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RESEARCH ARTICLE

Effect of salinity on tomato *(Lycopersicon esculentum* Mill.) during seed germination stage

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Abstract A study was conducted using ten genetically diverse genotypes along with their $45F_1$ (generated by diallel mating) under normal and salt stress conditions. Although, tomato (*Lycopersicon esculentum* Mill.) is moderately sensitive to salinity but more attention to salinity is yet to be required in the production of tomato. In present study, germination rate, speed of germination, dry weight ratio and Na^+/K^+ ratio in root and shoot, were the parameters assayed on three salinity levels; control, 1.0 % NaCl and 3.0 % NaCl with Hoagland's solution. Increasing salt stress negatively affected growth and development of tomato. When salt concentration increased, germination of tomato seed was reduced and the time needed to complete germination lengthened, root/shoot dry weight ratio was higher and Na^+ content increased but K^+ content decreased. Among the varieties, Sel-7 followed by Arka Vikas and crosses involving them as a parent were found to be the more tolerant genotypes in the present study on the basis of studied parameters.

Keywords *Lycopersicon esculentum* · Growth parameters · Salinity stress · Tomato · Effect of salinity

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Introduction

Salinity is currently one of the most severe abiotic factors, limiting agricultural production. In arid and semi arid lands, the plants are subjected throughout their life cycle to different stresses; some of these plants can tolerate these stresses in different ways depending upon plant species and type of stress. Excessive salinity reduces the productivity of many agricultural crops including most of the vegetables. Knowledge of salt tolerance in vegetable plants is necessary to increase productivity and profitability of crops irrigated with saline wastewaters. According to USDA report, out of all vegetables, tomato is moderately sensitive to salinity. Salt stress has three fold effects which reduces water potential and causes ion imbalance and toxicity (de la Peña and Hughes 2007). Salt stress affects some major processes such as germination, speed of germination, root/shoot dry weight and Na^+/K^+ ratio in root and shoot (Parida and Das 2005). Salinity tolerance is critical during the life cycle of any species. Large genetic variation of tolerance to salt level exists among tomato genotypes. However, salt tolerance breeding programs have been restricted by the complexity of the trait, insufficient genetic and physiological knowledge of tolerance-related traits, and lack of efficient selection domain. Most commercial cultivars of tomato are sensitive to moderate levels of salinity up to 2.5 dSm^{-1}, without significant yield reduction. Correcting saline condition in field and greenhouse would be expensive and temporary while selection and breeding for salt tolerance can be a wise solution to minimize salinity effects as well as improve production efficiency. So breeding tolerant cultivars of tomato under saline conditions is needed. Genetic characterization of useful germplasm is the first step toward releasing tolerant cultivars. This study tried to find any level of tolerance to saline conditions in 55 tomato genotypes.

The objective of the present work was to investigate the response of tomato genotypes to increasing salinity during the germination and seedling stages. It has been shown that crops which are tolerant at seedling stage also show improved salinity tolerance at adult stage (Akinci et al. 2004).

Materials and methods

Ten genetically diverse tomato varieties were collected from Division of Vegetable Science, IARI, New Delhi, with varying degree of salt tolerance named IIVR-Sel-2, Arka Vikas, Sel-7, Azad T-2, Punjab Upma, DARL-64, BSS-368, Himsona, Tom-187 and CO-3. These varieties were crossed in all possible combinations excluding reciprocals to generate 45 F_1s during *kharif,* 2007 at S.K.N. college of Agriculture. All crosses along with parents were evaluated in laboratory in 2008–09 in completely randomized block design.

