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Assessment of Tomato Accessions for Various Seedling Attributes Under NaCl Salt Stress

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ABSTRACT

In this study, the performance of twenty tomato genotypes was evaluated against two different NaCl concentrations (6 and 12 dSm^{-1}) along with a control in a glasshouse of the Faculty of Agriculture, University of Agriculture Faisalabad, Pakistan. The experiment was conducted under a completely randomized design (CRD) with three replications. The morphological characteristics such as plant height, root length, shoot length, fresh root weight, fresh shoot weight, dry root weight, dry shoot weight, fresh plant biomass, dry plant biomass, fresh root to shoot weight ratio, dry root to shoot weight ratio, root/shoot length ratio, Na^+ determination of roots and leaves, K^+ determination of roots and leaves, and Na^+/K^+ ratio of roots and leaves were recorded. Analysis of variance (ANOVA) was performed to estimate the variability among the tomato genotypes. The results showed that genotype CLN-2498A performed the best for all the studied traits under control conditions, while genotype Nadir performed poorly for these parameters. Genotype PGRI-17902 was considered as the best genotype for all traits under NaCl stress of 6 dSm^{-1}, while genotype PGRI-19905 performed poorly. Under the 12 dSm^{-1} stress condition, PGRI-17260 appeared to be the best genotype for all recorded traits, and Sundar revealed the least performance for all the above-mentioned characters. The outcomes of this study could be helpful in developing salt-tolerant tomato cultivars.

Key words: Tomato, Salinity Stress, Genetic Diversity.

INTRODUCTION

Tomato crop is highly sensitive to salinity particularly at seedling stage. Worldwide production of tomato is 182 million tons on an area of 4.7 million hectares (FAOSTAT, 2020). Salinity results in reduced yield due to decrease in photosynthetic rate, chlorophyll content, stomatal closure, total plant biomass and increase in oxidative stress (Abuarab et al., 2019; Mahmoud et al., 2020; Zafar et al., 2022). Salinity affects tomato plant growth and development by reducing water uptake, causing ion toxicity, and disrupting the balance of nutrient uptake. High salt concentration in the soil reduces water potential, leading to water stress and reduced plant growth. Salt also causes ion toxicity by disrupting the balance of essential ions such as calcium, magnesium, potassium, and nitrogen. Salt stress causes membrane damage, which leads to reduced photosynthesis, respiration, and transpiration rates. Salinity also affects the root system of tomato plants, leading to reduced root growth and nutrient uptake (Seleiman et al., 2020).

Two types of salinity stress, hyper-osmotic and hyper-ionic, can negatively impact crop yield and plant growth (Acosta-Motos et al., 2017). As salt stress increases, plants struggle to absorb nutrients from the soil, leading to reduced growth and production. Soil salinity levels can range from 0.6 to 3.2 dSm-1 and directly impact crop yield and effective salt concentration (Hamamoto et al., 2015).

Hyperosmotic stress occurs when plants are unable to absorb water due to soil salinity. Natural extracts such as seaweed extracts have been found to improve growth and salt tolerance in plants. A biotechnological approach to addressing saline soils involves diversifying hormone metabolism and signaling in roots, but a solid understanding of the adaptive roles of plant hormones is necessary (Albacete et al., 2014). The effect of high salinity levels (8-16 dSm-1) on root development depends on the plant species or genotype, with low to moderate salinity (2-8 dSm-1) potentially enhancing root growth (Julkowska and Testerink, 2015). Abscisic acid, in conjunction with other hormones, suppresses stress responses by reducing ethylene production in tomato shoots. Tomato plants can

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also accumulate ABA in their roots, xylem, and leaves in response to salinity stress. Ion toxicity occurs when the cells and tissues of a plant accumulate excessive levels of Na+, hindering its growth and development. Unlike animals, Na+ is a non-essential element for most plants, except for C4 plants, and its accumulation can be severely detrimental to plant growth. Maintaining high tissue K+/Na+ ratios, and consequently high cytosolic K+/Na+ ratios, has been a focus of recent research as it was deemed to prevent Na+ uptake and transport in salt-stressed plants. This has become a crucial characteristic of salt tolerance (Shabala and Pottosin, 2014).

