Predıctıng The Role Of Antıoxıdants And Irrıgatıon On Sunflower Yıeld Grown Under Salıne Condıtıons

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Abstract

A field experiment was executed to study the influence of salinity , antioxidant application and cultivars on plant yield . Prediction equations were developed and used to predict sunflower yield under two levels of soil salinity(4.7dSm^{-1} and 12.8dSm^{-1}) in addition to application of three types of antioxidants (ascorbic, salicylic and oxalic acids). Also models were used to predict sunflower yield when increasing the concentration of antioxidants up to 300 ppm . Furthermore models were used to reduce the harm effect of salinity and improve sunflower potential yield by increasing the amount of irrigation water by 10%, reducing soil pH by 0.3 through applying organic manure either using the same amount of irrigation water or conserving some . The results showed that sunflower yield was highly reduced under saline soil , although spraying plants with antioxidants especially oxalic acid was helpful in improving plant yield but was still lower than optimum. Modeling also proved that increasing the amount of irrigation resulted in yield improvement reaching 86.9% under high soil salinity level. Also , modeling revealed that reducing soil pH under high salinity level improved sunflower yield when using oxalic acid by 57.14%. While on limiting irrigation by 343 and 340 m^3/ fed and reducing soil pH under saline condition gave the most yield improvement when using ascorbic acid. Therefore it is recommended to spray sunflower plants with oxalic acid to relief salinity stress either under abundant amount of irrigation or reducing pH without an increase in the amount of water . Furthermore under deficit irrigation , spraying plants with ascorbic acid is preferable under saline soil and reduced pH .

Key words: salinity stress , irrigation deficit, yield, prediction equations, modeling.

INTRODUCTION

Sunflower is one of the most important edible oil crops in Egypt. Sunflower cultivars may vary with respect to their mean yield and their interaction with different environmental stresses [1]. Sunflower is moderately sensitive to soil salinity, where it can tolerate salinity up to EC equals to 1.7 dS/m [2]. Salt stress causes stomatal closure, which reduces the CO_2 to O_2 ratio in the leaves and inhibits CO_2 fixation [3]. These conditions increase the rate of reactive oxygen species (ROS) formation [4]. To combat the toxic effect of ROS, plants have an antioxidant defense system, which differ among different crops species in their ability to remove or scavenge ROS [5]. Salts in the soil water solution can reduce evapotranspiration by making soil water less available for plant root extraction. Furthermore, plant growth is reduced under saline conditions, which impacts transpiration by reducing ground cover [6]. Assessment of different adaptation options to be used to reduce the harm effects of soil salinity on sunflower yield can be easy done by Modeling. Under these conditions, modeling could be a tool to determine the best management package for sunflower production, which could save time and money. The objectives of this research are: (i) to predict sunflower yield under saline conditions and under the application of three different types of antioxidants. (ii) to estimate alternatives using models for reducing the harm effects of soil salinity on sunflower crop yield.

MATERIALS AND METHODS

Two field experiments were conducted during the summer season of 2004 and 2005 at two different sites of soil salinity levels (4.7 dSm^{-1} and 12.8 dSm^{-1}) on the experimental farm at Demo, Faculty of Agriculture, Fayoum University, Egypt. A randomized complete block design was used with three replications. The experiment was designed to study the influence of these two salinity levels of soil and three different types of antioxidants i.e. ascorbic acid, oxalic acid and salicylic acid (at 100 and 200 ppm concentration), in addition to control treatment (without antioxidant spray) on the yield of three sunflower cultivars (Euroflour, Vidoc and Sakha 53). Sowing was done on the last week of May for the two seasons. The experimental plots consisted of five rows; each was 5 m long and the 0.7 m width. The seeds were sown within the rows at 20 to 25 cm apart. Fertilization was accomplished using ammonium nitrate (33.5% N), calcium super phosphate (15.5% P_2O_2) and potassium sulfate (48.0 K_2O) at the rate of 200, 200, and 50 kg/fed, respectively. The total irrigation water applied was 766m^3/ha and 8174m^3/ha for the two soil sites (4.7 and 12.8 dSm^{-1}) salinity levels respectively, which were calculated and recorded within the farm, through surface irrigation system. The recommended cultural practices for the growing sunflower plants were followed. The tested antioxidants were sprayed twice at 30 and 60 days after planting. The antioxidants were mixed with tween-20 as a wetting agent. Harvest was done after 90 to 105 days after planting depending on the cultivar type. Soil physical and chemical analyses were done according to Jackson [7] (Table 1).

