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RESPONSE OF SOME TOMATO CULTIVARS, BEEDING LINES AND THEIR HYBRID COMBINATIONS TO SALINITY TOLERANCE

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ABSTRACT

Four commercial tomato cultivars (Imberial, Pakmore VF, Queen and Strain-B), two salinity tolerant breeding lines (BL 1076 and BL 1239, from Asian Vegetables Research and Development Center) and all their fifteen possible hybrid combinations in one direction were used in this study to evaluate their salinity tolerance and select starting materials for a salinity tolerance breeding program in tomato. Four weeks old seedlings were transplanted into the soil under greenhouse conditions. Six water salinity levels (1.2, 2.4, 4.8, 7.2, 9.6 and 12.0 dS m^{-1}) were imposed through a drip irrigation system. Plant height, stem thickness, leaf dry matter content, average fruit weight, average fruit number, total yield, and leaf concentrations of Na^+, Cl^-, Ca^{++} and K^+ were measured. All vegetative and fruit traits decreased significantly with increasing salinity levels, starting at 4.8 dS m^{-1}. Reduction in yield and average fruit weight were more than 50% for most genotypes at 12.0 dS m^{-1} level. Increasing salinity levels led to raising Na^+ and Cl^-, and diminishing Ca^{++} and K^+. Significant differences among genetic populations were detected in all traits suggesting that these traits could be taken into account when selecting for salt tolerant tomato genotypes. Based on the general performances of the parental and their F_1 hybrid genotypes under salinity levels, the additive gene effects contributed to the genetic variability more than the non-additive gene effects, since traits values of most F_1 hybrids were reported to be around their respective mid-parental values. The two cultivars Pakmore VF and Strain-B

reflected good performances for most studied traits under different salinity levels and could be selected as recurrent parents (female) in back-cross breeding programs. The breeding line BL 1076 exhibited the highest salinity tolerance by most traits and could be considered as a donor (male) parent in such breeding programs. The best hybrid combinations under salt stress conditions of this study appeared to be the two crosses Pakmore VF × BL 1076 and Strain-B × BL 1076. The mentioned parents and hybrid combination will be utilized as suitable genetic materials in a tomato breeding program for salinity tolerance.

Keywords: *Lycopersicon esculentum* Mill., growth, yield, salinity stress, ion concentrations, plant breeding.

INTRODUCTION

High salinity levels can impose a major environmental constraint to crop productivity. Low rainfall, high evaporation, saline irrigation water and poor water management can cause salinity problems in agricultural areas (Dasgan et al., 2002). Plants are stressed in saline soils due to water stress (low osmotic potential), toxic effects of ions; mainly Na^+ and Cl^-, and nutrient imbalance, or a combination of these factors (Lauchli, 1986 and Marschner, 1995). In addition to affecting crop yield and soil physical condition, irrigation water quality can affect soil fertility and irrigation system performance. Therefore, knowledge of irrigation water quality is critical to understand the necessary management changes for long-term productivity (Bauder et al., 2004).

When water resources are limited and the cost of non-saline water becomes high, crops of moderate to high salt tolerance can be irrigated with saline water (Ragab et al., 2005). Increasing salt tolerance of crops through plant breeding could increase the sustainability of irrigation with low quality water by reducing the need for leaching and allowing the use of poor quality water (Abdel-Gwad et al., 2005). Selection and breeding of cultivars that can grow and produce economic yield under saline conditions are more permanent and complementary solution to minimize detrimental effects of the salinity (Foolad, 1997). Genetic variability within a species is a valuable tool for screening and breeding for salt tolerance. A primary task in breeding for stress tolerance is the identification and genetic characterization of useful germplasm.

Tomato (*Lycopersicon esculentum* Mill.) is one of the important and widespread crops in the world and can act as a model crop for saline land recovery and use of poor-quality water, as there is a wealth of knowledge of the physiology and genetics of this species, and it is already grown in large areas where saline conditions are a problem (Reina-Sanchrz et al., 2005). Most commercial tomato cultivars are sensitive to moderate levels of salinity which means that they tolerate an E.C of the saturated soil extract up to 2.5 dS m^{-1} without a yield reduction (Mass, 1986). Many authors have reported large variation among tomato genotypes in their response to salinity (Alian et al., 2000; Romero-Aranda et al., 2001 and Dasgan et al., 2002). In general, most of the research in tomato salt tolerance has been developed in wild versus domesticated species (Shannon et al, 1987 and Sanchez-Blanco et al, 1991) under salinity levels were much higher than those usually present in commercial tomato crop production (Cuartero and Fernandez-Munoz, 1999). Very few reports on the genotypic variation in commercial cultivars are available, and they have been developed during a short period of salinization, giving only partial information about osmotic adjustment (Alian et al., 2000). According to Cuartero and Fernandez-Munoz (1999), breeding of tolerant cultivars to moderate salinity will only occur after pyramiding in a single genotype several characteristics, each one alone could not confer a significant increase in the salt tolerance.

This study is a part of a comprehensive breeding program aimed to breed tomato cultivars with high salt tolerance. The objectives of this study were: (a) to evaluate salinity tolerance of four tomato cultivars, two breeding lines and their fifteen hybrid combinations, and (b) to select starting materials for salinity tolerance breeding program in tomato.