Seeds of all the genotypes (parents and F_1s) were surface sterilized with 0.1 % mercuric chloride solution for five minutes, then washed with sterilized distilled water. 25 seeds of each genotype were sown per Petri plate per salinity level. Salinity levels were created by supplementing the Hoagland solution with NaCl; control (only Hoagland's solution), 1.0 % and 3.0 % NaCl with ECe values of 0.18, 2.5, and 4.5 dSm^{-1} respectively. Each Petri dish was layered with Whatman's No.1 filter paper and irrigated with 5 ml of test solution after draining the previous day's solution. The Petri dishes were kept under artificial light (9 hrs/day) at 20 °C in a culture room to complete the seedling growth. Whole set up was replicated twice. On the 14th day of the experiment, germination (%), speed of germination (days), dry weight ratio of root and shoot and Na^+/K^+ ratio in root and shoot was measured. Na^+ and K^+ concentration were determined by using atomic absorption spectrophotometer (Perkin Elmer 3110, United States). Significance of treatments was determined with the help of *F*-test.

Results and discussion

Three levels (control, 1.0 % NaCl and 3.0 % NaCl concentrations) of Hoagland's solution were used to evaluate the effect of salinity on different growth parameters of tomato genotypes.

Effect of salinity on germination

The germination of tomato seed was reduced at relatively low salinity (1 % NaCl). At higher salinity (3 % NaCl), the germination percentage declined drastically from 77.60 % (control) to 29.60 % (at 3 % NaCl) in parents and from 75.82 % (control) to 33.16 % (at 3 % NaCl) in F_1s. The establishment of competitive crop would be difficult in this salinity condition.

There were differences in the germination percentage between the parents and F_1s particularly in salinity. As for the parents, germination percentage ranged from 60 % to 90 % (control), 20 % to 80 % (at 1 % NaCl) and 4 % to 52 % (at 3 % NaCl). Whereas, among F_1s, the range was 20 % to 96 % (control), 4 % to 80 % (at 1 % NaCl) and 4 % to 64 % (at 3 % NaCl) (Table 1).

Among the parents, Sel-7 and in F_1s, Sel-7 x BSS-368 were least affected by higher salinity stress. The genotypes which are least affected may be potential source of salinity tolerance for tomato breeding (Cuartero and Munoz 1999; Hazer et al. 2006; Amir et al. 2011; Hamed et al. 2011). The effect of external salinity on seed germination may be partially osmotic or ion toxicity, which can alter physiological processes such as enzyme activities (Croser et al. 2001; Essa and Al-Ani 2001).

Effect of salinity on speed of germination

The salinity notably affects germination in many species but also lengthens the time needed to complete germination (Amir et al. 2011). In the present study also the speed of germination was reduced i.e. it took more days to complete the germination under salinity. In parents, this ranged from 4.90 days (control) to 13.20 days (at 3 % NaCl) and in F_1s, from 5.11 days (control) to 13.36 days (at 3 % NaCl) (Table 1). The earliest germinating parents and F_1s at higher salinity level were ArkaVikas, Sel-7 and Azad T-2; Azad T-2 x Himsona and Himsona x CO-3, respectively. Tomato seeds needed approximately 50 % additional time to germinate at 1 % NaCl than in control medium and almost 100 % more time at 3 % NaCl concentration (Table 1). Genotypes which germinate earlier at higher salinity are supposed to be more vigorous and may be used as parents or potential donor in salinity tolerance crop breeding programmes (Cuartero and Munoz 1999; Amir et al. 2011; Hamed et al. 2011). The stimulation of germination and days required for its completion, depend upon Gibbrelic Acid content in seed. A low level of GA in seed in saline medium was unable to break the mechanical resistance of endosperm against imbibition of water by seed and this leads to the reduction in speed of germination (Groot and Karssen 1992; Groot et al. 1988).

Effect of salinity on root/shoot dry weight ratio

In spite of the negative effects of salt on roots, the root growth in tomato appears to be less affected whereas, shoot was affected drastically, so that, the dry weight ratio was