Table (1): Soil physical and chemical analyses of the two sites used in the experiments

Property	Site1(4.7 dSm^{-1})	Site2 (12.8 dSm^{-})
Physical Clay % Silt% Sand % Soil texture	 29.5 20.5 50.0 Sandy clay loam	 29.8 21.7 50.5 Sandy clay loam
Chemical pH EC (dSm^{-1}) Organic matter % $CaCO_3$	 7.34 4.70 1.70 6.45	 8.10 12.8 0.84 11.62

Regression analysis [8] was used to develop models to predict sunflower yield. Two parameters were used to increase the precision, coefficient of determination (R^2) and standard error of estimates (SE%). In order to obtain a precision prediction, R^2 should be near to one and SE% should be near to zero. Coefficient of determination is the amount of variability due to all independent variables, and standard error of estimates is a measurement of precision i.e. closeness of predicted and observed yield to each other. Several models were developed to predict the yield of sunflower as followed:

Model[1]: predict sunflower yield under saline conditions.

Model[2]: predict sunflower yield under saline conditions and the application of ascorbic acid.

Model[3]: predict sunflower yield under saline conditions and the application oxalic acid.

Model[4]: predict sunflower yield under saline conditions and the application of salicylic acid.

These models were used to predict sunflower yield under the concentration of 300 ppm of the three antioxidants to determine the potential improvement in sunflower yield. Furthermore, to reduce the harm effect of salinity and improve sunflower potential yield, three alternatives were examined as followed:

1. Increasing of the amount of applied irrigation water by 10 %.
2. Reducing soil pH by 0.3 through applying organic manure and using the same amount of irrigation water.
3. Reducing soil pH by 0.3 and conserving some of the applied irrigation water.

RESULTS

The yield of the three chosen sunflower varieties (Euroflor, Vidoc and Sakha 53), was estimated under different soil salinity levels 4.7dSm^{-1} and 12.8 dSm^{-1} in addition to the use of three different antioxidants (ascorbic, oxalic and salicylic) with two concentration levels (100 and 200 ppm). Table (2 & 3).

Results recorded in Table (2 & 3) revealed that there was no great difference in yield between the three chosen varieties they were all seriously affected by salinity stress especially under 12.8 dSm^{-1}, although Sakha 53 showed a higher resistance to salinity more than the other varieties so, it was preferable to pool the yield average of the three sunflower varieties to be used in the predictive models.

Table (2): Yield of three varieties of sunflower (ton/ha) under 4.7 dSm^{-1} level as affected by antioxidants.

Treatment	Conc. (ppm)	Euroflor	Vidoc	Sakha 53	Average
Control		1.66	1.80	1.85	1.77
Ascorbic	100	1.99	2.30	2.35	2.22
	200	2.14	2.52	2.54	2.40
Oxalic	100	2.06	2.35	2.42	2.28
	200	2.23	2.57	2.59	2.46
Salicylic	100	1.97	2.33	2.35	2.22
	200	2.09	2.50	2.50	2.36

Table (3): Yield of three varieties of sunflower (ton/ha) under 12.8 dSm^{-1} level as affected by antioxidants.

