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SALINITY INDUCED CHANGES IN VEGETATIVE AND REPRODUCTIVE GROWTH IN TOMATO[1]

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ABSTRACT: Vegetative and reproductive growth were studied in five tomato (*Lycopersicon esculentum* Mill) cultivars under saline conditions imposed at the five-leaf stage by addition of 50 mM NaCl to half strength Hoagland nutrient solution. The plants were raised in pots filled with washed quartz sand kept in a greenhouse. Stem height and number of leaves in tomato plants were significantly reduced when irrigated with saline regimes in contrast with control plants that received only the Hoagland solution. The highest number of flowers were obtained in the cultivar Pearson and the least in cultivar Strain B. Fruit set and yield were little affected by varietal differences and were not related to vegetative growth. Fruit weight was suppressed with NaCl stress, but improvement in weight was achieved when potassium (K) and calcium (Ca) were added to the saline water. The most detrimental effect of NaCl stress was the reduction of biomass yield in tomatoes. However, the relative dry weights of Pearson and Monte Carlo were increased to 60% and 54%, respectively, when NaCl was supplemented with Ca. Large varietal differences in biomass occurred among the NaCl-treated and control plants. Tomato fruit quality (TSS) was improved by salinization.

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INTRODUCTION

Along the coastal plains of Northern Oman, and in many areas of the world, farmers use saline water for irrigation. Increasing levels of salinity were observed during years of drought and scarcity of rainfall. Irrigation water contains high amounts of NaCl which could antagonize uptake of nutrients, produce specific ion effects, and result in considerable crop losses. Salinity studies have indicated considerable differences in the responses of certain crop species to salinity stress (O'Leary, 1971). Most of the information and understanding of salt tolerance would contribute and facilitate formulation of agronomic techniques for salinity adaptation. For example, it is well known that K has a substantial effect on the water status of plants. Potassium is involved in stomatal movement and osmoregulation in plants (Raschke, 1975), and will increase leaf chloroplast numbers and leaf length (Passingham, 1980). Potassium will accumulate during drought (Ford and Wilson, 1981). This suggests that use of K might enhance plant growth under saline conditions. It is also known that increased Ca can reverse loss of membrane integrity caused by Na displacement of Ca (Cramer, 1985), and high Ca might maintain the K/Na selectivity (Kent, 1985).

In this study, we investigated the effects of K and Ca application on tomato cultivars subjected to NaCl stress. Vegetative and reproductive parameters were measured to evaluate growth and yield of tomato in response to salinity stress.

MATERIALS AND METHODS

The experiment was conducted at the College of Agriculture research farm during 1990-1992. Seedlings of tomato (*Lycopersicon esculentum* Mill) were transplanted at the five leaf stage to pots filled with coastal sand. Five tomato cultivars, Pearson, Monte Carlo, UC 82L, Strain B, and Pakmore were used. The study was performed in a greenhouse under natural day length, and mean day and night temperature of 28 and 18°C, respectively. The experiment al design was a randomized complete block design with four replications. Each block had 25 plants with five cultivars and five salt treatments.

Plants were irrigated with half-strength Hoagland nutrient solution supplemented with 0 and 50 mM NaCl solution; 50 mM NaCl + 20 mM $Ca(NO_3)_2$; 50 mM NaCl + 2 mM KNO_3; and 50 mM NaCl + 20 mM $Ca(NO_3)_2$ + 2 mM KNO_3.

Pots were leached fortnightly and the leachate was reused in subsequent irrigation of the same treatment.

Data were collected on vegetative and reproductive growth parameters. Harvested plants were separated into roots, stems, and leaves. Plant parts were dried in an oven at 70°C for 72 hours. Analysis of variance was carried out and means were separated by the least significant difference (LSD) test at the 0.05 level of confidence.

RESULTS AND DISCUSSION

Stem growth was frequently used in many studies to measure the extent of salinity stress on plant species. In our study, stem height and leaf formation were used to indicate variations in vegetative growth for the studied tomato cultivars in relation to NaCl stress alone or with added K and Ca. The cultivar Pearson had the highest stem height and leaf growth as compared to the other cultivars (Table 1a). The lowest stem growth was for cultivar UC 82L which was less than 50% of that obtained in cultivar Pearson.

The cultivar Strain B has the lowest number of leaves. The addition of NaCl alone or with Ca and K in the irrigation water resulted in a significant reduction in stem height and number of leaves compared with the control plants (Table 2b) which received the Hoagland nutrient solution only. Many researchers reported that the most obvious effect of salinity on plants is growth retardation (Epstein, 1980; Williamson and Coston, 1989; Satti and Ahmad, 1992).

