Salt Tolerance of Australian Channel Millet[1]

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ABSTRACT

Undomesticated plant species may be a valuable resource for increasing crop diversity and developing crops for use in semiarid and saline areas. Australian channel millet (*Echinochloa turnerana* (Domin) J. M. Black) is very drought tolerant; however, its salt tolerance has not been tested. In drum culture studies, conducted in the greenhouse, plant height, weight, and seed grain weight were measured as a function of saline stress. Concentrations of Na, Ca, and Cl in leaves and stems increased as soil salinity increased. At salinities above 1.5 S m^{-1}, *E. turnerana* is as salt tolerant as bermudagrass (*Cynodon dactylon* L.). The grain yield by *E. turnerana* was decreased by 50% by 2.4 S m^{-1} salinity; whereas, previous studies have shown that proportionate grain yield reductions of sorghum [*Sorghum bicolor* (L.) Moench] and barley (*Hordeum vulgare* L.) occur at 1.1 and 1.8 S m^{-1}, respectively. *E. Turnerana* has high salt tolerance as either a grain or forage crop, and as a forage displays superior digestibility. This species could be exploited for future use on marginal lands.

Additional index words: **Salinity, Grain, Plant stress, New crop, *Echinochloa turnerana* (Domin) J. M. Black.**

GENETIC improvement in salt tolerance among economic plants may be achieved by: 1) hybridizing and selecting among agronomic cultivars or 2) using wild germplasm sources to either develop new cultivated species or to provide commercial lines with increased variability. In recent years, emphasis has been on the need to increase crop diversity and to preserve and use wild germplasm resources (8).

Echinochloa turnerana (Domin) J. M. Black, commonly called channel millet or channel sorghum, has been recognized as a promising forage and grain crop (4). It is a palatable and nutritious fodder grass and makes excellent hay. Since it is a native of the arid channel region of inland Australia, this species might have good potential for saline areas. The following study was conducted to determine the salt tolerance of *E. turnerana* as a contribution in assessing its potential as an economic plant.

MATERIALS AND METHODS

Salt-tolerance experiments were conducted in the greenhouse in glazed ceramic crocks, 48 cm high and 38 cm (i.d.), according to previously established drum culture procedures (6).

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The crocks were filled with 84 kg of air-dry Pachappa (Mollic haploxeralf) fine sandy loam. One 4-probe conductivity sensor (5) was permanently centered in the soil profile of each crock and a tensiometer was placed between the 4-probe sensor and the crock wall at mid-soil depth to measure soil moisture.

In mid-December 1977, seed washed in concentrated sulphuric acid for 2 min, then rinsed thoroughly in water, was sown in each of 20 crocks and 25 liters of half-strength Hoagland's (2) solution was added. Three weeks after planting, the population was thinned to seven plants/container and salinity treatments were begun. Five treatments with four replications each, included a control (unsalinized) and four levels of salinity (Table 1). The total amounts of salts and waters added were based upon average moisture retention curves for Pachappa soil (7) and were calculated to give final saturation extract conductivities (κ_e) of 0.6, 1.2, 2.4, and 3.2 S m^{-1} for the four salinity treatments. Salts, consisting of 1:1 milliequivalent proportions of NaCl and $CaCl_2$, were added to the crocks in three weekly increments. First, one-third of the total salts to be added to each crock was mixed with water to a volume of 2 liters. From this saline solution, a calculated proportion was diluted to give 2 liters of solution at one-third of the final designated salinity (Table 1). The remainder of the highly saline solution was added to the top. One week later, another one-third of the total salt was diluted to a volume of 2 liters. This time, a calculated proportion was diluted to give 2 liters of solution at two-thirds of the final designated salinity. Again, the diluted solution was applied to the soil surface and the concentrated solution was subirrigated into the crock. At the beginning of Week 3, the remainder of the salt was added to the soil surface in an appropriate amount to give the final predicted soil-water salinity. Subsequent irrigations of tap water were applied when tensiometer readings exceeded 50 kPa. Greenhouse temperatures fluctuated between a daytime high of 29.5 C and a nighttime low of 20 C.

Salinity was applied in the form of NaCl and $CaCl_2$ to prevent soil destabilization and flocculation and to prevent Ca deficiency symptoms in the plants. Salts were applied in increments so that salt shock effects would not affect plant growth.