Treatment	Conc. (ppm)	Euroflor	Vidoc	Sakha 53	Average
Control		0.91	0.98	0.96	0.95
Ascorbic	100	1.01	1.18	1.20	1.13
	200	1.10	1.25	1.27	1.21
Oxalic	100	1.06	1.20	1.22	1.16
	200	1.13	1.30	1.30	1.24
Salicylic	100	1.01	1.08	1.08	1.06
	200	1.03	1.176	1.20	1.14

PREDİCTİON MODELS

Four models were developed to predict sunflower yield under saline conditions and under saline conditions and the application of antioxidants as followed:

Model [1]:
$Y_{control}$ =3.79-0.73*pH-0.0003*Saln+0.001*Irri
R^2 = 0.9356 SE% = 3.8635

Model [2]:
$Y_{Ascorbic}$ = 7.18+0.0006*Asc-0.0004*Saln-1.14* pH+0.001*Irri
R^2 = 0.9480 SE% = 3.9117

Model [3]:
Y_{Oxalic}=6.78+0.0005*Oxa-0.0004*Saln-1.08*pH+ 0.001*Irri
R^2 = 0.9442 SE% = 3.5942

Model [4]:
$Y_{Salicylic}$ = 3.86+0.0004*Sal-0.0004*Salin-0.68* pH+0.001*Irri
R^2 = 0.9330 SE% = 4.7178

These models are characterized by high R^2 and low SE%, which reflect the accuracy of it.

SUNFLOWER YİELD PREDİCTİON

Sunflower yield was predicted using the above mentioned models and predicted values was compared to actual yield to determine the accuracy of these models.

2.1. Predicted yield under control treatment

Model [1] was used to predict sunflower yield under control treatment and predicted yield was compared with the actual yield. Results in Table (4) indicated that model [1] predictions for both salinity levels were accurate, where percent difference between actual and predicted yield was low (1.89 and 2.00 % for both soil salinity levels).

Table (4): Actual and predicted sunflower yield for the control treatment

Soil salinity	Yield (ton/ha)		Percent difference
	Actual	Predicted	
4.7 dSm^{-1}	1.78	1.81	1.89
12.8 dSm^{-1}	0.96	0.94	2.00

2.2. Predicted yield under ascorbic acid treatment

Model [2] was used to predict sunflower yield under the application of ascorbic acid treatment and predicted yield was compared with actual yield (Table 5). Results revealed that the yield predictions of model [2] were close to the actual yield under the application of ascorbic acid for its two levels of concentrations. Percent difference between actual and predicted yields was between 0.98 and 2.90 % for both soil salinity levels. Moreover, the model predicted sunflower yield under the concentration of 300 ppm, where it was 2.44 and 1.32 ton/ha for the two levels of soil salinity of 4.7 dSm^{-1} and 12.8 dSm^{-1}, respectively.

Table (5): Actual and predicted sunflower yield for ascorbic acid treatment

Soil salinity	Ascorbic acid	Yield (ton/ha)		Percent difference
		Actual	Predicted	
4.7 dSm^{-}	100 ppm	2.22	2.19	0.98
	200 ppm	2.40	2.33	2.90
	300 ppm	-	2.47	-
12.8 dSm^{-1}	100 ppm	1.13	1.10	2.13
	200 ppm	1.21	1.18	1.80
	300 ppm	-	1.32	-

Predicted yield under oxalic acid treatment

Sunflower yield was predicted using Model [3] under the application of oxalic acid treatment. Predicted yield was compared with actual yield (Table 6). Results revealed that the yield predictions of model [3] were close to the actual yield under the application of oxalic acid for its two levels of concentrations. Percent difference between actual and predicted yields was between 0.58 and 3.98 % for both salinity levels. Furthermore, the model predicted sunflower yield under the concentration of 300 ppm, where it was 2.46 and 1.36 ton/ha for the two levels of soil salinity of 4.7 dSm^{-1} and 12.8 dSm^{-1}, respectively.

