, No. 6. 10.3390/ijms20061353.
47. Dolatabadian, A., S.A.M.M. Sanavy, M. Gholamhoseini, A.K. Joghan and M. Majdi *et al*., 2013. The role of calcium in improving photosynthesis and related physiological and biochemical attributes of spring wheat subjected to simulated acid rain. Physiol. Mol. Biol. Plants, 19: 189-198.
48. Chibu, H. and H. Shibayama, 2001. Effects of Chitosan Applications on the Growth of Several Crops. In: Chitin and Chitosan in Life Science, Uragami, T., K. Kurita and T. Fukamizo (Eds.)., Yamaguchi, Japan, pp: 235-239.
49. Khan, M.H., K.L.B. Singha and S.K. Panda, 2002. Changes in antioxidant levels in *Oryza sativa* L. roots subjected to NaCl-salinity stress. Acta Physiol. Plant., 24: 145-148.
50. Ma, X., J. Zheng, X. Zhang, Q. Hu and R. Qian, 2017. Salicylic acid alleviates the adverse effects of salt stress on *Dianthus superbus* (Caryophyllaceae) by activating photosynthesis, protecting morphological structure and enhancing the antioxidant system. Front. Plant Sci., Vol. 8. 10.3389/fpls.2017.00600.
51. Photchanachai, S., J. Singkaew and J. Thamthong, 2006. Effects of chitosan seed treatment on *Colletotrichum* sp. and seedling growth of Chili cv. 'Jinda'. Acta Hortic., 712: 585-590.
52. Joseph, B., D. Jini and S. Sujatha, 2010. Insight into the role of exogenous salicylic acid on plants grown under salt environment. Asian J. Crop Sci., 2: 226-235.
53. Daneshmand, F., M.J. Arvin and K.M. Kalantari, 2010. Acetylsalicylic acid ameliorates negative effects of NaCl or osmotic stress in *Solanum stoloniferum in vitro*. Biol. Planta., 54: 781-784.

54. Stibrova, M., M. Doubravova, A. Brezlova and A. Fridrich, 1986. Effects of heavy metals ions on growth and biochemical characteristics of photosynthesis of barley. Photosynthetica, 20: 416-425.
55. Abdallah, M.M.S., Z.A. Abdelgawad and H.M.S. El-Bassiouny, 2016. Alleviation of the adverse effects of salinity stress using trehalose in two rice varieties. S. Afr. J. Bot., 103: 275-282.
56. El-Bassiouny, H.M.S., A.A. Abd El-Monem, M.M.S. Abdallah and K.M. Soliman, 2018. Role of arbuscular mycorrhiza, α-tocopherol and nicotinamide on the nitrogen containing compounds and adaptation of sunflower plant to water stress. Biosci. Res., 15: 2068-2088.
57. Mohawesh, O.E., K.M. Al-Absi and M.J. Tadros, 2010. Effect of antitranspirant application on physiological and biochemical parameters of three orange cultivars grown under progressive water deficit. Adv. Hort. Sci., 24: 183-194.
58. Khan, M.I.R., N. Iqbal, A. Masood, T.S. Per and N.A. Khan, 2013. Salicylic acid alleviates adverse effects of heat stress on photosynthesis through changes in proline production and ethylene formation. Plant Signaling Behav., Vol. 8. 10.4161/psb.26374.
59. Bohnert, H.J. and R.G. Jensen, 1996. Metabolic engineering for increased salt tolerance-the next step. Funct. Plant Biol., 23: 661-667.
60. El-Miniawy, S.M., M.E. Ragab, S.M. Youssef and A.A. Metwally, 2013. Response of strawberry plants to foliar spraying of chitosan. Res. J. Agric. Biol. Sci., 9: 366-372.
61. Mathew, R. and P.D. Sankar, 2014. Comparison of major secondary metabolites quantified in elicited cell cultures, non-elicited cell cultures, callus cultures and field grown plants of *Ocimum* . Int. J. Pharm. Pharm. Sci., 6: 102-106.
62. Allah, M.M.S.A., H.M.S. El-Bassiouny, T.A.E. Elewa and T.N. El-Sebai, 2015. Effect of salicylic acid and benzoic acid on growth, yield and some biochemical aspects of quinoa plant grown in sandy soil. Int. J. ChemTech. Res., 8: 216-225.
63. El-Mageed, T.A., W.M. Semida, G.F. Mohamed and M.M. Rady, 2016. Combined effect of foliar-applied salicylic acid and deficit irrigation on physiological-anatomical responses and yield of squash plants under saline soil. S. Afr. J. Bot., 106: 8-16.
64. Costa, R.C.L., A.K.S. Lobato, C.F.O. Neto, P.S.P. Maia, G.A.R. Alves and H.D. Laughinghouse, 2008. Biochemical and physiological responses in two *Vigna uguiculata* (L.) walp. Cultivars under water stress. J. Agron., 7: 98-101.
65. Hefny, M.M., 2011. Agronomical and biochemical responses of white *Lupinus albus* L. genotypes to contrasting water regimes and inoculation treatments. J. Am. Sci., 7: 187-198.
66. Liu, F., M.N. Andersen and C.R. Jensen, 2003. Loss of pod set caused by drought stress is associated with water status and ABA content of reproductive structures in soybean. Funct. Plant Biol., 30: 271-280.
67. Andersen, M.N., F. Asch, Y. Wu, C.R. Jensen, H. Næsted, V.O. Mogensen and K.E. Koch, 2002. Soluble invertase expression is an early target of drought stress during the critical, abortion-sensitive phase of young ovary development in maize. Plant Physiol., 130: 591-604.
68. Bahawireth, M.A.M., 2011. Physiological and yield performance of some okra and eggplant genotypes under water stress conditions. Ph.D. Thesis, Department Horticulture and Vegetable Crops, Assiut University, Egypt.
69. Squeo, G., R. Silletti, C. Summo, V.M. Paradiso, A. Pasqualone and F. Caponio, 2016. Influence of calcium carbonate on extraction yield and quality of extra virgin oil from olive (*Olea europaea* L. cv. Coratina). Food Chem., 209: 65-71.
70. Abd-Alhamid, N., L.F. Hagagg, M.F. Maklad and M.A. Raslan, 2019. Effect of Kaolin and calcium carbonate on yield quantity and quality of Kalamata and Manzanillo olive trees. Middle East J. Applied Sci., 9: 191-200.
71. Bistgani, Z.E., S.A. Siadat, A. Bakhshandeh, A.G. Pirbalouti and M. Hashemi, 2017. Interactive effects of drought stress and chitosan application on physiological characteristics and essential oil yield of *Thymus daenensis* Celak. Crop J., 5: 407-415.
72. Malerba, M. and R. Cerana, 2018. Recent advances of chitosan applications in plants. Polymers, Vol. 10, No. 2. 10.3390/polym10020118.
73. Hayat, S. and A. Ahmad, 2007. Salicylic Acid-A Plant Hormone. Springer Publishers, Dordrecht, The Netherlands.
74. Hayat, Q., S. Hayat, M. Irfan and A. Ahmad, 2010. Effect of exogenous salicylic acid under changing environment: A review. Environ. Exp. Bot., 68: 14-25.
75. Sohrabi, O., A. Ghasemnezhad, A. Nadimi and M. Shahbazy, 2017. Effects of some agronomic techniques on oil yield and composition of *Oenothera biennis* L. J. Med. Plants By-Prod., 2: 181-189.