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Screening Tomato Genotypes for Salt Tolerance

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A B S T R A C T

Thirty three genotypes of tomato including three checks (NS-515, Arka Rakshak and US-440) were analysed to determine their tolerance levels against salt stress. Four different concentrations of NaCl *viz.*, 50mM, 75mM, 100 mM and 150mM were used along with control. Significant varietal and or salinity treatment effects were recorded on germination percentage, germination rate, root length, shoot length, root dry weight and shoot dry weight. With increasing concentration of NaCl growth parameters of tomato genotypes decreased proportionately. Among the commercial checks NS-516 while among crosses EC-619982 × EC-520078, EC-619982 × Pusa Ruby, EC-620428 × Punjab Chhuhara, EC-620360 × EC-620557, EC-620407 × Punjab Chhuhara and EC-608415 × Arka Saurabh responded positively against different NaCl concentrations. Confirmatory studies may be performed to access their potential under pot cultures before the internal physiological investigations for their variable response.

Introduction

Salinity is one of the most severe abiotic factors, limiting agricultural production in arid and semi-arid regions. Excessive salinity reduces the productivity of many agricultural crops. Salt stress affects major processes like germination, speed of germination, root/shoot dry weight and Na+/K+ ratio in root and shoot (Parida and Das, 2005). Excess salt in soil solution adversely affect plant growth, either through osmotic inhibition of root water uptake or by specific ion effect. Seed germination and early seedling growth are the most sensitive stages to environmental stresses such as salinity (Sivritepe *et al.*, 2003). Salinity may cause significant reductions in the rate and final percentage of germination, which in turn may lead to uneven stand establishment and reduced crop yields (Foolad *et al.*, 1999). The problem of soil salinity is now increasing at a rate of 10% annually (Flowers, 2004; Foolad, 2007). It is expected that by 2050, more than 50% of the land available for agriculture will be lost because of salinity (Hasanuzzaman *et al.*, 2014).

Tomato is one of the widely grown vegetables in the world. It is consumed in fresh form as salad and in various processed forms like soup, sauce, ketchup, paste, puree, powder and canned whole fruit etc. and tops the list of processed vegetables. Tomato is moderately sensitive to salinity (Peralta *et al.*, 2005), although considerable differences between

cultivars may be observed (Allen *et al.*, 1998). It can tolerate salinity up to 2.5-2.9 dS m-1 in the root zone without yield losses (Sonneveld and Vander Burg, 1991). The exact salinity level may vary depending on cultivar sensitivity (Caro *et al.*, 1991) and environmental conditions (Karlberg *et al.*, 2006). Therefore, the experiment was undertaken to evaluate the ability of tomato for growing under different saline conditions and screen them for salinity tolerance.

Materials and Methods

The study was conducted at Horticulture Laboratory of Central Research Institute for Dry Land Agriculture (CRIDA), Hyderabad during 2016. The method suggested by Panchalingam (1983) and Babu *et al.*, (1985) was followed to screen the genotypes against salt stress environment under laboratory conditions. Thirty crosses of tomato along with three commercial checks *viz.*, Arka Rakshak, US-440 and NS-516 were screened by employing germination test in an osmotic solution of NaCl (sodium chloride). Simultaneously, all the accessions were allowed to germinate in distilled water. Three replications of 10 seeds for each accession were counted and distributed over two layers of paper towel (11 × 11 cm) previously moistened with water equivalent to three times the dry weight of the paper and tied both ends with rubber band and kept in a plastic tray with different concentrations (50mM, 75mM, 100 M and 150mM) of sodium chloride (NaCl). Germination percentage was recorded for every 7 days. At the end of the 21st day, final germination per cent, germination rate, root length, shoot length, root dry weight and shoot weight were recorded in NaCl solution as against the distilled water was calculated. The experiment was designed as a completely randomized design with two factors. The first factor was the genotypes and the second one is external salt stress. The sheets were rolled and placed vertically in plastic beaker, covered with polythene bag and placed at 25±1°C in an illuminated germinator. A seed was considered to be germinated when the emerging radicle elongated to 1 mm. Radicle length, hypocotyl length, seedling fresh weight and dry weight were calculated as described by Uniyal *et al.*, (1998). Observations were recorded on germination percentage, germination rate, root length (cm), shoot length (cm), root dry weight (mg) and shoot dry weight (mg). Analysis of variance was carried out as described by Steel *et al.*, (1997). Statistical significance of means was tested by SPSS package.