Table (6): Actual and predicted sunflower yield for oxalic acid treatment

Soil salinity	Oxalic acid	Yield (ton/ha)		Percent difference
		Actual	Predicted	
4.7 dSm^{-1}	100 ppm	2.28	2.25	1.16
	200 ppm	2.46	2.37	3.98
	300 ppm	-	2.49	-
12.8 dSm^{-1}	100 ppm	1.16	1.12	2.71
	200 ppm	1.24	1.24	0.58
	300 ppm	-	1.36	-

Predicted yield under salicylic acid treatment

Model [4] was used to predict sunflower yield under the application of salicylic acid treatment and predicted yield was compared with actual yield (Table 7). Results revealed that the yield predictions of model [4] were close to the actual yield under the application of salicylic acid for its two levels of concentrations. Percent difference between actual and predicted yields was between 0.98 and 5.74 % for both soil salinity levels. Moreover, the model predicted sunflower yield under the concentration of 300 ppm, where it was 2.42 and 1.29 ton/ha for the two levels of soil salinity of 4.7 dSm^{-1} and 12.8 dSm^{-1}, respectively.

Table (7): Actual and predicted sunflower yield for salicylic acid treatment

Soil salinity	Salicylic acid	Yield (ton/ha)		Percent difference
		Actual	Predicted	
4.7 dSm^{-1}	100 ppm	2.21	2.23	0.98
	200 ppm	2.35	2.33	1.12
	300 ppm	-	2.42	-
12.8 dSm^{-1}	100 ppm	1.06	1.10	3.86
	200 ppm	1.13	1.19	5.74
	300 ppm	-	1.29	-

Reducing the harm effect of Salinity

Increasing the amount of applied irrigation

Increasing the amount of applied irrigation water by 10% could improve sunflower yield by leaching the harm salts from root zone, which could improve plants growth and yield.

Predicted yield under control treatment

Model [1] was used to predict sunflower yield under increasing irrigation amount (Table 8). Results in that table showed that sunflower yield could be improved by 42.31 and 86.99 % under soil salinity of 4.7 dSm^{-1} and 12.8 dSm^{-1}, when the amount of irrigation was increased by 10 %.

Table (8): Predicted sunflower yield under salinity and increasing irrigation amounts for control treatment

Soil salinity	Predicted Yield (ton/ha)		Percent difference
	Under salinity	Under salinity and irrigation	
4.7 dSm^{-1}	1.81	2.58	42.31
12.8 dSm^{-1}	0.94	1.76	86.99

Predicted yield under ascorbic acid application

Model [2] was used to predict sunflower yield under increasing irrigation amount and spraying with ascorbic acid with two concentrations (100 and 200 ppm). Furthermore, that model was used to predict sunflower yield if plants were sprayed with ascorbic acid at the rate of 300 ppm. Results in Table (9) showed that sunflower yield could be improved from 2.33 to 2.47 (ton/ha) if plants were sprayed ascorbic acid at the rate of 300 ppm under salinity of 4.7 dSm^{-1}. Furthermore, sunflower yield could be improved from 1.03 to 1.32 ton/ha, if plants were sprayed by ascorbic acid at the rate of 300 ppm under salinity of 12.8 dSm^{-1}. It was also indicated that under salinity level of 4.7 dSm^{-1} and though increasing the amount of irrigation by 10 %, sunflower yield could be increased from 2.47 to 3.25 ton/ha (30.94 % improvement in yield). Whereas, under soil salinity level of 12.8 dSm^{-1} and when the amount of irrigation was increased by 10 %, sunflower yield showed an increase which ranged between 1.32 and 2.14 ton/ha (61.89 % improvement in yield).