Several parameters have been recognized as critical indicators of a plant's salt stress tolerance under stressful conditions, such as fresh and dry biomass of the root and shoot, as well as fresh and dry weights of the root and shoot, which decrease significantly under all NaCl treatments (Kapoor and Pande, 2015). Studies have shown that tomato cultivars increase their Na+ absorption rapidly in leaves and roots while reducing K+ uptake as the concentration of NaCl increases, with leaves exhibiting higher ionic uptake than roots (Rahneshan et al., 2018; Yassin et al., 2019).

The objective of this present study was to investigate the effect of different NaCl concentrations on morphological traits of twenty tomato genotypes.

- To devise a selection criterion for salinity tolerance
- To select the salinity tolerant and non-tolerant genotypes

MATERIALS AND METHODS

Research Material

The experiment was conducted in the screen house of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. Twenty tomato genotypes were examined against control, 6 and 12 dSm^{-1} NaCl level. Seed material was obtained from different sources including seed bank of the Department of Plant Breeding and Genetics, Ayub Agriculture Research Institute (AARI), Plant Genetic Resource Institute (PGRI) and Nuclear Institute for Agriculture and Biology (NIAB). The experiment was performed into two factor factorial under completely randomized design (CRD) against three NaCl levels viz. T1 (control), T2 (6 dSm^{-1}NaCl) and T3 (12 dSm^{-1}NaCl) with three replications. The tomato genotypes involved in the research were as under table 1.

First, tomato seeds were sown to establish the nursery during crop season 2021 for the time period of 3 weeks. After 21 days, healthy plants of uniform size were transplanted from nursery into the plastic cups (width: 45 cm, height: 11 cm) that were already placed in the screen house, filled with approximately 800g of sand/cup for each replication. Three plants of each genotype were transplanted from nursery into the cups having one plant/cup. Tomato genotypes were arranged randomly by using lottery method.

Treatments

NaCl was applied in three treatment levels i.e., 0, 6 and 12 dSm^{-1} after 1 week of transplanting from the nursery to avoid severe transplant shock. For the application of NaCl and to provide proper nutrients to tomato genotypes, Hoagland’s solution was prepared. After 7 weeks, seedlings were harvested from the plastic cups and data of the following morphological and biochemical traits was recorded.

Determination of Na^+ and K^+ ions

Na^+ and K^+ ions concentration in roots and leaves of tomato genotypes were determined by using an instrument called flame photometer. The flame photometer was calibrated using the standard stock solution of sodium and potassium having (10, 20, 40, 60, 80, 100) ppm concentrations.

Morphological and Biochemical Traits

Data of the following morphological and biochemical traits was recorded at seedling stage.

Plant height(cm), Root length (cm), Shoot length (cm), Fresh root weight (g), Fresh shoot weight (g), Dry root weight (g), Dry shoot weight (g), Fresh plant biomass (g), Dry plant biomass (g), Fresh root/shoot weight ratio, Dry root/shoot weight ratio, Root/Shoot Length ratio, K^+ and Na^+ determination (ppm).

Statistical Analysis

Analysis of variance (ANOVA) (Steel *et al*., 1997) was performed to investigate the variation among the genotypes for these traits.

RESULTS AND DISCUSSION

The ANOVA results revealed significant differences among all treatments for both morphological and biochemical traits, except for K+ determination of roots. Genotypes also showed significant variations for all traits

Table 1: Name of genotypes used for the experiment

Sr. No.	Genotypes	Sr. No.	Genotypes
1	H-24	11	Target-T-66
2	CLN-2498A	12	PGRI-17256
3	PGRI-19900	13	PGRI-17260
4	PGRI-17902	14	PGRI-17263
5	Galia	15	CLN-2001A
6	PGRI-19908	16	Aut-318
7	BGH-24	17	PGRI-17255
8	PGRI-17884	18	Sundar
9	PGRI-19905	19	Peelo
10	Picdeneato	20	Nadir

Table 1: Mean sum of squares of all genotypes for seedling related traits under study