Flowering among the tomato cultivars showed significant differences in the total number of flowers produced. The cultivar Pearson had the highest flower number and the least was for for cultivar Strain B (Table 2a). Fruit set and yield was not affected by varietal differences, and thus, it is not related to vegetative development. Tomato plants, relative to cotton, show little competition between vegetative and reproductive growth. Salinity stress decreased flowering in all treatments relative to the control as shown in Table 2b. However, the addition of K and Ca with NaCl in irrigation water significantly increased fruit set over the control and NaCl-treated plants. The role of K on flowering and fruit yield was revealed in the work of Bradfield (1975), who indicated that increased flower production and fruit yields were obtained in strawberries when K was increased

Table 1a. Vegetative growth of tomato cultivars.

CULTIVAR	VEGETATIVE GROWTH	
	STEM HEIGHT (cm)	LEAF NUMBER
PEARSON	96.81 a	24.88 a
MONTECARLO	79.47 b	21.68 b
UC 82L	45.50 c	16.25 c
STRAIN B	49.50 c	13.50 d
PAKMORE	52.39 c	15.76 c

Means within columns, having the same letter are not significantly different from each other at 5% level (LSD).

Table 1b. Vegetative growth in response to salinity.

SALINITY TREATMENT	VEGETATIVE GROWTH	
	STEM HEIGHT (cm)	LEAF NUMBER
CONTROL	77.90 a	17.65 a
NaCl	59.15 b	15.15 bc
NaCl + Ca	60.82 b	15.10 bc
NaCl + K	63.46 b	16.35 ab
NaCl + Ca + K	62.34 b	14.55 c

Means within columns, having the same letter are not significantly different from each other at 5% level (LSD).

Table 2a. Flowering, fruit set and yield of tomato cultivars.

CULTIVAR	TOTAL NO. OF FLOWERS PER PLANT	PERCENT FRUIT SET	FRUIT YIELD/PLANT	
			NUMBER	WEIGHT (kg)
PEARSON	24.85 a	54.41 a	6.90 a	0.23 a
MONTECARLO	17.25 bc	54.58 a	4.05 b	0.24 a
UC 82L	18.05 bc	62.04 a	6.55 a	0.20 a
STRAIN B	16.20 c	54.03 a	4.40 b	0.23 a
PAKMORE	20.10 b	50.29 a	4.90 b	0.22 a

Means within columns, having the same letter are not significantly different from each other at 5% level (LSD).

Table 2b. Flowering, fruit set and yield in response to salinity.

SALINITY TREATMENT	TOTAL NO. OF FLOWERS PER PLANT	PERCENT FRUIT SET	FRUIT YIELD/PLANT	
			NUMBER	WEIGHT (Kg)
CONTROL	26.35 a	50.73 b	6.40 a	0.47 a
NaCl	14.80 c	43.23 b	2.85 a	0.10 d
NaCl + Ca	18.30 bc	61.39 a	6.20 a	0.19 bc
NaCl + K	20.45 b	60.19 a	5.95 a	0.22 b
NaCl + Ca + K	17.05 c	59.83 a	5.40 a	0.15 c

Means within columns, having the same letter are not significantly different from each other at 5% level (LSD).

from flowering through fruiting. Bolino (1981) recommend a leaf K level higher than 1.5% during fruiting.

Fruit weight was significantly suppressed by almost 20% due to the salinity treatment. The use of K and Ca with NaCl increased fruit weight and hence yield. It was apparent from the data shown in Table 2b, that salinity reduced tomato yield mainly by affecting fruit weight. Moreover, plants treated with K and Ca were able to overcome and alleviate the NaCl-effect on the reduction of fruit weight, possibly

Table 3 . Dry weight (g) of whole tomato plant.

CULTIVAR	SALINITY TREATMENT				
	CONTROL	NaCl	NaCl + Ca	NaCl + K	NaCl + Ca + K
PEARSON	a 47.54 A	a 21.50 C	a 28.92 B	a 22.06 C	a 25.68 BC
MONTECARLO	a 42.43 A	b 13.85 C	b 23.04 B	a 23.34 B	a 23.24 B
UC 82L	b 32.88 A	b 10.53 B	c 12.36 B	b 15.35 B	b 13.18 B
STRAIN B	c 22.36 A	b 8.62 B	c 13.33 B	b 11.47 B	b 12.67 B
PAKMORE	c 23.77 A	b 10.04 C	c 17.13 B	b 13.79 BC	b 14.60 BC

Means within rows and columns, having the same letter are not significantly different from each other at 5% level (LSD)(Capital letter for rows and small letter for columns).

Table 4. Number of fruits harvested/plant in tomato in response to salinity.

CULTIVAR	SALINITY TREATMENT				
	CONTROL	NaCl	NaCl + Ca	NaCl + K	NaCl + Ca + K
PEARSON	ab 7.25 B	a 1.50 A	c 8.75 B	cd 7.75 B	c 9.25 B
MONTECARLO	a 4.75 AB	a 2.25 A	a 4.25 AB	bc 6.50 B	a 2.50 A
UC 82L	b 8.00 B	a 4.00 A	bc 7.75 B	bc 6.75 AB	b 6.25 AB
STRAIN B	ab 5.25 A	a 3.00 A	ab 5.50 A	a 3.50 A	ab 4.75 A
PAKMORE	ab 6.75 B	a 3.50 A	a 4.75 AB	ab 5.25 AB	ab 4.25 AB

Means within rows and columns, having the same letter are not significantly different from each other at 5% level (LSD)(Capital letter for rows and small letter for columns).

