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The mineral content of river saltbush (*Atriplex amnicola*) changes when sodium chloride in the irrigation solution is increased

D. Masters*,*, M. Tiong*,**,***, H. Norman*,*** and P.E. Vercoe**,*****

*CSIRO Livestock Industries, Private Bag 5, Wembley WA 6913 (Australia)
**School of Animal Biology, Faculty of Natural & Agricultural Sciences, The University of Western Australia, 35 Stirling Highway, Crawley WA 6009 (Australia)
***Cooperative Research Centre for Plant-Based Management of Dryland Salinity, The University of Western Australia, 35 Stirling Highway, Crawley WA 6009 (Australia)

Abstract. Chenopod shrubs accumulate Na, K and Cl. There is little information available on factors affecting the accumulation of these and other minerals in the plants. In this experiment, the accumulation of Na, Cl, K, Ca, S, P, Mg, Cu, Zn and Mn was analysed in river saltbush (*Atriplex amnicola*). Six different river saltbush genotypes (cloned from different geographical regions) were grown in the glasshouse and irrigated with 1 of 5 NaCl concentrations (0, 50, 100, 200 or 400 mM). There were 6 replicates of each treatment (180 plants in total). Plants were harvested, dried and analysed after 8 weeks of treatment. Increasing the NaCl applied increased ($P < 0.05$) the concentrations of Na (+290%), Cl (+260%) and Mn (+36%) but decreased ($P < 0.05$) K (-47%), S (-18%), Ca (-46%), Cu (-43%) and Zn (-45%). Na and K concentrations in young river saltbush grown in the low NaCl irrigation solution were not high enough to depress intake or production of ruminants. At NaCl concentrations above 100 mM, the Na and K concentrations in the plants would be predicted to significantly depress intake and growth. The S and Mg concentrations in young river saltbush plants, at all levels of NaCl treatment, were above maximum tolerable levels for ruminants and may depress intake and production. The depression in concentration of K, Ca, Cu and Zn at high NaCl treatments may also predispose ruminants to deficiencies or imbalances depending on the fertility of soil and water.

Keywords. Shrubs – Nutritive value – Trace elements – Chenopod – Sodium – Sulfur – Copper.

La teneur en minéraux d'*Atriplex amnicola *varie avec l'augmentation de la salinité de l'eau d'irrigation

Résumé. *Les chénopodes accumulent Na, K, et Cl. On dispose de peu d'information sur les facteurs qui affectent l'accumulation de ces minéraux ou d'autres minéraux dans ces plantes. Dans la présente expérience, l'accumulation de Na, Cl, K, Ca, S, P, Mg, Cu, Zn et Mn a été étudiée dans le buisson de milieu saumâtre* Atriplex amnicola*. Six génotypes différents de cette espèce (clonés à partir de différentes régions) ont été plantés sous serre et irrigués avec une des cinq concentrations suivantes de chlorure de sodium : 0, 50, 100, 200 ou 400 mM. Chaque traitement a été répété 6 fois (180 plantes en tout). Les plantes ont été récoltées, séchées et analysées après 8 semaines de traitement. L'augmentation de NaCl a augmenté ($P < 0,05$) les concentrations de Na (+290%), Cl (+260%) et Mn (+36%), mais a diminué ($P < 0,05$) celles de K (-47%), S (-18%), Ca (-46%), Cu (-43%) et Zn (-45%). Les concentrations de Na et K dans les jeunes plants élevés avec la solution d'irrigation à faible teneur en Na n'étaient pas assez élevées pour réduire leur consommation par les ruminants ou leurs performances zootechniques. A des concentrations de NaCl supérieures à 100 mM, on peut s'attendre à une réduction significative de la consommation et de la croissance chez les animaux. Quel que soit le niveau de salinité étudié, les concentrations de S et de Mg dans les jeunes plantes ont été au-dessus des limites tolérables pour les ruminants et pourraient réduire leur consommation et les performances de croissance des animaux. Les concentrations réduites de K, Ca, Cu et Zn pourraient aussi prédisposer les ruminants à des déficiences ou des déséquilibres en fonction du sol et de l'eau.*

Mots-clés. *Arbustes – Valeur nutritive – Oligo-élément – Chénopode – Sodium – Soufre – Cuivre.*

I – Introduction

Halophytic shrubs, particularly those from the *Chenopodiaceae* family, are used in many arid and saline landscapes to provide feed for livestock. River saltbush is a chenopod shrub native to Australia and a species considered to be among the most productive natural forages in the Australian rangeland. River saltbush is also being planted in agricultural areas, where it has become an important tool in the revegetation and rehabilitation of salt-affected land. Studies on the feeding value of these salt tolerant shrubs have usually focussed on biomass, energy and protein (Watson, 1990; Gihad and El Shaer, 1994), or, to a lesser extent, minerals (Watson and O'Leary, 1993; Watson *et al.*, 1994). In these reports there is information from a range of different shrubs, grown under variable environmental conditions. The extent to which the feeding value of shrubs varies with changes in the salt content of the soil or water has not been reported. However, reports of negative correlations between Na and both N and K indicate environment may significantly affect nutrient composition (Atiq-ur-Rehman *et al.*, 1999). Others have also reported relationships between cation concentrations and the levels of toxic compounds such as oxalates in the plants (Osmond, 1967). In this study changes in mineral composition of river saltbush (*Atriplex amnicola*) grown under a range of different salinities are reported.