Source	DF	PH	SL	RL	FRW	FSW	FR	DRW	DSW	DR	LR	FPB	DPB	NR	NL	KR	KL	N/KR	N/KL
Treatment	2	6460.86**	1349.25**	2023.42**	9.426**	34.949**	0.160**	0.228**	0.988**	0.116**	0.926**	80.302**	2.157**	5.56×10^{8}**	2.05×10^{9}**	5.07×10^{6}NS	2.01×10^{7}**	7.93×10^{7}*	38.6**
Genotypes	19	834.95**	256.04**	276.81**	0.531**	2.437**	0.024**	0.013**	0.063**	0.047**	0.457**	4.825**	0.118**	2.99×10^{7}**	6.37×10^{6}**	1.55×10^{7}NS	2.74×10^{6}**	2.29×10^{7}NS	26.9**
Treatment*Genotypes	38	871.09**	282.73**	191.49**	0.178NS	1.087NS	0.015*	0.005NS	0.023NS	0.008NS	0.123NS	1.935NS	0.047NS	2.61×10^{7}**	1.16×10^{7}**	1.60×10^{7}NS	5.34×10^{6}**	2.29×10^{7}NS	4.62**
Error	120	104.62	47.88	33.25	0.169	0.973	0.009	0.004	0.018	0.015	0.088	1.813	0.036	8.50×10^{6}	1.79×10^{6}	1.51×10^{7}	9.12×10^{5}	2.57×10^{7}	232

N.S. = At probability value > 0.05, ** = At probability value < 0.01, * = At probability value > 0.01 or < 0.05. PH: Plant height (cm), RL: Root length (cm), SL: Shoot length (cm), FRW: Fresh root weight (g), FSW: Fresh shoot weight (g), DRW: Dry root weight (g), DSW: Dry shoot weight (g), FPB: Fresh plant biomass (g), DPB: Dry plant biomass (g), FR: Fresh root/shoot weight ratio , DR: Dry root/shoot weight ratio , LR: Root/Shoot Length ratio, KR: K^+ of roots (ppm), KL: K^+ of leaves (ppm), NR: Na^+ of roots (ppm), NL: Na^+ of leaves (ppm), N/KR: Na^+/K^+ ratio of roots, N/KL: Na^+/K^+ ratio of leaves

Table 2: Mean performance of all genotypes for seedling related traits under study at treatment 1

Genotypes	PH	SL	RL	FRW	FSW	FR	DRW	DSW	DR	LR	FPB	DPB	NR	NL	KR	KL	N/KR	N/KL
H-24	105.83	49.53	56.303	1.593	4.127	0.387	0.229	0.495	0.443	1.183	5.72	0.723	5643	952	3627	8143	2	0.118
CLN-2498A	79.32	45.953	33.363	1.86	5.117	0.377	0.245	0.725	0.35	0.838	6.977	0.972	8241	2107	3627	8789	2	0.242
PGRI-19900	52.22	31.750	20.470	1.24	3.55	0.34	0.178	0.537	0.327	0.649	4.79	0.717	8169	1024	3341	9434	3	0.107
PGRI-17902	40.24	22.86	17.380	1.703	4.097	0.43	0.285	0.702	0.413	0.776	5.8	0.972	8602	1313	3556	8430	2	0.153
Galia	44.28	25.470	18.807	2.087	4.193	0.517	0.309	0.541	0.567	0.753	6.28	0.851	7588	1097	5276	9649	1	0.112
PGRI-19908	42.64	23.080	19.557	1.617	3.343	0.497	0.19	0.411	0.45	0.851	4.96	0.599	6834	952	3341	8860	2	0.103
BGH-24	41.43	21.233	20.197	1.223	3.903	0.323	0.172	0.447	0.397	0.965	5.127	0.618	8385	2540	2624	9004	3	0.287
PGRI-17884	46.46	27.433	19.023	1.907	4.58	0.433	0.277	0.573	0.49	0.737	6.487	0.852	8241	1241	3197	10007	3	0.123
PGRI-19905	42.07	21.107	20.963	1.413	4.007	0.36	0.188	0.501	0.38	0.999	5.42	0.688	4644	2049	3087	7842	2	0.266
Picdeneato	43.33	22.683	20.650	1.42	3.763	0.38	0.181	0.496	0.393	0.949	5.183	0.676	5860	2973	3484	8789	2	0.337
Target-T-66	41.33	19	22.333	1.3	2.45	0.55	0.149	0.329	0.487	1.231	3.75	0.476	6004	2756	5706	8430	1	0.328
PGRI-17256	42.83	22.500	20.333	1.397	2.957	0.47	0.183	0.333	0.543	0.925	4.353	0.518	9901	3767	4487	8287	2	0.459
PGRI-17260	42	20	22.000	1.733	3.133	0.56	0.208	0.419	0.53	1.144	4.867	0.627	11128	3550	4703	9505	2	0.379
PGRI-17263	44.67	22.500	22.167	1.787	3.637	0.507	0.224	0.429	0.523	0.994	5.423	0.654	6942	2756	2910	7068	2	0.393
CLN-2001A	41	19.333	21.667	1.593	3.137	0.51	0.228	0.405	0.557	1.13	4.73	0.633	7232	3406	3341	8000	2	0.431
Aut-318	46.5	25.167	21.333	1.613	3.533	0.46	0.26	0.575	0.457	0.845	5.147	0.834	6818	1120	2592	9118	3	0.127
PGRI-17255	48.33	23.833	24.500	1.793	3.633	0.497	0.296	0.488	0.587	1.029	5.427	0.783	6509	1385	3484	8072	2	0.167
Sundar	41.83	22.333	19.500	1.013	3.16	0.32	0.122	0.325	0.387	0.879	4.173	0.448	8963	3262	3412	8000	3	0.414
Peelo	48.67	21.333	27.333	1.673	3.71	0.457	0.223	0.553	0.427	1.299	5.383	0.776	7086	1024	2839	8143	3	0.124
Nadir	38.67	16	22.667	0.963	2.067	0.467	0.094	0.21	0.45	1.431	3.03	0.304	7159	1313	3125	8645	2	0.154
Mean	48.682	25.155	23.527	1.547	3.605	0.442	0.212	0.474	0.458	0.98	5.151	0.686	7497	2029	3587.9	8610.7	2.2	0.241