Table (9): Predicted sunflower yield under soil salinity and under increasing irrigation amount for ascorbic acid treatment

Soil salinity	Ascorbic acid	Predicted yield (ton/ha)		Percent difference
		Under salinity	Under salinity and irrigation	
4.7 dSm^{-1}	100 ppm	2.19	2.95	35.02
	200 ppm	2.33	3.10	32.85
	300 ppm	2.47	3.24	30.94
12.8 dSm^{-1}	100 ppm	1.03	1.85	79.12
	200 ppm	1.18	2.00	69.45
	300 ppm	1.32	2.14	61.89

Predicted yield under oxalic acid application

Model [3] was used to predict sunflower yield under increasing irrigation amount and spraying with oxalic acid with two concentrations (100 and 200 ppm). Furthermore, that model was used to predict sunflower yield when plants were sprayed with oxalic acid at the rate of 300 ppm. Results in Table (10) showed that increasing oxalic acid concentration from 100 to 300 ppm could increase sunflower yield from 2.25 to 2.49 (ton/ha) under soil salinity level of 4.7 dSm^{-1}. Furthermore, sunflower yield could be improved from 1.12 to 1.36 ton/ha, when oxalic acid rate was increased from 100 to 300 ppm under soil salinity level of 12.8 dSm^{-1}. Results in that table also showed that, under soil salinity level of 4.7 dSm^{-1} and when the amount of irrigation was increased by 10 %, sunflower yield could be increased from 2.49 to 3.26 ton/ha (30.70 % improvement in yield). Whereas, under soil salinity level of 12.8 $dSm^{-1}$and when the amount of irrigation was increased by 10 %, sunflower yield was increased from 1.36 to 2.18 ton/ha (60.14 % improvement in yield).

Table (10): Predicted sunflower yield under soil salinity and under increasing irrigation amounts for oxalic acid treatment

Soil salinity	Oxalic acid	Predicted yield (ton/ha)		Percent difference
		Under salinity	Under salinity and irrigation	
4.7 dSm^{-1}	100 ppm	2.25	3.02	33.97
	200 ppm	2.37	3.14	32.25
	300 ppm	2.49	3.26	30.70
12.8 dSm^{-1}	100 ppm	1.12	1.94	73.02
	200 ppm	1.24	2.06	65.96
	300 ppm	1.36	2.18	60.14

Predicted yield under salicylic acid application

Model [4] was used to predict sunflower yield under increasing irrigation amount and spraying with salicylic acid using two concentrations (100 and 200 ppm). Furthermore, that model was used to predict sunflower yield when plants were sprayed with salicylic acid at the rate of 300 ppm. Results in Table (11) showed that sunflower yield could be improved from 2.23 to 2.42 ton/ha if plants were sprayed with salicylic acid at the rate of 300 ppm under soil salinity of 4.7 dSm^{-1}. Furthermore, sunflower yield could be improved from 1.10 to 1.32 ton/ha, if plants were sprayed salicylic acid at the rate of 300 ppm under soil salinity of 12.8 dSm^{-1}. Results in that table also showed that, under soil salinity level of 4.7 $dSm^{-1}$and when the amount of irrigation was increased by 10 %, sunflower yield could be increased from 2.42 to 3.12 ton/ha (31.62 % improvement in yield). Whereas, under soil salinity level of 12.8 dSm^{-1} and when the amount of irrigation was increased by 10 %, sunflower yield was increased from 1.29 to 2.11 ton/ha (63.50 % improvement in yield).

Table (11): Predicted sunflower yield under soil salinity and under increasing irrigation amounts for salicylic acid treatment

Soil salinity	Salicylic acid	Predicted yield (ton/ha)		Percent difference
		Under salinity	Under salinity and irrigation	
4.7 dSm^{-1}	100 ppm	2.23	3.00	34.34
	200 ppm	2.33	3.09	32.92
	300 ppm	2.42	3.19	31.62
12.8 dSm^{-1}	100 ppm	1.10	1.92	74.62
	200 ppm	1.19	2.01	68.61
	300 ppm	1.29	2.11	63.50

Reducing soil pH and using the same amount of applied irrigation

Soil pH can be reduced by applying organic manure, which could improve physical and chemical properties of the soil. Using the same amount of irrigation water with lower pH (reduced from 7.3 to 7.0 for site1(4.7 dSm^{-1}), and reduced from 8.1 to 7.8 for site2 (12.8 dSm^{-1}) could improve sunflower yield.