MATERIALS AND METHODS

Responses to salinity stress in tomato (*Lycopersicon esculentum* Mill.) were investigated under greenhouse conditions, during 2006 and 2007 seasons, at the Agricultural Research and Experiment Station of the Faculty of Food and Agricultural Sciences, King Saud University, Riyadh, Saudi Arabia. The genetic materials used in the present investigation were started with four commercial cultivars (Imberial, Pakmore VF, Queen, and Strain-B) and two salinity tolerance tomato breeding lines (BL 1076 and BL 1239). The commercial cultivars, obtained from a seed market in Saudi Arabia, were previously evaluated and selected as good cultivars under different environmental conditions (Alsadon and Wahb-allah, 2007 and Mohammed et al., 2007). The salinity tolerance breeding lines were provided by the Asian Vegetables Research and Development Center (AVRDC, Shanhua, Taiwan, ROC).

In the first season, seeds of the six parental tomato genotypes were sown on August 10, 2006 in Jiffy 7 pots. Four weeks old transplants were transformed into 30 cm diameter pots, filled with a soil mix (1 peat : 1 sand : 1 vermiculite). At the flowering stage, selfing and hybridization among the six genotypes were carried out in a diallel cross system in one direction. The commercial cultivars were used as females and the breeding lines were used as males. Enough seeds of all possible fifteen hybrids and new seeds of the six selfed parents were obtained after three months from transplanting.

In the second season, responses of the twenty-one tomato genotypes to salinity stress were investigated using six water salinity levels of NaCl (1.2, 2.4, 4.8, 7.2, 9.6 and 12.0 dS m^{-1}) through a drip irrigation system. Seeds of the genotypes were sown in seedling trays on February 12, 2007. One month old seedlings were transplanted into soil in a fiberglass greenhouse. Soil texture was sandy and the mechanical soil analysis was 84% sand, 8% silt and 8% clay. Temperature and relative humidity were averaged about 25 ± 0.5 °C and 75 ± 2 % during growth stages, respectively. Fertilization and other cultural practices were applied as commonly recommended for commercial tomato production in greenhouse.

Salinity treatments were started after seven days from transplanting using six containers ($1m^3$) connected to surface drip irrigation network. Each container was filled by one level of salinity (resulted from the addition of NaCl to the irrigation water) and connected to two dripper lines. The experimental layout was a split-plot system in randomized complete blocks design with three replications. Irrigation treatments were randomly allocated to the main plots; while, the tested genotypes were arranged in the sub-plots. The sub-plot area was 4 m^2 (2x2) and included 8 plants (4 plants to each dripper line). Planting distances were 50 cm and 100 cm between plants and lines, respectively.

A random sample of four plants from each sub-plot was chosen to record plant height and stem thickness (Forty-five days after transplanting). Total yield (the total weight of all harvested fruits/plot in the whole season), average fruit weight (total weight of all harvested fruits per plot divided by their number) and number of fruits per plant were also recorded. Leaf samples from the upper leaves, after 60 days from transplanting, were collected, washed in distilled water and dried at 70 °C in a forced air-oven till the weight became constant, then the dry matter contents were calculated. The dried materials were ground and used to determine leaf concentrations of Na^+, Cl^-, Ca^{++} and K^+, using the procedure reported in A.O.A.C (1992).

Data were statistically analyzed, using Statistical Analysis System (SAS), and treatment means were compared; using revised L.S.D. test at 0.05 level, according to Steel and Torrie (1980).

RESULTS AND DISCUTIONS

Influence of salinity stress on growth parameters

All growth parameters were greatly reduced by the successive increases in salinity levels. However, the rates of response varied among the different studied parameters (Table 1). High salinity levels (> 4.8 dS m^{-1}) caused significant reductions in plant height, stem thickness and leaf dry matter; compared to control (1.2 dS m^{-1}); while, the low level (2.4 dS m^{-1}) had insignificant effects. These results are in accordance with those of recorded by Kerkides et al. (1997) and Olympios et al. (2003). Irrigation with saline water at 4.8, 7.2, 9.6 and 12.0 dS m^{-1} levels reduced the stem thickness by 10.8 %, 9.3 %, 17.7 % and 15.0 %, and reduced leaf dry matter by 15.3 %, 13.4 %, 25.9 % and 28.3 %, respectively; compared to control. Negative effects of higher salinity levels on the leaf dry mass of tomato plants were reported by Van-Ieperen (1996), who found that the decrease in leaf dry weight by salinity (especially at levels above 6

Table 1. Influences of salinity levels on some growth parameters and leaf ion concentrations of tomato genotypes.

Salinity levels (dS m^{-1})	Plant height (cm)	Stem thickness (mm)	Leaf dry matter (%)	Average fruit weight (g)	Average fruit number/plant	Total yield (kg/plant)	Na (mg/100gm)	Cl (mg/100gm)	Ca (mg/100gm)	K (mg/100gm)
lg.2	90.7 a	13.0 ab	13.75 a	97.1 a	25.9 a	2.265 a	250 f	548 f	1682 b	2488 a
2.4	84.3 b	13.3 a	13.63 a	93.6 b	25.6 a	2.183 b	763 e	980 e	1695 a	2226 b
4.8	77.8 c	11.6 ab	11.56 b	74.6 c	24.5 b	1.838 c	969 d	1346 d	1677 b	2043 c
7.2	74.1 d	11.8 b	11.91 c	67.5 d	24.2 b	1.651 d	1150 c	1414 c	1635 c	1844 d
9.6	68.2 e	10.7 c	10.19 d	58.0 e	23.3 c	1.483 e	1309 b	1591 b	1605 d	1759 e
12.0	64.8 f	11.1 c	9.86 d	44.7 f	23.2 c	1.138 f	2466 a	1960 a	1525 e	1427 f

dS m^{-1}) is not caused by a reduction in the number of leaves, but by a reduction in leaf area. Cruz and Cuartero (1990) found that both stem and leaf dry weight of tomato plants were diminished in saline condition, but the reduction of leaf dry weight was greater than that of dry shoot weight.