Table 3: Mean performance of all genotypes for seedling related traits under study at treatment 2

Genotypes	PH	SL	RL	FRW	FSW	FR	DRW	DSW	DR	LR	FPB	DPB	NR	NL	KR	KL	N/KR	N/KL
H-24	50.33	17.333	33.000	1.653	3.02	0.543	0.168	0.34	0.48	1.891	4.673	0.508	14437	13220	6565	8843	2	1.503
CLN-2498A	39	21.667	17.333	1.033	3.053	0.33	0.116	0.333	0.327	0.839	4.087	0.449	14197	11705	5419	9290	3	1.269
PGRI-19900	54.00	29.333	24.667	1.373	3.677	0.377	0.133	0.447	0.308	0.85	5.05	0.58	11227	11416	4910	6566	2	1.742
PGRI-17902	50.33	26.667	23.667	1.587	4.313	0.37	0.2	0.553	0.367	0.888	5.9	0.753	15485	8891	3065	7857	5	1.136
Galia	44.96	22.183	22.773	1.617	3.017	0.557	0.179	0.348	0.53	1.06	4.633	0.526	9136	12434	1446	7992	29	1.559
PGRI-19908	26.23	13.167	13.067	1.003	2.697	0.37	0.12	0.272	0.44	0.962	3.7	0.394	15036	11112	3596	10921	4	1.034
BGH-24	52.32	19.47	32.853	1.127	2.16	0.49	0.134	0.264	0.487	1.752	3.287	0.399	11272	8385	4846	8789	2	0.956
PGRI-17884	37.09	18.963	18.123	0.983	2.61	0.363	0.119	0.285	0.407	0.973	3.593	0.406	9278	8818	1466	6781	8	1.301
PGRI-19905	94.83	46.143	48.683	0.577	2.01	0.287	0.07	0.216	0.343	1.128	2.587	0.285	10454	12680	1014	6122	14	2.078
Picdeneato	117.26	67.733	49.53	1.077	3.34	0.323	0.136	0.411	0.33	0.732	4.417	0.547	11919	9396	4078	10652	3	0.884
Target-T-66	85.26	48.767	36.493	1.59	3.49	0.46	0.193	0.418	0.473	0.838	5.08	0.611	10151	8746	2954	9362	3	0.94
PGRI-17256	38.27	15.58	22.687	0.607	1.497	0.397	0.073	0.154	0.48	1.499	2.103	0.229	12089	7808	6585	8573	2	0.929
PGRI-17260	47.75	17.027	30.723	1.28	2.483	0.527	0.134	0.242	0.543	1.786	3.763	0.377	10562	12585	3311	7216	3	1.748
PGRI-17263	42.67	18.29	24.380	1.087	2.063	0.527	0.139	0.283	0.537	1.356	3.15	0.424	13405	10695	5379	9290	3	1.157
CLN-2001A	93.13	36.553	56.58	0.847	1.873	0.457	0.112	0.213	0.573	1.595	2.72	0.323	14698	11142	5916	10784	3	1.041
Aut-318	44.79	22.24	22.550	1.303	2.707	0.483	0.154	0.319	0.483	1.013	4.01	0.472	14825	9107	5105	8789	3	1.039
PGRI-17255	45.55	18.963	26.587	1.21	2.37	0.507	0.131	0.243	0.543	1.406	3.58	0.372	16994	8313	5057	8860	3	0.94
Sundar	38.44	17.867	20.573	0.913	2.07	0.427	0.126	0.249	0.473	1.184	2.983	0.376	12945	10334	5801	8358	2	1.252
Peelo	35.22	17.367	17.857	0.707	1.787	0.4	0.082	0.191	0.45	1.072	2.493	0.273	13509	6942	4190	8932	3	0.775
Nadir	36.07	15.833	20.233	0.74	1.777	0.413	0.076	0.168	0.45	1.286	2.517	0.244	9111	11633	2285	9075	4	1.286
Mean	53.675	25.557	28.118	1.116	2.601	0.43	0.129	0.297	0.451	1.206	3.716	0.427	12536	10268	4149.3	8652.6	5.2	1.228

