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Response of Dry Matter Production of tef [*Eragrostis tef* (Zucc.) Trotter] Accessions and Varieties to NaCl Salinity

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Abstract: This study aimed to screen fifteen low land tef genotypes (10 accessions and 5 varieties) with respect to dry matter production at 0 dS/m (control), 2, 4, 8 and 16 dS/m salinity levels. Data analysis was carried out using SAS package (SAS version 8.2, 2001) and SPSS version 12. The two ways ANOVA showed significant variation with respect to Root Dry Weight per plant (RDW) at $p<0.001$ and Total Dry Weight per plant (TDW) at $p<0.05$ for accessions/varieties. Moreover, it was significant for treatment ($p<0.001$) with respect to all the above three parameters. On the other hand, the two ways ANOVA for accession/variety*treatment interaction was significant for above Ground Dry Weight per plant (AGDW) and Total Dry Weight per plant (TDW) at $p<0.01$. This implies that all the accessions and varieties respond to salinity stress differently with respect to these three dry matter production characters. However, the two ways ANOVA for the accession/variety*treatment interaction for Root Dry Weight per plant (RDW) was insignificant reflecting that the entire varieties and accessions react to salinity stress similarly. Accessions 212611, 55017, 231217 and varieties DZ-Cr-358 and DZ-01-1281 were salt sensitive genotypes whereas accessions 237131, 237186, 212928 and variety DZ-Cr-37 were salt tolerant genotypes of all. Varieties were more salt affected than accessions with respect to dry matter production.

Key words: Dry matter, *Eragrostis tef*, root weight, salinity, shoot weight, varieties

INTRODUCTION

Salt-affected soils are distributed throughout the world and no continent is free from the problem (Brady and Weil, 2002). Salinization of soil is one of the major factors limiting crop production particularly in arid and semi-arid regions of the world (Ahmed, 2009). Globally, a total land area of 831 million hectares is salt affected. African countries like Kenya (8.2 Mha), Nigeria (5.6 Mha), Sudan (4.8 Mha), Tunisia (1.8 Mha), Tanzania (1.7 Mha) and Ghana (0.79 Mha) are salt affected to various degrees (FAO, 2000). Salt stress is known to perturb a multitude of physiological processes (Noreen and Ashraf, 2008). It exerts its undesirable effects through osmotic inhibition and ionic toxicity (Munns *et al*., 2006). Increased salinity caused a significant reduction in germination percentage, germination rate, and root and shoots length and fresh root and shoots weights (Jamil *et al*., 2006).

In Ethiopia salt-affected soils are prevalent in the Rift Valley and the lowlands. The Awash Valley in general and the lower plains in particular are dominated by salt-affected soils (Gebreselssie, 1993). A significant abandonment of banana plantation and a dramatic spread to the adjacent cotton plantation of Melka Sadi Farm was reported (Abeaz, 1995). Moreover, of the 4000ha irrigated land of the above farm 57% has been salt-affected (Taddese and Bekele, 1996). Similarly, the occurrence of salinity problem in Melka Werer Research Farm was reported (Haider *et al*., 1988). Another study also depicted that of the entire Abaya State Farm, 30% has already been salt-affected (Tsige *et al*., 2000).

This problem is expected to be severe in years to come. Because under the prevailing situation of the country; there is a tendency to introduce and implement large-scale irrigation agriculture so as to increase productivity (Mamo *et al*., 1996). In the absence of efficient ways of irrigation water management, salt-build up is an inevitable problem. To alleviate the problem, we need to look for a solution (Gebre and Georgis, 1988). It can be done either using physical or biological practice (Gupta and Mihas, 1993; Marler and Mickelbart, 1993). Since environmental management (physical approach) is not economically feasible (El-Khashab *et al*., 1997) there is a need to concentrate on the biological approach or crop management (Ashraf and McNeilly, 1988;

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Ashraf *et al*., 2008; Ashraf, 2009). Nevertheless, to proceed with this approach, affirming the presence of genetically based variation for salt-tolerance in a particular crop is a prerequisite (Verma and Yadava, 1986; Marler and Mickelbart, 1993; Mahmood *et al*., 2009).