II – Materials and methods

Thirty clonal cuttings from each of 6 river saltbush genotypes were collected from 3 different locations in Western Australia (2 plants per location) between May and June. The plants used for the cuttings had shown significant variation in nutritive value in a previous study. Clones were approximately 5 cm tall when collected and were dipped in a commercial root-striking hormone (Striking Hormone: Medium Wood - Richgrow Garden Products, 3 g/kg Indol-Butyric Acid) and placed in 250 ml pots containing a 1:1 coco peat and washed gravel mix. Approximately 1 month later, each clone was removed from the pot carefully and rinsed in a bucket of water to remove excess coco peat and gravel from the roots. The plants were transferred to a glasshouse where they were transplanted individually into 140 ml pots containing a 9:1 mix of washed white sand and vermiculite. The bases of the pots were also lined with 1 mm^2 fly-wire mesh (10 cm x 10 cm) and a 1 cm layer of coarse gravel to prevent loss of the sand and vermiculite mix.

In the glasshouse, plants were watered with fresh water every two days using a watering can. A commercial liquid fertiliser (Greenpiece - Single Grow, Flairform) was also included when watering at the rate of 3 ml/l water (first month after potting) or 4.5 ml/l water (second month after potting). The liquid fertilizer, prior to dilution, contained the following mineral concentrations (%w/v): P 1.3, K 4.9, Ca 1.8, Mg 0.6, S 0.9, Fe 0.03, Mn 0.015, Cu 0.0015, Zn 0.0015, B 0.003 and Co 0.0002. Pots were watered to capacity with approximately 90 ml of the diluted fertiliser solution. Clones were examined weekly and those that appeared to grow upright had approximately 2 cm of the plant tips cut with scissors to encourage lateral shoot growth.

Two months after potting, clones were placed on 5 glasshouse benches measuring 200 cm x 90 cm x 90 cm (L x W x H). Each bench held 6 rows of clones and there were 6 replicates from each genotype within each row (36 cuttings per bench). Rows, as well as cuttings within rows, were repositioned randomly on the benches on a weekly basis, to minimise experimental bias. From each genotype, 6 individual cuttings were randomly assigned to 1 of 5 NaCl treatments; these were 0, 15, 30, 60 or 120 mM NaCl for the first 3 weeks of treatment followed by 0, 50, 100, 200 and 400 mM NaCl for the next 5 weeks of treatment. All groups received the same amount of water at each application.

At the end of both treatment periods, stems were cut 10 cm from the base of the plant and placed in labelled paper bags. The 180 samples were subsequently dried in an oven for 24 hours at 65℃ before being ground through a 1 mm sieve using a Cyclone grinder (CYCLOTECH 1093 Sample Mill) prior to analysis. P, K, S, Na, Ca, Mg, Cu, Zn and Mn concentrations were determined in a commercial laboratory (CSBP Soil and Plant Laboratory, Bibra Lake, WA, Australia) using the standard operating methods for the Thermo Iris Intrepid Duo ICP analyser. Plant samples were digested by the method of McQuaker *et al.* (1979) prior to analysis. Cl was measured with a Lachat Flow Injection Analyser using the method of Zall *et al.* (1959).

Data analysis was performed using the statistical software Genstat 5, Release 4.2. An analysis of variance (ANOVA) was used to test the statistical significance of differences among the means for salt treatments; the 6 clones per genotype were pooled for this analysis.

III – Results

The concentration of Na, Cl and Mn were increased ($P < 0.05$) by 290, 260 and 36% respectively when NaCl in the irrigation solution was increased from 0 to 400 mM. The concentrations of K, S, Ca, Cu and Zn were decreased ($P < 0.05$) by 47, 18, 46, 43 and 45% respectively when NaCl in the irrigation solution was increased from 0 to 400 mM (Table 1). Mg also tended to be lower (-31%) in plants irrigated with high concentrations of NaCl ($P = 0.07$).