Results and Discussion

The analysis of variance showed significant differences among the genotypes and treatments (Table 1). Significant differences were observed under different NaCl concentrations of 50mM, 75mM, 100 M and 150mM.

Germination percentage (%)

A decline in seed germination percentage with increasing stress has been recorded (Table 2). Significant differences were observed for germination percentage between the genotypes and different NaCl concentrations. Irrespective of NaCl concentrations, NS-516 recorded significantly maximum germination percentage (86.08%) compared to other genotypes. Germination percentage was lowest (34.31%) in the cross EC-620428 × EC-620557. At 50 mM concentration of NaCl, the cross NS-516 exhibited maximum (87.93%) and EC-620428 × EC-520078 exhibited minimum (32.82%) values. While at 75mM concentration genotypes NS-516 (85.66%) and EC-620428 × EC-520078 (26.24%) exhibited highest and lowest values respectively. In case of 100mM

concentration NS-516 (85.54%), EC-620428 × EC-520078 (26.24%) responded as maximum and minimum germination percentage respectively. With 150mM concentration of NaCl, NS-516 (82.87%) responded maximum and minimum in EC-620428 × EC-620557 (19.82%).

It was observed that germination percentage with decreasing water potential of the environment probably was triggered by the low hydraulic conductivity where, NaCl makes water unavailable to seeds, affecting the imbibition process of the seed which is fundamental for germination.

Results of the current study were in agreement with findings of El-Saifi *et al.,* (2010), Souguir *et al.,* (2013), Ravi *et al.,* (2011) and Alejandra *et al.,* (2010).

Germination rate

Significant differences were observed for germination rate between the genotypes and NaCl concentrations (Table 3). Irrespective of salt concentrations, NS-516 recorded maximum germination rate (8.27) compared to other genotypes. The germination rate was lowest (3.04%) in EC-620428 × EC-520078. At 50mM concentration of NaCl, maximum and minimum germination rates were recorded in NS-516 (8.91) and EC-620428 × EC-520078 (2.48%) respectively.

While at 75mM concentration, genotype NS-516 (8.26) and EC-620428 × EC-520078 (2.44) exhibited maximum and minimum values respectively. In case of 100mM concentration, maximum and minimum germination rate recorded in NS-516 (7.65) and EC-620428 × EC-520078 (2.33) while with 150mM maximum and minimum germination rates were recorded in NS-516 (7.43%) and EC-620407 × Punjab Chhuhara (1.74) respectively. The rate of germination seems to be more sensitive to water stress than final germination percentage caused a significant increase in mean germination time and decrease in germination. Present studies are intensely supported by the finding of El-Saifi *et al.,* (2010), Souguir *et al.,* (2013), Ravi *et al.,* (2011) and Alejandra *et al.,* (2010).

Root length (cm)

Root length is an important trait against salt stress in plant varieties, with longer root growth has resistant ability for salt. Early and rapid elongation of roots is an important indication of tolerance. Ability of continued elongation of root under water stress and longer root length at deeper layer are useful in extracting water in upland conditions (Kim *et al.,* 2001, Narayan, 1991). The plant embryo grows at germination and progresses radicles that become the primary roots and penetrate down into the soil.

Table.1 Analysis of variance for six characters in tomato

Mean sum of squares							
Source of variation	**df**	**Germination %**	**Germination rate**	**Root length**	**Shoot length**	**Shoot dry weight**	**Root dry weight**
Treatment (A)	4	1928.15**	15.68**	15.53**	13.19	44.65**	904.15**
Genotype (B)	32	325.51**	0.83**	1.23**	12.55**	6.09**	895.30**
A × B	156	561.61	6.28	5.88	17.49	12.63	1489.77
Error	424	26.75	0.14	0.11	0.10	0.10	6.91

Table.2 Effect of different concentration of NaCl (control, 50mM, 75mM, 100mM and 150mM on germination percentage of tomato genotypes

