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RESEARCH ARTICLE

Screening of barnyard millet genotypes (*Echinochloa frumentacea* Roxb.) for seedling-stage salinity tolerance

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Abstract

Barnyard millet is an under-utilized minor millet, which shows more resilience to various abiotic stress. Salinity is one of the abiotic stresses, where the crop yield gets affected. This study was carried out in 2024 at Chengalpattu district of Tamil Nadu, where initial stress imposition is a major factor that allows us to understand the changes in root length, shoot length, fresh weight and dry weight. Germination percentage and vigour index are the major parameters that were studied to screen the genotypes for salinity tolerance. The genotypes are subjected to sodium chloride treatment, to identify the tolerant genotypes. The treatments include control (without soaking), hydropriming, 50 mM NaCl, 100 mM NaCl, 150 mM NaCl and 200 mM NaCl, upon all the hundred genotypes. The differences in the performance of all the genotypes for each treatment were observed and recorded. Among the genotypes G_{34} (IEc 688), G_{25} (IEc 675), G_{18} (IEc154), G_{44} (IEc 360) and G_{43} (IEc 356) are found to be tolerant to salinity. The salinity tolerance in these genotypes has been exhibited due to cellular adjustment mechanisms and ionic balance that is achieved in the cytosol. This research provides insight into how varying salinity levels creates impact on the germination and vigour index of barnyard millet genotypes. The identification of salt-tolerant genotypes would potentially improve crop resilience in saline regions.

Keywords: cellular adjustment; germination percentage; salinity; vigour index

Introduction

Soil salinization is a major environmental concern, that affects production of various crops. The Global assessment of salt-affected soils in 50 years was done by Food and Agriculture Organization of United Nations (1). Over 1.4 billion hectares of land are affected by salinity, that was because of climate crisis and anthropogenic factors. In India, cereals serve as staple food, whose productivity is limited, due to the salinity stress. Millets are called "miracle crop", as they withstand multiple abiotic and biotic stress (2). Salinity poses a severe threat to the yield of minor millets like Barnyard millet. The problem of salinity spreads over arid and semi-arid tropics, where millets were grown majorly.

Barnyard millet is a stand-out millet that is an excellent source of dietary fibre with iron. This millet has low glycaemic index, more micronutrients and is also gluten-free and it is one of the oldest domesticated millets, which was predominantly found in arid and semi-arid tropics of Asia and Africa (3). The Indian Barnyard millet has wider adaptability with short duration and high yielding capacity, even under stress conditions (4).

Salinity stress would reduce the seedling length of the millet, which would impact negatively on the establishment of the seedling (5). The yield and grain quality of this millet are affected by salt stress. High salinity can also reduce the water use efficiency, especially during critical period of growth (6). The impact caused by salinity stress would facilitate the production of Reactive Oxygen Species (ROS), that is a free radical with no assigned function. The ROS would damage the membrane compartmentation and affect the ionic balance in cytosol. When salt accumulation in the soil is high, the osmotic pressure increases and water potential decreases. High salt concentration reduces quantity of flavonoids, amino acids and protein synthesis in the plant (7).

Salinity tolerance is exhibited by cellular adjustment mechanisms, including abscisic acid synthesis, which hardens the plant against excess salt and detoxification occurs due to the presence of ROS scavengers (8). Osmotic adjustment is achieved through accumulation of compatible osmolytes and osmoprotectants like proline, sugar, etc. (9). The genetic variability among the various genotypes can potentially contribute to traits like salinity sensitivity and salinity tolerance and it will vary in different plant growth stages. The production of salinity tolerant genotypes can increase the crop yield, increase the grain quality and increase consumption (10).

The present study is focussed on how different barnyard millet genotypes react to gradually increasing levels of salinity. The initial salt stress was imposed in barnyard millet by soaking of seeds in Sodium Chloride (NaCl) solution with a concentration of 50 mM NaCl, 100 mM NaCl, 150 mM NaCl and 200 mM NaCl. Seeds sown without soaking are used as the control. This is done to evaluate the salinity tolerance exhibited by different genotypes, at different concentrations of NaCl. The early growth characters like root length, shoot length, germination percentage, fresh weight, dry weight and vigour index were found to vary with the physiological and biochemical impacts caused by imposed levels of salinity.

Materials and Methods

The experiment was carried out in 2024, at the Genetics and Plant Breeding Laboratory, affiliated with Seed Science and Technology at the SRM College of Agricultural Sciences, Baburayanpettai, Tamil Nadu, India. One hundred genotypes of barnyard millet were obtained from the International Crop Research Institute for Semi-Arid Tropics (ICRISAT, Hyderabad). The genotypes are assessed for salt tolerance at early growth stages.

Salinity tolerance of each genotype was studied by treating the seeds with sodium chloride (NaCl). The NaCl treatment was applied across six treatments: T_0 (control, 0 mM NaCl), T_1 (hydro priming with distilled water) and T_2 to T_5 (50 mM NaCl, 100 mM NaCl, 150 mM NaCl and 200 mM NaCl, respectively). The Factorial Completely Randomized Design (FCRD) with four replicates are used for the analysis. The sand was sterilized in an Autoclave at 121 °C for 30-40 min. The sterilized sand is used to grow the seedlings and it was placed in plastic trays.

The initial stress is introduced to the genotypes by soaking seeds in distilled water and NaCl solutions for 3 hr. Hundred seeds per genotype are soaked for each treatment. The NaCl solutions were applied to the sanitized sand trays before sowing of the seed. The seeds are allowed to grow in the sand tray and observations are taken. The daily germination data was recorded to determine the characteristics of the seeds and how they responded to salt stress.

Germination (%)

The experiment was carried out in accordance with International Seed Testing Association (ISTA) guidelines (11). The germination data was recorded daily for each genotype. On the 14th day of emergence, the final counts were recorded and the percentage of germination was determined using the formula mentioned below.

$$\text{Germination (\%)} = \frac{\text{No. of seeds germinated}}{\text{Total no. of seeds sown}} \times 100$$

Root length (cm)

Ten healthy seedlings were selected from each replication for observing the root length, on the 14th day of emergence. The root length of the seedling was measured and it is denoted in centimeters (cm). The root length was measured starting from the surface to tip of the main root.

Shoot length (cm)

Ten randomly selected healthy seedlings were selected from each replication, on the 14th day of emergence and it is denoted in “cm”. The shoot length was measured from the leaf tip to the end of the shoot of seedling.

Fresh weight (mg 10 seedlings^{-1})

Ten healthy seedlings were selected from each replication, on the 14th day of emergence and it is denoted in “mg 10 seedlings^{-1}”. The seedlings were weighed immediately after removal from the sand tray and the fresh weight of roots and shoots can be calculated.

Dry weight (mg 10 seedlings^{-1})

The final root and shoot biomass were calculated by shade drying the ten uprooted healthy seedlings for 24 hr. After being dried in a hot air oven at 70 °C for 20 hr, the seedling was weighed using a digital weighing balance and it is expressed in “mg 10 seedlings^{-1}”.

Vigour index (VI)

Based on the previous studies (12), the values of the vigor index were calculated using the provided formula and the average values were shown as whole numbers. The total seedling length mentioned in the formula below is calculated by adding the root length and shoot length.

Vigour index = Germination percentage × Total seedling length (cm)

Statistical analysis

The data from each observation were analyzed using the standard errors from the replicates. The Factorial Completely Random Design (FCRD) was used for experimental set up. Duncan’s Multiple Range Test (DMRT) was used to compare the data, after the analysis of variance (ANOVA) was completed. Mean differences that had a *p*-value below 0.05 were considered significant. For the statistical analysis, SPSS version 16.0 was utilized (SPSS Inc. USA, Chicago).

Results and Discussion

Germination (%)

The sodium chloride treatment was given at different concentrations across all the genotypes and significantly alters the percentage of germination. The highest germination at 50 mM NaCl was recorded in G_{34} with 85 %, followed by G_{25} (83 %), G_{18} (82 %), G_{44} (81 %) and G_{43} (80 %). At 200 mM NaCl concentration, G_{34} (76 %) exhibited high germination percentage, followed by G_{25} (74 %), G_{18} (73 %), G_{44} (72 %) and G_{43} (71 %). It was seen that the control (T_0) showed lesser germination percentage than the hydro primed seeds (T_1). These results revealed the correlation between germination percentage and the concentration of NaCl, in the barnyard millet genotypes (Table 1).