Heading and flowering dates were noted. Plants were harvested by cutting the stems at ground level; roots were not harvested. Plant height, plant weight, primary and secondary tiller numbers, panicle length, grain weight, and 100-seed weight were recorded.

Proximate analyses were carried out by standard procedures of the Association of Official Analytical Chemists. Elements were determined by atomic absorption spectroscopy.

Straw digestibility was determined from an in vitro assay used to predict straw quality for ruminants (1).

RESULTS AND DISCUSSION

Salinity had no significant effect on initial flowering or heading dates. Heading began 39 days after seeding for some plants in all treatments, and within 10 days all plants were heading. Heading of primary and secondary tillers continued until harvest. Flowering began on Day 48 and also ranged over a 10-day period.

All factors contributing to yield were affected by the salinity treatment. Because of high variability, most yield parameters were not significantly reduced at κ_e of 0.7 or 1.45 S m^{-1}; however, at 3.21 S m^{-1}, primary and secondary tiller number, mature panicle number, panicle length, total grain weight, and 100-seed weight were all significantly reduced (Table 2).

Table 1. Applied and measured salinity treatments.

Predicted κ_e	Conductivity of irrigation water added by week to soil surface			Total added salt	Measured κ_e†
	1st	2nd	3rd		
	S m^{-1}			meq/kg soil	S m^{-1}
0.1 (Control)	0.04	0.04	0.04	0	0.11
0.6	0.09	0.15	0.33	15.3	0.70
1.2	0.18	0.33	0.78	35.8	1.45
2.4	0.36	0.62	1.09	55.6	2.36
3.2	0.48	0.87	1.45	75.2	3.21

† κ_e—conductivity of saturation extract; means of three measurements per replication.

Table 2. Effect of salinity on factors contributing to grain yield of *Echinochloa turnerana*.

Treatment κ_e	Tillers		Panicle		Grain	
	Primary number	Secondary number	Mature number	Length	wt/ plant	wt/100 grain
S m^{-1}				mm	g	mg
0.11	4.9 (1.3)†	3.1 (1.8)	1.8 (0.7)	164 (14)	1.5 (0.7)	457 (18)
0.7	4.2 (1.2)	2.5 (1.4)	1.5 (0.2)	160 (7)	1.1 (0.5)	441 (25)
1.45	3.4 (1.0)	1.4 (1.0)	1.2 (0.3)	150 (4)	0.9 (0.5)	407 (48)
2.36	3.2 (1.0)	0.9 (0.6)	1.1 (0.2)	150 (13)	0.8 (0.4)	407 (17)
3.21	2.9 (0.9)	0.8 (0.6)	1.0 (0.2)	135 (2)	0.5 (0.2)	376 (3)

† Mean with S.D. in parenthesis.

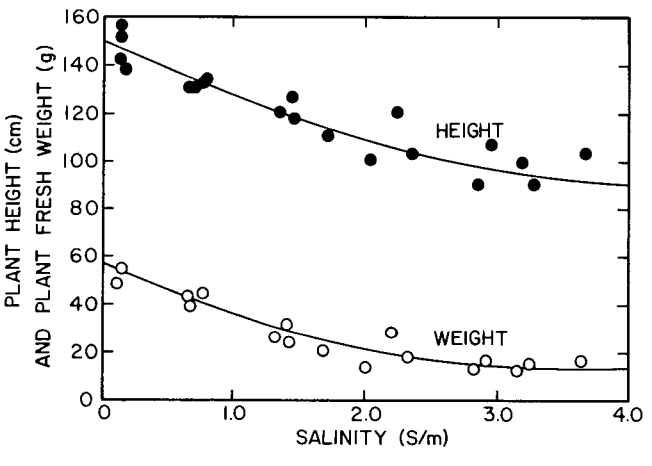

Fig. 1. *Echinochloa turnerana* plant height and weight as a function of salinity.
For height, y = 150.8 − 28.5x − 3.8x², r = 0.89.
For weight, y = 57.2 − 26.3x + 4.1x², r = 0.93.

