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MITIGATION OF THE ADVERSE EFFECTS OF WATER STRESS OF TOMATO PLANTS BY APPLICATION OF CCC AND MANGANESE

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ABSTRACT: *Two pot experiments were carried out at the Faculty of Agriculture, Minufiya University, during the two growing seasons 2006 and 2007. The study aimed to investigate the effect of cycocel (100 or 200 mg/L) and manganese (25 or 50 mg/L) as foliar application on reducing hazards of drought on tomato plants. The plants were grown under 3 levels of water stress (55, 75 and 100% of F.C.). The obtained results indicated that, all studied characters of growth, relative water content (RWC), photosynthetic pigments, total soluble sugars (TSS), minerals (N, P and K) contents in leaves, number of flowers / plant as well as yield and its quality showed a significant decrease by increasing water stress, meanwhile a significant increase were obtained in osmotic pressure (OP), water use efficiency (WUE), membrane integrity (MI), peroxidase and phenoloxidase activity and proline concentrations. The results revealed that, application of CCC or Mn increased all characters, with the exception of OP, MI, enzymes activity and proline compared with untreated control plants. Generally, the application of Mn was more effective than CCC in all parameters while, fruit quality as represented by total soluble solids (TSS), vitamin C and acidity were highest with the application of CCC. Presented results showed that CCC or Mn application on tomato plants grown under water stress exerted highly significant influences on all aspects under study except for number of leaves, root dry weight, No. of fruits / plant and fruit acidity. In general, the highest fruit yield / plant was obtained from the application of manganese (50 mg/L) under the lowest level of water stress (75% of F.C.).*

Key words: *Tomato plants, water stress, cycocel, manganese, water relations, enzymes activity, proline, yield and its quality.*

INTRODUCTION

Tomato plant is one of the most important vegetable crops in the world.

One of the most important factors affecting tomato production is soil moisture. Drought causes visible injury to leaves and induces stomatal closure, leaf rolling and other physiological disorders. Water stress also accelerates the decline of chlorophyll and protein contents, negatively alter both the structure and function of membranes (Basisak *et al.*, 1994). In addition, plant water status in response to soil water deficit, play an important role in tolerance to drought and in yield stability (Teulat *et al.*, 1997).

It is reasonable to state that chloromecuat (cycocel) can influence tomato growth, nutrients content and productivity (Abo-Korah *et al.*, 1982). Many investigators stated that application of cycocel (CCC) increased yield harvested by giving better change to water mineral absorption from soil (Rao, 1980 and Saad *et al.*, 1981). In addition, El-Zeiny (1981) and Kandil (1982) reported that CCC increased the effect drought tolerance in cotton and maize.

Micronutrients have a great role in the physiological and metabolic processes. The availability of soil micronutrients to plant grown under most of the soil in Egypt is considerably low as soil is characterized with high pH and low organic matter. Therefore, applying micronutrients, especially (Mn, Zn, Fe) has become necessary to acquire nutrient balance within plants of crops grown in Egypt as a total achieving high yield of field crops. Many investigators reported that foliar spraying of Mn has positive effects on the yield and growth of faba bean plants (Etman, 1992 and Hegazy *et al.*, 1993). Also, El-Sabbagh (2002) found that, foliar spraying of faba bean plants grown under drought conditions with Mn increased growth, yield and its components.

Therefore, the objective of the present investigation is to evaluate the effect of cycocel or manganese as foliar spray on tomato plants grown under water stress treatments on growth, water relations, chemical composition, flowering, yield and its components as well as its quality of tomato plants, in an attempt to the alleviate the negative effect under water stress.

MATERIALS AND METHODS

The present investigation was carried out in the Faculty of Agriculture, Minufiya University, Shibin El-Kom, during 2006 and 2007 seasons to study the effect of either cycocel (CCC) as the growth regulator or manganese chloride ($MnCl_2$) as the micronutrient on tomato plants grown under water stress.

The treatments were arranged in split plot design with four replications. The main plots were occupied by soil moisture levels which were:

1. W_0 (well watered at 100% of field capacity as control).
2. W_1 (well watered at 75% of field capacity).
3. W_2 (well watered at 55% of field capacity).

The sub-plots were assigned for foliar spray with CCC or $MnCl_2$ which were:

1. Control (spray with distilled water).
2. C_1 (CCC at 100 mg/L).
3. C_2 (CCC at 200 mg/L).
4. Mn_1 (Mn at 25 mg/L).
5. Mn_2 (Mn at 50 mg/L).

The previous treatments were applied at 30 and 60 days from transplanting. Tween 20 was added to the spraying solution at 0.5% as a surfactant. The uniform seedlings of tomato cv. Peto 86 (age 50 days) were planted in plastic pots (25 cm diameter and 20 cm deep) containing 5 kg of clay soil each on March 11 and 15, 2006 and 2007, respectively. Each pot contain 3 seedlings. Some physical and chemical properties of this soil determined according to Jackson (1967) and given in Table (1).

Table (1): Physical and chemical properties of the used soil.

Property	Volume
a) Physical properties:	
Sand (%)	5.63
Silt (%)	43.60
Clay (%)	49.07
$CaCO_3$ (%)	1.70
b) Chemical properties:	
pH	7.58
E.C (mmhs / cm)	0.52
C.E.C (mg / 100 g)	30.20
Organic matter	1.56
Soluble ions (mg/100 gm soil)	
Cations:	
Ca^{++}	30.2
Mg^{++}	1.30
Na^{+}	1.01
K^{+}	1.21
Anions:	
CO_3^{-}	–
HCO_3^{-}	1.1
Cl^{-}	1.5

Fertilization at the rate of 300 kg (1.5 g/pot) superphosphate was added before transplanting, 250 kg (1.25 g/pot) ammonium sulphate and 150 kg (0.75 g/pot) potassium sulphate. N and K were added into the two equal parts, after 20 and 45 days from transplanting. A representative sample of 6 plants of each treatment were taken randomly, 80 days after transplanting, for recording of various data as follows:

1. Vegetative growth characters:

Recorded data includes, plant height (cm), number of leaves / plant and total leaf area (cm^2) / plant according to Roods and Bloodworth (1964). All parts of vegetative sample were separated and dried in oven at 70°C for 72 hr. to determine root and shoot dry weights of plant (g).