Germination is a preliminary and important process in plant growth cycle, that is highly sensitive to environmental factors like temperature, moisture, light and oxygen (13). The percentage of germination is affected by various abiotic stresses like salinity,

Table 1. Effect of salinity stress on germination percentage of barnyard millet genotypes

Genotypes (G)	T0	T1	T2	T3	T4	T5
G_{1}	77 ± 0.08	81 ± 0.03	75 ± 1.12	69 ± 0.42	66 ± 0.49	60 ± 0.57
G_{2}	76 ± 0.80	78 ± 0.03	74 ± 1.01	63 ± 0.24	60 ± 0.29	56 ± 0.84
G_{3}	73 ± 0.47	76 ± 0.83	72 ± 0.24	64 ± 0.28	62 ± 0.99	57 ± 0.21
G_{4}	76 ± 0.98	79 ± 0.43	72 ± 0.78	70 ± 1.00	64 ± 0.85	59 ± 0.84
G_{5}	71 ± 0.51	73 ± 0.99	69 ± 0.28	68 ± 0.23	60 ± 0.47	54 ± 0.88
G_{6}	72 ± 1.15	75 ± 1.12	68 ± 0.79	69 ± 0.02	56 ± 0.34	53 ± 0.72
G_{7}	71 ± 1.09	76 ± 0.72	72 ± 0.66	66 ± 0.18	61 ± 0.64	55 ± 0.86
G_{8}	77 ± 0.86	78 ± 1.17	71 ± 1.11	67 ± 0.34	61 ± 0.56	54 ± 0.31
G_{9}	77 ± 0.55	80 ± 1.12	73 ± 0.75	70 ± 0.57	65 ± 0.55	63 ± 0.51
G_{10}	73 ± 0.32	79 ± 1.32	70 ± 1.10	69 ± 0.75	68 ± 0.02	64 ± 1.05
G_{11}	73 ± 0.94	79 ± 0.46	74 ± 1.21	68 ± 0.23	66 ± 0.74	63 ± 0.51
G_{12}	72 ± 0.69	81 ± 0.28	70 ± 1.02	68 ± 0.37	65 ± 0.62	63 ± 0.36
G_{13}	74 ± 1.21	82 ± 1.26	73 ± 0.65	71 ± 0.53	68 ± 0.69	65 ± 0.09
G_{14}	75 ± 1.17	78 ± 0.96	72 ± 0.42	66 ± 0.88	63 ± 0.54	57 ± 0.56
G_{15}	76 ± 0.52	77 ± 0.45	71 ± 0.24	63 ± 0.30	56 ± 0.27	51 ± 0.75
G_{16}	74 ± 1.08	81 ± 0.19	72 ± 1.08	69 ± 0.99	65 ± 0.73	57 ± 0.17
G_{17}	75 ± 0.26	79 ± 0.03	73 ± 1.12	70 ± 0.14	69 ± 0.42	58 ± 0.61
G_{18}	83 ± 0.85	89 ± 0.73	82 ± 0.61	78 ± 0.93	75 ± 0.33	73 ± 1.12
G_{19}	76 ± 0.13	79 ± 1.29	70 ± 0.26	60 ± 0.22	59 ± 0.04	55 ± 0.15
G_{20}	73 ± 0.30	81 ± 0.83	70 ± 0.21	66 ± 0.65	64 ± 0.94	62 ± 0.65
G_{21}	76 ± 0.18	78 ± 0.34	73 ± 0.67	64 ± 0.41	61 ± 0.58	59 ± 0.00
G_{22}	70 ± 0.55	73 ± 0.05	67 ± 0.48	71 ± 0.65	59 ± 0.80	55 ± 0.84
G_{23}	77 ± 0.26	82 ± 0.81	75 ± 1.05	70 ± 0.90	69 ± 1.06	62 ± 0.23
G_{24}	73 ± 1.09	75 ± 0.15	70 ± 0.10	62 ± 0.59	61 ± 0.37	51 ± 0.36
G_{25}	84 ± 0.74	89 ± 0.27	83 ± 0.71	78 ± 0.21	76 ± 1.22	74 ± 1.03
G_{26}	72 ± 0.44	80 ± 0.82	70 ± 0.50	66 ± 0.97	63 ± 0.88	62 ± 0.63
G_{27}	77 ± 1.00	79 ± 0.99	74 ± 0.25	72 ± 0.81	69 ± 0.40	62 ± 0.13
G_{28}	79 ± 0.73	84 ± 0.11	77 ± 0.29	74 ± 1.16	71 ± 0.12	69 ± 0.00
G_{29}	75 ± 0.41	81 ± 0.06	73 ± 0.35	70 ± 0.24	67 ± 0.75	64 ± 0.13
G_{30}	80 ± 0.38	85 ± 1.33	79 ± 0.40	75 ± 1.22	73 ± 0.60	70 ± 0.31
G_{31}	78 ± 1.17	83 ± 0.23	76 ± 0.96	72 ± 0.20	70 ± 0.95	67 ± 1.03
G_{32}	77 ± 0.65	79 ± 0.62	72 ± 0.86	70 ± 0.64	63 ± 0.56	55 ± 0.02
G_{33}	78 ± 0.82	84 ± 1.23	76 ± 0.28	73 ± 0.75	70 ± 0.36	68 ± 0.19
G_{34}	86 ± 0.91	90 ± 1.29	85 ± 0.06	79 ± 1.02	78 ± 0.32	76 ± 0.67
G_{35}	77 ± 1.13	81 ± 0.80	75 ± 0.23	70 ± 1.02	66 ± 0.63	59 ± 0.24
G_{36}	76 ± 1.06	79 ± 0.89	75 ± 1.12	70 ± 0.07	66 ± 0.22	64 ± 0.57
G_{37}	72 ± 0.05	79 ± 0.73	70 ± 0.69	67 ± 0.66	64 ± 0.72	60 ± 0.29
G_{38}	73 ± 0.94	79 ± 0.94	75 ± 0.41	71 ± 1.06	66 ± 1.06	58 ± 0.04
G_{39}	74 ± 0.98	81 ± 1.35	72 ± 0.42	69 ± 0.92	65 ± 0.66	62 ± 0.32
G_{40}	80 ± 1.22	85 ± 0.49	78 ± 0.85	75 ± 1.07	72 ± 0.47	70 ± 0.57
G_{41}	72 ± 0.73	78 ± 1.30	75 ± 0.94	68 ± 0.12	66 ± 0.27	62 ± 0.93
G_{42}	77 ± 1.05	78 ± 1.01	75 ± 0.03	69 ± 1.10	64 ± 0.59	60 ± 0.06
G_{43}	81 ± 0.69	86 ± 0.88	80 ± 1.14	76 ± 1.16	74 ± 0.20	71 ± 1.01
G_{44}	82 ± 0.67	88 ± 0.09	81 ± 1.10	77 ± 0.68	75 ± 0.05	72 ± 0.56
G_{45}	77 ± 0.37	78 ± 0.19	75 ± 1.10	67 ± 0.64	61 ± 0.95	55 ± 0.06
G_{46}	74 ± 0.86	76 ± 0.85	73 ± 1.02	67 ± 0.21	63 ± 0.26	56 ± 0.63
G_{47}	76 ± 0.41	81 ± 0.96	75 ± 0.31	71 ± 0.39	69 ± 0.28	59 ± 0.46
G_{48}	75 ± 0.89	81 ± 0.44	73 ± 1.14	71 ± 0.19	67 ± 0.14	61 ± 0.15
G_{49}	72 ± 0.07	77 ± 0.26	71 ± 1.16	68 ± 0.44	65 ± 0.82	52 ± 0.34
G_{50}	74 ± 1.01	75 ± 1.20	71 ± 1.06	66 ± 0.31	60 ± 1.00	54 ± 0.44