Predicted yield under control treatment

Model [1] was used to predict sunflower yield under soil salinity and soil pH reduction. Results in Table (12) showed that sunflower yield could be increased by 29.05 and 55.87 %, when soil pH was reduced by 0.3 for soil salinity level 4.7 dSm^{-1} and 12.8 dSm^{-1}, respectively.

Table (12): Predicted sunflower yield under soil salinity and soil pH reduction for control treatment

Soil salinity	Predicted Yield (ton/ha)		Percent improvement
	Under salinity	Under salinity + pH reduction	
4.7 dSm^{-1}	1.81	2.34	29.05
12.8 dSm^{-1}	0.94	1.47	55.87

Predicted yield under ascorbic acid treatment

Model [2] was used to predict sunflower yield under soil pH reduction and spraying with ascorbic acid (100, 200 and 300 ppm). Results in Table (13) showed that under soil salinity level of 4.7 $dSm^{-1}$and when soil pH was reduced, sunflower yield could be increased from 2.47 to 3.30 ton/ha (33.17 % improvement in yield). Whereas, under soil salinity level of 12.8 $dSm^{-1}$and reduced soil pH, sunflower yield was increased from 1.32 to 2.14 ton/ha (62.07 % improvement in yield).

Table (13): Predicted sunflower yield under soil salinity and soil pH reduction for ascorbic acid treatment

Soil salinity	Ascorbic acid	Predicted yield (ton/ha)		Percent improvement
		Under salinity	Under salinity and irrigation	
4.7 dSm^{-1}	100 ppm	2.19	3.01	37.54
	200 ppm	2.33	3.15	35.22
	300 ppm	2.47	3.30	33.17
12.8 dSm^{-1}	100 ppm	1.03	1.86	79.35
	200 ppm	1.18	2.00	69.65
	300 ppm	1.32	2.14	62.07

Predicted yield under oxalic acid treatment

Model [3] was used to predict sunflower yield under soil pH reduction and spraying with oxalic acid (100, 200 and 300 ppm). Results in Table (14) showed that under soil salinity level of 4.7 $dSm^{-1}$and when soil pH was reduced, sunflower yield could be increased from 2.49 to 3.27 ton/ha (31.18 % improvement in yield). Whereas, under soil salinity level of 12.8 dSm^{-1} and when soil pH was reduced, sunflower yield was increased from 1.36 to 2.14 ton/ha (57.14 % improvement in yield).

Table (14): Predicted sunflower yield under soil salinity and soil pH reduction for oxalic acid treatment

Soil salinity	Oxalic acid	Predicted yield (ton/ha)		Percent improvement
		Under salinity	Under salinity and irrigation	
4.7 dSm^{-1}	100 ppm	2.25	3.03	34.50
	200 ppm	2.37	3.15	32.76
	300 ppm	2.49	3.27	31.18
12.8 dSm^{-}	100 ppm	1.12	1.90	69.38
	200 ppm	1.24	2.02	62.67
	300 ppm	1.36	2.14	57.14

Predicted yield under salicylic acid treatment

Model [4] was used to predict sunflower yield under soil pH reduction and spraying with salicylic acid (100, 200 and 300 ppm). Results in Table (15) showed that under soil salinity level of 4.7 $dSm^{-1}$and when soil pH was reduced, sunflower yield could be increased from 2.42 to 2.91 ton/ha (20.22 % improvement in yield). Whereas, under soil salinity level of 12.8 dSm^{-1} and when soil pH was reduced, sunflower yield was increased from 1.29 to 1.79 ton/ha (37.99 % improvement in yield).