2. Water relations:

Relative water content (RWC) and osmotic pressure (OP) in fresh leaves were measured as the methods described by Barrs and Weatherley (1962) and Gosev (1960), respectively. Water use efficiency (WUE) was defined as the ratio of produce 1 g dry matter of plant to the weight of water used (kg). WUE calculated according to the following formula:

$$WUE = \frac{\text{Dry matter produced (g)}}{\text{Water lost (kg)}}$$

The leaf water potential (LWP) was determined by the modified dye method developed by Marathe (1989).

To indicate the extent of membrane damage in leaf tissues (Membrane integrity "MI") subjected to drought condition, measurements on leakage of solutes was determined following the method of Leopold *et al.* (1981).

3. Chemical analysis:

a) **Enzymes activity:** Peroxidase and phenoloxidase activity were measured in the fresh leaves using the methods described by Fehrman and Dimond (1967) and Broesh (1954), respectively.

b) **Photosynthetic pigments (chlorophyll a, b and carotenoids):** Was estimated in fresh leaves as described by Wettestein (1957), then expressed in mg / g dry weight.

c) **Total soluble sugars (TSS):** In dry leaves estimated according to the method described by Dubois *et al.* (1956).

d) **Proline concentration:** In fresh leaves measured using the method described by Bates *et al.* (1973).

e) Mineral concentration: Were measured in dry leaves, nitrogen was measured using micro-kjeldahl method described by A.O.A.C (1975), phosphorus was determined colourimetrically by method described by Snell and Snell (1954), potassium was measured using flamephotometer method described by Chapman and Pratt (1961).

4. Flowering:

The flowers of six plants from each treatment were tagged and the number of flowers per plant was recorded.

5. Yield and its components as well as fruit quality:

Red ripe fruits were harvested (started from 7 June till to 11 August), number and weight of fruits per plant were recorded. During the production peak representative fruit samples were collected to determine the following qualitative fruit characters. Also, total soluble solids (TSS %) using an Abe hand refractometer, fruit vit. C concentration (mg/100 g fresh weight) and fruit acidity (%) using the methods described by A.O.A.C. (1975).

All obtained data were subjected to statistical analysis with the help of COSTAT-C Program, and the L.S.D. at 5% level was calculated according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

1. Vegetative growth characters:

Data presented in Table (2) evident that all growth parameters represented as plant height, number of leaves / plant, leaf area / plant, root and shoot dry weights of tomato plants were significantly decreased with increasing water stress levels. Shorting plants and reductions in leaf area under conditions of low soil moisture level may be explained that water stress causes losses in tissue water, which reduces turgor pressure in the cell, thereby inhibiting enlargement and division of cells (Hsiao and Acevedo, 1974). Also, they added that, the reductions in leaf area under low moisture level may be attributed to the decrease in cell size and intercellular volume caused by water stress and its effect on crop growth depends upon the degree of stress and the development stage at which the stress occurs. Similar results were obtained by Sorial and El-Shafie (2002), Hammad and El-Gamal (2004) on pepper and El-Sabbagh (2002) on faba bean plants.

It is obvious from the same table that foliar spraying of either cycocel (CCC) or manganese (Mn) significantly increased all growth measurements of tomato plants grown under drought conditions or without supplemental addition control. In this respect, the positive effect of CCC may be due to the increasing effect of CCC on photosynthesis activity as mentioned by El-Sherbeny (1973) who added that, the increase or decrease in growth

Table (2): Morphological characters of vegetative growth of tomato plants as affected by water stress, cycocel and manganese chloroide treatments and their interaction in 2006 and 2007 seasons.