Thus in doing so, one has to focus on crops that have been cultivated for a long period of time in a country, and are able to provide reliable yield under unreliable agro-climatic conditions and make ranking first against area coverage, demand and market value. Tef [*Eragrostis tef* (Zucc) Trotter] is one of such crops, which has been cultivated in the country as a cereal crop for quite long (Purseglove, 1972). Furthermore, tef can be adapted to a broader range of agro-climatic environments. It can grow in altitudes ranging from sea level to 2800 m above sea level under different moisture, soil, temperature and rainfall regimes. It can tolerate anoxic situations better than maize, wheat and sorghum. It has ease of storage, tolerance to weevils and other pests. The straw is preferred to any other cereal straws and can fetch premium price (Ketema, 1993). According to Hailemelak *et al*. (1965), it contains higher amount of a number of minerals than wheat, barley or grain sorghum. As compared to other cereals, the largest cultivated land area is covered by tef. Moreover, the area used for tef production is increasing from time to time (Tefera and Ketema, 2000). For example, it covered 1,818, 375 (in 2001/02) and 1,989,068 (2003/04) hectares of land which is 28.5 and 28.4% of the area covered respectively by the whole cereals in each production year (CSA, 2004). Generally, tef is a reliable cereal under unreliable climate. That is why, in many areas where recurrent moisture stress occurs, tef production replaces the production of maize and sorghum (Ketema, 1993).

Therefore, this study attempted to screen fifteen genotypes (10 accessions and 5 varieties) of tef [*Eragrostis tef* (Zucc.) Trotter] with respect to dry matter production.

MATERIALS AND METHODS

This study was conducted from March 2004 to June 2005 at Melkasa Agricultural Research Center (MARC), Ethiopia. The experimental soil was taken from MARC at a depth of 0-20 cm and analyzed profoundly at the National Soil Testing Center (NSTC). It was loam with 2.4% $CaCO_3$, 16.3% total nitrogen, 1.596% organic matter and a pH (1:2.5 soil water ratio) of 9.1. It has adequate phosphorus supply (21.28) and the exchangeable K, Na, Ca and Mg were 3.41, 0.46, 44.31 and 19.97 meq/100 g soil. Its electrical conductivity, 0.235 dS/m was low. It has a bulk density of l.11 g/cm^3 and 45% of water saturation, and at field capacity it has moisture content of 31.35% while the permanent welting point was 17.31%. The amount of NaCl to be added per 4kg dry soil was calculated using the formula:

$$\text{Gram salt per 100g dry soil} = \frac{0.064 \text{ dS/m x water saturation\%}}{100\%}$$ (Mamo *et al*., 1996).

Based on this formula 2.314, 4.628, 9.257 and 18.514 g NaCl were dissolved in 250 mL distilled water to get 2, 4, 8 and 16 dS/m salinity levels, respectively. The experiment was conducted in a mesh house having a total area of 100 m^2 using plastic pots. The pots were filled with 4 kg dry soil, placed on dishes for collecting leachate (if any) and arranged in a randomized complete block design (RCBD) with four replications. The mesh house was covered with polyethylene plastic sheet to avoid the entrance of salts and other particles through wind and rain. The average temperature, relative humidity, sunshine, and evaporation of the area were 22.08^{o}C, 47.33%, 8.45 h/day and 7.48 mm, respectively. Supplemental nitrogen as ammonium nitrate (NH_4NO_3) was applied to the pots at a rate of 57.14 mg per pot in a solution form so as to ensure that nitrogen is not a limiting factor to the growth of tef. The NaCl treatments were applied in such a way that 50% before seeding and the remaining 50% in two splits 10 and 15 days after seeding. This is to avoid osmotic shock.

Twenty tef seeds were seeded per pot and at three leaf stage, they were thinned to 10 per pot (if any). Distilled water was applied as often as necessary. The leachate was collected on the dishes and returned to the pot. At maturity, plants were harvested by cutting at the soil surface using a cutter. The roots were uprooted after the soil has been dissolved completely. Then roots were washed and rinsed several times so as to avoid any adhering particles. Then the parts were inserted into paper bags and oven dried at 70^{0}C for 48 h and shoot and root dry weights were measured using sensitive balance.

Data analysis: Data analysis was carried out using SAS package (SAS version 8.2, 2001) and SPSS version 12. Since most accessions and varieties were salt sensitive at 16 dS/m, information from this salinity level has not been included in data analysis.

