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Reuse of Saline Groundwater in Landscaping

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Abstract: Groundwater resources are the main source of water supplies for 30% of the world's population. We have studied the use of saline groundwater to grow four turfgrass species (Paspalum vaginatum, Sporobolus virginicus, Distichlis spicata - three halophytes; and Pennisetum clandestinum – a nonhalophyte) over two years under saline irrigation (13 dS m^{-1}) groundwater or with fresh water, both at approximately 60% replacement of net evaporation. Under non-saline conditions, water use by Paspalum and Pennisetum was 91-93% of net evaporation, being higher than Distichlis (at 84%) and Sporobolus (at 75%). Under saline conditions, water use of Pennisetum and Paspalum were both significantly reduced (to 65-72% of net evaporation), whereas it was slightly reduced in Distichlis and Sporobolus water use. Soil salinity was assessed with the EM38 and by soil sampling, a strong correlation was found between the two methods (r2=96%). Soil chemical properties have been monitored as they influence soil-water relationships since not all of the moisture in the soil is available for plant to use, the proportion of exchangeable cations that has the highest fraction of exchangeable is Ca+2 (74% of total CEC) while Na was 41% of total CEC). Irrigation with saline water reduced turfgrass colour (i.e. 'greenness') in Pennisetum whereas it was not affected in Distichlis, Paspalum and Sporobolus. Growth, represented by clipping weight per m^2, was 1.5, 0.7, 0.5 and 0.3 in Paspalum, Pennisetum, Distichlis and Sporobolus, respectively. Na+ concentration in leaf tissues increased 3 fold more in Pennisetum compared with the halophytic grasses. Elucidation of quantitative relationships between growth, water use and root-zone salinity and water content will improve basic knowledge on the functioning of halophytes managed for turfgrass and contribute to the sustainable management of these species on under saline irrigation conditions.

Key words: Saline · Groundwater · Landscaping

INTRODUCTION

Worldwide there is one quarter billion ha irrigated using about 70% of the surface water [1]. A study in U.S. shows an average of 58% of the fresh water resources are used to irrigate the out-door landscape, while in Florida, the average is 71% [2]. In Australia, many rural and coastal towns have saline groundwater and/or saline soils. In Western Australia alone, more than 30 rural towns are adversely affected by dryland salinity, with threats to valuable infrastructure and amenity areas [3], likewise it is in the Arabian Peninsula [4].

Salinity impacts on community budgets to maintain, or repair, infrastructure; as well as increasing social costs, due to the resulting poor quality of ovals and turfgrass amenity areas. Salt-tolerant turfgrasses will improve the aesthetics of public open spaces and ovals, with benefits to the community. Moreover, use of saline water, rather than potable water supplies, to irrigate turfgrass areas will help conserve our precious high-quality water resources and reduce net input of water within town sites.

According to International Water Management Institution (IWMI) Libya was listed under group 1, which represents countries that face physical water scarcity in 2025. These countries have an annual

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freshwater availability of less than 1000 m^3 per capita (the index for water scarcity) and also they need to convey and regulate 25 percent or more of the 1995 levels to meet their 2025 needs. Thus, it is worthwhile to consider the available massive amount of saline water resources [5].

A high saline water table is threatening the farming systems in the wheat belt of Western Australia, The Shire of Wagin has suffered from the rising in water table and to combat the problem, production bores for dewatering were installed during 2005. The pumped groundwater has an electrical conductivity (EC_w) of ~13.5 dS m^{-1}, about one-quarter of the salinity of seawater and is pumped out to nearby salt lakes for evaporation. We proposed putting this saline water source into use, given that good quality drinking water was being used to irrigate the recreational areas and sporting ovals in the town. Use of the saline groundwater could therefore conserve valuable potable water sources.

Groundwater resources are the main source of water supplies for 30% of the world's population [6]. However, many limitations threaten these sources (i.e. salinity and chemical pollution from either industrial residues or agricultural pesticides) and in the agricultural zone of Australia much of the ground water is saline [7].

The research evaluated the performance of three halophytic grass species (*S. virginicus, P. vaginatum* and *D. spicata*) that can be grown as turfgrasses, compared with the current standard, (*P. clandestinum*), a non-halophyte. Halophytes are plants that naturally grow in saline habitats, such as on the shores of salt lakes or in salt marshes [8]. The three halophytic grasses were identified as 'best-bet' species, but required evaluation; with the exception of *P. vaginatum*, knowledge on these species was limited. Yet, use of salt tolerant turfgrasses holds much promise for improvement of amenity areas in regions affected by salinity.