Table 1. Effect of NaCl concentration in the irrigation solution on the concentration [dry matter (DM) basis] of macro and micro minerals in river saltbush

Mineral	Sodium chloride concentration in the irrigation solution (mM)					Standard error of mean	P
	0	50	100	200	400		
Sodium (g/kg)	23.9	38.7	46.0	54.3	69.3	2.95	<0.001
Chloride (g/kg)	31.8	50.5	58.0	68.4	82.4	3.35	<0.001
Manganese (mg/kg)	43.8	58.4	55.7	61.8	59.8	3.52	<0.05
Potassium (g/kg)	41.5	35.5	30.5	28.1	26.3	1.53	<0.001
Phosphorus (g/kg)	5.11	5.43	4.71	4.47	4.47	0.50	>0.1
Sulfur (g/kg)	5.87	5.59	5.27	5.02	4.84	0.22	<0.05
Calcium (g/kg)	6.96	5.54	4.60	4.09	3.75	0.35	<0.001
Magnesium (g/kg)	9.82	9.72	8.34	7.38	6.80	0.86	=0.07
Copper (mg/kg)	12.9	10.4	8.3	7.7	7.4	0.52	<0.001
Zinc (mg/kg)	80.2	109.2	48.0	41.7	44.5	13.3	<0.01

IV – Discussion

The results of this study indicate that consumption of salt accumulating *Atriplex* shrubs may disrupt animal production by providing minerals in excess, imbalance or possibly deficiency. Using the prediction equations of Masters *et al.* (2005) to estimate the production potential from these plants (based on Na and K content), young Merino sheep would consume approximately 1.3 kg organic matter (OM)/d and grow at 180 g/day if given *ad libitum* access to plants grown with no NaCl in the irrigation solution. At the other extreme, consumption would be predicted to fall to 0.67 kg OM/d and liveweight gain to 20 g/day if the same sheep were fed the saltbush irrigated with 400 mM NaCl. Sulfur concentrations, although reduced with high NaCl irrigation, were very high across all treatments. Others have reported appetite and growth depression in sheep and cattle fed 3-4 g S/kg DM (Kandylis, 1984). All plants analysed in the current experiment contained more than 4 g/kg and similar high concentrations have been reported in adult plants in the field (Norman *et al.*, 2004), so the possibility of sulfide toxicity from saltbush is real. Similarly, the concentration on Mg tended to decrease as NaCl treatment increased. The concentrations of Mg in the plants were always well above the deficiency range (0.4-2.0 g/kg DM) but also above the maximum tolerable level of 6 g/kg DM for sheep and cattle (National Research Council, 2005).

K, Ca, P, Cu, Zn were all within the adequate range for livestock production and health (Underwood and Suttle, 1999). However, the reduction in concentrations of some of these elements requires further consideration. Concentrations of K, Ca, Cu and Zn were all reduced by more than 40% at the highest concentrations of NaCl in the irrigation solution. This occurred even though the plants were all provided with a multi-mineral fertiliser for the first 2 months of growth. Under commercial conditions, application of fertiliser is much less likely as the return on fertiliser investment from salinised and/or arid land is low. The potential for high NaCl to depress the concentration of essential minerals in plants grown in soils with low fertility therefore justifies further investigation.

Finally, these plants are unusual in that the concentrations of some elements exceed the maximum tolerable levels while others are close to the deficient range. This predisposes livestock to mineral imbalances. From the data collected, the best example of this is the interaction between Cu and S. In ruminants consuming a hay diet, increasing the S content from 1 to 5 g/kg DM reduced the absorbability of Cu by 50% (Underwood and Suttle, 1999). In the current study, S in saltbush was always above 4 g/kg DM but, importantly, the ratio of S to Cu went from 455:1 with no NaCl treatment to 654:1 at the highest. These ratios are higher than the range reported for temperate green pastures (238-465) that were collected and analysed every 2 months for a full year (Langlands *et al.*, 1981). Potential for induced Cu deficiency is therefore high. Similarly, there are complex interactions between Ca, K, Na, Mg, P, S and Cl that influence Ca supply to pregnant and lactating ruminants. Acidic diets, those where the cation-anion balance (calculated in milliequivalents) is below 100, enhance vitamin D activity and Ca absorption and are therefore favourable for Ca homeostasis (Underwood and Suttle, 1999). The river saltbush plants in the current study had a cation-anion balance in excess of 1500 indicating a potential risk of Ca deficiency in grazing ruminants at times of high demand during pregnancy and lactation. The potential for this imbalance to influence production and Ca homeostasis in growing ruminants is less well known although young lambs have high feed intakes and daily live weight gains with a cation-anion balance up to 700 (Fauchon *et al.*, 1995).

V – Conclusions

The concentrations of Na and K in young river saltbush grown in a low NaCl irrigation solution are not high enough to depress intake and production of ruminants. At NaCl concentrations in the irrigation solution above 100 mM, the Na and K concentrations in the plants would depress intake and growth significantly. The S and Mg concentrations in young river saltbush plants, at all levels of NaCl treatment, were above maximum tolerable levels for ruminants and may depress intake and production. Depending on the range and concentrations of minerals supplied to these plants from soil and water, the depression in concentration of K, Ca, Cu and Zn caused by increased NaCl in the irrigation solution may also predispose grazing ruminants to deficiencies or imbalances.

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