Crosses/Hybrids	Germination percent (%)					
	Treatments					
	Control	50mM	75mM	100mM	150mM	Mean
EC-620407 × Arka Saurabh	57.08	52.45	54.34	42.10	38.26	48.85
EC-620407 × Arka Abha	65.38	64.47	55.88	53.70	49.90	57.87
EC-620407 × Punjab Chhuhara	64.90	54.08	47.51	41.49	41.44	49.88
EC-620407 × Pusa Ruby	40.71	36.13	35.02	33.34	33.31	35.70
EC-620407 × EC-520078	71.04	65.48	61.47	53.24	52.92	60.83
EC-620407 × EC-620557	76.33	67.04	66.72	56.17	54.99	64.25
EC-620428 × Arka Saurabh	46.09	45.34	40.89	35.56	32.57	40.09
EC-620428 × Arka Abha	44.67	35.59	34.76	33.90	30.29	35.84
EC-620428 × Punjab Chhuhara	58.02	56.31	44.98	43.05	42.67	49.01
EC-620428 × Pusa Ruby	76.01	69.69	66.57	63.83	60.76	67.37
EC-620428 × EC-520078	67.78	32.82	28.09	26.24	24.82	35.95
EC-620428 × EC-620557	43.22	41.75	38.49	28.25	19.82	34.31
EC-620360 × Arka Saurabh	64.55	62.69	60.01	48.80	46.17	56.44
EC-620360 × Arka Abha	82.66	67.23	62.03	44.25	43.81	59.99
EC-620360 × Punjab Chhuhara	71.64	46.74	45.67	32.39	33.15	45.92
EC-620360 × Pusa Ruby	61.30	46.52	42.53	39.90	34.09	44.87
EC-620360 × EC-520078	52.38	47.86	41.21	40.25	42.01	44.74
EC-620360 × EC-620557	52.95	51.93	51.34	43.08	39.02	47.66
EC-608415 × Arka Saurabh	61.01	55.07	53.57	49.69	40.39	51.95
EC-608415 × Arka Abha	66.84	61.97	57.44	55.47	53.67	59.08
EC-608415 × Punjab Chhuhara	69.30	63.65	61.49	53.31	48.35	59.22
EC-608415 × Pusa Ruby	83.56	54.21	53.80	38.94	33.24	52.75
EC-608415 × EC-520078	67.30	46.61	38.76	32.85	21.28	41.36
EC-608415 × EC-620557	63.01	53.59	50.77	35.91	27.90	46.24
EC-619982 × Arka Saurabh	57.46	50.67	46.69	36.59	30.96	44.47
EC-619982 × Arka Abha	79.90	63.64	61.73	56.62	40.88	60.55
EC-619982 × Punjab Chhuhara	85.15	64.67	60.38	44.59	43.78	59.71
EC-619982 × Pusa Ruby	82.66	72.48	66.88	64.59	52.54	67.83
EC-619982 × EC-520078	84.93	73.94	72.76	61.68	54.72	69.61
EC-619982 × EC-620557	74.62	70.67	64.19	59.80	44.23	62.70
US-440	89.81	85.01	84.47	82.84	70.36	82.50
Arka Rakshak	89.96	85.81	82.75	80.52	77.67	83.34
NS-516	88.42	87.93	85.66	85.54	82.87	86.08
Mean	67.89	58.60	55.11	48.43	43.72	
	S.Em±			CD (0.01)		
Treatment (A)	1.33			3.72		
Genotype (B)	0.52			1.45		
A × B	2.99			8.31		

Table.3 Effect of different concentration of NaCl (control, 50mM, 75mM, 100 M and 150mM on germination rate of tomato genotypes