Characters / Treatments		2006 season					2007 season				
		Plant height (cm)	No. of leaves / plant	Leaf area (cm^2 / plant)	Root dry weight (g/plant)	Shoot dry weight (g/plant)	Plant height (cm)	No. of leaves / plant	Leaf area (cm^2 / plant)	Root dry weight (g/plant)	Shoot dry weight (g/plant)
	W_0	46.13	8.46	131.10	0.49	4.31	43.80	9.20	130.22	0.47	4.98
	W_1	43.26	7.86	118.34	0.45	4.10	41.20	8.66	115.08	0.44	4.34
	W_2	35.73	6.13	86.14	0.38	2.97	35.66	7.20	84.80	0.36	2.87
	0.0	36.55	6.11	87.95	0.36	3.09	34.00	7.00	74.87	0.37	3.12
	CCC_1	42.44	7.77	111.67	0.45	3.91	41.33	8.55	111.50	0.42	4.27
	CCC_2	40.44	7.33	102.26	0.43	3.73	39.22	8.11	102.90	0.40	4.04
	Mn_1	44.00	8.22	123.13	0.48	4.04	42.44	8.88	125.83	0.45	4.40
	Mn_2	45.11	8.00	134.27	0.49	4.20	44.11	9.22	135.07	0.48	4.50
W_0	0.0	43.33	7.33	111.55	0.45	3.97	41.00	8.33	114.60	0.42	4.21
	CCC_1	46.00	8.67	131.10	0.48	3.37	44.67	9.33	129.10	0.46	5.21
	CCC_2	44.00	8.00	120.10	0.46	4.10	42.33	8.67	118.60	0.45	4.81
	Mn_1	48.00	9.00	140.10	0.52	4.50	44.67	9.67	137.81	0.48	5.32
	Mn_2	49.33	9.33	150.00	0.56	4.63	46.67	10.00	154.33	0.55	5.41
W_1	0.0	36.00	6.00	85.10	0.35	3.07	33.33	6.67	63.10	0.38	3.03
	CCC_1	44.00	8.00	115.00	0.47	4.26	41.67	9.00	119.30	0.45	4.61
	CCC_2	43.67	7.67	110.30	0.46	4.06	41.33	8.67	109.70	0.44	4.42
	Mn_1	45.67	8.67	133.10	0.50	4.50	44.00	9.33	139.60	0.49	4.82
	Mn_2	47.00	9.00	148.20	0.48	4.62	45.67	9.67	143.70	0.51	4.91
W_2	0.0	30.33	5.00	67.20	0.30	2.23	27.67	6.00	50.20	0.31	2.19
	CCC_1	37.33	6.67	85.60	0.40	3.11	37.67	7.33	86.10	0.37	3.00
	CCC_2	33.67	6.33	76.40	0.38	3.04	34.00	7.00	80.40	0.36	2.90
	Mn_1	38.00	7.00	96.20	0.42	3.21	39.00	7.67	100.10	0.38	3.10
	Mn_2	39.00	5.67	105.30	0.44	3.35	40.00	8.00	107.20	0.40	3.20
LSD 5%		W=1.8 A=0.98 W×A=1.7	W=0.79 A=0.89 W×A=n.s	W=5.59 A=4.52 W×A=7.84	W=0.02 A=0.02 W×A=n.s	W=0.27 A=0.20 W×A=0.34	W=0.52 A=1.57 W×A=2.70	W=0.84 A=1.04 W×A=n.s	W=17.4 A=10.6 W×A=18.4	W=0.05 A=0.04 W×A=n.s	W=0.14 A=0.21 W×A=0.35

W = levels of water stress A = Cycocel and Manganese treatments. W × A = Interaction

characters caused by CCC might depend up on the balance between the endogenous promoters and inhibitors found in the plant tissues affecting more or less cell division. Several authors have investigated similar increase in growth characters due to CCC among them El-Beheidi *et al.* (1991), Etman *et al.* (1991), El-Quesni *et al.* (1992) on faba bean plants and Bardisi (2004) on pea plants. Mn had more stimulative effect on vegetative growth reported by Ibrahim (1989) on pea, Hassanein *et al.* (1993) on faba bean and Shawky *et al.* (2002) on palm. It is well known that, Mn act as Co factor of many biological processes such as photosynthesis reactions, nucleic acids metabolism, protein and carbohydrate biosynthesis as well as growth regulation (Shkolnik, 1984 and Ali, 2005) on faba bean.

Regarding the interaction between supplemental application under water stress. There were significant differences in plant height, leaf area and dry weight of shoots of tomato plants as compared with control. The best results under water stress condition were owing to addition of CCC or Mn application at the first drought treatment (75% of field capacity) compared with the control plants, but Mn gained best effect than CCC. Also data indicate that, there was no significant in the number of leaves and root dry weight per plant. These results were true in both seasons.

2. Water relations:

In both seasons, results in Table (3) indicate that, water stress levels significantly affected relative water content (RWC), osmotic pressure (OP), leaf water potential (LWP), water use efficiency (WUE) and membrance integrity (MI), there was a gradual reduction in RWC and LWP, meanwhile there was a gradual increase in OP, WUE and MI of tomato plants as compared with control plants. The maximum reduction in RWC and LWP recorded under the second level of water stress (55% of field capacity) which reached about 30.5 and 32.1% for RWC and 45.5% as well as 66.7% for LWP in the first and second seasons, respectively compared with control. The highest increase in OP, WUE and MI were about 62.6, 53.9 and 78.3%, respectively in the first season as well as 46.7, 54.1 and 70.6%, respectively in the second season were obvious at the second water deficit treatments (W_2). Similar results were observed by Abd El-Fattah and Sorial (2001) on taro plants, Sorial and El-Shafie (2002), Hammad and El-Gamal (2004) on pepper. In this regard, Gawish and Fattahallah (1997) reported that RWC of taro leaves decreased as the level of moisture regime decreased. This indicated greater resistance to water flow at the soil-root interface or decreased hydraulic conductivity of soil at low soil moisture. In addition, Ranney *et al.* (1991) as well as, other workers who proved that with osmotic adjustment mechanism, there is lowering osmotic potential of the cells and hence participates in maintaining of full turger of tissue under water stress condition.

Table (3): Water relations of tomato plants as affected by water stress, cycocel and manganese chloroide treatments and their interaction in 2006 and 2007 seasons.