MATERIALS AND METHODS

The experiment was conducted to compare the responses of four grass species to irrigation with saline groundwater, with control plots being irrigated with scheme water. The experiment was conducted in the field at Wagin. An area of public open space (GPS location - 33°18'38.54"S and 117°20'52.99"E).

Randomised block design was followed with 4 species x 2 irrigation salinity treatments x 3 replicates = 24 plots, arranged in with irrigation water salinity as the block factor. Each plot was 3 x 3 m.

Plots were planted as plugs in October 2006 and irrigated with non-saline water during the establishment phase. Plots were managed using current industry practices. Mowing at 30 mm every second week, using a walk-behind rotary mower, commenced several weeks after planting. Saline irrigation treatments commenced in mid-January 2007.

Plots were irrigated using a pop-up sprinkler system MP2000 Rotator, controlled via a RainBird irrigation controller. Non-saline water was 'scheme drinking water', whereas saline groundwater was sourced from a production bore 700 meters away. Irrigation was applied before sunrise. Irrigation volumes were adjusted every 2 weeks, to replace ~60% of net evaporation based on the average daily net evaporation data from the previous week. Weather data was collected from onsite standard weather station.

Soil salinity was measured at fortnightly intervals during irrigation and monthly during times with no irrigation, by collecting soil samples at two depths, 0-25 cm ('topsoil') and 25-50 cm ('subsoil'), using a 7 cm diameter soil auger. Samples were wet weighed, oven dried at 105°C and weighed again to calculate soil water content. Measurements of soil $EC_{1:5}$ were conducted for subsamples (20 g) of dry soil extracted in 100 ml of DI water, shaken for 16 hours and then centrifuged at 3000 rpm for 5 min. Turf clippings were collected from each plot individually (mowing fortnightly), weighed, a subsample taken and weighed and then oven-dried at 65°C.

RESULTS AND DISCUSSION

The four turfgrasses varied in the time taken to fully cover the plots. *P. clandestinum* and *P. vaginatum* had established full cover by the start of the first irrigation season, whereas *S. virginicus* and *D. spicata* had only covered about 80-85%. Thus, data for the second irrigation season (27th September 2007 to 7th April 2008) will be reported here.

Soil Salinity: Soil salinity initially showed slight decreases in plots irrigated with non-saline water, so in control plots the soil salinity was low compared with levels in those irrigated with saline groundwater (Figure 1A). In plots irrigated with saline groundwater, $EC_{1:5}$ (EC of a 1:5 soil:water extract) in both the topsoil and subsoil initially showed small increases, but substantial increases occurred during summer when larger volumes of saline irrigation water were applied owing to

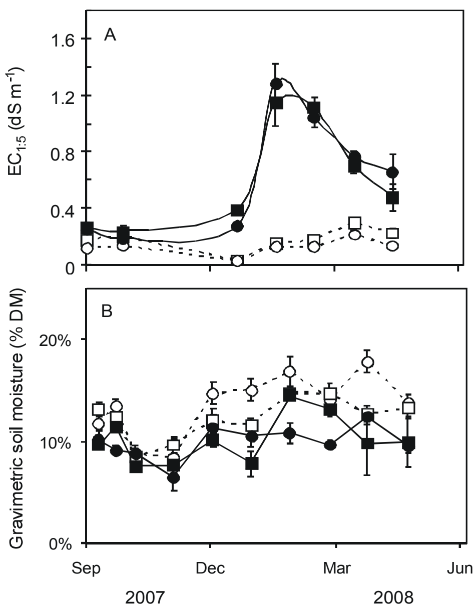

Fig. 1: Soil salinity (A) and soil water content (B) in turf plots irrigated with non-saline water (open symbols) or saline groundwater (EC_w 13.5 dS m^{-1}) (closed symbols). Measurements were taken for topsoil (0-25 cm) (circles) and subsoil (25-50 cm) (squares) in 9 m^2 field plots at Wagin, Western Australia. Values are the means of 5 replicates with each replicate being an individual plot. Bars denote standard errors. The continuous line under the graph indicates the irrigation season; the dotted line indicates the subsequent period without irrigation

the increasing evaporative demand (Figure 1A). Soil water content showed no significant difference between plots receiving saline and non-saline irrigation water (Figure 1B). Soil water content was, however, dynamic across the irrigation season; depending on sampling date it ranged from 8-15% of soil dry mass. The data on $EC_{1:5}$ (Figure 1A) and soil water content (Figure 1B), providing information on the intensity of salinity likely experienced by the plant roots. EC was similar to levels in the saline irrigation water during the first few weeks of saline irrigation, but then increased substantially during summer. Thus, the turfgrasses were exposed to high levels of salinity during the summer irrigation period, but levels then decreased the following winter as salts were leached by rainfall.