RESULTS AND DISCUSSION

Above Ground Dry Weight per plant (AGDW): The two ways ANOVA found to be insignificant with respect to above Ground Dry Weight per plant (AGDW) for accessions/varieties ($p>0.05$). However it was significant for both treatments ($p<0.001$) and treatment*accession/variety interaction ($p>0.01$). Above Ground Dry Weight (AGDW) was stimulated at 2 dS/m in accessions 205217, 212928, 236512, 236514, 237131 and 237186 and in all varieties except variety DZ-Cr-358. Similarly, at 4dS/m it was stimulated in accessions 212611, 212928, 229747,

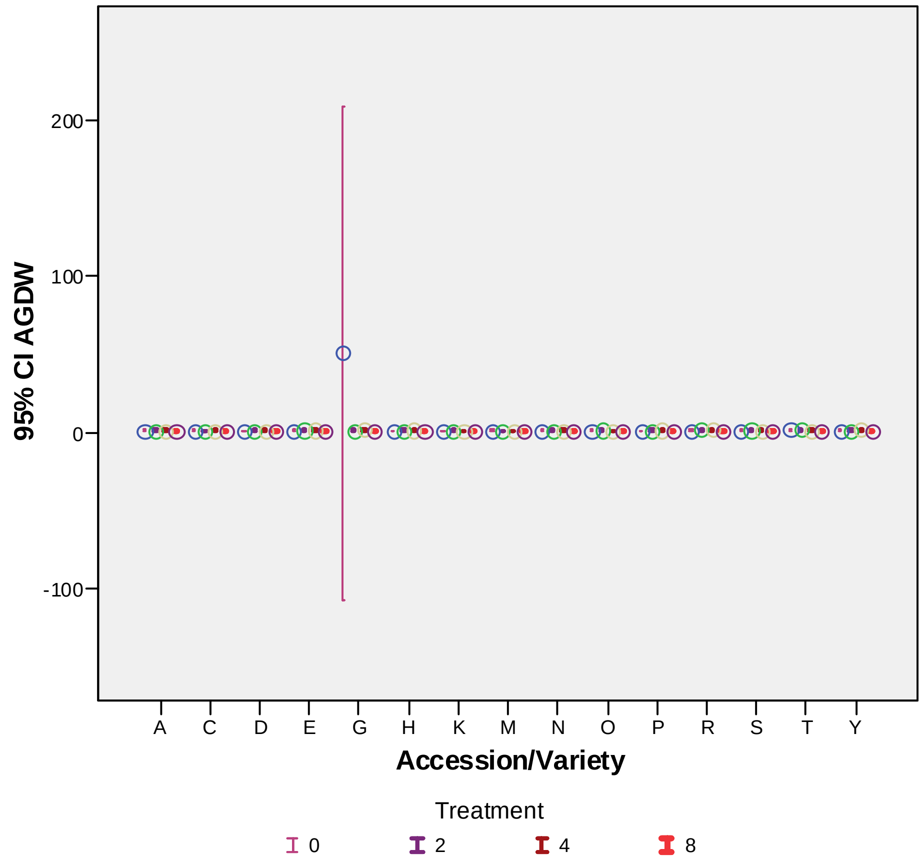

Fig. 1: Effects of salinity on above Ground Dry Weight per plant (AGDW) of tef [*Eragrostis tef* (Zucc.) Trotter)] accessions and varieties. Key to accessions: A = 231217, C = 212611, E = 229747, G = 236514, H = 236512, M = 55017, N = 237186, O = 237131, R = 212928 and S = 205217; Key to varieties: D = DZ-01-196, K = DZ-Cr-37, P = DZ-01-1281, T = DZ-01-168 and Y = DZ-Cr-358)