Crosses/Hybrids	Germination rate (%)					
	Treatments					
	Control	50mM	75mM	100mM	150mM	Mean
EC-620407 × Arka Saurabh	4.80	4.66	4.40	3.96	3.67	4.30
EC-620407 × Arka Abha	5.73	5.71	4.93	4.80	4.57	5.15
EC-620407 × Punjab Chhuhara	5.05	4.79	4.48	3.99	1.74	4.01
EC-620407 × Pusa Ruby	3.85	3.33	3.30	3.05	3.04	3.31
EC-620407 × EC-520078	7.02	6.59	5.65	4.71	2.83	5.36
EC-620407 × EC-620557	6.48	6.06	5.89	5.57	4.74	5.75
EC-620428 × Arka Saurabh	3.59	4.82	3.55	3.52	3.37	3.77
EC-620428 × Arka Abha	3.40	3.03	2.91	2.89	2.66	2.98
EC-620428 × Punjab Chhuhara	4.46	4.56	4.51	4.07	3.09	4.14
EC-620428 × Pusa Ruby	6.51	6.34	6.24	5.84	3.64	5.71
EC-620428 × EC-520078	5.76	2.48	2.44	2.33	2.18	3.04
EC-620428 × EC-620557	4.55	4.16	4.00	2.35	1.69	3.35
EC-620360 × Arka Saurabh	6.25	5.86	5.69	4.22	3.73	5.15
EC-620360 × Arka Abha	6.44	5.79	5.23	5.00	4.00	5.29
EC-620360 × Punjab Chhuhara	4.47	4.39	4.14	3.72	2.96	3.94
EC-620360 × Pusa Ruby	4.71	4.47	4.44	3.70	2.51	3.97
EC-620360 × EC-520078	4.42	4.37	4.23	3.78	3.02	3.96
EC-620360 × EC-620557	4.75	4.55	4.48	3.97	3.89	4.33
EC-608415 × Arka Saurabh	6.03	5.78	3.75	3.59	5.28	4.89
EC-608415 × Arka Abha	6.57	6.39	6.21	5.74	5.18	6.02
EC-608415 × Punjab Chhuhara	5.97	5.43	5.60	5.28	4.86	5.43
EC-608415 × Pusa Ruby	5.11	4.88	4.33	4.27	3.17	4.35
EC-608415 × EC-520078	4.48	3.98	3.51	3.48	2.99	3.69
EC-608415 × EC-620557	7.85	3.53	3.32	2.36	2.62	3.94
EC-619982 × Arka Saurabh	7.96	6.48	5.34	2.91	2.15	4.97
EC-619982 × Arka Abha	6.45	5.88	5.56	3.98	3.41	5.06
EC-619982 × Punjab Chhuhara	7.46	5.75	4.28	4.10	3.25	4.97
EC-619982 × Pusa Ruby	7.40	6.88	6.32	5.22	5.11	6.19
EC-619982 × EC-520078	7.12	6.49	5.86	5.49	5.27	6.05
EC-619982 × EC-620557	7.18	7.02	5.60	5.35	4.81	5.99
US-440	8.78	8.52	8.02	7.59	7.38	8.06
Arka Rakshak	8.68	8.03	7.52	7.04	6.99	7.65
NS-516	9.11	8.91	8.26	7.65	7.43	8.27
Mean	6.01	5.45	4.97	4.41	3.86	
	S.Em±			**CD (0.01)**		
Treatment (A)	0.096			0.267		
Genotype (B)	0.037			0.104		
A × B	0.214			0.596		

Table.4 Effect of different concentration of NaCl (control, 50mM, 75mM, 100 M and 150mM on root length of tomato genotypes

Crosses/Hybrids	Root length (cm)					
	Treatments					
	Control	50mM	75mM	100mM	150mM	Mean
EC-620407 × Arka Saurabh	5.69	5.67	5.27	4.41	4.39	5.09
EC-620407 × Arka Abha	5.02	4.38	3.92	3.26	2.82	3.88
EC-620407 × Punjab Chhuhara	5.01	5.03	4.52	3.91	3.69	4.43
EC-620407 × Pusa Ruby	4.33	4.20	3.54	3.02	2.62	3.54
EC-620407 × EC-520078	6.11	5.56	5.41	4.89	4.73	5.34
EC-620407 × EC-620557	5.35	5.04	4.15	3.51	3.10	4.23
EC-620428 × Arka Saurabh	4.96	4.48	4.20	3.58	3.34	4.11
EC-620428 × Arka Abha	6.03	5.91	5.75	4.98	4.64	5.46
EC-620428 × Punjab Chhuhara	7.87	7.24	6.84	6.32	5.97	6.85
EC-620428 × Pusa Ruby	8.36	8.16	7.40	7.05	6.82	7.56
EC-620428 × EC-520078	4.25	3.63	3.40	2.86	2.74	3.38
EC-620428 × EC-620557	6.01	5.39	5.14	4.61	4.05	5.04
EC-620360 × Arka Saurabh	3.51	2.88	2.16	2.32	1.50	2.47
EC-620360 × Arka Abha	4.89	4.56	3.41	3.03	2.82	3.74
EC-620360 × Punjab Chhuhara	3.51	2.92	2.65	2.35	2.15	2.72
EC-620360 × Pusa Ruby	5.06	4.41	4.19	3.44	1.93	3.81
EC-620360 × EC-520078	3.61	3.31	3.13	2.41	2.11	2.91
EC-620360 × EC-620557	5.26	4.82	4.33	3.34	3.19	4.19
EC-608415 × Arka Saurabh	4.28	4.25	3.80	3.51	2.74	3.72
EC-608415 × Arka Abha	5.08	4.50	4.00	3.61	3.31	4.10
EC-608415 × Punjab Chhuhara	4.88	4.60	4.21	3.58	3.38	4.13
EC-608415 × Pusa Ruby	5.64	4.70	4.51	4.13	3.27	4.45
EC-608415 × EC-520078	7.11	6.55	6.39	5.42	4.57	6.01
EC-608415 × EC-620557	6.30	5.94	5.22	5.02	4.21	5.34
EC-619982 × Arka Saurabh	6.95	6.75	6.47	5.76	5.58	6.30
EC-619982 × Arka Abha	6.20	5.64	5.44	4.69	4.61	5.32
EC-619982 × Punjab Chhuhara	5.74	5.39	5.28	4.64	4.13	5.04
EC-619982 × Pusa Ruby	8.03	7.32	6.95	6.62	5.79	6.94
EC-619982 × EC-520078	2.62	2.09	1.99	1.39	1.26	1.87
EC-619982 × EC-620557	6.07	5.66	5.55	4.89	4.55	5.34
US-440	7.73	7.52	7.34	6.45	4.91	6.79
Arka Rakshak	7.29	7.21	7.14	6.65	6.15	6.89
NS-516	8.08	7.90	7.58	6.88	5.98	7.28
Mean	5.66	5.26	4.89	4.32	3.85	
	S.Em±			**CD (0.01)**		
Treatment (A)	0.084			0.234		
Genotype (B)	0.033			0.091		
A × B	0.188			0.523		