Table 1 Effect of salinity on the different traits of the tomato

Genotypes	Germination (%)			Speed of germination (days)			Root/Shoot dry weight ratio		
	Control	1 % NaCl	3 % NaCl	Control	1 % NaCl	3 % NaCl	Control	1 % NaCl	3 % NaCl
IIVR-Sel-2	76.00	52.00	36.00	5.00	7.00	13.00	0.571	0.588	0.629
Arka Vikas	64.00	36.00	24.00	5.00	8.00	12.00	0.516	0.539	0.647
Sel.-7	96.00	80.00	52.00	4.00	7.00	12.00	0.765	0.793	0.875
Azad T-2	92.00	64.00	40.00	5.00	7.00	12.00	0.500	0.583	0.600
Punjab Upma	60.00	48.00	40.00	5.00	10.00	13.00	0.555	0.684	0.786
DARL-64	76.00	28.00	4.00	5.00	9.00	14.00	0.531	0.560	0.647
BSS-368	60.00	20.00	16.00	5.00	10.00	14.00	0.500	0.524	0.563
Himsona	80.00	64.00	44.00	5.00	11.00	14.00	0.457	0.475	0.516
Tom-187	80.00	52.00	20.00	5.00	7.00	14.00	0.449	0.500	0.567
CO-3	92.00	48.00	20.00	5.00	9.00	14.00	0.417	0.429	0.580
Mean	77.60	49.20	29.60	4.90	8.50	13.20	0.53	0.57	0.64
IIVR-Sel-2 x Arka Vikas	44.00	36.00	24.00	5.00	9.00	12.00	0.389	0.429	0.526
IIVR-Sel-2 x Sel.-7	36.00	32.00	16.00	5.00	7.00	14.00	0.400	0.470	0.539
IIVR-Sel-2 x Azad T-2	84.00	72.00	60.00	5.00	6.00	13.00	0.436	0.477	0.563
IIVR-Sel-2 x Punjab Upma	68.00	52.00	40.00	5.00	8.00	14.00	0.375	0.410	0.448
IIVR-Sel-2 x DARL-64	92.00	68.00	48.00	6.00	9.00	12.00	0.421	0.444	0.472
IIVR-Sel-2 x BSS-368	60.00	52.00	28.00	5.00	10.00	14.00	0.436	0.482	0.522
IIVR-Sel-2 x Himsona	72.00	56.00	40.00	5.00	10.00	14.00	0.528	0.555	0.666
IIVR-Sel-2 x Tom-187	84.00	72.00	52.00	6.00	9.00	14.00	0.419	0.465	0.548
IIVR-Sel-2 x CO-3	72.00	32.00	20.00	5.00	8.00	14.00	0.594	0.666	0.736
Arka Vikas x Sel.-7	72.00	60.00	32.00	5.00	6.00	14.00	0.298	0.306	0.324
Arka Vikas x Azad T-2	84.00	68.00	56.00	5.00	6.00	14.00	0.489	0.500	0.606
Arka Vikas x Punjab Upma	88.00	72.00	60.00	5.00	9.00	14.00	0.412	0.450	0.533
Arka Vikas x DARL-64	44.00	32.00	28.00	7.00	11.00	14.00	0.542	0.556	0.615
Arka Vikas x BSS-368	64.00	20.00	12.00	5.00	10.00	14.00	0.472	0.577	0.632
Arka Vikas x Himsona	72.00	20.00	12.00	5.00	11.00	14.00	0.409	0.444	0.482
Arka Vikas x Tom-187	20.00	4.00	4.00	7.00	12.00	14.00	0.474	0.500	0.571
Arka Vikas x CO-3	76.00	20.00	20.00	5.00	8.00	14.00	0.465	0.563	0.652
Sel.-7 x Azad T-2	80.00	68.00	40.00	6.00	11.00	13.00	0.407	0.435	0.486
Sel.-7 x Punjab Upma	84.00	68.00	52.00	5.00	8.00	13.00	0.526	0.566	0.652
Sel.-7 x DARL-64	88.00	40.00	16.00	5.00	10.00	14.00	0.447	0.475	0.552
Sel.-7 x BSS-368	92.00	76.00	64.00	4.00	9.00	13.00	0.453	0.489	0.514
Sel.-7 x Himsona	64.00	32.00	20.00	5.00	9.00	14.00	0.486	0.536	0.760
Sel.-7 x Tom-187	88.00	60.00	28.00	5.00	10.00	13.00	0.511	0.553	0.621
Sel.-7 x CO-3	84.00	48.00	20.00	5.00	9.00	13.00	0.511	0.541	0.615
Azad T-2 x Punjab Upma	84.00	60.00	32.00	5.00	9.00	14.00	0.468	0.528	0.680
Azad T-2 x DARL-64	92.00	60.00	20.00	4.00	7.00	13.00	0.439	0.548	0.645
Azad T-2 x BSS-368	96.00	72.00	48.00	4.00	6.00	12.00	0.422	0.471	0.513
Azad T-2 x Himsona	96.00	80.00	60.00	4.00	7.00	11.00	0.433	0.500	0.548
Azad T-2 x Tom-187	76.00	48.00	36.00	5.00	10.00	14.00	0.525	0.594	0.727
Azad T-2 x CO-3	80.00	64.00	28.00	5.00	8.00	14.00	0.550	0.625	0.739
Punjab Upma x DARL-64	68.00	60.00	32.00	6.00	10.00	14.00	0.581	0.652	0.722
Punjab Upma x BSS-368	76.00	48.00	24.00	5.00	9.00	13.00	0.594	0.654	0.737
Punjab Upma x Himsona	80.00	60.00	40.00	5.00	11.00	14.00	0.568	0.600	0.625
Punjab Upma x Tom-187	84.00	60.00	48.00	5.00	7.00	13.00	0.434	0.475	0.516
Punjab Upma x CO-3	64.00	40.00	28.00	6.00	10.00	14.00	0.516	0.565	0.667
DARL-64 x BSS-368	80.00	60.00	40.00	5.00	9.00	13.00	0.537	0.567	0.650

