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EFFECT OF SALINITY ON THE GROWTH AND SOME MORPHOLOGICAL TRAITS OF PEARL MILLET

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Abstract

A study was conducted at the Faculty of Agriculture, An Najah National University, Palestine, during the 2016-2017 growing season to investigate the effects of different salinity levels on the growth and development of eight pearl millet (*Pennisetum glaucum*) accessions. Three salinity levels were used (freshwater as control, 75 and 150 mM NaCl), with three replicates. Increasing NaCl concentration resulted in a significant reduction in plant height. Accession IP6104 had the highest plant height, and accession ICMV155 was the shortest (84.05 and 75.60 cm, respectively). The average tiller number was not affected by salinity, while significant differences were observed among accessions on tiller number. Salinity decreased chlorophyll content and SPAD was reduced from 62.04 under the control treatment to 19.41 under 150 mM NaCl. Significant differences were observed in fresh and dry weight of roots and fresh weight of shoots, while dry weight of shoots was not significantly affected. The present study showed that pearl millet can grow under saline conditions. This indicates that this forage crop has good potential for cultivation in areas with high soil salinity.

Key words: *Pennisetum glaucum*, Root/shoot ratio, Salt tolerance, SPAD.

Introduction

Water scarcity is classified as one of the most important limiting factors for crop production in the world (Seghatoleslami *et al*., 2008; Shadeed & Alawna, 2021). Palestine is one of the countries with the most limited renewable water resources. Agriculture consumes 51.5 percent of the total water. Moreover, irrigated land in the West Bank accounts for only 8% of the total agricultural land (MoA, 2014).

Water scarcity is one of the main problems limiting the production of forage crops in arid and semi-arid countries in general, and in Palestine in particular (MoA, 2014). Livestock production in Palestine plays an important economic role, especially for the rural population. Fodder legumes are a valuable source of fodder. However, since they represent only 4% of the total cultivated area (Alhaj Hussein *et al*., 2010); the amount of fodder produced is less than the demand. Due to these circumstances, there is an urgent need to increase forage production in Palestine.

Pearl millet (*Pennisetum glaucum* L) is classified as a main crop in arid and semi-arid areas because it consumes less water compared to other forage crops (Rostamza *et al*., 2011). Landraces of pearl millet generally have high biomass production and vegetative vigor. Although it requires less water than other forage crops, it is classified as a summer-irrigated crop and is considered to be fairly salt tolerant (Krishnamurthy *et al*., 2007). Many countries suffering from water scarcity have advocated the use of non-conventional water resources for agriculture (Gatta *et al*., 2018). However, the salinity of these non-conventional water sources is often higher than the tolerance threshold of crops (Hu *et al*., 2005). The accumulation of salt in the soil solution causes salt stress and makes it very difficult for roots to take up the required water from the surrounding soil (Jamal *et al*., 2011). To ensure future productivity, it is important to select and characterize salt-resistant species. Therefore, the objective of this study was to investigate the effects of different salinity levels on the growth of different deer genotypes.

Materials and Methods

Plant material and experimental design: Eight pearl millet accessions obtained from ICBA were used (Table 1). The experiment was conducted at the Faculty of Agriculture and Veterinary Medicine. Med, An-Najah National University, Palestine (32.31519º N, 35.02033º W). Pearl millet seeds were sown in plastic pots (30x30x50 cm) filled with agricultural sand. Three NaCl treatments (0.0 (control), 75 and 150 mM) were arranged in a completely randomized design. Five seeds per pot were seeded with three replicates per treatment. All treatments were irrigated with tap water for three weeks. After three weeks of seeding, saline irrigation water was prepared by mixing NaCl with tap water and used to irrigate millet seedlings until the experiment was terminated.

Irrigation requirements: The irrigation requirement was calculated based on the average climatic parameters in Tulkarm region. The plants were irrigated every three days. Plants were fertilized with 6-6-6 (N-P2O5-K2O) liquid fertilizer at a concentration of 3 mL per liter of irrigation water. Salt water was applied three weeks after seed germination.

Plant observation: The following measurements were taken on each accession at maturity as an average of three plants:

- Plant height: from the ground to the tip of the plant shoot.
- Plant and root fresh weight.
- Plant and root dry weight: plants were placed in the oven at 105°C for 24 hours.
- Root/shoot (R/S): The R/S ratio was calculated as described by Shtaya *et al*., (2021).

Table 1. Pearl millet (*Pennisetum glaucum* L.) accessions used in the experiment.

Accessions #	Accessions codes
1	IP3616
2	IP6104
3	IP6110
4	IP19612
5	Sudan pop III
6	ICMS7704
7	MC94C2
8	ICMV155

Data analysis: Analysis of variance was performed using PROC GLM SAS/STAT software. Multiple comparisons between pairs of accessions were performed with Tukey's test, $p \leq 0.05$.