Table.5 Effect of different concentration of NaCl (control, 50mM, 75mM, 100 M and 150mM on shoot length (cm) of tomato genotypes

Crosses/Hybrids	Shoot length (cm)					
	Treatments					
	Control	50mM	75mM	100mM	150mM	Mean
EC-620407 × Arka Saurabh	4.85	4.43	3.76	3.34	3.17	3.91
EC-620407 × Arka Abha	3.85	3.37	3.30	2.49	2.41	3.09
EC-620407 × Punjab Chhuhara	4.77	4.54	4.23	3.72	3.60	4.17
EC-620407 × Pusa Ruby	8.23	7.82	7.39	6.72	6.52	6.74
EC-620407 × EC-520078	5.27	4.73	4.27	3.57	3.45	4.85
EC-620407 × EC-620557	7.24	6.77	6.40	5.46	5.42	5.82
EC-620428 × Arka Saurabh	5.04	2.50	1.51	1.39	1.25	2.78
EC-620428 × Arka Abha	3.60	3.26	2.47	2.50	1.85	2.73
EC-620428 × Punjab Chhuhara	5.11	4.65	4.31	3.59	3.42	3.93
EC-620428 × Pusa Ruby	3.69	2.03	1.57	1.49	1.16	2.27
EC-620428 × EC-520078	8.54	8.00	7.79	5.40	2.01	6.35
EC-620428 × EC-620557	9.37	6.15	5.35	4.68	4.44	6.00
EC-620360 × Arka Saurabh	6.64	6.00	5.93	5.41	5.09	5.81
EC-620360 × Arka Abha	2.67	1.60	1.54	1.32	1.20	2.48
EC-620360 × Punjab Chhuhara	6.67	3.38	3.29	2.63	2.35	2.65
EC-620360 × Pusa Ruby	4.16	4.14	3.96	3.36	3.07	3.74
EC-620360 × EC-520078	4.96	4.17	3.47	2.91	2.78	3.66
EC-620360 × EC-620557	10.77	10.09	8.93	8.91	8.91	9.49
EC-608415 × Arka Saurabh	7.20	6.58	6.33	6.02	5.41	6.31
EC-608415 × Arka Abha	2.02	1.61	1.40	1.60	0.41	2.48
EC-608415 × Punjab Chhuhara	7.37	5.27	4.57	4.19	4.05	4.02
EC-608415 × Pusa Ruby	6.99	6.44	5.98	5.60	5.26	6.05
EC-608415 × EC-520078	8.03	7.89	7.43	7.36	7.32	7.61
EC-608415 × EC-620557	2.51	2.15	1.87	1.63	1.57	3.20
EC-619982 × Arka Saurabh	3.52	3.43	2.26	1.59	1.54	2.19
EC-619982 × Arka Abha	8.78	8.12	7.50	6.71	6.63	6.50
EC-619982 × Punjab Chhuhara	7.98	6.43	4.10	3.00	2.51	4.80
EC-619982 × Pusa Ruby	5.60	4.34	3.99	3.67	2.36	3.99
EC-619982 × EC-520078	4.96	3.73	3.32	2.69	2.40	3.42
EC-619982 × EC-620557	5.24	4.28	3.62	3.57	2.21	3.78
US-440	9.87	8.24	8.20	8.13	5.26	7.94
Arka Rakshak	9.98	9.41	8.34	8.02	7.92	8.73
NS-516	5.99	5.43	4.88	4.68	4.29	5.05
Mean	6.11	5.18	4.64	4.16	3.67	
	S.Em±			**CD (0.01)**		
Treatment (A)	0.081			0.226		
Genotype (B)	0.032			0.088		
A × B	0.182			0.506		