Treatments	Characters	2006 season					2007 season				
		Relative water content (%)	Osmotic pressure (atm.)	Leaf water potential (-MPa)	Water use efficiency (g DM /kg H_2O)	Membrane integrity (MI %)	Relative water content (%)	Osmotic pressure (atm.)	Leaf water potential (-MPa)	Water use efficiency (g DM /kg H_2O)	Membrane integrity (MI %)
	W_0	81.59	8.30	-10.60	1.59	35.71	84.32	8.77	-8.60	1.81	32.34
	W_1	74.02	10.13	-11.00	1.78	47.91	75.28	10.65	-9.80	2.11	46.79
	W_2	69.48	11.52	-12.80	1.94	55.01	69.35	11.47	-11.40	2.32	53.70
	0.0	65.64	11.05	-14.00	1.84	51.27	69.47	11.91	-12.33	2.27	50.98
	CCC_1	76.81	9.90	-11.00	1.76	47.06	77.50	9.97	-9.66	1.96	43.63
	CCC_2	75.14	10.07	-12.00	1.61	48.81	76.14	10.24	-10.66	1.83	45.67
	Mn_1	76.76	9.53	-10.66	1.75	44.51	78.65	9.80	-9.00	2.16	42.03
	Mn_2	80.80	9.36	-9.66	1.91	39.41	79.83	9.55	-8.00	2.18	39.07
W_0	0.0	81.04	8.32	-11.00	1.41	37.18	82.20	9.42	-9.00	1.72	38.81
W_0	CCC_1	83.55	8.41	-11.00	1.65	36.88	84.80	8.61	-9.00	1.86	32.10
W_0	CCC_2	82.11	8.51	-12.00	1.44	37.00	83.60	9.00	-10.00	1.80	33.60
W_0	Mn_1	83.10	8.20	-10.00	1.64	35.80	85.02	8.52	-8.00	1.85	31.30
W_0	Mn_2	84.40	8.10	-9.00	1.80	33.40	86.00	8.33	-7.00	2.01	30.00
W_1	0.0	67.00	11.42	-15.00	1.95	52.03	69.11	12.52	-13.00	2.45	51.00
W_1	CCC_1	76.00	10.10	-10.00	1.66	48.21	75.40	10.32	-9.00	1.80	46.60
W_1	CCC_2	74.00	10.30	-11.00	1.63	51.44	74.62	10.51	-10.00	1.75	48.11
W_1	Mn_1	75.10	9.40	-10.00	1.79	47.40	77.00	10.10	-9.00	1.97	45.21
W_1	Mn_2	78.00	9.20	-9.00	1.91	40.50	80.30	9.82	-8.00	2.22	42.11
W_2	0.0	55.00	13.20	-16.00	2.17	66.29	57.11	13.82	-15.00	2.65	66.20
W_2	CCC_1	71.00	11.20	-12.00	1.99	56.11	72.32	11.00	-11.00	2.20	52.20
W_2	CCC_2	69.33	11.40	-13.00	1.76	58.00	70.21	11.22	-12.00	1.96	55.30
W_2	Mn_1	72.10	11.00	-12.00	1.82	50.33	74.10	10.80	-10.00	2.30	49.60
W_2	Mn_2	80.00	10.80	-11.00	2.05	44.33	73.20	10.51	-9.00	2.50	45.20
LSD 5%		W=1.56 A=2.27 W×A=3.94	W=0.27 A=0.41 W×A=0.70	W=0.41 A=0.99 W×A=1.68	W=0.24 A=0.14 W×A=0.25	W=2.08 A=2.12 W×A=3.68	W=2.74 A=3.16 W×A=5.47	W=0.37 A=0.36 W×A=0.62	W=0.71 A=0.99 W×A=1.72	W=0.27 A=0.21 W×A=0.36	W=6.79 A=2.87 W×A=4.98

W = levels of water stress A = Cycocel and Manganese treatments. W × A = Interaction

The increase in WUE under water condition mainly due to the reduction in the mean assimilation rate which was much less compared to the percent decrease in rate of water loss resulting in a considerable increase in WUE (Hammad, 2000).

Concerning the effects of spraying CCC or Mn, data in Table (3) showed clearly significant increments in RWC and WUE of tomato plants compared to untreated. Presented results showed that the application of both substances improving OP, LWP and MI of tomato leaves compared with control plants. In general, application of Mn gave the best results. These results were true in both seasons. These results are in a good line with those reported by Abo El-Khier *et al.* (1994) on two soybean cultivars. In this regard, Kharanyan and Vikhireva (1976) found that ATPase, catalase and cytochrome oxidase activities in the leaves of CCC-treated plants, grown under water stress were higher. These effects were attributed to improve water relations and metabolic activity caused by CCC treatment.

Concerning the interaction between water stress and foliar application of CCC or Mn, data in Table (3) showed that CCC or Mn treatments positively correlated with all water relations studied under moisture stress conditions and significant differences in RWC, OP, LWP, WUE and MI were recorded. Data revealed that under moisture stress, CCC or Mn as foliar spray increased RWC and LWP of tomato plants compared to its controls and alleviated the depressive effect of drought by improving OP and MI. In this regard application of Mn (50 mg/L) gave the best results. These results were true in both seasons.

3. Chemical analysis:

a) Enzyme activity:

Data presented in Table (4) showed that, water stress increased significantly the activity of peroxidase and phenoloxidase in tomato leaves. In this respect, the greater activity was observed with W_2 (55% of F.C.) treatment of both peroxidase and phenoloxidase compared to control in both seasons. These results are in agreement with those obtained by Zhou and Gang (1997) on peas and Hammad (2000) on sweet basil and peppermint plants. Increase the activity of peroxidase caused by water stress may reflect the thermodynamic state of the water inside the plant as leaf water potential decreased, indicating the state of water deficit in plant tissues. Furthermore, the important systems in the polyphenoloxidase which oxidase some phenols to quinones which are important in the electron transport chain to respiration (Bewley, 1981).

Obtained results in the same table demonstrated that, the usage of CCC or Mn caused significant decrease in peroxidase and phenoloxidase activity compared with untreated plants. Application of Mn was more effective. These results were true in both seasons.

Table (4): Enzyme activity, photosynthetic pigments and total soluble sugars of tomato plants as affected by water stress, cycocel and manganese chloroide treatments and their interaction in 2006 and 2007 seasons.