Results

Analysis of Variance: The analysis of variance shows a highly significant effect of salinity on studied traits ($p<0.0001$), except for SPAD, which was < 0.0167. There were no significant differences among accessions for any of the traits studied, except for root/shoot ratio and tiller number. No significant interaction effects between salinity and accessions were observed except for root dry weight and shoot fresh weight.

Effect of salinity on plant height: The effects of three salinity levels on the plant height of pearl millet are shown in Tables 3 and 4. Plant height decreased significantly with increasing salinity ranged from 88.23 cm under control to 75.45 cm under 150 mM NaCl. No significant difference was observed between accessions (Table 3). Accession IP6104 had the highest plant height, however, accession ICMV155 exhibited shortest one (84.05 and 75.60 cm, respectively). No significant interaction was observed between treatment and accessions (Table 4).

Effect of salinity on number of tillers: The number of tillers per plant did not significantly decrease under salinity conditions (Table 3). The different millet accessions had significantly different numbers of shoots per plant. IP3616, MC94C2, and ICMV155 produced the highest tiller number per plant (3.11, 2.67, and 2.11 tillers per plant, respectively). No significant interaction between treatment and accessions was observed in tiller number (Table 4).

Table 2. Analysis of variance results (mean squares) of data on eight pearl millet accessions. The model included the effects of accession, treatment and treatment*accession interaction.

Trait	Effects fitted in the model					
	Accession		Treatment		Treatment*Accession	
	Mean square	p-value	Mean square	p-value	Mean square	p-value
Ash %	124.9	0.166	1835.0	0.0001	113.7	0.175
Root DW	1332.2	0.085	62456.6	0.0001	1312.5	0.050
Root FW	6409.0	0.425	393338.0	0.0001	6374.0	0.449
Shoot DW	5300.0	0.738	547560.0	0.0001	5561.0	0.810
Shoot FW	34860.0	0.084	4376109.0	0.0001	33676.0	0.055
Root/Shoot ratio	0.13646	0.002	0.32387	0.0001	0.11416	0.001
SPAD	214.8	0.163	682.8	0.0167	415.4	0.060
Shoot length	84.5	0.364	1112.5	0.0001	93.0	0.280
Tillers numbers	10.2	0.004	3.8	0.280	2.1	0.755

Table 3. Effect of NaCl treatments and accessions on shoot length, tiller number, chlorophyll content (SPAD) and ash % parameters of pearl millet.

Main factor		Plant height (cm)	Tillers number	SPAD	Ash (%)
NaCl treatments	Control	88.23^{a}	1.33	62.04^{a}	18.79^{c}
	75 mM	80.10^{b}	1.95	38.72^{ab}	27.18^{b}
	150 mM	74.45^{c}	1.21	19.41^{b}	36.27^{a}
	p-value	***	*NS*	**	***
Accessions	IP3616	76.78	3.11^{a}	73.66	25.34
	IP6104	84.05	0.31^{d}	42.32	31.21
	IP6110	83.11	0.33^{d}	58.30	25.14
	IP19612	82.98	0.56^{cd}	41.44	24.48
	Sudan pop II	80.98	1.56^{abcd}	52.84	32.32
	ICMS7704	81.87	1.33^{bcd}	47.11	24.24
	MC94C2	82.04	2.67^{ab}	39.94	25.61
	ICMV155	75.60	2.11^{abc}	47.41	32.66
	p-value	*NS*	**	*NS*	*NS*

; $p<0.001$, *; $p<0.0001$ and NS; not significant

Means that do not share a letter are significantly different (Tukey test, $p<0.05$)

Table 4. Effect of NaCl treatments and accessions on root fresh weight, root dry weight, shoot fresh weight, shoot dry weight and root/shoot ratio parameters of pearl millet.

Main factor		Root FW (g)	Root DW (g)	Shoot FW (g)	Shoot DW (g)	Root/Shoot ratio
NaCl Treatments	Control	238.23^{a}	94.68^{a}	804.32^{a}	294.58^{a}	0.34^{a}
	75 mM	26.01^{b}	9.04^{b}	105.99^{b}	50.31^{b}	0.23^{b}
	150 mM	8.07^{b}	3.84^{b}	29.40^{b}	18.51^{b}	0.19^{b}
	p-value	***	***	***	***	***
Accessions	IP3616	125.47	54.27	388.24	153.73	0.71^{a}
	IP6104	68.06	15.54	239.07	125.78	0.35^{c}
	IP6110	97.88	44.03	327.39	125.86	0.0.44^{bc}
	IP19612	61.21	24.37	378.87	152.61	0.40^{bc}
	Sudan pop II	131.30	44.76	326.37	122.11	0.52^{abc}
	ICMS7704	96.77	35.71	356.12	96.23	0.64^{ab}
	MC94C2	75.06	34.04	236.93	86.95	0.58^{abc}
	ICMV155	70.40	34.11	258.87	105.78	0.46^{abc}
	p-value	*NS*	*NS*	*NS*	*NS*	**

; $p<0.001$, *; $p<0.0001$ and NS; not significant

Means that do not share a letter are significantly different (Tukey test, $p<0.05$)

Table 5. Interaction effects of NaCl treatments and accessions on root fresh weight, root dry weight, shoot fresh weight, shoot dry weight and root/shoot ratio of pearl millet.