$\mathbf{G}_{51}$	72 ± 0.61	77 ± 0.21	69 ± 0.56	62 ± 0.51	58 ± 0.61	53 ± 0.04
$\mathbf{G}_{52}$	73 ± 1.07	80 ± 0.05	71 ± 0.00	69 ± 0.05	65 ± 0.93	60 ± 0.92
$\mathbf{G}_{53}$	76 ± 1.27	79 ± 0.59	74 ± 0.45	72 ± 0.17	68 ± 0.09	65 ± 1.00
$\mathbf{G}_{54}$	71 ± 0.41	76 ± 0.10	74 ± 0.15	63 ± 0.94	63 ± 0.94	55 ± 0.19
$\mathbf{G}_{55}$	73 ± 0.72	76 ± 0.34	71 ± 0.80	63 ± 0.77	60 ± 0.14	54 ± 0.31
$\mathbf{G}_{56}$	77 ± 0.37	79 ± 1.21	71 ± 0.05	68 ± 0.58	65 ± 0.46	60 ± 0.65
$\mathbf{G}_{57}$	74 ± 0.43	78 ± 0.32	71 ± 0.77	68 ± 0.53	65 ± 1.06	56 ± 0.48
$\mathbf{G}_{58}$	76 ± 0.00	77 ± 0.18	66 ± 0.81	63 ± 0.92	58 ± 0.06	56 ± 0.65
$\mathbf{G}_{59}$	76 ± 0.16	78 ± 1.01	72 ± 0.24	69 ± 0.21	65 ± 0.07	58 ± 0.51
$\mathbf{G}_{60}$	74 ± 0.91	79 ± 0.35	71 ± 0.77	68 ± 0.79	65 ± 0.29	63 ± 0.84
$\mathbf{G}_{61}$	74 ± 0.58	81 ± 1.02	72 ± 1.15	67 ± 0.66	64 ± 0.83	61 ± 0.35
$\mathbf{G}_{62}$	75 ± 1.05	78 ± 0.64	72 ± 0.42	70 ± 0.98	63 ± 0.02	60 ± 0.96
$\mathbf{G}_{63}$	72 ± 1.10	81 ± 0.11	70 ± 0.43	68 ± 0.99	66 ± 0.43	61 ± 0.98
$\mathbf{G}_{64}$	74 ± 0.58	77 ± 0.31	67 ± 0.96	64 ± 0.98	60 ± 0.63	54 ± 0.26
$\mathbf{G}_{65}$	74 ± 0.38	79 ± 0.05	75 ± 0.51	68 ± 0.12	65 ± 0.38	64 ± 0.87
$\mathbf{G}_{66}$	76 ± 0.85	80 ± 1.28	71 ± 0.87	67 ± 0.43	60 ± 0.88	58 ± 0.20
$\mathbf{G}_{67}$	74 ± 0.10	79 ± 0.91	74 ± 0.58	70 ± 0.62	69 ± 0.12	61 ± 0.48
$\mathbf{G}_{68}$	72 ± 1.13	78 ± 0.29	71 ± 1.11	68 ± 0.30	63 ± 0.64	56 ± 0.65
$\mathbf{G}_{69}$	76 ± 0.28	79 ± 0.51	75 ± 0.89	69 ± 1.03	66 ± 0.72	61 ± 0.56
$\mathbf{G}_{70}$	75 ± 1.12	80 ± 0.95	72 ± 0.66	71 ± 0.72	69 ± 1.08	65 ± 0.20
$\mathbf{G}_{71}$	72 ± 0.24	75 ± 0.46	69 ± 1.15	69 ± 0.12	61 ± 0.35	54 ± 0.39
$\mathbf{G}_{72}$	75 ± 0.33	77 ± 1.28	70 ± 0.43	64 ± 0.54	62 ± 0.30	55 ± 0.86
$\mathbf{G}_{73}$	77 ± 0.94	79 ± 0.62	73 ± 1.17	68 ± 0.16	64 ± 0.02	61 ± 0.93
$\mathbf{G}_{74}$	76 ± 0.47	80 ± 0.16	71 ± 0.80	69 ± 0.87	64 ± 0.72	60 ± 0.16
$\mathbf{G}_{75}$	77 ± 0.24	80 ± 0.54	74 ± 0.18	71 ± 0.43	68 ± 0.05	63 ± 0.19
$\mathbf{G}_{76}$	75 ± 0.28	79 ± 0.16	70 ± 0.71	64 ± 0.98	62 ± 0.59	57 ± 0.17
$\mathbf{G}_{77}$	73 ± 0.50	82 ± 1.17	70 ± 0.67	68 ± 0.90	65 ± 0.33	61 ± 0.46
$\mathbf{G}_{78}$	75 ± 0.26	79 ± 0.51	69 ± 0.45	67 ± 0.52	64 ± 0.65	62 ± 0.63
$\mathbf{G}_{79}$	73 ± 0.89	78 ± 0.58	72 ± 0.93	63 ± 0.30	60 ± 0.88	54 ± 0.31
$\mathbf{G}_{80}$	73 ± 0.20	79 ± 0.30	73 ± 1.22	69 ± 1.01	67 ± 0.80	60 ± 0.82
$\mathbf{G}_{81}$	77 ± 1.00	81 ± 0.80	74 ± 0.45	70 ± 0.86	64 ± 0.85	58 ± 0.59
$\mathbf{G}_{82}$	72 ± 0.64	82 ± 0.61	71 ± 0.48	70 ± 0.81	67 ± 1.00	61 ± 0.77
$\mathbf{G}_{83}$	74 ± 1.23	80 ± 0.05	73 ± 0.77	70 ± 0.10	68 ± 0.00	59 ± 0.42
$\mathbf{G}_{84}$	77 ± 0.68	80 ± 0.35	75 ± 0.87	66 ± 0.13	64 ± 0.26	60 ± 0.04
$\mathbf{G}_{85}$	72 ± 0.61	80 ± 1.09	70 ± 1.14	68 ± 0.72	62 ± 0.86	55 ± 0.43
$\mathbf{G}_{86}$	76 ± 1.03	79 ± 1.16	72 ± 0.91	66 ± 0.74	62 ± 0.32	59 ± 0.40
$\mathbf{G}_{87}$	73 ± 0.32	77 ± 0.37	68 ± 0.02	66 ± 0.72	61 ± 0.44	58 ± 0.43
$\mathbf{G}_{88}$	76 ± 0.31	80 ± 0.41	74 ± 1.18	69 ± 0.80	68 ± 1.04	65 ± 0.33
$\mathbf{G}_{89}$	73 ± 0.22	81 ± 0.06	72 ± 0.83	68 ± 0.19	64 ± 0.54	60 ± 0.55
$\mathbf{G}_{90}$	75 ± 0.66	78 ± 0.11	73 ± 0.47	69 ± 1.03	62 ± 0.95	57 ± 0.27
$\mathbf{G}_{91}$	76 ± 0.44	78 ± 0.16	71 ± 0.22	61 ± 0.91	60 ± 0.35	57 ± 0.23
$\mathbf{G}_{92}$	71 ± 0.70	78 ± 0.42	74 ± 1.01	65 ± 0.33	62 ± 0.95	59 ± 0.00
$\mathbf{G}_{93}$	73 ± 1.17	82 ± 0.78	72 ± 0.66	69 ± 0.77	66 ± 0.20	63 ± 0.39
$\mathbf{G}_{94}$	74 ± 1.13	76 ± 0.67	73 ± 0.47	69 ± 0.42	60 ± 0.12	53 ± 0.38
$\mathbf{G}_{95}$	72 ± 0.15	75 ± 0.97	71 ± 0.10	64 ± 1.05	62 ± 0.53	50 ± 0.77
$\mathbf{G}_{96}$	77 ± 1.28	80 ± 1.12	72 ± 0.02	70 ± 0.10	67 ± 0.41	64 ± 0.26
$\mathbf{G}_{97}$	77 ± 0.52	79 ± 0.24	73 ± 0.62	71 ± 0.89	65 ± 0.33	60 ± 0.51
$\mathbf{G}_{98}$	72 ± 0.39	79 ± 1.26	73 ± 1.19	72 ± 0.07	67 ± 1.12	58 ± 0.39
$\mathbf{G}_{99}$	75 ± 1.25	80 ± 0.71	72 ± 0.71	70 ± 0.21	66 ± 0.67	62 ± 1.03
$\mathbf{G}_{100}$	76 ± 0.59	80 ± 1.28	70 ± 0.17	67 ± 1.03	64 ± 0.41	62 ± 0.44

Seed germination (Mean ± SE, *n* = 4) of different treatments (T): (T_0 – Control, T_1 – Hydropriming, T_2 – 50 mM of NaCl, T_3 – 100 mM of NaCl, T_4 – 150 mM of NaCl, T_5 – 200 mM of NaCl). The analysis of variance was carried out and compared by Duncan's multiple range test (DMRT) at 5 % significance level.

drought, etc. (14). The imposition of salinity stress consequently led to reduction in the number of seeds that germinate and delays in germination (15). Salt uptake disrupts the water absorption by the seeds and it ultimately leads to decrease in water potential and resulting in osmotic stress. Excess of sodium and chloride ions can affect biochemical processes like enzymatic reactions of the seed, thus altering the germination percentage. The percentage of germination varied with level of salinity exposure. The data proves that germination percentage varies with different NaCl concentrations and it may be due to the osmotic stress and ionic toxicity created (16).

Root length (cm)

The analysis of seedling root length revealed that, length of the root from the tip of the primary root was affected by salinity. With increase in salt concentration, root length was reduced significantly. The genotype G_{34} (8.28) exhibited maximum root length and it was followed by G_{25} (8.20), G_{18} (8.12), G_{44} (8.02) and G_{43} (7.06) at 50 mM NaCl. Subsequently at 200 mM NaCl, the genotype G_{34} recorded highest root length, followed by G_{25}, G_{18}, G_{44} and G_{43}. The above results show that root length reduces according to the increasing NaCl concentration (Fig. 1).

The roots play a pivotal role in water and nutrient absorption, anchoring of plants and food storage (17). They respond negatively to oxygen deprivation and conditions like excess salt and water deficit. Due to this, the spreading area of the root is more influenced by excessive salt uptake (18). Hydropriming treatment facilitated imbibition of water and does not alter the K^+ uptake in plants (19). So, the root growth will also be highest in this treatment. But the Na^+ and Cl^- uptake increased and K^+ uptake reduced in rest of the treatments. The reduction in root growth consequently leads to reduction in parameters like shoot growth, seedling biomass and vigour index (20). The findings suggest that roots are highly susceptible to the salt stress and can impact the overall growth of the plant.