Table 1 (continued)

Genotypes	Germination (%)			Speed of germination (days)			Root/Shoot dry weight ratio		
	Control	1 % NaCl	3 % NaCl	Control	1 % NaCl	3 % NaCl	Control	1 % NaCl	3 % NaCl
DARL-64 x Himsona	64.00	16.00	4.00	6.00	11.00	14.00	0.533	0.546	0.667
DARL-64 x Tom-187	84.00	68.00	32.00	5.00	7.00	13.00	0.512	0.586	0.652
DARL-64 x CO-3	92.00	72.00	36.00	4.00	10.00	12.00	0.521	0.553	0.616
BSS-368 x Himsona	68.00	28.00	20.00	5.00	9.00	14.00	0.515	0.538	0.611
BSS-368 x Tom-187	76.00	48.00	24.00	6.00	11.00	13.00	0.465	0.500	0.546
BSS-368 x CO-3	64.00	28.00	16.00	6.00	10.00	14.00	0.548	0.611	0.643
Himsona x Tom-187	88.00	68.00	52.00	5.00	8.00	13.00	0.522	0.539	0.600
Himsona x CO-3	96.00	76.00	60.00	4.00	7.00	11.00	0.529	0.550	0.571
Tom-187 x CO-3	92.00	60.00	20.00	4.00	6.00	12.00	0.500	0.527	0.600
Mean	75.82	51.91	33.16	5.11	8.82	13.36	0.48	0.52	0.60
SD mean (σm)	24.45			3.55			0.095		
SEm	0.81			0.83			0.06		
CD (P=0.05)	2.26			2.31			0.17		