Table (15): Predicted sunflower yield under soil salinity and soil pH reduction for salicylic acid treatment

Soil salinity	Salicylic acid	Predicted yield (ton/ha)		Percent improvement
		Under salinity	Under salinity + pH irrigation	
4.7 dSm^{-1}	100ppm	2.23	2.72	21.96
	200ppm	2.33	2.82	21.05
	300ppm	2.42	2.91	20.22
12.8 dSm^{-1}	100ppm	1.10	1.59	44.64
	200ppm	1.19	1.68	41.05
	300ppm	1.29	1.78	37.99

Reducing soil pH and conserving of some of applied irrigation water

Under deficit irrigation, a slightly increase or decrease in the actual yield amount of sunflower could be obtained with lower irrigation amount if we could reduce soil pH by 0.3. Actual sunflower yield had been presented in Tables (2-6).

Predicted yield under control treatment

Model [1] was used to predict sunflower yield under deficit irrigation and soil pH reduction. Results in Table (16) showed that reducing irrigation amount by 548 and 528 m^3/ha and reduce soil pH under soil salinity level of 4.7 dSm^{-1} and 9000 ppm, respectively slightly increased yield under soil salinity of 4.7 dSm^{-1} and slightly reduced sunflower yield under soil salinity of 12.8 dSm^{-1}.

Table (16): Proposed irrigation amounts under different soil salinity levels and application of and soil pH reduction

Soil salinity	Irrigation (m^3/ha)		Saved irrigation amount (m^3/ha)	Predicted yield (ton/ha)
	Actual	Proposed		
4.7 dSm^{-1}	7663	7116	548	1.81
12.8 dSm^{-1}	8172	7644	528	0.94

Predicted yield under ascorbic acid treatment

Model [2] was used to predict sunflower yield under deficit irrigation and soil pH reduction. Results in Table (17) showed that reducing irrigation amount by 823 and 816 m^3/ha and reduce soil pH under soil salinity level of 4.7 dSm^{-1} and 12.8 dSm^{-1}, respectively showed a slight increase or decrease in sunflower yield when sprayed with ascorbic acid.

Table (17): Proposed irrigation amounts under different soil salinity levels as well as soil pH reduction and application of ascorbic acid.

Soil salinity	Ascorbic acid	Irrigation (m^3/ha)		Saved irrigation amount (m^3/ha)	Predicted yield (ton/ha)
		Actual	Proposed		
4.7 dSm^{-1}	100 ppm	7663	6840	823	2.19
	200 ppm	7663	6840	823	2.33
12.8 dSm^{-1}	100 ppm	8172	7356	816	1.03
	200 ppm	8172	7356	816	1.18

Predicted yield under oxalic acid treatment

Model [3] was used to predict sunflower yield under deficit irrigation and soil pH reduction. Results in Table (18) indicated that reducing irrigation amount by 775 and 780 m^3/ha in addition to soil pH reduction under soil salinity level of 4.7 dSm^{-1} and 12.8 dSm^{-1}, respectively slightly reduced sunflower yield grown under soil salinity of 4.7 dSm^{-1} and did not reduce sunflower yield grown under soil salinity of 12.8 dSm^{-1} when plants were sprayed with oxalic acid. Table (18): Proposed irrigation amounts under different soil salinity levels and soil pH reduction under application of oxalic acid

Soil salinity	Oxalic acid	Irrigation (m^3/ha)		Saved irrigation amount (m^3/ha)	Predicted yield (ton/ha)
		Actual	Proposed		
4.7 dSm^{-1}	100 ppm	7663	6888	775	2.25
	200 ppm	7663	6888	775	2.37
12.8 dSm^{-1}	100 ppm	8172	7392	780	1.12
	200 ppm	8172	7392	780	1.24

Predicted yield under salicylic acid treatment

Model [4] was used to predict sunflower yield under deficit irrigation and soil pH reduction. Results in Table (19) indicated that reducing irrigation amount by 463 and 468 m^3/ha and reducing soil pH under soil salinity level of 4.7 dSm^{-1} and 12.8 dSm^{-1}, respectively slightly decreased or increased sunflower yield grown under soil salinity of 4.7 dSm^{-1} or 12.8 dSm^{-1}.