Turfgrass Growth: Turf growth was evaluated as the dry mass of clippings collected at each mowing (data not shown). Comparison of the saline versus non-saline irrigated plots showed that saline irrigation decreased total clipping dry mass by 31% for *P. clandestinum*, whereas the changes for the three halophytic species were slight: 10 and 6% reductions for *P. vaginatum* and *S. virginicus*, respectively and a 4% increase for *D. spicata*. Growth of *P. clandestinum* was inhibited during the summer months when salinity tended to be highest.

The species differ in inherent biomass production. *P. vaginatum* produced most clippings under saline and non-saline irrigation. Relative to *P. vaginatum*, the other three species declined in clippings produced in the order *P. clandestinum* (64% and 54% of dry mass in non-saline and saline irrigation, respectively) > *D. spicata* (46% and 53%, respectively) > *S. virginicus* (34% and 35%, respectively).

Thatch accumulation in *P. clandestinum* was also reduced by salinity, whereas this growth parameter was not affected in the three halophytic species (Table 1).

Irrigation with saline water restricted growth of weeds in and adjacent to, those plots. No weeds were evident in the blocks irrigated with saline water, whereas 14 weed species were present in the non-saline blocks.

Turfgrass Colour: Colour is an important quality characteristic of turfgrass surfaces and is also considered a good indicator of turf health [9]. Salinity can cause damage to leaves, the appearance of brown leaf tips has been termed "leaf firing". Under saline irrigation, *P. clandestinum* showed a large degree of leaf firing by mid-summer, whereas such damage was not evident in the three halophytic turfgrasses. These changes in turfgrass colour can be detected using a Chroma meter to measure spectral properties of reflected light. Surfaces with a higher hue angle remained green. The three halophytic turf species, *D. spicata, S. virginicus* and *P. vaginatum* remained green; hue angles were similar to plots irrigated with non-saline water (Figure 2). By contrast, *P. clandestinum* that turned brown and hue angle had declined markedly (Figure 2). Interestingly, when rainfall commenced and use of saline irrigation water was ceased, the colour of *P. clandestinum* recovered (Figure 2).

Ion Concentrations: Leaf damage in *P. clandestinum* was associated with high concentrations of salt (i.e. Na and Cl) and lower K:Na ratio, in the leaf tissues. Leaf ion concentrations were measured at regular intervals, the data during mid-summer are discussed here as this was when symptoms of damage were most extreme. When irrigated with saline water, leaf Cl concentration (mmol g^{-1} dry mass) in *P. clandestinum* had increased to 0.92±0.13,

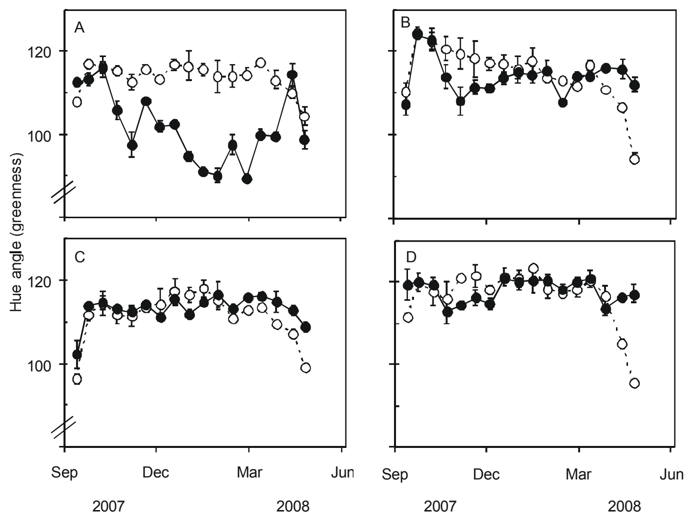

Fig. 2: Hue angle (greenness) of turfgrass species irrigated with non-saline water (--○--) or saline groundwater (EC_w 13.5 dS m^{-1}) (---●---), for (A) *P. clandestinum*, (B) *P. vaginatum*, (C) *S. virginicus* and (D) *D. spicata*. Grown in 9 m^2 field plots in Wagin, Western Australia and sampled every 2 weeks. Values are the mean of 3 replicates ± standard errors. The continuous line under the graph indicates the irrigation season; the dotted line indicates the subsequent period without irrigation