Treatment x Accession	Root FW (g)	Root DW (g)	Shoot FW (g)	Shoot DW (g)	Root/Shoot Ratio
Control x IP3616	337.67^{a}	145.63^{a}	1045.63^{a}	404.43^{a}	0.79abc
Control x IP6104	171.42^{abc}	33.68^{cde}	546.16^{cd}	308.33^{ab}	0.23c
Control x IP6110	258.27^{ab}	121.22^{ab}	802.39^{abc}	393.33 ^{abc}	0.82ab
Control x IP19612	146.00^{abc}	60.65^{bcde}	989.70^{ab}	376.37a	0.32abc
Control x Sudan pop II	366.87^{a}	124.03^{ab}	872.00^{abc}	300.36^{abc}	0.84ab
Control x ICMS7704	244.45^{abc}	92.39^{abcd}	896.33^{abc}	207.33^{abc}	0.87a
Control x MC94C2	192.19^{abc}	84.28^{abcd}	599.67^{bc}	194.57^{abc}	0.48abc
Control x ICMV155	188.98^{abc}	95.58^{abc}	682.63^{abc}	271.88^{abc}	0.76abc
75 mM x IP3616	30.65^{bc}	13.06^{cde}	92.05^{e}	43.55^{bc}	0.63abc
75 mM x IP6104	24.02^{bc}	9.24^{e}	136.43^{de}	46.88^{bc}	0.46abc
75 mM x IP6110	30.11^{bc}	7.57^{e}	142.98^{de}	60.81^{bc}	0.23c
75 mM x IP19612	28.42^{bc}	7.99^{e}	121.78^{e}	63.02^{bc}	0.32abc
75 mM x Sudan pop II	18.20^{bc}	6.28^{e}	72.46^{e}	45.11^{bc}	0.27bc
75 mM x ICMS7704	35.40^{bc}	10.41^{de}	148.48^{de}	65.84^{bc}	0.32abc
75 mM x MC94C2	24.39^{bc}	13.72^{cde}	84.19^{e}	49.85^{bc}	0.65abc
75 mM x ICMV155	16.88^{bc}	4.02^{e}	49.56^{e}	27.41^{bc}	0.32abc
150 mM x IP3616	8.09^{c}	4.11^{e}	27.04^{e}	13.20^{c}	0.72abc
150 mM x IP6104	8.73^{c}	3.70^{e}	34.63^{e}	22.14^{bc}	0.36anc
150 mM x IP6110	5.26^{c}	3.33^{e}	36.83^{e}	23.43^{bc}	0.27bc
150 mM x IP19612	9.21^{c}	4.47^{e}	25.14^{e}	18.44^{bc}	0.57abc
150 mM x Sudan pop II	8.84^{c}	3.95^{e}	34.65^{e}	20.85^{bc}	0.45abc
150 mM x ICMS7704	10.47^{bc}	4.34^{e}	23.54^{e}	15.51^{c}	0.74abc
150 mM x MC94C2	8.60^{c}	4.12^{e}	26.92^{e}	16.44^{c}	0.60abc
150 mM x ICMV155	5.35^{c}	2.73^{e}	26.42^{e}	18.06^{bc}	0.30abc
p-value	**	**	**	**	*NS*

; $p<0.001$, *; $p<0.0001$ and NS; not significant

Means that do not share a letter are significantly different (Tukey test, $p<0.05$)

Effect of salinity on SPAD: Significant differences between treatments were observed for leaf chlorophyll (Table 3). The highest chlorophyll content was observed in control plants (SPAD = 62.04) and the lowest in plants under 150 mM NaCl (SPAD = 19.41). No significant difference was observed between the control and 75 mM NaCl. No significant differences in chlorophyll content were observed between the different pearl millet accessions. Accession IP3616 showed the highest chlorophyll content and accession MC94C2 the lowest chlorophyll content (73.66 and 39.94, respectively). The observed interaction between treatments and accessions was not significant (Table 4).