Treatments	Characters	2006 season Peroxidase activity (O.D / g f.wt.)	2006 season Phenoloxidase activity (O.D / g f.wt.)	2006 season Chl. a + b (mg / g d.w.)	2006 season Carotenoids (mg/g d.w.)	2006 season Total soluble sugars (mg/g d.w.)	2007 season Peroxidase activity (O.D / g f.wt.)	2007 season Phenoloxidase activity (O.D / g f.wt.)	2007 season Chl. a + b (mg / g d.w.)	2007 season Carotenoids (mg/g d.w.)	2007 season Total soluble sugars (mg/g d.w.)
	W_0	0.33	0.23	5.95	2.34	9.24	0.30	0.24	5.92	2.69	9.58
	W_1	0.40	0.33	5.80	2.16	8.97	0.43	0.32	5.41	2.57	9.08
	W_2	0.48	0.38	4.06	1.58	8.14	0.52	0.44	3.87	1.60	8.42
	0.0	0.48	0.39	4.32	1.63	7.96	0.50	0.40	4.12	1.85	8.13
	CCC_1	0.38	0.27	5.23	2.09	8.90	0.40	0.32	4.97	2.29	9.14
	CCC_2	0.42	0.28	5.07	1.88	8.48	0.43	0.35	5.23	2.25	8.92
	Mn_1	0.38	0.33	5.72	2.23	9.01	0.38	0.32	5.42	2.49	9.28
	Mn_2	0.34	0.31	6.02	2.29	9.56	0.36	0.29	5.60	2.54	9.65
W_0	0.0	0.38	0.25	5.35	2.07	8.70	0.35	0.29	5.11	2.51	9.11
	CCC_1	0.35	0.23	5.87	2.33	9.20	0.30	0.25	6.01	2.82	9.55
	CCC_2	0.37	0.24	5.53	2.20	8.90	0.33	0.27	5.72	2.71	9.20
	Mn_1	0.31	0.22	6.33	2.44	9.31	0.28	0.23	6.20	2.95	9.62
	Mn_2	0.25	0.19	6.67	2.51	10.10	0.26	0.19	6.41	3.01	10.51
W_1	0.0	0.47	0.36	4.62	1.80	8.10	0.50	0.35	4.25	2.00	8.00
	CCC_1	0.39	0.34	5.70	2.20	9.10	0.41	0.32	5.60	2.70	9.30
	CCC_2	0.42	0.36	5.59	2.10	8.80	0.45	0.33	5.35	2.61	9.20
	Mn_1	0.41	0.27	6.51	2.30	9.22	0.40	0.31	5.85	2.80	9.40
	Mn_2	0.39	0.26	6.59	2.41	10.00	0.38	0.30	6.00	2.91	9.50
W_2	0.0	0.61	0.56	2.99	1.40	7.10	0.65	0.55	3.01	1.20	7.30
	CCC_1	0.45	0.42	4.12	1.75	8.40	0.50	0.40	3.91	1.70	8.62
	CCC_2	0.48	0.46	4.10	1.36	8.10	0.52	0.45	3.85	1.45	8.36
	Mn_1	0.44	0.35	4.32	1.82	8.51	0.48	.042	4.21	1.77	8.82
	Mn_2	0.43	0.34	4.81	1.92	8.60	0.44	0.39	4.40	1.90	9.00
LSD 5%		W=0.04 A=0.03 W×A=0.05	W=0.03 A=0.02 W×A=0.03	W=0.24 A=0.25 W×A=0.43	W=0.07 A=0.09 W×A=0.15	W=0.24 A=0.22 W×A=0.38	W=0.04 A=0.01 W×A=0.03	W=0.02 A=0.02 W×A=0.04	W=0.19 A=0.12 W×A=0.21	W=0.11 A=0.16 W×A=0.27	W=0.46 A=0.25 W×A=0.43

W = levels of water stress A = Cycocel and Manganese treatments. W × A = Interaction

Concerning the interactive effect of water deficit and supplemental applications, data in the same table showed a significant decrease in enzymes activity. The lowest mean values were recorded in plants treated with W_1 (75% F.C.) plus Mn (50 mg/L) as compared with their controls in both seasons.

b) Photosynthetic pigments:

Data given in Table (4) indicate that, there were significant decrease in chlorophyll a + b and carotenoids concentrations under drought conditions compared with unstressed plants. In this regard, many investigators recorded similar reduction in photosynthetic pigments due to water conditions, among them El-Adgham and Sorial (1995) on tomato, Abd El-Fattah *et al.* (2002) on sweet potato and Hammad and El-Gamal (2004) on pepper plants. In this regard, Abo El-Kheir *et al.* (1994) reported that, the effect of water stress on chlorophyll content may be attributed to the disturbance of chlorophyll synthesis rather than its destruction.

Presented results showed that, plants sprayed with CCC or Mn showed significant increase in total chlorophyll and carotenoids compared with untreated control. The highest mean values were recorded in plants treated with Mn_2 (50 mg/L). These results were true in both seasons. These results confirmed those reported by El-Kady and Aboushoba (1990). They indicated that applying faba bean plants with CCC increased chl. a, chl. b and total photosynthetic pigments content as compared with control treatment. Similar results were also obtained by El-Beheidi *et al.* (1991), El-Quesni *et al.* (1992) and Ali (2005) on faba bean. In addition Abd El-Megeed *et al.* (1997) found that, spraying bean plants with manganese led to an increase in total chlorophyll content. Likewise, Ali (2005) found that, foliar application of Mn or CCC caused a significant increase in chl. a, chl. b, total chlorophyll (a + b) and carotenoids compared with untreated plants.

As regard to interaction between water stress and foliar application of CCC or Mn treatments, it can be noticed that, the application of CCC or Mn alleviated the negative effect of drought stress and significantly enhanced photosynthetic pigments, especially at W_1 treatment. The second season followed the same trend.

c) Total soluble sugars:

Data presented in Table (4) showed that imposing tomato plants to water stress led to a significant decrease in total soluble sugars (TSS) compared with control in both seasons. The highest decrement was observed at moisture stress which was low soil moisture level (W_2). These results confirmed those reported by El-Ghinbihi and Abd El-Fallah (2001) on taro and Hammad and El-Gamal (2004) on pepper plants. In this connection, Gawish and Fattahallah (1997) reported a reduction in leaf total carbohydrates content (%) which largely reflect the efficiency of photosynthesis process as affected by moisture regimes on taro plants.