Shoot length (cm)

The shoot length of the seedling was computed on the 14th day of emergence and it was found to be impacted negatively due to the varied concentration of sodium chloride ranging from 50 mM NaCl to 200 mM NaCl. The genotypes G_{34} showed notable shoot length values at 50 mM NaCl, 100 mM NaCl, 150 mM NaCl and 200 mM NaCl with 10.42 cm, 8.96 cm, 8.59 cm and 7.50 cm shoot length respectively. At the maximum concentration of 200 mM NaCl, the result demonstrates shoot length of genotype G_{34}followed by G_{25}, G_{18}, G_{44} and G_{43}. As depicted, the root and shoot length are highly influenced by the salinity levels (Fig. 2).

The shoot length was much affected than the root length, especially in barnyard millet and the reduced shoot length in millets was associated with limited nutrient absorption due to external stresses. But some genotypes might exhibit greater tolerance and has ability to maintain robust shoot growth even under stress conditions (21). The salinity reduces shoot growth by affecting internode growth and speeding up of leaf abscission, due to ethylene and abscisic acid production (22). Leaf initiation and leaf expansion was declined with increasing levels of NaCl. This reveals the nexus between root and shoot length of barnyard millet under stress. The observation shows that shoot length was also impacted due to the ionic toxicity and decreased water potential.

Fresh weight (mg 10 seedlings^{-1})

The application of salinity significantly altered the fresh weight of the uprooted seedlings at different NaCl concentration. When the seedlings are subjected to 50 mM NaCl, the genotype G_{34} (1400.53) recorded the highest fresh weight and it was followed by G_{25} (1387.22), G_{18} (1366.79), G_{44} (1235.43) and G_{43} (1191.49). At 200 mM NaCl, the genotype G_{34} (707.87) showed greater results, succeeded by G_{25}, G_{18}, G_{44} and G_{43}. This was observed in the maximum NaCl concentration. The higher the NaCl concentration, the lower the fresh weight values across every genotype (Fig. 3).

Studies have shown that fresh weight of barnyard millet is significantly impacted by the salt stress. The highest sensitivity was seen in G_{14},which showed 57 % deviation from the genotype G_{34} at the same concentration. It is due to inhibition of water uptake, which is essential for the cell growth and also the cell expansion was affected, because of the level of osmotic stress that was created by salinity (23). The limited availability of nutrients and water decreases both root and shoot fresh weight (24). The significant reduction of root length and shoot length due to salinity, contributed to reduction of root biomass and shoot biomass (25). It provides a valuable insight about how the fresh biomass is altered according to the level of sensitivity of the genotype to salinity stress.

Dry weight (mg 10 seedlings^{-1})

Higher variation in values of dry weight was observed among all the treatments in all the genotypes, as response to salinity. The genotype G_{34}(230.59), followed by G_{25} (226.29), G_{18} (205.13), G_{44} (195.31) and G_{43} (192.67) has higher dry weights comparatively, even at a maximum concentration of 200 mM NaCl. The above result demonstrates that the dry weight production of Barnyard millet genotypes negatively varied according to the levels of NaCl concentration (Fig. 4).

The dry biomass production significantly varies with the fresh weight of the genotypes (26). At maximum concentration of NaCl, the genotype G_5 showed maximum sensitivity, which accounted to 58 % of dry weight of the genotype G_{34}. The plant tissues showed reduced carbon gain in root and shoot, due to unavailability of oxygen (27). This will lead to lesser accumulation of dry matter and therefore the dry weight is much reduced. The ionic effects of Na^+ and Cl^- along with osmotic imbalance, have affected the root and shoot biomass (28). The factors that impact the root and shoot length will directly impact the dry weight of root and shoot.

Vigour index (VI)

From the observations, it is evident that NaCl induced adverse effect on vigour index of barnyard millet. The effects were significantly negative across all the treatments with wider changes in the values. Results show that the genotype G_{34} (1696), in the control group (T_0) was more than the vigour index of the same genotype G_{34} (1094) at 200 mM NaCl. At the concentration of 200 mM NaCl, the genotypes G_{25} (1046), G_{18} (1018), G_{44} (994) and G_{43} (949) showed maximum vigour index values, after the G_{34}. It is found that the other genotypes also followed the pattern of reduced seedling vigour index with respect to the increased NaCl concentration (Table 2).

Vigour index is the overall representation of how altered salt levels would significantly impact the growth parameters in barnyard millet (29). The genotype G_{95} showed the maximum sensitivity, that represents only 37 % of vigour index of the best performing genotype G_{34}. The reported sensitivity is due to inhibition of cell

Table 2. Effect of salinity stress on vigour index of barnyard millet genotypes

Genotypes (G)	T0	T1	T2	T3	T4	T5
G_1	1030 ± 8.06	1349 ± 0.92	942 ± 7.69	861 ± 7.91	696 ± 4.97	497 ± 3.55
G_2	1070 ± 1.46	1381 ± 11.28	934 ± 5.72	757 ± 2.32	724 ± 9.61	566 ± 3.27
G_3	994 ± 14.20	1231 ± 10.89	886 ± 5.43	723 ± 2.95	666 ± 4.76	536 ± 1.46
G_4	1018±10.74	1161 ± 6.71	896 ± 4.88	855 ± 6.11	709 ± 8.20	485 ± 3.13
G_5	941 ± 8.32	1129 ± 0.38	893 ± 2.73	807 ± 9.33	614 ± 0.63	506 ± 8.44
G_6	978 ± 10.31	1101 ± 7.49	871 ± 3.85	817 ± 4.45	578 ± 8.65	452 ± 5.07
G_7	964 ± 16.07	1157 ± 5.51	909 ± 1.24	733 ± 7.73	630 ± 5.36	472 ± 5.94
G_8	1061 ± 1.08	1247 ± 18.24	912 ± 10.55	820 ± 8.65	702 ± 5.73	467 ± 5.08
G_9	1016±10.37	1449 ± 15.28	898 ± 12.53	806 ± 2.74	735 ± 7.75	527 ± 1.97
G_{10}	961 ± 15.37	1274 ± 12.14	864 ± 9.99	798 ± 0.54	711 ± 7.26	525 ± 0.71
G_{11}	963 ± 8.52	1299 ± 16.35	952 ± 15.22	853 ± 12.77	655 ± 10.92	554 ± 4.71
G_{12}	976 ± 6.31	1251 ± 6.81	881 ± 0.60	765 ± 2.34	640 ± 2.18	559 ± 7.42
G_{13}	1022±14.26	1338 ± 13.20	991 ± 2.70	885 ± 7.23	797 ± 8.95	670 ± 7.98
G_{14}	1071±15.30	1327 ± 18.51	934 ± 6.04	814 ± 1.38	711 ± 10.16	634 ± 4.31
G_{15}	1031±10.17	1413 ± 21.63	879 ± 12.56	773 ± 8.15	571 ± 1.55	501 ± 1.36
G_{16}	1054 ± 8.96	1345 ± 9.15	935 ± 7.95	861 ± 4.69	798 ± 10.86	568 ± 0.39
G_{17}	1045 ± 7.11	1364 ± 8.82	947 ± 13.85	869 ± 11.53	769 ± 8.37	630 ± 1.50
G_{18}	1579±20.41	2047 ± 13.93	1501 ± 8.17	1292±13.19	1162 ± 0.40	1018 ± 9.35
G_{19}	1033 ± 9.49	1322 ± 18.89	832 ± 13.30	657 ± 10.06	655 ± 4.46	539 ± 1.65
G_{20}	999 ± 1.70	1183 ± 14.49	876 ± 14.31	808 ± 1.10	736 ± 8.26	588 ± 3.00
G_{21}	965 ± 14.77	1308 ± 9.79	885 ± 4.22	666 ± 0.68	607 ± 9.09	549 ± 5.60
G_{22}	883 ± 6.91	1209 ± 5.35	791 ± 7.80	795 ± 12.44	550 ± 0.00	483 ± 5.09
G_{23}	1014 ± 3.79	1399 ± 11.90	996 ± 13.21	844 ± 2.01	776 ± 6.60	668 ± 7.95
G_{24}	1022±10.43	1332 ± 11.78	936 ± 9.55	765 ± 5.99	701 ± 11.45	494 ± 6.22
G_{25}	1622±26.49	2071 ± 22.55	1539 ±14.14	1308 ± 16.91	1186±17.35	1046 ± 2.85
G_{26}	1021 ± 1.04	1262 ± 13.74	885 ± 5.72	806 ± 10.69	704 ± 11.26	598 ± 1.22
G_{27}	1039 ± 6.36	1230 ± 7.11	987 ± 0.34	914 ± 12.13	793 ± 9.17	529 ± 7.38
G_{28}	1261 ± 5.15	1693 ± 20.16	1207 ± 0.82	1074 ± 6.58	993 ± 6.76	845 ± 4.02
G_{29}	1074 ± 8.04	1358 ± 12.47	997 ± 7.80	872 ± 12.46	782 ± 9.05	684 ± 7.91
G_{30}	1414 ±12.51	1836 ± 18.74	1355 ± 18.44	1169 ± 14.32	1072±17.87	909 ± 0.62
G_{31}	1186 ± 9.68	1577 ± 6.44	1142 ± 7.38	1019 ± 11.79	939 ± 7.67	791 ± 1.61
G_{32}	1036 ± 1.06	1345 ± 17.39	985 ± 3.02	865 ± 7.95	726 ± 0.74	568 ± 1.35
G_{33}	1197 ±17.51	1608 ± 7.66	1151 ± 4.31	1037 ± 5.64	959 ± 15.33	813 ± 8.57
G_{34}	1696 ±14.42	2113 ± 2.88	1590 ± 20.01	1336 ± 9.54	1236 ± 5.05	1094 ± 17.86
G_{35}	1015 ± 1.04	1308 ± 12.46	948 ± 12.90	840 ± 9.14	736 ± 8.26	547 ± 4.84
G_{36}	1039 ±15.20	1358 ± 19.87	968 ± 4.61	776 ± 3.43	676 ± 1.38	579 ± 6.30
G_{37}	963 ± 13.76	1401 ± 11.44	914 ± 15.24	864 ± 1.18	730 ± 0.75	633 ± 9.04
G_{38}	1029 ±15.75	1283 ± 6.11	916 ± 14.96	809 ± 0.28	777 ± 10.31	560 ± 2.29
G_{39}	1032 ± 9.83	1361 ± 15.28	962 ± 7.53	891 ± 13.94	694 ± 3.07	555 ± 4.34
G_{40}	1356 ±15.68	1770 ± 23.48	1289 ± 6.14	1127 ± 4.98	1033 ±11.95	879 ± 0.90
G_{41}	1034 ±17.24	1242 ± 10.99	1036 ± 12.69	857 ± 8.75	801 ± 11.99	575 ± 2.74
G_{42}	985 ± 3.02	1215 ± 2.07	920 ± 13.77	799 ± 1.36	744 ± 4.05	638 ± 7.38
G_{43}	1452 ±13.34	1879 ± 7.67	1388 ± 12.28	1197 ± 15.88	1096 ± 4.85	949 ± 14.21
G_{44}	1513 ± 1.54	1970 ± 30.83	1443 ± 20.62	1244 ± 11.85	1154 ±14.92	994 ± 8.12
G_{45}	986 ± 7.72	1334 ± 22.24	908 ± 5.56	731 ± 2.24	654 ± 4.67	528 ± 8.80
G_{46}	1065 ±13.41	1349 ± 13.77	980 ± 3.67	815 ± 0.83	666 ± 1.59	437 ± 1.04
G_{47}	1059 ± 6.49	1329 ± 15.82	976 ± 2.66	912 ± 4.34	767 ± 8.87	601 ± 8.59
G_{48}	1013 ±13.44	1375 ± 2.81	912 ± 7.45	861 ± 2.05	762 ± 4.67	551 ± 5.81
G_{49}	977 ± 6.98	1166 ± 13.88	885 ± 12.34	808 ± 6.87	693 ± 9.19	502 ± 1.54
G_{50}	1012 ± 8.26	1307 ± 20.01	860 ± 4.68	688 ± 10.53	617 ± 8.19	490 ± 1.83