Yield components as determined by average fruit weight, average fruit number and total weight of fruits per plant were significantly affected and decreased with increasing salinity level. The successive increase in salinity level caused reductions in average fruit weigh by 3.6 %, 23.8 %, 30.5 %, 40.3 % and 53.9 %, respectively; compared with the control. The corresponding reductions of number of fruits per plant were 1.2 %, 5.4 %, 6.6 %, 10.1 % and 10.5 %; whereas, the reductions in total yield per plant were 3.6 %, 18.8 %, 27.1 %, 34.5 % and 49.7 %, respectively. The reductions in yield, even at a relatively low concentration of salinity, (i.e. 2.4 dS/m^{-1}) in the irrigation water supported the finding of Cuartero and Fernandez-Munoz (1999), that even under normal growing conditions, the EC of the root solution was close to the threshold for yield reduction. They suggested that, when irrigating with fresh water and fertilizing normally, the saturated soil extract varied between 1.6 and 3.1 dS/m. Van-Ieppren (1996) reported a significant reduction in average fruit weight, but not in fruit number, even at low levels of salinity, applied for the whole experimental period. The results showed that, at high ECs (above 7.2 dS/m^{-1}), there was a serious reduction in average fruit weight and total yield (Table 1). These results appeared to be in a general agreement with the finding of Olympios et al. (2003). The effects of salinity on yield became more marked as the harvest period progressed, due initially to a restriction on fruit size during the first four weeks of harvest, but later it was to a decrease in fruit number (Adams and Ho 1989, and Cuartero and Fernandez-Munoz 1999).

Increase in salinity level in irrigation water increased leaf Na^+ and Cl^- concentrations. The rise in Na and Cl^- concentrations in the leaves lowers the osmotic potential (Cuartero and Fernandez-Munoz, 1999); contributing to the maintenance of the water potential difference between the leaves and the soil, required to obtain water from the saline solution. Accordingly; any plant, able to accumulate more Na^+ and Cl^- would absorb water more easily and be more tolerant to salinity. However, increased salinity levels reduced leaf

Ca^{++} and K^{+} concentrations. Plants which take up more Ca and K from the medium will have lower Na^{+}/K^{+}, Na^{+}/Ca^{++} ratios and equilibrium of nutrients more similar to the non salinised plants (Cuartero et al., 1992 and Perez-Alfocea et al., 1993).

Responses of tomato genotypes to salinity stress

Tomato genotypes showed wide differences in studied growth and yield traits (Table 2). In general, the parental cultivars differed significantly from one another in all recorded characters. The significant highest values for plant height among all genotypes were those of the cultivar Pakmore VF (85.1 cm); whereas, the lowest values were reflected by BL 1067 (65.3 cm). Among parental genotypes, Pakmore VF gave the highest value for leaf dry matter content (11.84%). The data of the first generation hybrids illustrated, generally, that most of the F_1' s produced average values around their respective mid-parental values or deviated towards the values of the higher parents. These results seemed to suggest that the inheritance of the three mentioned traits involved additive and partial dominance for the high value over their alternative forms, and that the additive gene effects contributed to the genetic variability more than the non-additive gene effects.

The means of the different genotypes showed a wide range of variability in average fruit weight, average fruit number and total weight of fruits per plant (Table 2). The cultivar Pakmore VF had significantly the largest average fruit weight; while, the hybrid F_1 of the cross Strain B x BL 1067 (P4 x P5) had the largest average fruit weight and the hybrid F_1 of the cross Pakmore VF x BL 1067 (P2 x P5) had the highest total yield. All F_1's produced averages fruit weight that deviated towards the respective smaller fruited parents, reflecting the dominance of small- over large-fruit weight. On the other hand, all F_1' hybrids showed significant superiority in fruits number and total productivity over their respective higher parents. Therefore, the later result indicated that pronounced degrees of dominance and over-dominance were involved in the inheritance of these two traits.

The comparisons among the various genotypes showed relatively greater differences in leaf Na^{+} and Cl^{-} concentrations; while, slight variations for their leaf K^{+} and Ca^{++} were observed (Table 2). The breeding line BL 1076 had significantly the highest leaf Na^{+} and Cl^{-} content, which would indicate that this line had a higher leaf tissue

Table 2. Growth parameters and leaf ion concentrations of tomato genotypes as affected by different salinity levels.