Table 4: Mean performance of all genotypes for seedling related traits under study at treatment 3

Genotypes	PH	SL	RL	FRW	FSW	FR	DRW	DSW	DR	LR	FPB	DPB	NR	NL	KR	KL	N/KR	N/KL
H-24	35.67	13.667	22.000	0.77	1.813	0.423	0.073	0.19	0.367	1.626	2.583	0.263	8175	12932	1613	7355	46	1.759
CLN-2498A	37	20	17.000	0.843	2.503	0.31	0.106	0.26	0.373	0.853	3.347	0.366	9340	8674	2683	7498	36	1.164
PGRI-19900	40.67	20.667	20.000	0.643	2.047	0.327	0.067	0.247	0.27	0.988	2.69	0.313	9114	9684	2929	8645	39	1.124
PGRI-17902	41	22	19.000	1.193	3.21	0.363	0.147	0.357	0.4	0.863	4.403	0.503	7922	11561	1995	8932	22	1.295
Galia	32.67	16	16.667	0.677	1.763	0.367	0.08	0.157	0.5	1.047	2.44	0.237	7543	13353	2273	6693	497	2.015
PGRI-19908	30.33	16.667	13.667	0.713	2.083	0.363	0.09	0.213	0.433	0.846	2.797	0.303	14226	15385	2159	9434	46	1.635
BGH-24	29	14.333	14.667	0.397	1.3	0.293	0.043	0.123	0.327	1.016	1.697	0.167	25448	14542	18088	6803	18077	2.141
PGRI-17884	32.67	17.333	15.333	0.823	2.04	0.383	0.074	0.19	0.447	0.873	2.863	0.264	11394	14231	2195	5276	57	2.736
PGRI-19905	30.67	16	14.667	0.42	0.947	0.547	0.033	0.113	0.29	0.925	1.367	0.147	13403	15385	2280	9290	54	1.663
Picdeneato	34.67	20.333	14.333	0.927	2.767	0.303	0.111	0.307	0.3	0.696	3.693	0.417	14526	13155	2658	5231	9399	2.586
Target-T-66	35.33	16	19.333	0.59	1.76	0.357	0.061	0.177	0.357	1.23	2.35	0.239	10569	12860	2996	6710	19	1.921
PGRI-17256	31.67	17	14.667	0.827	2.183	0.39	0.093	0.207	0.457	0.877	3.01	0.3	11821	10839	3270	7211	18	1.501
PGRI-17260	36	16.667	19.333	1.243	3.087	0.37	0.247	0.55	0.407	1.341	4.33	0.797	12865	11918	4193	7873	61	1.523
PGRI-17263	39	21	18.000	1.403	3.563	0.39	0.173	0.31	0.563	0.879	4.967	0.482	13653	13172	5204	11488	3	1.148
CLN-2001A	37.33	14.333	23.000	0.753	1.723	0.433	0.077	0.18	0.427	1.658	2.477	0.257	13004	11200	4487	7570	3	1.495
Aut-318	36.33	20.667	15.667	1.107	2.707	0.353	0.152	0.28	0.497	0.774	3.813	0.433	11408	14038	2717	6835	9889	2.067
PGRI-17255	35.33	18.333	17.000	0.693	2.503	0.27	0.085	0.207	0.417	0.917	3.197	0.291	20750	18663	3835	7590	419	2.468
Sundar	22	12	10	0.253	1.013	0.187	0.029	0.103	0.217	0.762	1.267	0.134	15470	16443	2072	6142	1145	2.697
Peelo	31.67	16	15.667	0.453	1.713	0.26	0.042	0.187	0.223	0.965	2.167	0.228	17817	15097	3482	7068	70	2.146
Nadir	25.67	14	11.667	0.367	1.417	0.253	0.045	0.15	0.303	0.903	1.783	0.192	11128	13549	3627	8934	3	1.531
Mean	33.733	17.15	16.583	0.755	2.107	0.347	0.091	0.225	0.379	1.002	2.862	0.316	12979	13334	3737.8	7628.9	1995.2	1.83