$\mathbf{G}_{51}$	961 ± 8.17	1322 ± 17.09	890 ± 13.02	728 ± 1.24	578 ± 5.70	479 ± 0.98
$\mathbf{G}_{52}$	948 ± 4.19	1375 ± 5.15	847 ± 12.68	737 ± 5.01	687 ± 0.70	550 ± 1.31
$\mathbf{G}_{53}$	1094 ±16.75	1386 ± 13.20	999 ± 15.63	940 ± 1.60	811 ± 10.21	678 ± 2.08
$\mathbf{G}_{54}$	975 ± 4.64	1247 ± 18.24	1002 ± 16.36	862 ± 11.14	773 ± 10.26	561 ± 8.97
$\mathbf{G}_{55}$	1075 ± 5.49	1262 ± 9.02	944 ± 9.96	809 ± 2.48	746 ± 8.63	568 ± 3.29
$\mathbf{G}_{56}$	1007 ±16.44	1195 ± 8.13	868 ± 4.43	782 ± 2.93	690 ± 0.47	582 ± 4.75
$\mathbf{G}_{57}$	976 ± 1.66	1221 ± 5.40	871 ± 1.78	787 ± 10.17	741 ± 5.29	514 ± 8.22
$\mathbf{G}_{58}$	1052 ± 6.80	1244 ± 11.85	918 ± 8.43	862 ± 4.11	709 ± 2.89	514 ± 5.60
$\mathbf{G}_{59}$	1002 ± 4.09	1362 ± 11.58	912 ± 9.00	822 ± 1.96	749 ± 2.29	639 ± 3.91
$\mathbf{G}_{60}$	1013 ±14.47	1308 ± 17.80	941 ± 13.77	880 ± 5.99	690 ± 9.39	548 ± 8.58
$\mathbf{G}_{61}$	1088 ± 5.55	1331 ± 10.87	1003 ± 12.28	882 ± 2.40	770 ± 3.14	611 ± 2.29
$\mathbf{G}_{62}$	997 ± 11.19	1250 ± 16.16	894 ± 6.69	799 ± 3.53	686 ± 3.03	544 ± 2.41
$\mathbf{G}_{63}$	998 ± 11.88	1345 ± 10.07	942 ± 7.69	853 ± 12.48	745 ± 6.59	631 ± 8.80
$\mathbf{G}_{64}$	1012 ±10.33	1255 ± 13.66	876 ± 10.13	788 ± 6.43	615 ± 5.44	429 ± 2.19
$\mathbf{G}_{65}$	1082 ± 9.94	1327 ± 0.45	983 ± 10.70	858 ± 5.84	818 ± 1.67	563 ± 7.47
$\mathbf{G}_{66}$	1015 ± 5.18	1475 ± 0.50	859 ± 9.06	721 ± 12.02	607 ± 2.89	481 ± 1.64
$\mathbf{G}_{67}$	1023 ±10.09	1203 ± 17.60	943 ± 11.23	851 ± 6.08	776 ± 7.39	555 ± 6.23
$\mathbf{G}_{68}$	1038 ± 2.47	1267 ± 11.21	906 ± 2.16	840 ± 4.86	760 ± 10.34	590 ± 0.40
$\mathbf{G}_{69}$	1000 ± 0.68	1360 ± 11.57	954 ± 12.98	771 ± 4.20	708 ± 11.80	537 ± 5.85
$\mathbf{G}_{70}$	1020 ± 3.82	1295 ± 3.08	878 ± 7.17	824 ± 4.49	741 ± 0.50	601 ± 0.82
$\mathbf{G}_{71}$	1031 ± 4.21	1223 ± 12.48	849 ± 2.89	828 ± 9.30	688 ± 0.23	571 ± 6.02
$\mathbf{G}_{72}$	1048 ±12.48	1152 ± 12.54	915 ± 14.63	758 ± 0.26	732 ± 11.21	538 ± 4.76
$\mathbf{G}_{73}$	1103 ±13.88	1352 ± 19.78	1002 ± 10.57	897 ± 6.10	719 ± 4.65	608 ± 4.76
$\mathbf{G}_{74}$	1004 ± 2.73	1255 ± 16.22	854 ± 6.39	785 ± 4.81	751 ± 5.11	568 ± 5.99
$\mathbf{G}_{75}$	1074 ± 7.31	1382 ± 6.58	944 ± 9.63	836 ± 10.24	741 ± 7.06	521 ± 7.27
$\mathbf{G}_{76}$	1090 ±10.01	1405 ± 1.43	897 ± 9.77	747 ± 2.54	670 ± 7.98	506 ± 0.00
$\mathbf{G}_{77}$	1026 ± 8.73	1453 ± 6.92	875 ± 2.38	798 ± 8.42	720 ± 9.31	651 ± 10.19
$\mathbf{G}_{78}$	959 ± 7.83	1360 ± 9.72	873 ± 8.32	754 ± 2.57	758 ± 11.09	487 ± 3.48
$\mathbf{G}_{79}$	994 ± 2.71	1306 ± 10.22	899 ± 1.84	764 ± 9.10	619 ± 4.21	505 ± 7.90
$\mathbf{G}_{80}$	1077 ±17.95	1243 ± 6.34	962 ± 1.96	876 ± 3.28	840 ± 3.14	575 ± 0.78
$\mathbf{G}_{81}$	1031 ± 9.12	1186 ± 7.26	936 ± 0.64	865 ± 9.42	697 ± 5.93	531 ± 3.07
$\mathbf{G}_{82}$	1005 ± 6.15	1353 ± 16.11	889 ± 14.21	861 ± 5.86	818 ± 1.11	664 ± 10.17
$\mathbf{G}_{83}$	1032 ±15.80	1357 ± 12.93	968 ± 7.25	819 ± 4.74	703 ± 2.63	483 ± 1.31
$\mathbf{G}_{84}$	1023 ± 4.18	1338 ± 8.65	863 ± 6.46	702 ± 6.21	626 ± 8.73	532 ± 5.25
$\mathbf{G}_{85}$	996 ± 0.34	1342 ± 15.07	928 ± 10.73	857 ± 9.04	755 ± 3.85	558 ± 1.52
$\mathbf{G}_{86}$	1034 ± 1.06	1354 ± 21.65	885 ± 10.84	765 ± 9.11	709 ± 3.38	483 ± 7.56
$\mathbf{G}_{87}$	918 ± 6.87	1346 ± 9.62	870 ± 7.99	779 ± 12.46	647 ± 10.13	560 ± 2.29
$\mathbf{G}_{88}$	957 ± 4.23	1398 ± 13.32	833 ± 12.47	750 ± 8.93	709 ± 2.65	519 ± 3.35
$\mathbf{G}_{89}$	1020 ±17.00	1396 ± 5.70	876 ± 13.11	795 ± 2.70	716 ± 9.99	575 ± 4.11
$\mathbf{G}_{90}$	990 ± 0.00	1273 ± 12.56	941 ± 5.12	796 ± 4.60	631 ± 6.44	524 ± 7.13
$\mathbf{G}_{91}$	1043 ± 5.32	1321 ± 17.08	921 ± 2.82	747 ± 9.15	632 ± 1.72	528 ± 5.75
$\mathbf{G}_{92}$	946 ± 13.84	1384 ± 18.36	1013 ± 16.20	849 ± 5.49	781 ± 1.16	564 ± 7.48
$\mathbf{G}_{93}$	1015 ±14.16	1226 ± 1.25	933 ± 0.32	872 ± 10.68	764 ± 13.35	545 ± 8.16
$\mathbf{G}_{94}$	978 ± 2.00	1237 ± 19.36	972 ± 15.87	815 ± 4.44	712 ± 11.09	418 ± 5.26
$\mathbf{G}_{95}$	915 ± 13.70	1398 ± 23.30	870 ± 14.21	707 ± 8.42	626 ± 0.48	412 ± 1.12
$\mathbf{G}_{96}$	1070 ± 3.64	1345 ± 8.24	995 ± 11.85	890 ± 1.82	775 ± 2.12	670 ± 6.38
$\mathbf{G}_{97}$	1157 ±15.74	1141 ± 14.36	1020 ± 7.29	920 ± 11.58	800 ± 6.57	656 ± 8.03
$\mathbf{G}_{98}$	968 ± 14.16	1237 ± 19.36	957 ± 0.00	870 ± 3.26	730 ± 10.95	510 ± 0.35
$\mathbf{G}_{99}$	1030 ± 1.05	1394 ± 17.07	912 ± 13.34	828 ± 1.69	702 ± 9.30	532 ± 3.62
$\mathbf{G}_{100}$	983 ± 7.02	1249 ± 3.40	909 ± 8.97	745 ± 7.86	652 ± 7.60	588 ± 9.60