Table (19): Proposed irrigation amounts under different soil salinity levels and soil pH reduction under application of salicylic acid

Soil salinity	Salicylic acid	Irrigation (m^3/ha)		Saved irrigation amount (m^3/ha)	Predicted yield (ton/ha)
		Actual	Proposed		
4.7 dSm^{-1}	100 ppm	7663	7200	463	2.26
	200 ppm	7663	7200	463	2.35
12.8 dSm^{-1}	100 ppm	8172	7704	468	1.12
	200 ppm	8172	7704	468	1.21

Discussion

Four models were developed to predict sunflower yield under saline conditions in addition to application of antioxidants. Oosterhuis and Wullschleger [9] proved that sunflower plant exhibited a moderate ability for osmotic adjustment. Also, Iturriag [10], concluded that availability of water is the most limiting factor for crop productivity and yield. Therefore there is a strong need to understand plant adaptation mechanism against adverse environmental conditions to improve stress tolerance. This comprises enzyme catalyzing the synthesis of osmoprotectants or antioxidants, lipid desaturases, water channels and ion transporters. Furthermore, Sairam et al [11] and Amor et al [12]. Deduced that high salinity (200mM NaCl) induced mineral nutrition disturbance within the plant shoots. Also NaCl decreased relative water content (RWC), chlorophyll content, membrane stability index (MSI) and ascorbic acid (AA) content, and increased oxidative contents. The limitation of plant growth at 200 mM NaCl was concomitant with lesser efficiency of these protective enzymes. Also it has been noticed that Ascorbic acid has been known as an antioxidant that protects plants against damage resulting from aerobic metabolism, photosynthesis and a range of pollutants [13].

Yamane et al [14], investigated kinds of active oxygen species leading to the destruction of chloroplast ultrastructure in salt-stressed rice plants. Pretreatment with ascorbate and benzoate which scavange H_2O_2 and OH respectively, effectively suppressed the reduction of chlorophyll content and the destruction of the chloroplast by NaCl in light. Also, Serio et al [15], found that yield reduction of tomato plant grown under saline condition was compensated by improvement of dry matter, total soluble solids and vitamin C.

Models were also used to predict sunflower yield under deficit irrigation and soil pH reduction. It has been known that the heighst improvement in yield was obtained when oxalic acid. It has been known that oxalic acid acts as enzyme co-factor especially hydrolase enzyme, electron transport, oxalate and tartarate synthesis [16].

CONCLUSION

Modeling is a mathematical representation of a system. In this paper we proved that modeling can be used as a technique to determine the best management package to be used under saline soil. The results showed that sunflower yield was highly reduced under saline soil. Spraying with the three different antioxidants was helpful in improving sunflower yield. However, the yield was still lower than optimum. Therefore, modeling proved that increasing the amount of irrigation resulted in high yield improvement, especially for soil salinity level of 12.8 dSm-1. The highest improvement in yield was obtained when oxalic acid was sprayed. If irrigation water is not abundant, another alternative can be used, which is reducing soil pH and using the same amount of irrigation water. Modeling revealed that reducing soil pH could improve sunflower yield, especially for soil salinity level of 12.8 dSm-1and when oxalic acid was sprayed. However, if we want to conserve some of irrigation water without yield losses. Thus, we model the effect of reduction in soil pH with a reduced irrigation amount. The lowest amount of irrigation water was used for both soil salinity levels was obtained when ascorbic acid was sprayed. Therefore, it is recommended to spray sunflower plants with oxalic acid to relief salinity stress either under abundant amount of irrigation or reducing soil pH with the same irrigation amount. Furthermore, under deficit irrigation, spraying ascorbic acid is preferable under saline soil and reduced pH.

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