Genotypes	Plant height (cm)	Stem thickness (mm)	Leaf dry matter (%)	Average fruit weight (g)	Average fruit number/plant	Total yield (kg/plant)	Na (mg/100gm)	Cl (mg/100gm)	Ca (mg/100gm)	K (mg/100gm)
Imberial (P1)	75.7 e-h	12.0 a	11.78 a-f	91.7 a	15.3 l	1.379 o	1108 k	1293 j	1662.d	1898 r
Pakmore VF (P2)	85.1 a	12.5 a	11.84 a-d	91.6 a	18.9 j	1.704 k	773 r	994 r	1610 h	1963j
Queen (P3)	77.0 e	11.2 a	11.73 a-f	65.3 k	17.0 k	1.097 q	781 q	1236 m	1671 c	2176 c
Strain B (P4)	75.9 e-g	11.7 a	11.53 b-g	84.7 e	21.9 i	1.844 i	1533 h	1378 f	1691 a	2240 a
BL 1076 (P5)	65.3 j	10.6 a	11.16 g	66.5 j	13.7 m	0.916 r	1825 a	1541 a	1611 h	1683 u
BL 1239 (P6)	78.0 b-e	11.4 a	11.24 fg	51.4 o	13.9 n	0.719 s	1236 f	1368 g	1558 j	1863 o
P1 x P2	82.1 ab	12.3 a	12.03 ab	89.7 b	23.6 h	2.085 g	950 o	1153 p	1646 e	1905 n
P1 x P3	77.4 e	11.8 a	11.88 a-d	75.6 f	21.4 i	1.591 l	945 o	1265 l	1667 cd	1991 j
P1 x P4	77.0 e	12.1 a	11.65 a-g	87.0 d	26.7 e	2.292 d	1135 j	1340 h	1681 b	2028 h
P1 x P5	71.2 i	11.4 a	11.54 b-g	74.6 g	24.1 gh	1.780 j	1471 d	1422 d	1642 e	1700 t
P1 x P6	77.5 de	11.8 a	11.57 b-g	68.1 j	25.3 f	1.709 k	1805 h	1338 h	1618 gh	1859 p
P2 x P3	82.0 a-c	12.0 a	12.19 a	75.7 f	24.7 fg	1.845 i	797 p	1135 q	1661 d	2100 e
P2 x P4	81.8 a-d	12.2 a	12.00 bc	87.8 c	28.7 d	2.505 b	983 m	1206 n	1671 c	2131 d
P2 x P5	76.5 ef	11.6 a	11.70 a-b	76.0 f	32.3 c	2.436 c	1309 e	1278 k	1621 g	1843 q
P2 x P6	78.6 b-e	12.1 a	11.74 a-f	86.4 i	34.2 c	2.254 e	1015 l	1191 o	1594 i	1950 l
P3 x P4	77.5 de	11.5 a	11.83 a-e	69.4 h	28.5 d	1.939 h	967 n	1307 j	1682 b	2208 b
P3 x P5	72.0 g-i	11.1 a	11.52 b-g	61.5 m	24.4 gh	1.487 m	1308 e	1393 e	1646 e	1934 m
P3 x P6	78.1 b-e	11.5 a	11.59 b-g	55.1 n	26.5 e	1.448 n	1009 l	1302 j	1615 gh	2036 g
P4 x P5	71.5 hi	11.4 a	11.39 d-f	69.3 h	37.1 a	2.548 a	1497 c	1467 b	1659 d	1969 k
P4 x P6	77.6 c-e	11.8 a	11.42 c-g	64.1 l	34.5 b	2.196 f	1200 g	1378 f	1630 f	2073 f
P5 x P6	72.3 f-i	11.6 a	11.27 e-g	50.3 p	24.7 fg	1.180 p	1534 b	1459 c	1589 i	1794 s

tolerance to ion accumulation than the others genotypes (tissue tolerance having the meaning of Yeo et al., 1988). The lowest contents of Na^+ and Cl^- were reflected by Pakmore VF, which indicated that this cultivar transported less Na^+ and Cl^- to the leaves. The restriction of Na^+ entry, the plant was shown to be an important adaptive character contributing to salt tolerance (Romero-Aranda et al., 2001). The significant high values for leaf Ca^{++} and K^+ contents were for the two cultivars; i.e., Strain B and Imberial, whereas, the lowest values were reflected by the cultivar Pakmore VF for Ca^{++} and the breeding line BL 1239 for k^+ content.

All first generation hybrids had values for leaf concentrations of Na^+, Cl^- , K^+ and Ca^{++} that appeared to be around their respective mid-parental values. Therefore, additive gene effects appeared to have relatively more importance than non-additive gene effects in the inheritance of these traits.

Interaction effects between salinity levels and tomato genotypes

The interactions between salinity levels and tomato genotypes had significant influences on all studied traits, except for stem thickness and leaf dry matter content, (Tables 3-10). The general performances of the different genotypes under non salt stress treatment (EC 1.2 dS/m^{-1}) showed that the genotypes had wide ranges of variability in most traits. The best parental genotypes, under non salt stress condition, that showed the highest values, were Strain B for plant height (Table 3). Imperial for average fruit weight (Table 4), Strain B for number of fruits (Table 5), Pakmore VF for total yield (Table 6), BL 1076 for leaf Na^+ content (Tables 7), BL 1239 for leaf Cl^- content (Tables 8), Pakmore VF for Ca^+ (Table 9) and Strain B for k^+ content (Table 10). Successive increases in salinity levels were associated with significant decreases in all traits, except leaf Na^+ and Cl^- concentrations which increased with high salinity levels. The relative effects varied and the classification of the genotypes for salt tolerance would vary according to a specific trait. The lowest reductions in plant height with increased salinity levels were reflected by BL 1239; whereas, Queen had the highest reduction percentages (Table 3). Pakmore VF had the lowest reductions in average fruit weight (Table 4). BL 1076, Strain B and Pakmore VF reflected the lowest reductions for both number of fruits and total yield per plant (Tables 5 and 6). Generally, the best hybrid combination under salt

Table 3. Plant height (cm) of four tomato cultivars, two breeding lines and their hybrid combinations as affected by different salinity levels.