Respecting the effect of the application of tomato plants with CCC or Mn, data presented herein indicated that TSS significantly increased by applying CCC or Mn compared with control in both seasons. Generally, the application of Mn was more effective in increasing TSS concentration than CCC. Similar results were also obtained by Ali (2005) on faba bean who observed significant increase in total carbohydrates due to foliar application of CCC or Mn.

Data recorded in the same table indicated that under moisture stress, the application of either CCC or Mn markedly eliminated the negative effect of water deficit and significantly increase TSS concentration in both seasons. The highest increment in these values was achieved by using Mn_2 under 75% F.C.

d) Mineral concentration:

Data for mineral concentration are presented in Table (5). It was observed that N, P and K concentrations were significantly decreased in water stress tomato leaves compared with controls in the first and second season. These results are in accordance with those obtained by Gawish and Fattahallah (1997) on taro plants, Sorial and El-Shafie (2002) and Hammad and El-Gamal (2004) on pepper regarding the decrease of N, P and K uptake as a result of water stress treatments. The reduction in P concentration may be due to the dieback of the absorbing roots during the exposure of plants to drought conditions (Larson, 1975).

The application of CCC or Mn significantly enhanced mineral concentration in tomato leaves. The increment was more pronounced at Mn_2 application comparing with untreated plants. These results were true in both seasons. The results are in harmony with those achieved by El-Quesni *et al.* (1992) and Ali (2005) on faba bean. Also, Shawky *et al.* (2002) reported that, spraying Mn increased the concentration of N, P and K in leaves of palm. Likewise, El-Nimr (1986) found that applying CCC increased N, P and K contents in cowpea and spinach, and added that CCC enhance mineral absorption and translocation from root to leaves of plants.

Significant differences in the concentrations of P and K were noticed due to the interaction between water stress and the supplemental application (CCC or Mn). Moreover, the treatment which included W_1 (75% F.C.) with the application of Mn_2 (50 mg/L) showed the highest significant mean values. Nitrogen concentration was not significantly affected by the application of CCC or Mn. These results were true in both seasons.

Table (5): Mineral concentration and proline concentrations of tomato plants as affected by water stress, cycocel and manganese chloroide treatments and their interaction in 2006 and 2007 seasons.

Treatments \ Characters		2006 season				2007 season			
		N (%)	P (%)	K (%)	Proline (g/g d.w.)	N (%)	P (%)	K (%)	Proline (g/g d.w.)
	W_0	3.21	0.41	2.03	124.86	3.51	0.46	2.06	123.02
	W_1	3.11	0.38	1.85	152.37	3.29	0.41	1.84	157.28
	W_2	2.50	0.26	1.41	166.96	2.18	0.26	1.35	180.79
	0.0	2.42	0.29	1.37	176.76	2.45	0.28	1.40	172.28
	CCC_1	2.98	0.35	1.78	143.86	3.04	0.37	1.73	152.86
	CCC_2	2.86	0.33	1.68	150.23	2.87	0.35	1.62	156.86
	Mn_1	3.16	0.39	1.96	139.16	3.23	0.42	1.92	146.90
	Mn_2	3.29	0.40	2.03	130.30	3.37	0.46	2.08	139.56
W_0	0.0	2.91	0.36	1.66	136.10	3.02	0.40	1.72	130.50
	CCC_1	3.14	0.39	1.97	125.20	3.51	0.45	1.95	126.10
	CCC_2	3.02	0.37	1.85	130.40	3.30	0.43	1.86	129.30
	Mn_1	3.44	0.45	2.30	121.20	3.81	0.50	2.29	120.40
	Mn_2	3.55	0.49	2.40	111.40	3.91	0.56	2.51	108.80
W_1	0.0	2.55	0.30	1.33	172.60	2.42	0.25	1.30	175.20
	CCC_1	3.16	0.38	1.91	146.40	3.40	0.43	1.88	155.30
	CCC_2	3.06	0.37	1.87	150.10	3.31	0.41	1.80	161.20
	Mn_1	3.31	0.43	2.05	145.10	3.62	0.46	2.07	150.10
	Mn_2	3.51	0.44	2.10	141.30	3.70	0.50	2.16	144.60
W_2	0.0	1.82	0.21	1.12	215.22	1.91	0.20	1.20	211.30
	CCC_1	2.66	0.28	1.48	160.00	2.21	0.25	1.36	177.20
	CCC_2	2.50	0.26	1.33	170.20	2.01	0.23	1.26	180.10
	Mn_1	2.75	0.30	1.55	151.20	2.28	0.30	1.41	170.20
	Mn_2	2.81	0.28	1.60	138.20	2.51	0.33	1.58	165.30
LSD 5%		W=0.16 A=0.15 W×A=n.s	W=0.01 A=0.01 W×A=0.02	W=0.06 A=0.08 W×A=0.14	W=8.10 A=9.01 W×A=15.6	W=0.29 A=0.26 W×A=n.s	W=0.02 A=0.02 W×A=0.04	W=0.08 A=0.11 W×A=0.16	W=2.55 A=4.68 W×A=8.11

W = levels of water stress A = Cycocel and Manganese treatments. W × A = Interaction

e) Proline concentration:

It is obvious from Table (5) that, there are a remarkable increase in leaf proline concentration under moisture stress condition when compared with unstressed plants or other treatments. These findings were supported by those obtained by Hammad (2000) on sweet basil and peppermint, Zhou and Gang (1997) on pea, El-Ghinbihi and Abd El-Fattah (2001) on taro and El-Garhy (2002) on faba bean. In this respect Pedersen *et al.* (1996) reported that, there was a positive correlation between proline concentration and membrane integrity of tobacco leaves and proline is believed to stabilize membrane phospholipids which helps the plants to overcome period of drought stress.