Table 1: Comparison of thatch dry mass of four turfgrass species at the conclusion of the trial. Cores were taken from each of the 9 m^2 plots. Thatch, the plant matter present above the soil surface, was washed free of soil, dried at 65°C and weighed. Values are means of 3 replicates ± standard errors

	Thatch dty mass (kg m^{-2})	
Species	Non-saline	Saline
Pennisetum clandestinum	7.60±1.91	4.83±0.72
Paspalum vaginatum	3.70±0.57	3.70±0.85
Sporobolus virginicus	3.72±0.87	3.80±0.48
Distichlis spicata	2.74±0.34	2.60±0.27
LSD ($P < 0.05$) species	1.89	
LSD ($P < 0.05$) treatment	1.34	
LSD ($P< 0.05$) (species x treatment)	2.68	

Table 2: Tissue K:Na ratio for four species irrigated with non-saline and saline water. Data represents pooled values for measurements made every two weeks and averaged during the irrigation seasons, season (1: Jan-Apr 07; 2: May-Sep 07; 3: Sep 07-Apr 08; 4: Apr-Jun 08). The concentration of ions was calculated in mmol g^{-1} dry weight of leaf tissue samples

Species	Treatment	K:N Rotio (Irrigated season 1)	K:N Ratio (Non-irrigated season 2)	K:N Ratio (Irrigated season 3)	K:N Ratio (Non-irrigated season 4)
Pennisetum clandestinum	Non-saline	4.2±0.4	8.3±0.7	2.3±0.3	3.0±0.7
	Saline	0.5±0.03	2.4±0.6	0.5±0.2	0.3±0.1
Paspalum vaginatum	Non-saline	3.1±0.4	7.4±1.3	2.5±0.4	1.7±0.6
	Saline	0.7±0.004	3.8±1.1	0.6±0.05	1.3±0.6
Sporobolus virginicus	Non-saline	6.1±1.0	5.6±0.9	3.2±0.3	3.0±0.006
	Saline	1.1±0.1	1.9±0.2	1.5±0.2	1.2±0.8
Distichlis spicata	Non-saline	7.4±1.3	8.1±1.3	8.4±0.9	7.5±2.2
	Saline	1.5±0.1	3.3±0.4	1.7±0.2	2.9±0.6

whereas Cl concentrations in the three halophytic species were: *P. vaginatum*, 0.56±0.06; *S. virginicus,* 0.46±0.02; *D. spicata*, 0.30±0.04. Leaf K:Na ratio in *P. clandestinum* had declined to 0.22, whereas in the three halophytic species it was: *P. vaginatum*, 0.46; *S. virginicus,* 1.21; *D. spicata*, 1.48. These differences indicate a poor capacity for leaf ion regulation in *P. clandestinum*, as compared with the three halophytic species.

K:Na ratio in the *P. clandestinum* was 4-fold more than the average of the other 3 tested halophytic species, this ratio dropped in the first irrigation season (112 days) to 0.2 of the initial ratio for plots irrigated with control water and 0.03 to saline irrigated plots, for *P. vaginatum* the same drop in the ratio was for the control irrigated plots but higher for the saline irrigated ones (0.8). The ratio was slightly improved in *S. virginicus* under control irrigation and declined to 0.2 of the initial ration under saline irrigation, *D. spicata* had a ratio of 0.9 for control irrigated plots and 0.2 for saline irrigated plots.

Over all the study period *D. spicata* and *S. virginicus* coordinated to maintain high K:Na ratio for both saline and control irrigated plots when compared to the other 3 species and *P. vaginatum* shows quick recovery in regards to having high K:Na [10].

CONCLUSION

This study demonstrated the potential use of halophytic turfgrasses as high quality turf surfaces when irrigated with saline water, [11, 12] reported that proper saline irrigation scheduling lead to sustainable farming. It has been reported earlier that *Distichlis spicata* tolerates up to 35 dS m^{-1} [13], but such high tolerance was associated with 50% reduction in growth. The reduction, however could be an advantage in turf industry as it reduces the maintenance requirements such as mowing, aeration and fertilizer application which are the most expensive costs in turf industry [14].

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