except K+ and Na+/K+ contents of roots, and exhibited dissimilarities from one another. The interaction between treatments and genotypes was mostly non-significant for all traits, except for plant height, shoot length, root length, fresh root/shoot weight ratio, Na+ determination of roots and leaves, K+ determination of leaves, and Na+/K+ ratio of leaves.

Plant height decreased significantly with increasing NaCl stress levels. Among the genotypes, Picdeneato, PGRI-19905, and CLN-2001A performed the best under the first stress condition (6 dSm-1NaCl), with maximum values of 117.26 cm, 94.83 cm, and 93.13 cm, respectively. In contrast, the performance of PGRI-19908 and Peelo was the worst, with values of only 26.23 cm and 35.22 cm, respectively. Under 12 dSm-1NaCl stress, the genotypes PGRI-17902 and PGRI-19900 showed the highest values (41 cm and 40.67 cm, respectively), while the genotypes Sundar and Nadir exhibited the lowest values (22 cm and 25.67 cm, respectively). In line with these findings, Sassine et al. (2020) suggested that increasing salinity levels had a negative impact on all parameters in control plants, with plant height and stem diameter being reduced at 4 and 6 dSm-1 salinity stress.

As the NaCl stress level increased, a significant reduction in root length was observed. Lovelli et al. (2011) have previously reported that root length and elongation rate decrease under salinity stress. The genotypes CLN-2001A and H-24 showed the highest values for root length under the 3rd treatment, with 23.00 cm and 22.00 cm, respectively. Conversely, the lowest values were exhibited by genotypes PGRI-19908 and Picdeneato, with 13.67 cm and 14.33 cm, respectively. Under control conditions, genotype PGRI-17260 had the maximum value of 0.56 for the fresh root/shoot weight ratio, while genotypes BGH-24 and Sundar had the minimum and nearly equal values of 0.32 and 0.323, respectively. For the 2nd treatment (6 dSm-1), genotypes H-24, Galia, and PGRI-7263 had the highest values of 0.543, 0.557, and 0.527, respectively. Meanwhile, genotypes PGRI-19905, Picdeneato, and CLN-2498A had the lowest values of 0.287, 0.323, and 0.33, respectively, for the fresh root/shoot weight ratio. The maximum values of 0.563 and 0.5 for the dry root/shoot weight ratio were exhibited by the genotypes PGRI-17263 and Galia, respectively. Conversely, genotypes Sundar and PGRI-19900 had lower values of 0.217 and 0.27, respectively.

In a CRD experiment conducted by (Tahir et al., 2018), thirty tomato genotypes were subjected to varying levels of NaCl stress to study the impact on germination percentage and root length. The results indicated that both traits were significantly reduced by increasing salt stress. Interestingly, tomato shoots were found to be more sensitive to salinity stress than roots, thus highlighting the importance of evaluating both roots and shoots for selection of tolerant genotypes against saltiness, as noted by (Van zelm et al., 2020).