Table.6 Effect of different concentration of NaCl (control, 50mM, 75mM, 100 M and 150mM on root dry weight (mg) of tomato genotypes

Crosses/Hybrids	Root dry weight (mg)					
	Treatments					
	Control	50mM	75mM	100mM	150mM	Mean
EC-620407 × Arka Saurabh	6.95	6.23	6.01	5.58	5.52	4.56
EC-620407 × Arka Abha	3.32	2.88	2.79	2.83	2.58	4.38
EC-620407 × Punjab Chhuhara	10.27	9.36	8.78	4.06	3.87	6.43
EC-620407 × Pusa Ruby	3.20	2.34	1.90	1.85	1.80	3.05
EC-620407 × EC-520078	7.69	7.06	5.90	5.46	5.19	6.26
EC-620407 × EC-620557	9.55	8.33	5.42	4.12	0.93	5.08
EC-620428 × Arka Saurabh	2.77	2.67	1.43	1.17	0.90	2.38
EC-620428 × Arka Abha	3.73	3.00	2.99	2.32	1.98	2.80
EC-620428 × Punjab Chhuhara	7.55	5.82	5.29	4.10	2.75	5.10
EC-620428 × Pusa Ruby	4.14	3.77	3.52	3.11	1.22	3.70
EC-620428 × EC-520078	5.37	5.17	4.60	3.95	3.75	4.02
EC-620428 × EC-620557	5.47	4.94	4.44	3.93	3.80	3.97
EC-620360 × Arka Saurabh	2.96	1.62	1.47	1.95	1.08	2.36
EC-620360 × Arka Abha	5.21	4.46	3.70	2.10	1.92	3.48
EC-620360 × Punjab Chhuhara	2.97	2.82	2.37	2.19	1.95	2.46
EC-620360 × Pusa Ruby	2.92	2.19	1.76	1.75	1.88	2.10
EC-620360 × EC-520078	4.37	3.19	2.84	2.37	1.81	2.92
EC-620360 × EC-620557	4.21	3.43	3.01	2.95	2.04	3.13
EC-608415 × Arka Saurabh	3.44	3.25	2.59	2.41	2.23	2.78
EC-608415 × Arka Abha	5.30	4.00	3.04	2.49	1.92	2.98
EC-608415 × Punjab Chhuhara	2.94	2.20	2.16	1.60	0.93	2.34
EC-608415 × Pusa Ruby	5.88	4.17	3.03	2.81	2.33	3.64
EC-608415 × EC-520078	5.19	5.33	3.88	3.05	2.97	4.08
EC-608415 × EC-620557	5.67	4.89	4.03	3.14	2.77	4.10
EC-619982 × Arka Saurabh	4.34	3.31	3.25	3.09	2.91	3.38
EC-619982 × Arka Abha	5.06	3.96	3.72	3.53	2.73	3.80
EC-619982 × Punjab Chhuhara	5.15	4.80	4.41	4.26	4.13	4.55
EC-619982 × Pusa Ruby	8.85	6.02	5.92	4.30	3.87	5.23
EC-619982 × EC-520078	7.54	6.02	4.37	3.81	3.17	5.55
EC-619982 × EC-620557	7.53	5.37	5.36	3.80	3.23	5.06
US-440	10.95	10.76	9.90	9.44	8.56	9.92
Arka Rakshak	11.37	9.92	9.56	8.80	8.25	9.58
NS-516	11.61	10.55	10.06	9.53	8.88	10.13
Mean	5.86	4.96	4.35	3.69	3.15	4.40
	S.Em±			CD (0.01)		
Treatment (A)	0.084			0.233		
Genotype (B)	0.033			0.091		
A × B	0.187			0.521		

Table.7 Effect of different concentration of NaCl (control, 50mM, 75mM, 100 M and 150mM on shoot dry weight (mg) of tomato genotypes