231217, 236512, 236514 and 237186 and in all varieties except DZ-01-1681. In general, treatment 2 and 4 dS/m stimulated AGDW in most accessions and almost in all varieties. Nevertheless, significant reduction was evident at 8 dS/m especially in intermediate and sensitive genotypes. Consequently, a reduction of 6.4-51.95% in accessions and 26.6-53.9% in varieties was recorded in comparison with the control. This result is in agreement with reports in tomato (Swiecki and McDonald, 1991), Kenaf (Francois *et al.*, 1992), wheat (Holloway and Alston, 1992), cowpea (Murillo-Amador and Troyo Die'guez, 2000), sugar beet cultivars (Dadkhah and Grrifiths, 2006), maize (Ekeer *et al.*, 2006), lettuce (Al-Maski *et al.*, 2010) and *Cicer arietinum* (Mudgal *et al.*, 2010). In accessions 236514, 236512, 212611 and 55017 as well as varieties DZ-01-1281 and DZ-Cr-358 the largest decline was recorded relative to the rest genotypes (Fig. 1). On the other extreme, at the highest salt concentration (8 dS/m), AGDW was increased by 13.5% and 28.4% in accession 237131 and variety DZ-Cr-37, respectively as compared to the control. Similar report was made in durum wheat (Almansouri *et al.*, 1999). This facilitated above ground growth may be responsible for their salt tolerance. Because during facilitated growth, shoot relative water content would increase and in turn this could dilute the toxic effects of excess Na^+ and Cl^-. A similar conclusion was made in rice varieties, new plant type (NPT) and Pokkali (Lee and Senadhira, 1998).

Root Dry Weight per plant (RDW): The two ways ANOVA found to be significant with respect to Root Dry Weight per plant (RDW) for both accessions/varieties and treatments ($p<0.001$). However, it was insignificant for treatment*accession/variety interaction ($p>0.05$). Root dry weight per plant (RDW) was stimulated at 2 dS/m in accessions 55017, 212928, 229747, 237131 and 237186 and varieties DZ-Cr-358, DZ-01-196, DZ-01-1681 and DZ-Cr-37. In the same way, it was stimulated at 4 dS/m in accession 222928 and variety DZ-01-16. No remarkable reduction was observed at 2 and 4 dS/m

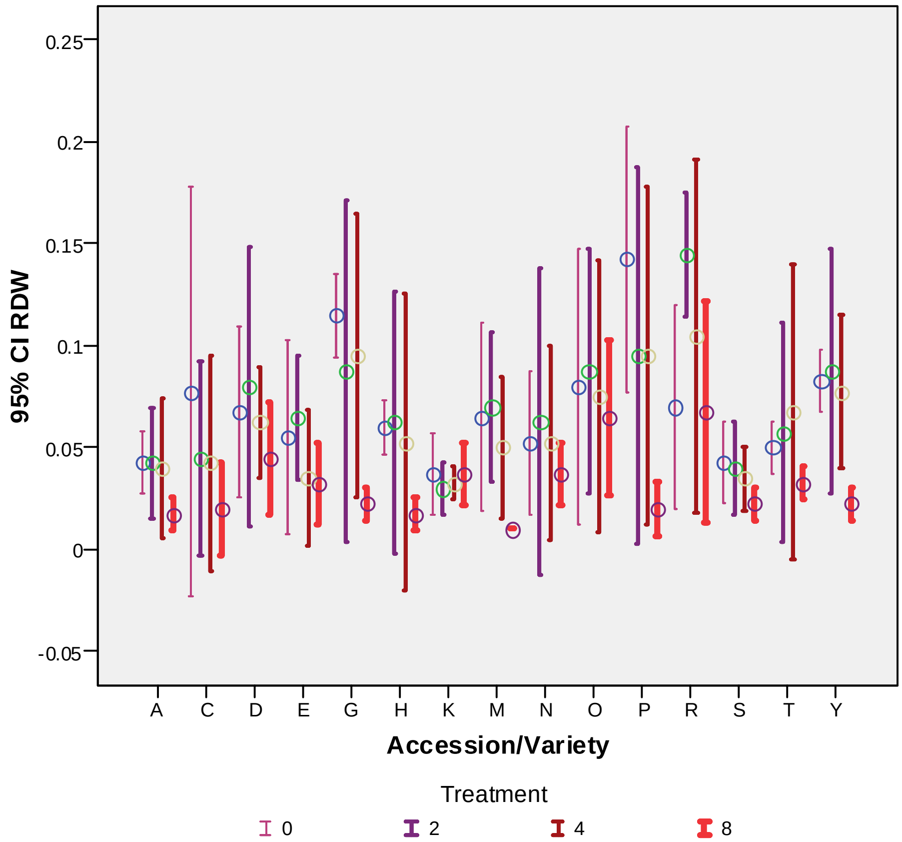

Fig. 2: Effects of salinity on Root Dry Weight per plant (RDW) of tef [*Eragrostis tef* (Zucc.) Trotter)] accessions and varieties. Key to accessions: A = 231217, C = 212611, E = 229747, G = 236514, H = 236512, M = 55017, N = 237186, O = 237131, R = 212928 and S = 205217; Key to varieties: D = DZ-01-196, K = DZ-Cr-37, P = DZ-01-1281, T = DZ-01-168 and Y = DZ-Cr-358)