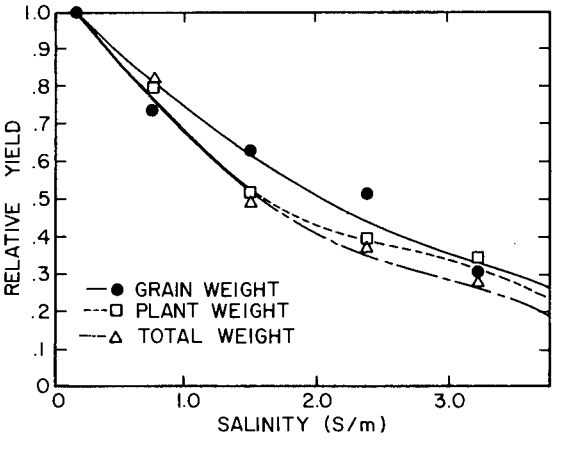

Fig. 2. *Echinochloa turnerana* fresh vegetative top weight, total plant top weight, and grain weight as a function of salinity; relative to control plants.
For vegetative weight, y = 23.3 − 68.1x + 352x², r = 0.92.
For total top weight, y = 29.5 − 82.3x + 412x², r = 0.90.
For grain weight, y = 14.4 − 28.9x + 109x², r = 0.88.

Table 3. Ion composition of combined leaves and stems of *Echinochloa turnerana* subjected to salinity.

Treatment κ_e	Na	Ca	K	Cl	NO_3
S m^{-1}	meq/100 g dry wt				
0.11	15.6 (2.6)†	20.5 (2.5)	83.4 (10.7)	33.2 (14.1)	11.5 (4.2)
0.70	25.2 (2.2)	29.5 (2.5)	89.3 (7.4)	88.7 (2.5)	14.5 (3.1)
1.45	36.5 (5.7)	35.5 (5.5)	105.4 (16.9)	116.6 (14.4)	31.6 (10.2)
2.36	48.7 (10.0)	45.0 (7.5)	103.3 (11.3)	136.9 (22.8)	24.7 (8.7)
3.21	59.1 (10.0)	52.5 (10.0)	95.4 (4.9)	143.7 (18.6)	23.1 (6.0)

† Mean with S.D. in parenthesis.

Although all plants survived the salinity treatments, the vegetative characteristics of plant height and fresh weight were notably reduced (Fig. 1). The relationship between plant weight (x, grams) and height (y, centimeters) over the salinity treatments is described by the linear equation: $y = 1.21x + 82.45$ ($r^2 = 0.93$).

Decreases in fresh vegetative weight, grain weight, and total plant weight with increasing salinity are shown in Fig. 2. In general, grain weight, although reduced, was less affected by salinity treatment than vegetative growth. The contribution of reduced grain size to the reduced grain yield was trivial (Table 2). Other factors, such as reduced tiller and panicle number, were not influential.

The ion concentration of millet leaves and stems increased as salinity levels increased (Table 3). Sodium, Ca, and Cl consistently increased; whereas, K and NO_3 levels increased at the lower salinity concentrations and then decreased slightly at the two highest salinity concentrations. For seed, we noted no significant differences in Na, Ca, or K contents with treatment; but Cl content increased from 2.4 to 5.9 meq/100/g dry weight as salinity levels were increased. Average Na, Ca, and K contents of the grain were 4.4, 4.9, and 12.6 meq/100 dry weight, respectively. We noted few differences in seed levels of Mg, Zn, Mn, Fe, and Cu among salinity treatments.

Proximate analysis of dehusked seed indicated the following composition: water, 17.75%; N, 1.86%; protein (N × 5.7), 10.6%; crude fat, 4.56%; crude fiber, 3.54%; ash, 1.55%; carbohydrates by difference, 62%. In an in vitro assessment of forage digestibility (1), channel millet straw registered a digestibility value about 14% higher than that measured for straws from wheat and barley. While it may be unrealistic to compare forage qualities for straw from a drum culture study to rangeland straw, the superior digestibility of the channel millet straw is encouraging as far as its overall agronomic potential is concerned.

Channel millet is resistant to high salinity levels even though it is only moderately tolerant at lower salt concentrations. For example, a κ_e of 0.7 S m^{-1} decreased grain yield by 25%, but 2.4 S m^{-1} was required to decrease it 50%. By comparison, grain yield of sorghum and barley were decreased 50% by a κ_e of 1.1 and 1.8 S m^{-1}, respectively (3). As a forage, channel millet ranks between bermudagrass and tall wheatgrass in salt tolerance (3). The saturation extract salinities for 50% forage-yield reductions are 1.9, 1.6, and 1.5 S m^{-1} for tall wheatgrass, channel millet, and bermudagrass, respectively. Thus, channel millet displays both drought (4) and salt tolerance to a high degree. These positive attributes for a plant which conceivably could be cultivated in marginal areas warrant further studies on assessing its food and feed potential.

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