Results recorded in the same table demonstrated that, the application of CCC or Mn significantly reduced the accumulation of proline in tomato leaves compared with untreated plants. The highest depression in proline accumulation were recorded with the application of Mn at the first level (25 mg/L). These results were true in both seasons.

Data in Table (5) showed that, the application of supplemental treatments (CCC or Mn) under water deficit treatments significantly reduced proline accumulation in tomato leaves compared with untreated plants in both seasons. The best results were recorded in plants grown under the first level of water stress (75% F.C.) with the second level of Mn (50 mg/L).

4. Flowering:

Data presented in Table (6) clearly showed that ,number of flowers / plant was significantly decreased under water stress treatments compared with control. The highest reduction was obvious at the second water deficit treatment (55% of F.C.). These results were true in both seasons. These results are in agreement with those achieved by El-Garhy (2002) on faba bean.

Presented results show that application of tomato plants with CCC or Mn positively enhanced No. of flowers / plant compared with control. The highest mean values were recorded in plants treated with Mn_2 (50 mg/L) in both seasons. Similar results were also obtained by Mobarak (1999) on faba bean and Abd El-Megeed *et al.* (1997) who found that spraying bean plants with manganese led to an increase in the No. of flowers and added that, the enhancing effect of Mn on both flowering process and No. of flowers / plant may be due to the increase in dry matter content / plant. In addition Khattab *et al.* (1988) found that application of CCC on pelargonium plants led to significant increase in the No. of inflorescences / plant. Likewise, Abdalla *et al.* (1989) found that CCC increased No. of flowers of chrysanthemum plants. Also, Ali (2005) found that, application of Mn or CCC increased No. of flowers of faba bean plant.

Table (6): Flowering, yield and its components and fruit quality of tomato plants as affected by water stress, cycocel and manganese chloroide treatments and their interaction in 2006 and 2007 seasons.

Characters / Treatments		2006 season						2007 season					
		No. of flowers / plant	No. of fruits / plant	Fruit yield (g)/plant	T.S.S. (%)	Vit. C (mg / 100 g f.w)	Acidity (%)	No. of flowers / plant	No. of fruits / plant	Fruit yield (g)/plant	T.S.S. (%)	Vit. C (mg / 100 g f.w)	Acidity (%)
	W_0	20.20	12.00	155.50	7.22	0.27	18.13	21.60	12.73	167.40	8.42	0.32	14.12
	W_1	19.26	10.80	140.18	9.48	0.32	19.34	19.60	11.53	151.58	8.66	0.35	18.49
	W_2	14.46	8.20	102.35	8.64	0.37	19.84	14.40	9.00	112.98	9.32	0.45	20.86
	0.0	14.66	8.00	104.42	9.53	0.33	20.13	14.77	8.88	114.23	9.90	0.38	20.41
	CCC_1	17.77	10.55	132.86	8.23	0.32	19.12	19.11	11.22	146.77	8.56	0.35	17.64
	CCC_2	15.55	9.77	120.63	8.60	0.30	19.32	16.00	10.55	133.60	8.93	0.33	18.30
	Mn_1	19.88	11.33	148.53	8.06	0.31	18.63	20.55	12.11	158.70	8.40	0.38	16.87
	Mn_2	22.00	12.00	156.93	7.80	0.35	18.30	22.22	12.67	166.64	8.20	0.41	15.90
W_0	0.0	18.33	9.33	122.30	8.80	0.24	18.60	17.00	10.67	136.10	9.20	0.28	15.91
	CCC_1	20.33	12.00	160.10	6.70	0.28	18.18	22.33	12.67	170.42	8.20	0.32	14.21
	CCC_2	19.00	11.33	138.50	7.60	0.26	18.28	18.67	11.67	152.31	8.60	0.30	14.40
	Mn_1	21.33	13.33	174.10	6.60	0.29	18.00	24.00	14.00	182.01	8.10	0.33	13.51
	Mn_2	25.33	14.00	182.50	6.40	0.31	17.60	26.00	14.67	195.20	8.00	0.35	12.60
W_1	0.0	14.67	8.00	105.30	9.60	0.32	20.20	15.33	9.00	115.21	9.70	0.36	21.02
	CCC_1	19.33	11.00	133.20	8.60	0.30	19.40	20.00	11.67	151.60	8.50	0.31	18.33
	CCC_2	18.67	10.00	125.10	8.70	0.28	19.70	19.33	11.00	142.31	8.80	0.29	19.21
	Mn_1	21.00	12.00	162.20	8.30	0.34	18.90	22.00	12.67	170.50	8.30	0.37	17.40
	Mn_2	23.00	13.00	175.10	8.00	0.36	18.50	24.67	13.33	178.32	8.00	0.41	16.51
W_2	0.0	11.33	6.67	85.80	10.20	0.44	21.60	12.00	7.00	90.40	10.80	0.50	24.31
	CCC_1	13.00	8.67	105.60	9.40	0.38	19.80	15.00	9.33	118.30	9.00	0.42	20.40
	CCC_2	12.67	8.00	98.30	9.50	0.36	20.00	13.33	9.00	106.22	9.40	0.39	21.30
	Mn_1	17.33	8.67	109.30	9.30	0.30	19.00	15.67	9.67	123.60	8.80	0.45	19.70
	Mn_2	17.67	9.00	113.20	9.00	0.37	18.18	16.00	10.00	126.41	8.60	0.48	18.60
LSD 5%		W=0.79 A=1.34 W×A=2.32	W=1.55 A=0.85 W×A=n.s	W=7.50 A=9.20 W×A=16	W=0.23 A=0.22 W×A=0.38	W=0.03 A=0.03 W×A=0.05	W=0.57 A=0.66 W×A=n.s	W=1.49 A=1.40 W×A=2.45	W=0.88 A=1.18 W×A=n.s	W=7.43 A=6.70 W×A=11.6	W=0.27 A=0.17 W×A=0.43	W=0.02 A=0.02 W×A=0.04	W=0.78 A=1.06 W×A=n.s