Vigour index (Mean ± SE, *n* = 4) of different treatments (T): (T_0 – Control, T_1 – Hydropriming, T_2 – 50 mM of NaCl, T_3 – 100 mM of NaCl, T_4 – 150 mM of NaCl, T_5 – 200 mM of NaCl). The analysis of variance was carried out and compared by Duncan's multiple range test (DMRT) at 5 % significance level.

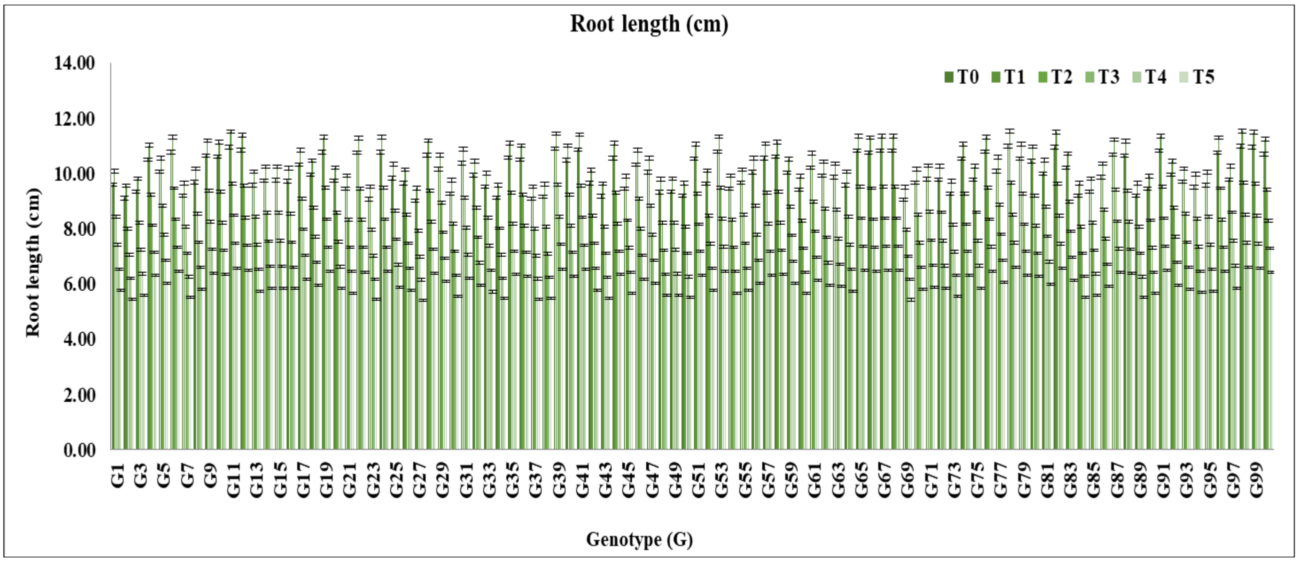

Fig. 1. Effect of salinity stress on root length (cm) of barnyard millet genotypes. Root length (Mean ± SE, *n* = 4) of different treatments (T): (T_0 – Control, T_1 – Hydropriming, T_2 – 50 mM of NaCl, T_3 – 100 mM of NaCl, T_4 – 150 mM of NaCl, T_5 – 200 mM of NaCl). The analysis of variance was carried out and compared by Duncan's multiple range test (DMRT) at 5 % significance level.

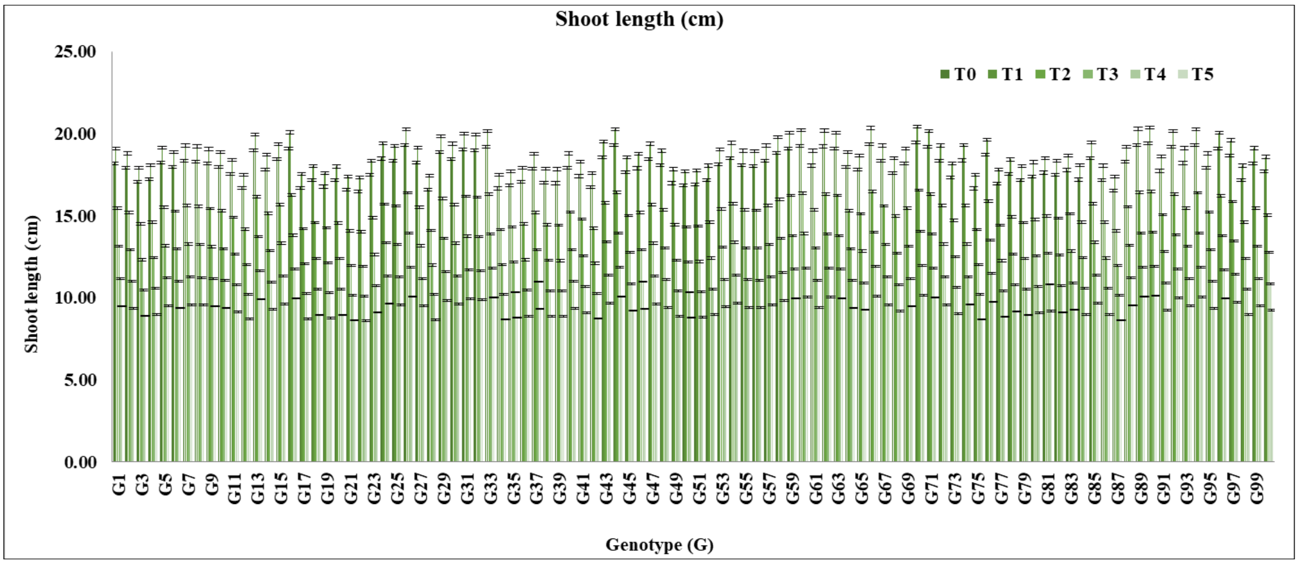

Fig. 2. Effect of salinity stress on shoot length (cm) of barnyard millet genotypes. Shoot length (Mean ± SE, n = 4) of different treatments (T): (T_0 – Control, T_1 – Hydropriming, T_2 – 50 mM of NaCl, T_3 – 100 mM of NaCl, T_4 – 150 mM of NaCl, T_5 – 200 mM of NaCl). The analysis of variance was carried out and compared by Duncan's multiple range test (DMRT) at 5 % significance level.