Effect of salinity on ash content: The ash content was significantly increased by the NaCl treatments (Table 3). The highest ash content was observed at 150 mM NaCl (36.27%) and the lowest in the control plants (18.79%). The difference in ash content among the different pearl millet accessions was not significant. The ICMV155 accession had the highest ash content and the ICMS7704 accession had the lowest ash content (32.66 and 24.24%, respectively). No interaction between treatments and accessions was observed for ash content.

Effect of salinity on fresh weight and dry weight of shoots and roots: The data show that fresh and dry shoot weights decreased with increased salinity (Table 4). The highest fresh weight and dry weight of shoots were obtained under control conditions (804.32 and 294.58 g, respectively). The fresh and dry weights of roots also decreased with increasing salinity. The highest fresh and dry weights of roots were obtained under control conditions (238.23 and 94.68 g, respectively). No significant differences were observed between accessions in fresh and dry weight of roots and shoots. A significant interaction between treatments and accessions was observed in dry weight of roots and fresh weight of shoots. Accession IP3616 showed the highest shoot fresh weight (1045.63 g/plant) under control conditions. Accession ICMS7704 exhibited the relatively highest shoot fresh weight (148.48 g/plant) under 75 mM NaCl. All tested accessions reacted the same under 150 mM NaCl. No significant interaction was observed for root fresh weight and shoot dry weight (Table 5).

Effect of salinity on root/shoot ratio: To test the effect of different NaCl concentrations on plant growth, the root/shoot ratio was calculated (Table 2). The results show that NaCl significantly affected the root/shoot ratio. The highest R/S ratio was observed under control conditions and the lowest under 150 mM NaCl (0.34 and 0.19, respectively). No significant difference was observed between 75 and 150 mM NaCl (0.23 and 0.19, respectively). No significant interaction between treatment and accession was observed (Table 5).

Discussion

Reduction of plant development in saline environments is a common phenomenon, but it occurs in reverse in a variety of plant parts. For example, in the current study, salt stress reduced the dry weight of shoots more than that of roots. Jamil *et al*., (2007) found that as stress increased, radicle dry weight and plumule dry weight decreased significantly. Tuna *et al*., (2005) reported that fruit dry weight of tomato under salt stress was lower than plants grown under control conditions. Abu-Qaoud *et al*., (2021) reported that NaCl reduced the fresh weight of wheat shoots and roots. This reduction could be due to the toxic effect of high NaCl concentration (Werner & Finkelstien, 1995). The main reason for the growth reduction in pearl millet could be dependent on ion toxicity and water scarcity caused by salinity. According to Hussain *et al*., (2010), the increase in plant growth could be related to turgor potential, which decreases when water is scarce due to high soil salinity.

The results show that NaCl did not affect the R/S ratio in all accessions, suggesting that roots and shoots are in the same range of sensitivity to NaCl stress. Higher root shoot ratio suggests that selection for stress tolerance could improve grain yield (Mazhar *et al*., 2020).

Chlorophyll content was reduced by the salt treatments but was not significantly affected in the eight accessions. In contrast, other researchers reported an increase in chlorophyll content in salt-tolerant plants such as pearl millet. The results are consistent with those reported in other crops such as wheat (Abu-Qaoud *et al*., 2021) and chickpea (Mafakheri *et al*., 2010). Pourbabaee *et al*., (2016) and Bahmani *et al*., (2016) reported increased chlorophyll content in wheat grown under saline conditions.

Seedling growth (root and shoot length) was tested under both stress and control conditions. Overall seedling growth was reduced in all accessions during salt stress. Reduction in plant growth due to salinity was observed in wheat (Abu-Qaoud *et al*., 2021), sorghum seedlings (Yakubu *et al*., 2006) and millet varieties (Kafi *et al*., 2009; Yakubu *et al*., 2010). Nutrient uptake limitation and physiological water stress caused by high soil NaCl concentration may affect plant growth (Folorunso *et al*., 2005). This could be due to the toxicity of NaCl as well as uneven nutrient uptake by seedlings (Jamil *et al*., 2006). Reduced growth under salt stress has been attributed to osmotic or ionic effects as well as inhibition of cell division and cell elongation. (Ranganayakulu *et al*., 2013). In this study, the number of tiller was not significantly reduced by salt treatment as accessions showed significant differences in the number of tiller. Kafi *et al*., (2009) reported similar results in millet. The decreased tillers numbers are evidence of an adaptation mechanism resulting from water stress, which reduces the transpiration zone and thus helps the plant to endure water stress (Ismail, 2012).

Conclusions

The results of this study showed that salinity significantly affected the growth of the different pearl millet accessions, but with different effects among the different accessions. Moreover, the different accessions showed different responses to the measured variables under the salinity levels tested, making it possible to screen out salt-tolerant accessions among the tested ones. The present study showed that pearl millet can grow under saline conditions. This indicates that this forage crop has good potential for cultivation in areas with high soil salinity.

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