Table 2 Effect of salinity on the different traits of the tomato

Genotypes	Na^+/K^+ ratio in root			Na^+/K^+ ratio in shoot		
	Control	1 % NaCl	3 % NaCl	Control	1 % NaCl	3 % NaCl
IIVR-Sel-2	2.52	3.22	2.02	1.78	1.92	1.89
Arka Vikas	1.01	3.37	1.61	0.75	4.32	2.80
Sel.-7	1.62	2.25	2.08	1.50	2.28	2.72
Azad T-2	2.28	2.38	2.28	3.19	2.15	4.47
Punjab Upma	2.15	4.40	2.63	2.73	2.94	3.46
DARL-64	2.55	2.42	2.53	3.85	4.57	5.04
BSS-368	3.12	2.49	2.47	3.14	1.74	2.00
Himsona	3.32	2.80	3.65	2.04	2.78	2.68
Tom-187	2.46	3.52	7.22	3.28	3.97	5.18
CO-3	3.38	3.47	3.36	2.54	3.20	3.10
Mean	2.44	3.03	2.99	2.48	2.99	3.33
IIVR-Sel-2 x Arka Vikas	2.38	3.24	4.90	1.96	3.11	5.54
IIVR-Sel-2 x Sel.-7	2.42	3.77	5.64	0.67	3.15	2.15
IIVR-Sel-2 x Azad T-2	1.71	1.81	2.24	2.24	3.29	7.99
IIVR-Sel-2 x Punjab Upma	3.73	2.92	2.21	4.94	3.49	1.81
IIVR-Sel-2 x DARL-64	3.31	2.97	7.28	0.22	2.12	7.22
IIVR-Sel-2 x BSS-368	2.89	2.91	4.02	1.58	1.99	2.94
IIVR-Sel-2 x Himsona	3.61	2.07	2.85	4.01	4.40	8.81
IIVR-Sel-2 x Tom-187	2.64	3.98	4.03	1.38	5.45	2.42
IIVR-Sel-2 x CO-3	1.43	4.48	6.67	0.73	0.96	4.19
Arka Vikas x Sel.-7	2.58	3.56	8.60	2.03	1.63	7.00
Arka Vikas x Azad T-2	4.23	3.98	11.00	0.37	1.06	4.50
Arka Vikas x Punjab Upma	2.97	5.40	2.96	1.05	3.36	5.69
Arka Vikas x DARL-64	2.43	9.28	7.80	3.44	8.52	5.61
Arka Vikas x BSS-368	2.57	5.71	7.79	2.60	4.82	2.81
Arka Vikas x Himsona	2.76	6.85	7.90	2.22	7.97	3.70
Arka Vikas x Tom-187	3.46	10.20	3.52	2.41	6.02	2.23

Table 2 (continued)

Genotypes	Na^+/K^+ ratio in root			Na^+/K^+ ratio in shoot		
	Control	1 % NaCl	3 % NaCl	Control	1 % NaCl	3 % NaCl
Arka Vikas x CO-3	2.88	3.36	4.82	2.05	3.82	6.10
Sel.-7 x Azad T-2	2.08	4.04	3.10	3.31	2.83	3.35
Sel.-7 x Punjab Upma	2.90	3.43	2.82	2.00	2.97	3.98
Sel.-7 x DARL-64	2.78	3.39	2.67	1.31	3.70	4.11
Sel.-7 x BSS-368	3.37	3.44	3.13	2.13	2.90	2.63
Sel-7 x Himsona	4.21	3.19	2.80	3.07	2.66	2.52
Sel-7 x Tom-187	3.31	3.57	3.07	1.93	2.19	1.97
Sel.-7 x CO-3	3.58	3.02	2.82	2.84	3.01	2.48
Azad T-2 x Punjab Upma	2.41	2.19	2.12	1.82	1.45	1.79
Azad T-2 x DARL-64	3.68	1.84	1.62	1.50	1.78	1.58
Azad T-2 x BSS-368	2.36	2.31	2.46	1.79	2.18	2.20
Azad T-2 x Himsona	3.23	3.29	2.61	2.25	2.42	2.49
Azad T-2 x Tom-187	2.96	2.80	2.22	1.97	3.06	2.07
Azad T-2 x CO-3	2.55	2.15	2.06	2.21	1.95	2.03
Punjab Upma x DARL-64	3.89	2.26	2.25	2.54	2.27	2.37
Punjab Upma x BSS-368	5.86	4.30	8.74	4.62	5.99	3.43
Punjab Upma x Himsona	5.63	3.38	4.39	2.79	1.81	1.87
Punjab Upma x Tom-187	3.60	3.13	2.40	1.88	1.90	1.95
Punjab Upma x CO-3	6.34	4.62	4.17	2.52	2.97	2.41
DARL-64 x BSS-368	1.71	1.64	1.52	4.21	1.79	1.67
DARL-64 x Himsona	3.07	3.00	2.71	2.14	2.45	2.72
DARL-64 x Tom-187	3.03	2.63	2.34	4.56	4.67	3.12
DARL-64 x CO-3	3.66	2.82	3.70	2.70	2.75	2.24
BSS-368 x Himsona	3.25	3.18	2.97	2.33	2.42	2.16
BSS-368 x Tom-187	3.16	2.84	3.01	2.65	2.97	2.58
BSS-368 x CO-3	2.92	2.80	2.78	1.91	2.35	2.10
Himsona x Tom-187	2.39	3.35	3.17	1.42	2.85	2.59
Himsona x CO-3	3.35	3.13	3.19	2.64	3.06	2.59
Tom-187 x CO-3	3.77	4.75	3.51	2.02	3.65	2.12
Mean	3.18	3.62	3.97	2.29	3.16	3.33
SD Mean (σm)	1.65			1.50		
SEm	1.48			0.39		
CD (P=0.05)	4.12			1.09		