Table 5. Total soluble solids (TSS) in tomato fruits in response to salinity.

CULTIVAR	% TSS	SALINITY TREATMENT	% TSS
PEARSON	9.90	CONTROL	5.20
MONTECARLO	8.30	NaCl	7.20
UC 82L	7.90	NaCl + Ca	10.50
STRAIN B	7.40	NaCl + K	8.80
PAKMORE	7.30	NaCl + Ca + K	10.60

via increased concentration of solutes in the plant tissue. Watad et al. (1991) found that there was an adaptation of glycophyte cells to NaCl results in increased capacity for K uptake, and this capacity is even greater under saline conditions.

Dry matter yield of tomato cultivars (Table 3) in response to salinity stress clearly indicated that NaCl has the most detrimental effect on biomass reduction. The cultivar Pearson accumulated a significant amount of dry matter in contrast to other tomato cultivars. Relative dry weights (NaCl related to control) were 45%, 42%, 38%, 33%, and 32% for the cultivars Pearson, Pakmore, Strain B, Monte Carlo, and UC 82L, respectively.

The inclusion of Ca and K in the nutrient solution significantly increased the relative dry weight for the Pearson and Montecarlo cultivars to 60% and 54%, respectively. It appears that dry weight data and vegetative growth (stem height) are very much related parameters for evaluation of tomato cultivars under salinity stress. The cultivar Pearson had the highest dry matter in the saline treatments, having the highest stem growth. Tomato yield and vegetative growth are, for many reasons, independent of salinity stress. It is likely that stress, after ample growth could check leaf growth, impose nutritional deficiencies, reduce photosynthesis, and as such, effecting the sink-source supply that would affect fruit growth and yield.

The number of fruits harvested from tomato plants in response to salinity is given on Table 4. Large varietal differences in fruit number occurred between the NaCl-treated and control plants. The relative reduction in fruit number varies between 80% for the Pearson and 40% for the Strain B cultivars. The addition of K and Ca with NaCl in the irrigation water resulted in a dramatic increase in fruit number which was similar to the control plants in most of the cultivars. However, yield reduction under salinity stress is not solely attributed to fruit number but fruit weight is probably most limited by photosynthate source. The rate of photosynthetic CO_2 assimilation has been found to be reduced by salinity (Downton and Robinson, 1985; Seeman and Critchey, 1985). This reduction is partly due to reduced stomatal conductance and consequently unavailability of CO_2 for carboxylation.

The total soluble solids percent (TSS) of tomato fruits were increased by the presence of NaCl by 7.2% in contrast to 5.2% in the control plants (Table 5). Further increases in TSS were obtained when Ca and K were added to the nutrient solution. Variations in TSS between tomato cultivars ranged between 9.9% in Pearson to 7.3% in Pakmore. Mizrahi (1988) reported a significant increase in total soluble solid percentage of tomato irrigated with diluted sea water at the late stage of development. Similar improvement in tomato fruit quality were observed by Adams (1988) when NaCl was increased to 67 mM levels in irrigation water.

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A QUICK TEST PROCEDURE FOR SOIL NITRATE-NITROGEN

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ABSTRACT: A procedure for extraction and measurement of nitrate-nitrogen (NO_3-N) in soil is described. Extracting solution [0.025M $Al_2(SO_4)_3$] and field-moist soil are measured volumetrically, with NO_3-N concentration measured by nitrate-sensitive colorometric test strips or nitrate-selective electrode. Across a range of soil texture, moisture content, and NO_3-N concentration, the procedure was well correlated with conventional laboratory analysis of 2N KCl soil extracts ($r^2 = 0.94$). This quick test procedure is proposed as an on-farm monitoring technique to improve N management.

INTRODUCTION

In the California vegetable crop industry, soil testing for mineral N has generally been limited to preplant sampling for residual NO_3-N. There has been a widely held perception that, particularly for shallow-rooted crops, soil NO_3-N content fluctuated widely with water management and could not be counted on to supply substantial nutrition to the crop; consequently, heavy application of N fertilizer has been common practice for decades in areas, like the Salinas Valley, with virtually no in-season soil NO_3-N analysis performed to guide fertilizer application. However, increasingly serious groundwater pollution with NO_3-N of agricultural origin is now focusing attention on better N management practices.

The paucity of quick, accurate, and inexpensive on-farm soil NO_3-N analytical procedures is a limiting factor in improving N management practices. Suction lysimetry is a technique of some utility, but the stratification of NO_3-N in the soil profile and spatial variability in the field make its use problematic (Litaor, 1988; Hartz et al., 1992). Soil testing kits designed for on-farm use are widely

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