Genotypes	Salinity levels (dS m^{-1}) 1.2	2.4	4.8	7.2	9.6	12.0
Imberial (P1)	85.3	84.3	78.6	72.3	69.0	65.0
Pakmore VF (P2)	93.3	93.6	89.3	83.6	74.6	75.6
Queen (P3)	91.6	84.0	77.6	75.0	72.0	61.6
Strain B (P4)	95.6	79.6	80.6	78.6	61.0	60.0
BL 1076 (P5)	79.0	76.3	61.6	60.6	56.3	57.6
BL 1239 (P6)	95.3	84.0	75.6	77.3	72.0	63.6
P1 x P2	91.3	90.6	84.6	78.6	75.0	72.0
P1 x P3	89.6	84.6	79.0	74.3	72.0	64.6
P1 x P4	92.0	83.0	80.6	76.6	66.0	63.6
P1 x P5	83.3	81.6	70.6	66.4	63.4	62.0
P1 x P6	91.0	85.0	78.0	75.6	71.3	64.3
P2 x P3	93.3	90.0	84.0	80.3	73.6	70.6
P2 x P4	95.0	89.0	85.6	82.0	69.0	70.0
P2 x P5	86.6	86.7	77.0	74.7	66.1	68.3
P2 x P6	95.6	89.3	84.0	58.0	74.0	70.6
P3 x P4	94.3	82.6	79.6	77.3	69.0	62.0
P3 x P5	86.0	80.6	70.3	69.3	65.3	60.7
P3 x P6	94.7	84.3	76.7	77.0	72.7	63.3
P4 x P5	88.3	78.6	72.0	70.6	59.0	60.6
P4 x P6	95.6	82.6	79.0	78.0	67.3	63.3
P5 x P6	88.0	80.6	69.6	69.7	64.7	61.7
Revised L.S.D	12.5					

stress condition was the crosses Pakmore VF x BL 1076 and Strain B x BL 1076. Based on the studied growth traits, the salt tolerance of the different parental genotypes might be classified in the descending order as: BL 1076 > BL 1239 > Pakmore VF > Strain B > Imperial > Queen.

Based on ions concentration (Tables 7 - 10), the result showed that the two breeding lines BL 1076 and BL 1239 had the highest values for Na^+ and Cl^- contents. These genotypes had higher leaf tissue tolerance to ions accumulation than the other genotypes and can be classified as salt tolerant. However, the two cultivars Strain B and Pakmore VF had relatively low concentration of Na^+ and Cl^-, and high concentration of K^+ and Ca^+ under high salinity levels. These two cultivars transported less Na^+ and Cl^- to the leaves. The restriction of Na^+ entry in the plant contributes to salt tolerance. Cuartero and Fernandez-Munoz (1999) hypothesized that a salt tolerance related trait would have the capacity of absorbing water and nutrients while rejecting Na^+. The relationship between total Na^+ content in the shoot and total Na^+ content in the nutrient solution absorbed by the plant is a measure of the root Na selective and Na^+ transport to the shoot, as a balance between the root capacity to discriminate against Na^+ entrance and the capacity of the root to extrude Na^+ to the medium (Reina-Sanchez et al., 2005). Other authors have pointed out that salt tolerance in some plant species has negative correlation with Na^+ in plant shoots and the salt tolerant plants generally exclude Na^+ from their shoots to prevent Na^+ enrichment in the leaves (Gorhame et al., 1985 and Cuartero et al., 1992). Perez-Alfocea et al., (1993) reported that, in *L. esculentum*, different degrees of salt tolerance were associated with different responses to salinity; some genotypes can show an inclusion mechanism allowing the replacement of K^+ for Na^+; however, others can show an exclusion mechanism with K^+ selectivity. A large amount of the used plant materials in the present study, generally, showed an inverse relationship between Na^+ concentration and salt tolerance.

Salt tolerance of plants has been usually expressed as the yield decrease at a given level of salinity in the root zone as compared with the yield of non-saline plant. The performances of the parental genotypes under salt stress for most studied traits indicated that the breeding line BL 1076 had the lowest reduction in average fruit

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Table 4. Average fruit weight (gm) of four tomato cultivars, two breeding lines and their hybrid combinations as affected by different salinity levels.

Genotypes	Salinity levels (dS m^{-1})					
	1.2	2.4	4.8	7.2	9.6	12.0
Imberial (P1)	130.0	124.1	94.9	84.5	67.6	49.4
Pakmore VF (P2)	124.0	120.9	97.9	86.8	68.2	52.1
Queen (P3)	101.0	94.9	66.7	53.5	43.4	32.3
Strain B (P4)	112.0	108.6	90.7	79.5	66.1	51.5
BL 1076 (P5)	70.0	70.1	67.9	65.1	64.4	61.6
BL 1239 (P6)	55.0	55.1	51.7	50.6	49.5	46.7
P1 x P2	126.0	120.3	94.5	80.6	66.7	50.4
P1 x P3	114.0	107.1	78.6	63.8	51.3	38.7
P1 x P4	120.0	115.2	92.4	78.0	67.2	49.2
P1 x P5	98.0	95.1	77.4	71.5	62.7	43.1
P1 x P6	90.0	86.8	68.4	67.5	54.9	40.5
P2 x P3	111.0	104.8	78.8	64.4	55.4	39.9
P2 x P4	116.0	111.3	93.9	84.1	69.6	52.2
P2 x P5	95.0	92.1	80.7	73.1	66.5	48.4
P2 x P6	87.0	85.2	70.5	65.7	59.1	42.6
P3 x P4	104.0	98.3	71.7	58.5	50.9	33.2
P3 x P5	83.0	79.3	63.1	56.4	48.1	39.0
P3 x P6	75.0	71.4	57.7	50.2	42.7	33.7
P4 x P5	87.0	84.9	73.9	66.1	57.4	46.1
P4 x P6	81.0	79.1	65.6	62.4	55.1	41.7
P5 x P6	60.0	60.1	60.0	54.0	51.0	46.7
Revised L.S.D	5.2					