higher in plant grown under salt stress than in control environment. In the present study, the root/shoot dry weight ratio was increased from 0.53 (control) to 0.64 (at 3 % NaCl) in parents and from 0.48 (control) to 0.64 (at 3 % NaCl) in F_1s. The highest root/shoot dry weight ratio was observed at higher salinity for parent, Sel-7 and in F_1s, for Sel-7 x Himsona (Table 1). The rise in root/shoot dry weight in tomato under salt stress must be accompanied by changes in the allocation of assimilates between root and shoot i.e. greater proportion of assimilates for root compared with shoot (Maggio et al. 2007; Amir et al. 2011; Hamed et al. 2011; Chookhampaeng et al. 2007).

Effect of salinity on Na^+/K^+ ratio in root and shoot

A higher Na^+ concentration in root or shoot increases the osmotic potential and decreases water uptake, while K^+ concentration in root or shoot of tomato plants, changes little under saline environment. Thus, increased concentration of K^+ in plant is consequently advisable in the present study for further breeding programme that is based on salinity tolerance. The mean values of Na^+/K^+ ratio in root, varied from 2.44 (control) to 2.99 (at 3 % NaCl) in parents and from 3.18 (control) to 3.97 (at 3 % NaCl) in F_1s (Table 2).

Whereas, in shoot, the mean value of Na^+/K^+ ratio raised from 2.48 (control) to 3.33 (at 3 % NaCl) in parents and from 2.29 (control) to 3.33 (at 3 % NaCl) in F_1s (Table 2).

The lower value of Na^+/K^+ ratio, indicated more uptake of K^+ from soil/medium by plants and such types of plants are similar to non-salinized plant i.e. salt tolerant. The desirable parents and F_1s having the lowest Na^+/K^+ ratio in root, at high salinity level, were ArkaVikas and DARL-64 x BSS-368, respectively. Whereas, in shoot, lowest Na^+/K^+ ratio was observed for parent IIVR-Sel-2 and cross Azad T-2 x DARL-64. The genotypes which have low Na^+/K^+ ratio may be used in further breeding for salinity tolerance in tomato (Cuartero and Munzo 1999; Dasgan et al. 2002).

Conclusions

In the present study, Sel-7 followed by Arka Vikas and crosses involving them as a parent were found to be more tolerant genotypes among all the varieties on the basis of parameters studied. Tomato breeding should also resort to pyramiding the characteristics since no described traits alone is likely to produce a tolerant genotype. Threshold limit of salinity for tomato, up to which yield reduces very little or no reduction occur, is 2.5-3.0 dSm^{-1} and after it, every increase of 1.0 dSm^{-1} in ECe results in a yield reduction of about 9–10 %. The upper limit of salinity for tomato crop improvement is 6.0 dSm^{-1}. Beyond this, breeding programmes are not feasible because yield loss surpasses 50 %.

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