treatment levels. The variation among accessions and varieties becomes evident at 8 dS/m. At this salt concentration, a reduction of 12.5-85.7% in accessions and 8.2-85.7% in varieties was recorded as compared to the control. This is in line with reports in sorghum (Boursier and Läuchli, 1992), tomato (Cruz and Cuartero, 1991), pearl millet (Ashraf and Idrees, 1993), cotton (Lin *et al*., 1997), sugar beet cultivars (Dadkhah and Grrifiths, 2006), maize (Ekeer *et al*., 2006), wheat genotypes (Hameed *et al*., 2008), lettuce (Al-Maski *et al*., 2010) and *Cicer arietinum* (Mudgal *et al*., 2010). Accessions 55017 and 212611 and varieties DZ-01-1281 and DZ-Cr-358 were most salt affected genotypes (Fig. 2).

Nevertheless, RDW was stimulated at 8 dS/m in accession 212928 by 14% as compared to the control unlike the case in other accessions and varieties. This is in agreement with the report made in forage grasses and turf grasses (Marcum, 1999). The increased rooting and the associated increased surface area is an adaptation to the osmotic and nutrient deficiency caused by salt stress. Contrary to this, other reports indicate that RDW was remained un-affected in tall wheat grass and crested wheat grass (Johnson, 1991), alfalfa (Al-Neimi *et al*., 1992) and maize (Shalhevet *et al*., 1995).

Total Dry Weight per plant (TDW): The two ways ANOVA found to be significant with respect to Total Dry Weight per plant (TDW) for both accessions/varieties ($p<0.05$) and treatments ($p<0.001$). Moreover, it was also significant for treatment*accession/variety interaction ($p<0.01$). In this context, Total Dry Weight (TDW) is the sum of AGDW and RDW. It was stimulated at 2 dS/m in accessions 205217, 212928, 229747, 236512, 236514, 237131 and 237186 and varieties DZ-01-1281, DZ-01-196, DZ-01-1681 and DZ-Cr-37 as well as at 4 dS/m in accessions 212611, 212928, 229747, 231217, 236512, 236514, 237131, and 237186 and varieties DZ-Cr-358, DZ-01-196, DZ-01-1281 and DZ-Cr- 37. However, it was affected significantly at 8 dS/m and consequently a reduction of 7.1-55.2% in accessions and 27.1-63.6% in varieties was recorded in comparison with the control. Similar findings were reported in pearlmillet (Ashraf and