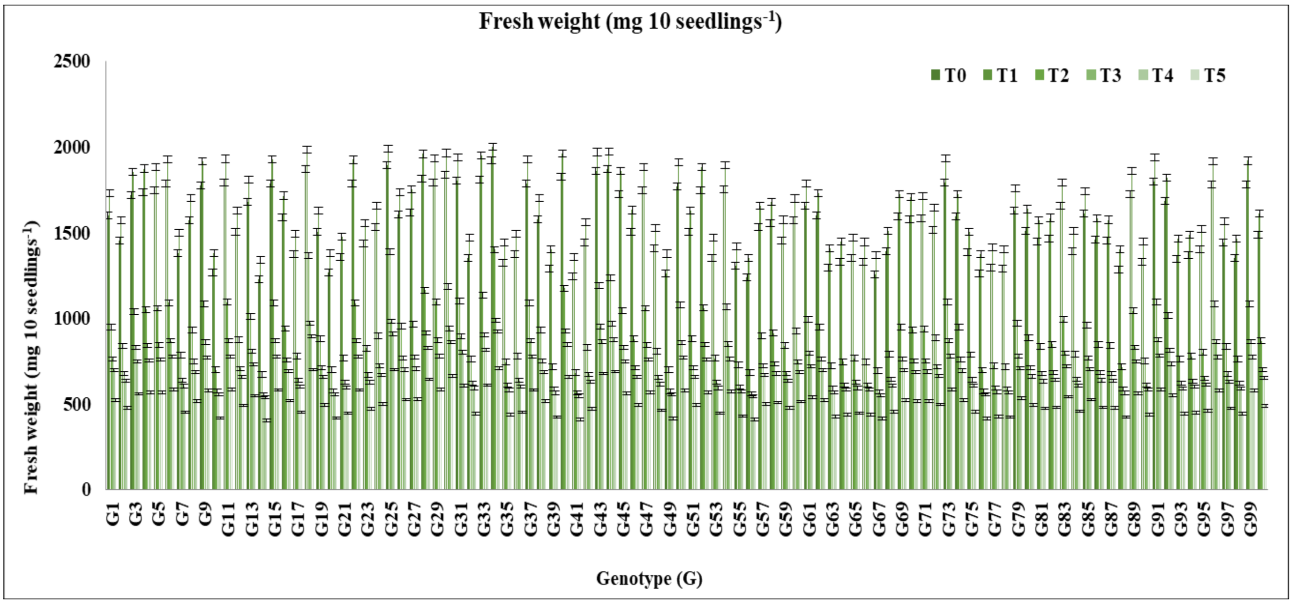

Fig. 3. Effect of salinity stress on fresh weight (mg 10 seedlings^{-1}) of barnyard millet genotypes. Fresh weight (Mean ± SE, *n* = 4) of different treatments (T): (T_0 – Control, T_1 – Hydropriming, T_2 – 50 mM of NaCl, T_3 – 100 mM of NaCl, T_4 – 150 mM of NaCl, T_5 – 200 mM of NaCl). The analysis of variance was carried out and compared by Duncan's multiple range test (DMRT) at 5 % significance level.

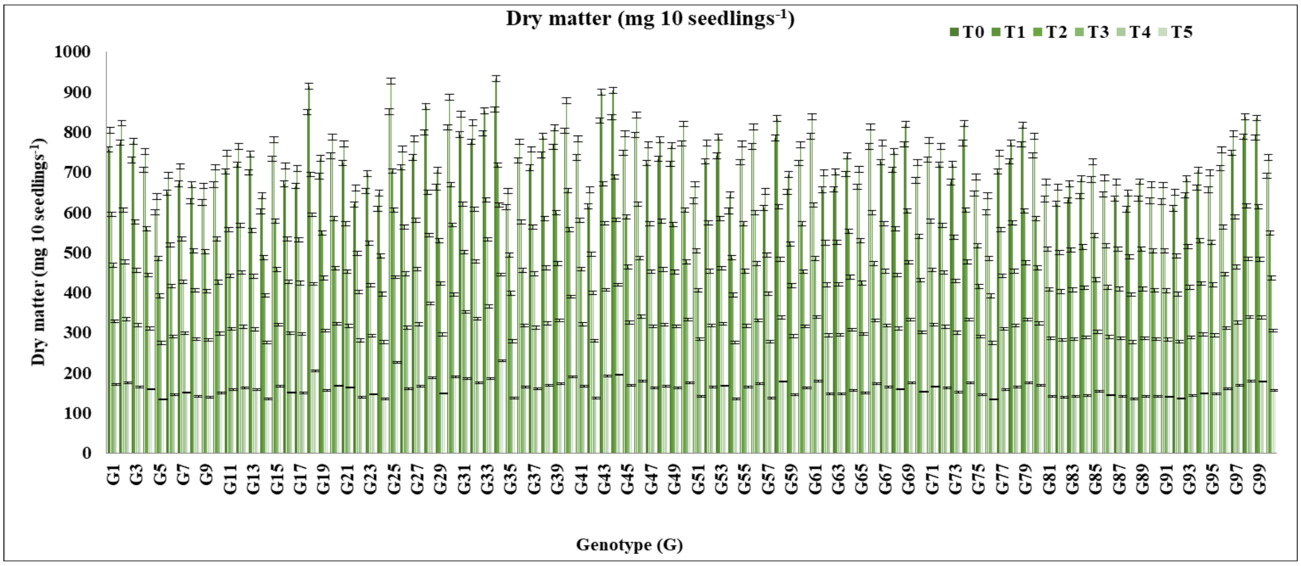

Fig. 4. Effect of salinity stress on dry weight (mg 10 seedlings^{-1}) of Barnyard millet genotypes. Dry matter production (Mean ± SE, n = 4) of different treatments (T): (T$_0$ – Control, T$_1$ – Hydropriming, T$_2$ – 50 mM of NaCl, T$_3$ – 100 mM of NaCl, T$_4$ – 150 mM of NaCl, T$_5$ – 200 mM of NaCl). The analysis of variance was carried out and compared by Duncan's multiple range test (DMRT) at 5 % significance level.

growth, that ultimately led to reduced mobilization of seed nutrient reserves (30). The enzymatic activities are impacted due to Na$^+$ and Cl$^-$ uptake and decline in K$^+$ uptake and this would create ionic imbalances, from the stage of germination till the stage of field establishment (31). The higher the salt tolerance, higher will be the vigour index value of the crop (32-34). The above findings would facilitate in identifying salt-tolerant and salt-sensitive genotypes.

Conclusion

This research encompasses treatment of hundred barnyard millet genotypes to various concentrations of NaCl. This was done to identify the genotypes that are tolerant to salinity stress at 0-200 mM NaCl. The factors like osmotic balance and genetic variations would contribute to the expression of salinity tolerance. Germination percentage, root length, shoot length, fresh weight, dry weight and vigour index were found to be significantly impacted by imposed salinity. The genotypes G$_{34}$ (IEc 688), G$_{25}$ (IEc 675), G$_{18}$(IEc 154), G$_{44}$(IEc 360) and G$_{43}$(IEc 356) have expressed resilience towards the salinity stress. The future research can focus on identifying the genes that play a role in osmotic adjustment and scavenging of reactive oxygen species, which will enable the breeder to create more salt-tolerant varieties and this breeding programme would increase the crop resilience towards changing climate.