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Table 5. Average fruit number of four tomato cultivars, two breeding lines and their hybrid combinations as affected by different salinity levels.

Genotypes	Salinity levels (dS m^{-1})					
	1.2	2.4	4.8	7.2	9.6	12.0
Imberial (P1)	17.1	16.5	15.1	14.8	14.1	14.4
Pakmore VF (P2)	20.8	20.4	18.3	18.5	17.7	17.8
Queen (P3)	17.8	18.6	16.9	16.5	15.9	16.2
Strain B (P4)	22.9	23.2	21.6	21.6	21.2	21.1
BL 1076 (P5)	14.0	14.1	14.0	14.0	13.5	12.8
BL 1239 (P6)	14.3	14.3	14.5	13.9	13.5	13.2
P1 x P2	25.6	24.7	24.0	22.8	22.2	22.3
P1 x P3	22.6	23.4	21.7	21.1	19.9	20.2
P1 x P4	29.1	27.6	27.3	25.7	25.3	25.4
P1 x P5	25.5	25.1	24.2	23.8	23.4	22.9
P1 x P6	26.8	26.5	25.1	25.4	24.3	24.1
P2 x P3	26.1	25.3	25.1	24.8	23.3	23.4
P2 x P4	30.2	29.5	28.6	28.3	27.9	27.6
P2 x P5	33.9	33.5	32.1	32.0	31.0	30.9
P2 x P6	34.9	35.0	33.2	32.9	31.7	31.5
P3 x P4	30.9	29.5	28.5	28.3	26.5	26.7
P3 x P5	25.6	25.9	24.2	24.1	23.0	23.0
P3 x P6	28.0	27.8	26.3	26.5	25.2	25.2
P4 x P5	38.6	39.0	37.1	36.9	35.3	35.1
P4 x P6	35.8	35.8	34.4	34.1	33.0	32.2
P5 x P6	21.8	21.4	21.1	20.5	21.8	21.2
Revised L.S.D	1.1					

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Table 6. Total yield/pant (kg) of four tomato cultivars, two breeding lines and their hybrid combinations as affected by different salinity levels.

Genotypes	Salinity levels (dS m^{-1})					
	1.2	2.4	4.8	7.2	9.6	12.0
Imberial (P1)	1.873	1.760	1.404	1.273	1.123	0.842
Pakmore VF (P2)	2.209	2.142	1.811	1.590	1.391	1.082
Queen (P3)	1.645	1.513	1.102	0.904	0.804	0.575
Strain B (P4)	2.362	2.302	1.960	1.724	1.535	1.181
BL 1076 (P5)	0.980	0.989	0.950	0.911	0.872	0.793
BL 1239 (P6)	0.785	0.788	0.749	0.706	0.667	0.620
P1 x P2	2.805	2.670	2.159	1.935	1.654	1.290
P1 x P3	2.304	2.131	1.658	1.382	1.198	0.875
P1 x P4	3.046	2.908	2.317	2.132	1.858	1.413
P1 x P5	2.247	2.190	1.842	1.730	1.572	1.101
P1 x P6	2.172	2.113	1.737	1.694	1.455	1.086
P2 x P3	2.606	2.449	1.954	1.615	1.407	1.042
P2 x P4	3.212	3.115	2.665	2.409	2.055	1.573
P2 x P5	2.938	2.864	2.585	2.350	2.232	1.645
P2 x P6	2.761	2.705	2.319	2.181	2.070	1.490
P3 x P4	2.787	2.605	2.034	1.672	1.504	1.031
P3 x P5	1.924	1.847	1.539	1.366	1.250	1.000
P3 x P6	1.891	1.805	1.531	1.323	1.191	0.945
P4 x P5	3.070	3.008	2.732	2.456	2.241	1.780
P4 x P6	2.669	2.610	2.268	2.161	1.975	1.494
P5 x P6	1.274	1.312	1.223	1.159	1.095	1.019
Revised L.S.D	0.128					

Table 7. Leaf Na^+ concentration (%) of four tomato cultivars, two breeding lines and their hybrid combinations as affected by different salinity levels.