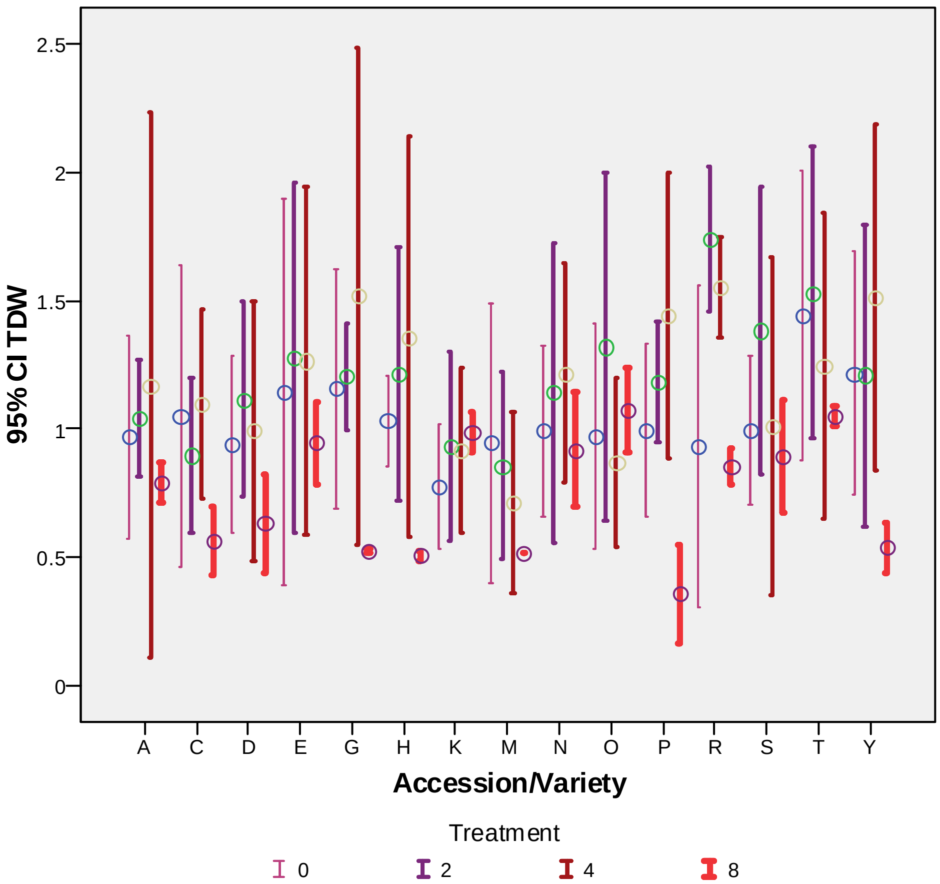

Fig. 3: Effects of salinity on Total Dry Weight per plant (TDW) of tef [*Eragrostis tef* (Zucc.) Trotter)] accessions and varieties. Key to accessions: A = 231217, C = 212611, E = 229747, G = 236514, H = 236512, M = 55017, N = 237186, O = 237131, R = 212928 and S = 205217; Key to varieties: D = DZ-01-196, K = DZ-Cr-37, P = DZ-01-1281, T = DZ-01-168 and Y = DZ-Cr-358)

McNilly, 1987), Sorghum (Azhar and McNcilly, 1987; Boursier and Läuchli, 1992), rice (Heenan *et al*., 1988; Lee and Senadhira, 1998; Shannon *et al*., 1998), cowpea (Murillo-Amador and Troyo-Die'guez, 2000) and *vigna* sp. (Raptan *et al*., 2001). Accessions have broad intraspecific variation relative to varieties; on the other hand, varieties were more affected by salinity than accessions. Varieties DZ-01-1281 and DZ-Cr-358 and accessions 236514, 236512, 212611 and 55017 were comparatively more salt affected than the rest genotypes (Fig. 3).

However, in accession 237186 and variety DZ-Cr-37, TDW was increased by 11.3 and 26.9%, respectively at 8 dS/m as compared to the control. This is in agreement with the report made in forage grasses and turf grasses (Marcum, 1999). RDW was more salt affected than AGDW and TDW where the latter two vary more or less similarly. Similar results were reported in wheat and triticale (Shalaby *et al*., 1993), cotton (Lin *et al*., 1997), sugar beet (Dadkhah and Grrifiths, 2006) and maize (Ekeer *et al*., 2006) and nevertheless, it is in contrast with reports of Dudeck *et al*. (1983) in cynodon turfgrass and Papadopoulos and Rendig (1983) in tomato were root dry weight was less affected than shoot dry weight. Plant weight at harvest is the most appropriate character to estimate plants absolute salt tolerance (Rawson *et al*., 1988) and adequate relationship between biomass and grain yield was reported (Al-Neimi *et al*., 1992). In this study also a positive correlation was obtained between grain yield per main panicle (GY/MP) (in other related study) and dry matter production.

CONCLUSION

In comparison with the control, 2 dS/m salinity level enhanced growth with respect to above Ground Dry Weight per plant (AGDW), Root Dry Weight per plant (RDW) and Total Dry Weight per plant (TDW) in some accessions and varieties; however, at 16 dS/m all accessions and varieties found to be salt sensitive with regard to all the three dry matter production parameters. Accessions 212611, 55017 and varieties DZ-Cr-358 and DZ-01-1281 were salt sensitive whereas accessions 237131, 237186, 212928 and variety DZ-Cr-37 were salt tolerant of all the genotypes studied. Root Dry Weight per plant (RDW) was more affected than AGDW and TDW where the latter two vary more or less similarly. Varieties were more salt affected than accessions.

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