The growth response of tropical and sub-tropical forage species to increasing salinity

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Introduction

There is currently a growing coal seam gas (CSG) industry in Queensland, Australia. The industry requires beneficial-use strategies to consume the significant volumes of water released during CSG extraction. Irrigation of tropical and sub-tropical forage species for beef production is one option, however coal seam (CS) water is of varying quality due to moderate to high salinity and alkalinity. The application of chemically amended CS water over time could potentially increase soil salinity, which is known to reduce plant biomass production. While there were studies of salinity tolerance of many tropical and sub-tropical forage species 30 years ago, there is a need to examine the tolerance of more recently released species and cultivars which are suitable for planting in the Queensland CSG area.

Methods

A flood and drain hydroponic system was used to study the dry matter (DM) response of several tropical and sub-tropical forage species (Table 2) to increasing salinity in a semi-controlled environment at Cleveland, Australia from December 2011 to June 2012. Three hundred and thirty-six pots (180 mm deep, 90 mm wide) were arranged as a split-plot incomplete block design with 7 salinity treatments (Table 1). There were 3 duplicates of each treatment and 2 replications. Within each of the 7 salinity treatments, species were segregated based on growth rate and habit to prevent shading. Otherwise species and cultivars were randomised.

Salinity treatments were established based on increasing rates of NaCl and $CaSO_4{\cdot}2H_2O$ to prevent sodium induced calcium deficiency. The calcium activity ratio (CAR) of the bulk solution was maintained at ≥0.03 (Deifel *et al.* 2006). The electrical conductivity (EC) of the basal nutrient solution was ~1.1 dS/m and comprised 5.1 g ‘Flowfeed EX7’, 10.2 g KNO_3, 13 g $MgSO_4$ and 51.1 g CaH_3NHNO_3 in 92 L of water. Plants were grown for 10 weeks before salinity treatments were increased incrementally (by a maximum of 1.5 dS/m/day) until the desired level was attained. The pH of the solutions was adjusted to 6 every second day and the solutions replaced every 7 days. To prevent an overestimation of salinity tolerance, salinity estimates were based on total accumulated regrowth (DM) over 100 days at the maximum salinity treatment (Deifel *et al.* 2006). Four intermittent harvests occurred during this period.

Table 1. Concentrations of NaCl and Ca (as $CaSO_4{\cdot}2H_2O$) used to achieve the respective solution electrical conductivities (ECs) (approximate) and maintain a CAR ≥ 0.03.

Soil solution EC (dS/m)	1.1	2.4	4.8	11.5	14.4	17.3	20.1
NaCl (mM)	2.6	18.5	46.6	97.7	124.4	151.1	177.7
$^1Ca^{2+}$ (mM)	2.6	2.6	2.6	8.4	10.1	11.7	12.6

[1] includes 2.6 mM Ca^{2+} from the basal nutrient solution

Results and discussion

The relationship between salinity and DM yield was non-linear for all species as observed by Steppuhn (2005) and Kopittke *et al.* (2009). Dry matter (DM) yield response with increasing salinty was modelled as DM yield = A(ln(salinity))+B. EC_{75} and EC_{50} thresholds were calculated (Table 2) for each species to demonstrate the salinity level that reduced growth by 25% and 50% respectively, relative to the control. As anticipated, *Chloris gayana* was the most salt tolerant species. The maximum salinity treatment was not sufficient to cause a EC_{50} in *Chloris gayana* cv. Finecut, with a maximum biomass reduction of 44% at the highest salinity treatment of 20.1 dS/m. The EC_{50} of *Chloris gayana* cv. Toro (19 dS/m) was lower than the published threshold for *Chloris gayana* cv. Pioneer (Table 3). An EC_{50} of between 6.2 and 5.2 dS/m was observed in *Medicago sativa* cultivars; significantly lower than the published threshold of 10.2 dS/m for *Medicago sativa* cv. Hunter grown in soil media. There was no significant difference in DM among the cultivars of *Medicago sativa* (P = 0.168) or *Chloris gayana* (*P* = 0.241). *Leucaena leucocephala* had an EC_{50} at 4.8 dS/m, consistent with findings of Hansen and Munns (1988) in similar experimental conditions.

Differences in salinity thresholds between studies may be attributed to a number of factors: (1) methodology (it is suggested that the effect of salinity may be exacerbated in solution culture due to the absence of matric potential and cation exchange capacity present in soil based systems); (2) failure to account for sodium induced calcium deficiency; (3) differences in evapotranspiration demand (ETD) (low

Table 2. Estimated salinity tolerance of several tropical and sub-tropical forage species based on a 25% and 50% DM reduction relative to the control.

Species	EC_{75}	EC_{50}	Variance explained by model
Chloris gayana cv. Finecut	5.8	*	0.87
Chloris gayana cv. Toro	4.6	19.0	0.73
Medicago sativa cv. Multileaf	2.6	6.4	0.99
Medicago sativa cv. Titan 9	2.5	5.7	0.95
Medicago sativa cv. L91	2.5	5.7	0.95
Medicago sativa cv. Force 10	2.4	5.2	0.94
Leucaena leucocephala cv. Tarramba	2.3	4.9	0.96

*DM yield reduction <50% at 20.1 dS/m

Table 3. Published salinity tolerance thresholds based on 50% yield reduction relative to the control.

Species	EC_{50}	Experimental system	Reference
Chloris gayana cv. Pioneer	23.2	Small pots - soil media	(Russell 1976)
Medicago sativa cv. HunterRiver	10.2	Small pots - soil media	(Russell 1976)
Leucaena leucocephala cv. K8	~5	Sand/solution culture	(Hansen and Munns) 1988)

ETD results in reduced salt uptake and an increased ability to grow at a given salinity); (4) duration of exposure (short-term studies may not wholly reflect the effect of specific ion toxicity); (5) choice of model to explain results; and (6) intraspecific variation (Kopittke *et al.* 2009; Tavakkoli *et al.* 2010).

Conclusion

Rhodes grass (*Chloris gayana*) was the most salt tolerant species tested followed by lucerne (*Medicago sativa*) and then leucaena. Intraspecific variation was not evident within cultivars of *Chloris gayana* and *Medicago sativa*. The lower EC_{50} thresholds obtained for *Chloris gayana* and *Medicago sativa* in comparison to those published by Russell (1976) may be due to the different cultivars tested and also to differences in the experimental system and ETD.

On-going analysis of specific ion uptake will provide further understanding of the response of the forage species to increasing salinity. Further work is also needed to identify improved salinity tolerance within lucerne and leucaena cultivars.

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