Genotypes	Salinity levels (dS m^{-1})					
	1.2	2.4	4.8	7.2	9.6	12.0
Imberial (P1)	190	840	740	600	810	3470
Pakmore VF (P2)	230	360	890	710	790	1660
Queen (P3)	210	500	950	280	1010	1740
Strain B (P4)	220	1290	1160	670	980	2600
BL 1076 (P5)	330	1010	1660	2860	1330	3760
BL 1239 (P6)	290	810	1040	1700	2040	1540
P1 x P2	220	610	825	665	810	2575
P1 x P3	200	440	670	845	910	2605
P1 x P4	210	640	900	955	1070	3040
P1 x P5	268	931	1074	1204	1734	3619
P1 x P6	248	818	948	1228	1328	2513
P2 x P3	240	450	515	940	920	1720
P2 x P4	245	845	710	905	1045	2150
P2 x P5	290	695	1070	1285	1795	2720
P2 x P6	270	710	810	1305	1385	1610
P3 x P4	215	475	895	995	1055	2170
P3 x P5	273	760	1175	1310	1575	2755
P3 x P6	250	770	910	1160	1325	1640
P4 x P5	282	1158	1163	1418	1773	3188
P4 x P6	260	900	1170	1435	1360	2075
P5 x P6	314	1029	1074	1684	2454	2654
Revised L.S.D	16					

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Table 8. Leaf Cl^- concentration (mg/100gm) of four tomato cultivars, two breeding lines and their hybrid combinations as affected by different salinity levels.

Genotypes	Salinity levels (dS m^{-1})					
	1.2	2.4	4.8	7.2	9.6	12.0
Imberial (P1)	490	1110	1240	1350	1460	2110
Pakmore VF (P2)	560	730	1050	1226	1100	1300
Queen (P3)	500	990	1340	1400	1490	1700
Strain B (P4)	540	1010	1290	1400	1780	2250
BL 1076 (P5)	530	890	1520	1600	2100	2610
BL 1239 (P6)	640	1120	1530	1560	1600	1760
P1 x P2	535	930	1210	1243	1290	1715
P1 x P3	495	1050	1345	1320	1475	1905
P1 x P4	520	1065	1325	1325	1625	2185
P1 x P5	518	1006	1439	1424	1784	2364
P1 x P6	573	1123	1448	1408	1538	1943
P2 x P3	550	880	1215	1333	1315	1520
P2 x P4	570	890	1190	1333	1460	1795
P2 x P5	555	820	1295	1423	1610	1965
P2 x P6	610	935	1300	1403	1360	1540
P3 x P4	520	1000	1315	1400	1635	1975
P3 x P5	518	945	1435	1505	1800	2160
P3 x P6	570	1055	1435	1480	1545	1730
P4 x P5	542	958	1413	1508	1948	2438
P4 x P6	595	1070	1415	1485	1659	2010
P5 x P6	589	1009	1529	1584	1854	2189
Revised L.S.D	22					

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Table 9. Leaf Ca^{++} concentration (mg/100gm) of four tomato cultivars, two breeding lines and their hybrid combinations as affected by different salinity levels.

	Salinity levels (dS m^{-1})					
Genotypes	1.2	2.4	4.8	7.2	9.6	12.0
Imberial (P1)	1730	1700	1700	1660	1640	1543
Pakmore VF (P2)	1760	1723	1600	1580	1540	1460
Queen (P3)	1750	1810	1630	1610	1640	1590
Strain B (P4)	1720	1690	1790	1680	1640	1630
BL 1076 (P5)	1690	1590	1600	1670	1650	1470
BL 1239 (P6)	1560	1660	1670	1610	1430	1420
P1 x P2	1755	1660	1721	1630	1600	1511
P1 x P3	1665	1740	1755	1635	1640	1566
P1 x P4	1700	1750	1675	1640	1630	1596
P1 x P5	1703	1651	1634	1659	1694	1519
P1 x P6	1638	1688	1673	1633	1588	1489
P2 x P3	1635	1775	1786	1615	1610	1545
P2 x P4	1760	1665	1776	1650	1605	1570
P2 x P5	1655	1715	1666	1600	1615	1475
P2 x P6	1701	1605	1590	1635	1585	1450
P3 x P4	1660	1735	1600	1645	1635	1615
P3 x P5	1705	1663	1705	1660	1610	1535
P3 x P6	1595	1735	1640	1625	1590	1505
P4 x P5	1697	1698	1693	1648	1658	1563
P4 x P6	1630	1730	1680	1625	1580	1535
P5 x P6	1629	1629	1639	1644	1544	1449
Revised L.S.D				25		

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Table 10. Leaf K^+ concentration (mg/100gm) of four tomato cultivars, two breeding lines and their hybrid combinations as affected by different salinity levels.

Genotypes	Salinity levels (dS m^{-1})					
	1.2	2.4	4.8	7.2	9.6	12.0
Imberial (P1)	2100	2100	2160	1780	1900	1350
Pakmore VF (P2)	2130	2480	1870	1850	1910	1480
Queen (P3)	2680	2260	2560	2100	2050	1410
Strain B (P4)	3040	2000	2830	2200	1800	1570
BL 1076 (P5)	2050	2200	1730	1270	1200	1150
BL 1239 (P6)	2770	2370	1610	1480	1520	1430
P1 x P2	2215	2300	1915	1852	1750	1425
P1 x P3	2390	2020	2330	1975	1855	1380
P1 x P4	2575	2470	2055	1895	1710	1465
P1 x P5	2083	1911	1759	1689	1504	1254
P1 x P6	2443	2143	1553	1703	1818	1498
P2 x P3	2515	2540	2005	2075	2000	1465
P2 x P4	2695	2675	2075	1945	1855	1545
P2 x P5	2190	2045	1885	1815	1800	1325
P2 x P6	2550	2010	2150	1685	1740	1567
P3 x P4	2860	2695	2130	2125	1950	1490
P3 x P5	2368	2155	2000	1920	1880	1285
P3 x P6	2725	2040	2210	1935	1790	1520
P4 x P5	2552	2008	2058	1958	1873	1368
P4 x P6	2910	2290	2180	1810	1645	1605
P5 x P6	2414	2039	1844	1674	1399	1394
Revised L.S.D	14					