Plant salinity damage is influenced by several factors, such as the amount of NaCl salt present, the duration of exposure, the weather, and plant genetic variation. NaCl salinity can reduce plant growth and biomass output in some glycophyte species. A study conducted by (Sivakumar et al., 2020) investigated salinity tolerance among tomato germplasms using PCA. Different NaCl concentrations were administered to tomato germplasms that were classified as sensitive or tolerant based on criteria such as fresh root weight and dry root weight. The ability of plants to maintain water relations is hindered by NaCl salt, resulting in a significant decrease in fresh weight but not dry weight of shoots (Mimouni et al., 2016).

The salt tolerance of several tomato germplasms varied significantly at the beginning of the seedling stage. As the external NaCl concentration increased, a linear decline was observed in both fresh root, shoot weight and dry root, shoot weight. (Alzahib et al., 2021) experimented with increasing NaCl stress levels and observed a significant reduction in fresh and dry plant biomass for all tomato genotypes. At a NaCl stress level of 6 dSm-1, the genotypes PGRI-17902, Target-T-66 and PGRI-19900 exhibited the highest values of 0.75 g, 0.61 g, and 0.58 g, respectively, for dry plant biomass. Conversely, the genotypes PGRI-17256 (0.22 g), Nadir (0.24 g), and PGRI-19905 (0.28 g) exhibited the lowest values for dry plant biomass under the same stress level.

At a NaCl stress level of 12 dSm-1, the genotypes PGRI-17260, PGRI-17902, and PGRI-17263 exhibited the highest values of 0.797, 0.503, and 0.482, respectively, while Sundar (0.134) and PGRI-19905 (0.147) exhibited the lowest values. Overall, these findings underscore the need to carefully select tomato genotypes that can tolerate salt stress, which can have a significant impact on both the germination and growth of the plant.

Secondary osmotic stress resulting from excessive salinity can affect the osmotic potential of root cells, leading to an increase in root biomass following salt treatment. Since the root is the first organ to encounter saline soil or medium, plants usually allocate additional photoassimilates to the roots in response to salinity stress, as reported by Ahmadi and Souri (2018). However, the decrease in biomass has been associated with the negative impact of salinity on cell division and elongation, according to Heidarpour et al. (2013).

Furthermore, salinity stress can cause a nutrient imbalance, overproduction of reactive oxygen species (ROS), and inhibition of enzymatic activities, all of which significantly affect cellular components and biological membranes, leading to a reduction in biomass production. The concentration of Na+ in roots and leaves significantly increases while K+ concentration in roots and leaves decreases as salinity stress increases. These results were explained by Benazzouk et al. (2018).

Based on the data presented in the table, the genotypes PGRI-19900, BGH-24, PGRI-17884, Aut-318, Sundar, and Peelo showed the same and highest value (3) under no salinity stress, while the genotypes Galia and Target-T-66 showed the same and minimum value (1) for the Na+/K+ ratio of roots.

At a NaCl stress level of (6 dSm-1), the genotypes Galia (10921) and PGRI-19905 (14) recorded the highest values, while the genotype PGRI-19900 (2) had the lowest value. At the same stress level, genotype BGH-24 recorded the highest value (18077) among all genotypes under treatment 3 (12 dSm-1), while genotype CLN-2001A had the minimum value (3) for the Na+/K+ ratio of roots. Furthermore, under treatment 3 (12 dSm-1), genotype PGRI-17884 recorded the highest value (2.736) among all genotypes, and genotype PGRI-19900 had the minimum value (1.124) for the Na+/K+ ratio of leaves. It has been found that plant cells have higher Na+ concentrations under salinity stress, but lower Na+ to K+ ratios (Silva et al., 2015). It is worth noting that plant salt tolerance varies among species and even within a species.

Conclusion

The current study aimed to evaluate the genetic variation and diversity among tomato genotypes in response to environmental stresses that impact morphological and biochemical yield-related traits. The assessment of genetic diversity provided valuable information about the significant and non-significant differences among the tested genotypes. The results showed that genotype PGRI-17902 performed the best for all traits under NaCl stress (6 dSm-1), while genotype PGRI-17260 was the best performer for all traits under (12 dSm-1) NaCl condition.

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