Crosses/Hybrids	Shoot dry weight (mg)					
	Treatments					
	Control	50mM	75mM	100mM	150mM	Mean
EC-620407 × Arka Saurabh	46.36	42.93	32.56	28.15	25.99	35.20
EC-620407 × Arka Abha	32.61	27.89	23.96	18.26	15.01	23.54
EC-620407 × Punjab Chhuhara	66.99	65.23	60.93	50.60	18.87	45.67
EC-620407 × Pusa Ruby	24.12	22.25	19.50	14.33	11.72	28.44
EC-620407 × EC-520078	81.44	76.12	72.83	67.69	24.70	64.55
EC-620407 × EC-620557	72.04	71.37	59.24	44.59	35.81	66.61
EC-620428 × Arka Saurabh	27.07	22.76	21.19	19.32	13.69	30.80
EC-620428 × Arka Abha	31.01	30.53	28.68	26.03	17.26	34.70
EC-620428 × Punjab Chhuhara	56.11	54.66	43.74	32.30	15.73	46.51
EC-620428 × Pusa Ruby	42.75	35.53	28.99	26.86	14.61	32.95
EC-620428 × EC-520078	54.03	53.64	46.96	42.61	20.80	51.01
EC-620428 × EC-620557	73.67	71.59	63.92	37.11	25.87	61.43
EC-620360 × Arka Saurabh	45.69	34.64	31.45	26.24	20.11	27.43
EC-620360 × Arka Abha	82.30	78.39	71.96	65.03	29.95	72.92
EC-620360 × Punjab Chhuhara	30.67	28.64	24.23	22.53	17.73	24.76
EC-620360 × Pusa Ruby	40.86	39.14	35.36	32.20	15.85	42.68
EC-620360 × EC-520078	51.74	43.31	41.96	37.66	19.04	38.74
EC-620360 × EC-620557	58.63	47.78	45.88	41.40	30.07	44.75
EC-608415 × Arka Saurabh	88.07	82.49	66.08	50.68	30.92	69.65
EC-608415 × Arka Abha	38.71	36.41	33.55	31.26	26.54	33.29
EC-608415 × Punjab Chhuhara	79.38	50.40	49.07	43.04	15.41	51.46
EC-608415 × Pusa Ruby	31.12	30.48	28.00	24.45	19.78	27.96
EC-608415 × EC-520078	43.41	41.10	40.51	32.39	20.36	38.76
EC-608415 × EC-620557	49.63	43.26	41.41	34.52	24.92	38.75
EC-619982 × Arka Saurabh	80.31	79.74	70.88	39.03	22.38	66.47
EC-619982 × Arka Abha	70.10	68.36	64.03	45.79	32.92	60.24
EC-619982 × Punjab Chhuhara	29.75	29.27	25.78	22.78	13.08	35.40
EC-619982 × Pusa Ruby	61.39	35.62	31.49	24.24	16.72	40.09
EC-619982 × EC-520078	49.80	44.16	39.65	22.38	12.02	40.40
EC-619982 × EC-620557	50.48	50.13	40.21	30.20	19.79	46.16
US-440	85.86	83.10	64.16	53.15	29.72	83.20
Arka Rakshak	86.48	84.18	64.30	44.09	20.76	83.96
NS-516	82.71	77.80	75.05	34.03	22.51	84.42
Mean	55.92	51.00	45.08	35.30	21.23	
	S.Em±			**CD (0.01)**		
Treatment (A)	0.681			1.895		
Genotype (B)	0.265			0.738		
A × B	1.523			0.438		

After radicle emergence, hypocotyl emerges and lifts the growing tip above the ground. Under drought stress condition, the root develops faster than the hypocotyls to acclimatize the drought stress. Therefore, the growth of radicle and hypocotyls should reflect the adaptability of plant to drought stress (Zhu *et al.,* 2006).

Significant differences were observed for root length between the genotypes and different NaCl concentrations (Table 4). Irrespective of the salt concentrations, EC-620428 × Pusa Ruby recorded significantly maximum root length (7.56 cm) compared to all others. Root length was lowest (1.87 cm) in the genotype EC-619982 × EC-520078. At 50mM concentration of NaCl, maximum and minimum root length was recorded in EC-620428 × Pusa Ruby (8.16 cm) and EC-619982 × EC-520078 (2.09 cm) respectively. While at 75mM concentration, genotypes NS-516 (7.58 cm) and EC-619982 × EC-520078 (1.99 cm) exhibited maximum and minimum root lengths. With 100mM concentration of NaCl, genotypes EC-620428 × Pusa Ruby (7.05 cm) and EC-619982 × EC-520078 (1.39 cm) responded as maximum and minimum root lengths. In case of 150mM concentration, genotypes EC-620428 × Pusa Ruby (6.82 cm) and EC-619982 × EC-520078 (1.26 cm) responded as maximum and minimum root length respectively. Similar results were observed by Souguir *et al.,* (2013) Aamir *et al.,* (2012).