weight, number of fruits and total yield; while, it had the highest concentrations of Na^+ and Cl^- in the leaves. The two cultivars Pakmore VF and Strain B had good performances and values for most traits, especially average fruit weight and total yield, under different levels of salinity. The best hybrid combinations under salt stress conditions of this study were the crosses Pakmore VF × BL 1076 and Strain-B × BL 1076. These results suggested that the three genotypes BL 1076, Pakmore VF and Strain B could be selected as donor parental materials for a salinity tolerant breeding program in tomato.

The ultimate goal of many of breeding projects, such as the present research, is to breed cultivars with high salt tolerance. The performances of the parental and their F_1 hybrid genotypes under salinity levels indicated that the additive gene effects contributed to the genetic variability more than the non-additive gene effects for most studied traits, since values of most F_1 hybrids were reported to be around their respective mid parental values, and the studied traits related with salinity tolerance were not combined together in a single donor but in several genotypes. A number of donors should be employed in the breeding program for pyramiding all traits in a single cultivar which would exhibit a salinity tolerance surpassing that of any existent cultivars. These results agreed to a great extent with that reported by Cuartero and Fernandez-Munoz (1999), who reported that breeding of tolerant cultivars of tomato will occur only after pyramiding in a single genotype several characteristics, each of one alone could not confer a significant increase in the salt tolerance.

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الملخص العربي

استجابة بعض أصناف وسلالات الطماطم والهجن الناتجة بينها لتحمل الملوحة

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أجريت هذه الدراسة بهدف تقييم مدى تحمل بعض أصناف وسلالات الطماطم والهجن الناتجة بينها للإجهاد الملحي، وكذلك انتخاب التراكيب الوراثية الملائمة لبدء برنامج تربية لتحمل الملوحة في الطماطم. ولتحقيق هذه الأهداف استخدم أربعة أصناف من الطماطم التجارية (امبريال، وباكمور في اف ان، وكويك، والمقرين بلي) وسلالتان ناتجتان من التربية الداخلية (بي ال 1067، وبي ال 1239 من المركز الاسيوي للبحوث وتطوير الخضروات) وكل الهجن الممكنة بينهما (15 هجينا). وقد عرضت هذه التراكيب الوراثية لستة مستويات من الملوحة (وهي 1.2، 2.4، 4.8، 7.2، 9.6، و12.0 ديسيسيمنز/متر) وذلك خلال نظام الري بالتنقيط للنباتات المنزرعة بالبيت المحمي.

وقد تم قياس كل من ارتفاع النبات، سمك الساق، نسبة المادة الجافة بالأوراق، متوسط وزن وعدد الثمار، والمحصول الكلي للنبات، وكذلك محتوى الأوراق من كل من الصوديوم والكلوريد والكالسيوم والبوتاسيوم. وأوضحت النتائج ان زيادة مستويات الملوحة بدءا من 4.8 ديسيسيمنز/متر قد صاحبها انخفاض معنوي في كل صفات النمو الخضري والثمري. وقد لوحظ أن الانخفاض في المحصول الكلي ومتوسط وزن الثمرة تجاوز النصف لمعظم التراكيب الوراثية وذلك عند أعلى مستوى من مستويات الملوحة المستخدمة (12.0 ديسيسيمنز/متر). كما أوضحت النتائج أن الزيادة في مستوي الملوحة يصاحبها زيادة محتوي الأوراق من عنصري الصوديوم والكلور، وصاحبها أيضا انخفاض في المحتوي من الكالسيوم والبوتاسيوم.

وقد أظهرت النتائج وجود اختلافات معنوية بين التراكيب الوراثية المختلفة في جميع الصفات موضع الدراسة، مما يوضح أن هذه الصفات تؤخذ في الاعتبار عند الانتخاب لتحمل الإجهاد الملحي في الطماطم.

واعتمادا علي السلوك العام للآباء والهجن الناتجة بينها تحت ظروف الإجهاد الملحي، أوضحت النتائج أهمية الفعل الجيني المضيف مقارنة بالفعل الجيني غير المضيف في مدي مساهمته في الاختلافات الوراثية، حيث وجد أن معظم الهجن الناتجة أظهرت قيما تتوسط قيم الآباء الناتجة منها لكل الصفات.

وقد بينت النتائج ان الصنفين باكمورفي اف و استرين بي قد عكسا سلوكا عاما جيدا لمعظم الصفات تحت مستويات الملوحة المختلفة، مما يوضح إمكانية انتخابهم كآباء متكررة بينما أظهرت السلالة بي ال 1076 أعلي تحمل للملوحة المرتفعة، ويمكن انتخابها كأب معطي يحمل جينات تحمل الملوحة في برامج التربية. وأفضل هجين تحت ظروف الإجهاد الملحي في هذه الدراسة كان التهجين الناتج من التلقيح بين باكمورفي اف و بي ال 1076، وكذلك التهجين بين استرين بي و بي ال 1076 . هذه الآباء الثلاثة والهجن الناتجة بينها سيتم استخدامها في برنامج تربية لتحمل الإجهاد الملحي في الطماطم.