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Authors' contributions

VR, TA and SS performed the experiments and statistically analysed results. VN, VR, JM and GS analysed data. SS, VR and TK wrote the draft of the manuscript. VN and JM conducted the critical revision of the manuscript. VN, JM, TK, GS and VR worked out the concept and design, supervised and funded the experiments. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

References

1. FAO. Global status of salt-affected soils – Main report. Rome; 2024. https://doi.org/10.4060/cd3044en
2. Hu D, Li R, Dong S, Zhang J, Zhao B, Ren B, et al. Maize (*Zea mays* L.) responses to salt stress in terms of root anatomy, respiration and antioxidative enzyme activity. BMC Plant Biol. 2022;22(1):602. https://doi.org/10.1186/s12870-022-03972-4
3. Dhanalakshmi R, Subramanian A, Thirumurugan T, Elangovan M, Kalaimagal T. Genetic variability and association studies in barnyard millet (*Echinochloa frumentacea* (Roxb.) Link) germplasm under sodic soil condition. Electron J Plant Breed. 2019;10(2):430–9. https://doi.org/10.5958/0975-928X.2019.00055.3
4. Kuraloviya M, Vanniarajan C, Sudhagar R, Vetriventhan M. Phenotypic diversity and stability of early maturing barnyard millet (*Echinochloa* sp.) germplasm for grain yield and its contributing traits. Indian J Exp Biol. 2022;60(12):918–24. https://doi.org/10.56042/ijeb.v60i12.36064
5. Powell AA. Seed vigour in the 21st century. Seed Sci Technol. 2022;50(2):45–73. https://doi.org/10.15258/sst.2022.50.1.s.04
6. Williams G, Vanniarajan C, Vetriventhan M, Thiageshwari S, Anandhi K, Rajagopal B. Genetic variability for seedling stage salinity tolerance in barnyard millet (*Echinochloa frumentaceae* (Roxb.) Link). Electron J Plant Breed. 2019;10(2):552–8. https://doi.org/10.5958/0975-928X.2019.00069.3
7. Singh R, Tariyal YS, Chauhan JS. Effect of plant growth promoting rhizobacteria (PGPR) on salt stress tolerance of barnyard millet (*Echinochloa frumentacea*). Biochem Anal Biochem. 2021;10(9):403.
8. Arthi N, Rajagopal B, Geethanjali S, Nirmalakumari A, Senthil N. Screening of barnyard millet (*Echinochloa frumentacea*) germplasm for salinity tolerance. Electron J Plant Breed. 2019;10(2):659–66. https://doi.org/10.5958/0975-928X.2019.00083.8

9. Nedunchezhiyan V, Velusamy M, Subburamu K. Seed priming to mitigate the impact of elevated carbon dioxide associated temperature stress on germination in rice (*Oryza sativa* L.). Arch Agron Soil Sci. 2020;66(1):83–95. https://doi.org/10.1080/03650340.2019.1599864

10. Ardie SW, Khumaida N, Nur A, Fauziah N. Early identification of salt tolerant foxtail millet (*Setaria italica* L. Beauv). Proc Food Sci. 2015;3:303–12. https://doi.org/10.1016/j.profoo.2015.01.033

11. International Seed Testing Association (ISTA). International rules for seed testing. International Seed Testing Association; 2012.

12. Abdul Baki AA, Anderson JD. Vigor determination in soybean seed by multiple criteria. Crop Sci. 1973;13(6):630–3. https://doi.org/10.2135/cropsci1973.0011183X001300060013x

13. Adhikari B, Dhital PR, Ranabhat S, Poudel H. Effect of seed hydro-priming durations on germination and seedling growth of bitter gourd (*Momordica charantia*). PLoS One. 2021;16(8):e0255258. https://doi.org/10.1371/journal.pone.0255258

14. Soujanya J, Bara BM, Rai PK, Pal AK. Impact of salinity on germination percentage and seedling growth in sorghum (*Sorghum bicolor* L.) var. CSH–14. Biol Forum Int J 2022;14(4):198–202.

15. Lemmens E, Deleu LJ, De Brier N, De Man WL, De Proft M, Prinsen E, Delcour JA. The impact of hydro-priming and osmo-priming on seedling characteristics, plant hormone concentrations, activity of selected hydrolytic enzymes and cell wall and phytate hydrolysis in sprouted wheat (*Triticum aestivum* L.). ACS Omega. 2019;4(26):22089–100. https://doi.org/10.1021/acsomega.9b03210

16. Krishnamurthy L, Serraj R, Rai KN, Hash CT, Dakheel AJ. Identification of pearl millet [*Pennisetum glaucum* (L.) R. Br.] lines tolerant to soil salinity. Euphytica. 2007;158:179–88. https://doi.org/10.1007/s10681-007-9441-3

17. Yakubu H, Ngala AL, Dugje IY. Screening of millet (*Pennisetum glaucum* L.) varieties for salt tolerance in semi-arid soil of Northern Nigeria. World J Agric Sci. 2010;6(4):374–80.

18. Jha S, Singh J, Chouhan C, Singh O, Srivastava RK. Evaluation of multiple salinity tolerance indices for screening and comparative biochemical and molecular analysis of pearl millet [*Pennisetum glaucum* (L.) R. Br.] genotypes. J Plant Growth Regul. 2022;41(4):1820–34. https://doi.org/10.1007/s00344-021-10424-0

19. Wu C, Zhang M, Liang Y, Zhang L, Diao X. Salt stress responses in foxtail millet: physiological and molecular regulation. Crop J. 2023;11(4):1011–21. https://doi.org/10.1016/j.cj.2023.06.001

20. Swarna R, Jinu J, Dheeraj C, Talwar HS. Salinity stress in pearl millet: from physiological to molecular responses. In: Pearl Millet in the 21st Century. Singapore: Springer; 2024. p. 361–94. https://doi.org/10.1007/978-981-99-5890-0_14

21. Zhao C, Zhang H, Song C, Zhu JK, Shabala S. Mechanisms of plant responses and adaptation to soil salinity. The Innovation. 2020;1(1):100017. https://doi.org/10.1016/j.xinn.2020.100017

22. Abdel-Farid IB, Marghany MR, Rowezek MM, Sheded MG. Effect of salinity stress on growth and metabolomic profiling of *Cucumis sativus* and *Solanum lycopersicum*. Plants. 2020;9(11):1626. https://doi.org/10.3390/plants9111626

23. Subramanian A, Raj RN, Jeyaprakash P. *In vitro* and *in vivo* screening of barnyard millet (*Echinochloa frumentacea* (Roxb.) Link) germplasm for salinity tolerance. Plant Arch. 2020;20(2):7389–97.

24. Pradhan PP, Bhuyan P, Nag G, Sahoo JP. Genetic improvement of barnyard millet (*Echinochloa esculenta*): prospective and challenges. Technol Agron. 2024;4(1):e027. https://doi.org/10.48130/tia-0024-0024

25. Zuffo AM, Steiner F, Aguilera JG, Teodoro PE, Teodoro LP, Busch A. Multi-trait stability index: a tool for simultaneous selection of soya bean genotypes in drought and saline stress. J Agron Crop Sci. 2020;206(6):815–22. https://doi.org/10.1111/jac.12409

26. Vijayalakshmi D, Kishor Ashok S, Raveendran M. Screening for salinity stress tolerance in rice and finger millet genotypes using shoot Na+/K+ ratio and leaf carbohydrate contents as key physiological traits. Indian J Plant Physiol. 2014;19:156–60. https://doi.org/10.1007/s40502-014-0090-y

27. Saha D, Choyal P, Mishra UN, Dey P, Bose B, Gupta NK, et al. Drought stress responses and inducing tolerance by seed priming approach in plants. Plant Stress. 2022;4:100066. https://doi.org/10.1016/j.stress.2022.100066

28. Negrão S, Schmöckel SM, Tester MJ. Evaluating physiological responses of plants to salinity stress. Ann Bot. 2017;119(1):1–11. https://doi.org/10.1093/aob/mcw191

29. El-Badri AM, Batool M, Wang C, Hashem AM, Tabl KM, Nishawy E, et al. Selenium and zinc oxide nanoparticles modulate molecular and morpho-physiological processes during seed germination of *Brassica napus* under salt stress. Ecotoxicol Environ Saf. 2021;225:112695. https://doi.org/10.1016/j.ecoenv.2021.112695

30. Saddiq MS, Iqbal S, Hafeez MB, Ibrahim AM, Raza A, Fatima EM, et al. Effect of salinity stress on physiological changes in winter and spring wheat. Agronomy. 2021;11(6):1193. https://doi.org/10.3390/agronomy11061193

31. Ashraf M. Some important physiological selection criteria for salt tolerance in plants. Flora. 2004;199(5):361–76. https://doi.org/10.1078/0367-2530-00165

32. Amoah JN, Adu-Gyamfi MO. Effect of drought acclimation on sugar metabolism in millet. Protoplasma. 2025;262(1):35–49. https://doi.org/10.1007/s00709-024-01976-5

33. Sehrawat A, Mann A, Sehrawat AR. Recent advances towards abiotic stresses tolerance and improvement in barnyard millet: a climate-resilient crop for food security. In: Cutting edge technologies for developing future crop plants. Singapore: Springer; 2025. p. 381–417. https://doi.org/10.1007/978-981-96-2508-6_19

34. Samineni S, Gummadi S, Thushar S, Khan DN, Gkanogiannis A, Becerra Lopez-Lavalle LA, et al. Exploring proso millet resilience to abiotic stresses: high-yield potential in desert environments of the Middle East. Agronomy. 2025;15(1):165. https://doi.org/10.3390/agronomy15010165

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