Shoot Length (cm)

The results revealed significant difference in shoot length between the genotypes and different NaCl concentrations (Table 5). Irrespective of salt concentrations, EC-620360 × EC-620557 recorded significantly maximum shoot length (9.49 cm) while lowest (2.27 cm) was in EC-620428 × Pusa Ruby among all genotypes. At 50mM concentration of NaCl, maximum and minimum shoot length was recorded in EC-620360 × EC-620557 (10.09 cm) and EC-620360 × Arka Abha (1.60 cm) genotypes respectively. While at 75mM concentration of NaCl, genotype EC-620360 × EC-620557 (8.93 cm) and EC-608415 x Arka Abha (1.40 cm) exhibited maximum and minimum shoot lengths. In case of 100mM concentration, genotypes EC-620360 × EC-620557 (8.91 cm) and EC-620360 × Arka Abha (1.32 cm) responded with maximum and minimum shoot length respectively. With 150mM concentration of NaCl, genotypes EC-620360 × EC-620557 (8.91 cm) and EC-608415 × Arka Abha (0.41 cm) recorded with maximum and minimum shoot length respectively.

Genotypes with indeterminate growth habit showed more reduction in shoot length as compared to determinate type. It indicates that determinate tomato can be well suited to drought areas than indeterminate growth habit. Present experimental results were similar to earlier studies of Aamir *et al.,* (2012).

Root dry weight (mg)

Highest root weight was exhibited by NS-516 (10.13) (Table 6). Regardless of the salt concentrations, root dry weight was lowest (2.10) in EC-620360 × Pusa Ruby. In 50mM concentration of NaCl, maximum and minimum root dry weight was recorded in NS-516 (10.55 mg) and EC-620360 × Pusa Ruby (2.19 mg) respectively. While at 75mM concentration, genotypes NS-516 (10.06 mg) and EC-620428 × Arka Saurabh (1.43 mg) exhibited maximum and minimum root dry weight respectively. In case of 100 mM concentration of NaCl, genotypes NS-516 (9.53 mg) and EC-620428 × Arka Saurabh (1.17 mg) had responded as maximum and minimum root dry weight respectively. With

150mM concentration of NaCl, genotypes NS-516 (8.88 mg) and EC-620428 × Arka Saurabh (0.90 cm) had responded as maximum and minimum root dry weight respectively

Growth parameters like dry weight is known to have a profound effect on water limited conditions. In the present study a reduction in root dry weight was recorded in stressed conditions in all the genotypes. Present investigation is in confirmation with Ahmet *et al.,* (2009) and Soughir *et al.,* (2013). Root dry weight depends on the germination percent and root length, low water uptake and restricted metabolic activities were given to decrease in the root dry weight. Most of the tolerant genotypes accumulated more dry matter under control that too increased under stress however moderately tolerant or susceptible genotypes recorded comparatively less increase or even decrease in dry weight of roots.

Shoot dry weight (mg)

Irrespective of the NaCl concentrations, NS-516 recorded significantly maximum shoot dry weight (84.42 mg) among all genotypes (Table 7) with lowest (23.54 mg) in EC-620407 × Arka Abha. In 50mM concentration, maximum and minimum shoot dry weight was recorded in Arka Rakshak (84.18 mg) and EC-620407 x Pusa Ruby (22.25 mg) respectively. While at 75mM concentration of NaCl, genotype NS-516 (75.05 mg) and EC-620407 × Pusa Ruby (19.50 mg) exhibited maximum and minimum shoot dry weight. With 100mM concentration EC-620407 × EC-520078 (67.69 mg) and EC-620407 × Pusa Ruby (14.33 mg) had responded with maximum and minimum shoot dry weight respectively. In case of 150mM concentration of NaCl, genotypes EC-620407 × EC-620557 (35.81 mg) and EC-620407 × Pusa Ruby (11.72 mg) had responded with maximum and minimum shoot dry weight.

High levels of salinity reduced shoot dry weight. This is probably due to the reaction of salinity, which reduces the contribution of phytohormones in the biosynthesis (Cuartero *et al.,* 2006). These results are in accordance with Ahmet *et al.,* (2009) and Soughir *et al.,* (2013).

Salinity is a major constraint to economic use of land for agriculture especially in the coastal regions. Among the commercial checks NS-516 while among crosses EC-619982 × EC-520078, EC-619982 × Pusa Ruby, EC-620428 × Punjab Chhuhara, EC-620360 × EC-620557, EC-620407 × Punjab Chhuhara and EC-608415 × Arka Saurabh responded positively against different NaCl concentrations. The genotypes can be further tested under pot culture studies and if found promising field level experiments may be carried out for confirming their potential.

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