W = levels of water stress   A = Cycocel and Manganese treatments.   W × A = Interaction

Concerning the interaction between water stress and the application of CCC or Mn, data in Table (6) showed that a significant increment in the No. of flowers / plant following the applying of these substances under water moisture conditions. The highest improvement was achieved by using the combination treatment of Mn_2 and W_1 (50 mg/L with 75% of F.C.) in both seasons.

5. Yield and its components:

Number of fruits / plant and fruits weight (g / plant) were significantly reduced in plants grown under drought conditions when compared with those grown under normal condition in both seasons. The present results are in agreement with those reported by Hegde (1987) on radish, Bhattacharya *et al.* (1990) on sweet potato and Hammad and El-Gamal (2004) on pepper plants. This reduction in tomato yield under water stress conditions may be attributed to the reduction in vegetative growth characters and the depression of the chemical and bio-chemical composition of tomato leaves, which were recorded and discussed previously.

Regarding the effect of CCC or Mn spraying, it can be noticed that, there was a significant increase in the number and weight of fruits / plant compared with control plants in both seasons. The best results were recorded with Mn_2. These results are in harmony with obtained by Derar and Gendy (1994) on bean, Hassanein *et al.* (1993) on faba bean, Kamble and Desal (1996) on ber, El-Sabbagh (2002) on bean and Ali (2005) on faba bean, they reported that foliar application of CCC increased yield and its components. Also, Etman *et al.* (1991), El-Quensi *et al.* (1992) and Ali (2005) on faba bean and Desouky (1999) on *Hibiscus rosa*, they reported that, the increase in yield and its components resulted in the response of plants to foliar application of CCC.

The application of cycocel and manganese as foliar spray under water stress conditions significantly increased fruit yield / plant in both seasons. The highest values were recorded with Mn_2 under W_1 treatment (Mn at 50 mg/L with 75% of F.C). Moreover, data presented in Table (6) indicated that, there were no significant differences in the No. of fruits / plant, with respect to the interaction among treatments in both studied seasons.

6. Tomato fruit quality:

Regarding fruit quality, TSS, vitamin C and acidity concentrations in tomato fruits were enhanced under water stress treatments compared with untreated plants in both seasons. Similar results were observed by Lynch *et al.* (1995) on potato and Hammad and El-Gamal (2004) on pepper plants.

Concerning the effects of CCC or Mn application on tomato fruit quality, data in Table (6) showed significantly improvement in all tomato quality characteristics as a results of foliar application with CCC or Mn in both seasons compared with the control treatments. In this connection, Mn treatments recorded the best results.

Respecting the interaction effects of water stress and the application of CCC or Mn, data in Table (6) indicated that, TSS and vit. C were enhanced while there were no significant differences in acidity concentrations in tomato fruits as compared with untreated plants (water stress only) in both seasons. In this regard, the best results were recorded with Mn at the second level with the first level of water stress (50 mg/L of Mn + 75% of F.C.).

Finally, it could be recommend that, foliar application of CCC or Mn might be used to mitigate the deleterious effects of water stress on physiological behaviour, WUE and yield with good quality of tomato plants grown under water stress.

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تخفيف التأثيرات الضارة للإجهاد المائى فى نباتات الطماطم باستخدام السيكوسيل والمنجنيز

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الملخص العربى

أجريت تجربتى أصص بالمزرعة البحثية بكلية الزراعة جامعة المنوفية خلال موسمى ٢٠٠٦ ، ٢٠٠٧ لدراسة تأثير استخدام الرش بالسيكوسيل (١٠٠ أو ٢٠٠ مليجرام / لتر) والمنجنيز (٢٥ أو ٥٠ مليجرام / لتر) على تقليل الأضرار فى نباتات الطماطم صنف بتتو ٨٦ النامية تحت ٣ مستويات من الإجهاد المائى (٥٥ ، ٧٥ ، ١٠٠% من السعة الحقلية) . وقد أشارت النتائج المتحصل عليها إلى الآتى :

- أن جميع الصفات المدروسة للنمو الخضرى ومحتوى الماء النسبى والكلوروفيل والسكريات الكلية الذائبة والنيتروجين والفوسفور والبوتاسيوم فى الأوراق وعدد الأزهار / نبات وأيضاً محصول النبات من الثمار وجودته قد نقصت معنوياً بزيادة الإجهاز المائى بينما الضغط الأسموزى وكفاءة الاستهلاك المائى ونفاذية الجدر الخلوية والنشاط الإنزيمى قد زادت معنوياً .
- كان لاستخدام المنجنيز أكثر تأثيراً فى كل الصفات المدروسة بينما جودة الثمار المتمثلة فى زيادة المواد الصلبة الكلية ، فيتامين ج ، الحموضة قد حققت أعلى القيم باستخدام السيكوسيل .
- وجد أن رش نباتات الطماطم النامية فى ظروف الإجهاد المائى بالسيكوسيل أو المنجنيز أدى إلى زيادة جميع الصفات المدروسة معنوياً عدا عدد الأوراق ووزن الجذر وعدد الثمار / نبات وحموضة الثمار .
- قد أدى رش المنجنيز بمعدل ٥٠ مليجرام / لتر عند ٧٥% من السعة الحقلية إلى الحصول على أعلى محصول ثمار / نبات .