Research note: Responses of the perennial Australian native grass *Eriachne benthamii* to flooding

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Abstract

The perennial grass *Eriachne benthamii* (Hartley swamp wanderrie) (Poaceae) is native to central Australia. The present laboratory study demonstrates that the ability of this species to survive in seasonally wet grasslands is already present at an early seedling stage. While flooding of seedlings for 1–4 weeks at ages of 4–9 weeks reduced shoot weight, height, number of leaves and leaf area, plants survived and grew well. Research is required on the morphological and/or physiological mechanisms, which lead to the observed tolerance to flooding in *E. benthamii*. Since it can tolerate prolonged flooding, *E. benthamii* may be a useful species for the rehabilitation of disturbed and degraded rangeland areas, which are prone to periodic flooding.

Introduction

The importance of Australian native grasses for sustainable agriculture and environmental management is now well recognised. Native perennial grasses can be useful in natural or artificial seeding of rangelands and low maintenance recreational areas (Archer and Robinson 1988; Robinson and Archer 1988), in colonisation of areas degraded by erosion and overgrazing (Water and Rivers Commission 2003) and during land restoration of mined areas (Lodge and Whalley 1981; Lodge 1981).

Perennial grass species found in arid tropical Australia are exposed to periodic flooding, which can vary in duration. Grasses adapted to regular flooding have developed morphological and physiological mechanisms to cope with waterlogged conditions (Setter and Waters 2003). Tolerance to flooding is defined as the absence of a negative response in growth to flooding (Dias-Filho and Carvalho 2000), and more specifically, as the ability to produce biomass under flooded conditions relative to unflooded conditions (Kercher and Zedler 2004).

The genus *Eriachne* is native to Australia with 48 species, of which 6 extend to Asia (Lazarides 1995; Lazarides *et al.* 2005). Plants occur on poor soil in monsoonal and tropical arid to semi-arid areas, are drought-tolerant and respond to winter and summer rain. *Eriachne benthamii* (Hartley swamp wanderrie) (Poaceae) (Lazarides 1995) occurs in South Australia, Western Australia, Queensland and the Northern Territory and is often the dominant perennial species in seasonally wet grasslands on heavy-textured clay soils (Lazarides *et al*. 2005). In Western Australia, *E. benthamii* is abundant on the Roebourne Plains and along the valleys of major rivers, such as the Fortescue, DeGrey and Oakover (Payne and Mitchell 2002). Tropical cyclones generally occur during summer and autumn (December-May), and the heavy rainfall causes widespread flooding of the major river systems.

The preference for swampy areas strongly indicates that *Eriachne benthamii* is tolerant of flooding. The present laboratory study examines whether duration and timing of flooding affect the growth of seedlings and young plants of *E. benthamii.*

Materials and methods

Collection and germination of seed; testing the response of seedlings to various flooding regimes in pot trials

In 2001, seed of *E. benthamii* was collected at Jackson's Bore on Ethel Creek station in the

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Fortescue River floodplain. Seeds were stored in airtight containers in the dark at a constant temperature of 6ºC, before sowing on sterilised coarse sand on June 12, 2006. Three weeks later (July 5, 2006), seedlings were transplanted into individual pots (7 x 7 x 10 cm) and placed in a greenhouse over heat mats. The potting mix was based on University of California soil mix 1 (Baker 1957; for details see Geurts *et al.* 2005). The pH of the potted soil ranged from 6 to 7 throughout the experiment, reaching a pH of 7 at day 63.

After potting, 20 seedlings of similar size were randomly allocated to each of a control and 4 flooding treatments:

1. Control - no flooding,
2. Flooded for 1 week, at 4 weeks of age (1 wk–4 wk),
3. Flooded for 2 weeks, at 5 weeks of age (2 wk–5 wk),
4. Flooded for 4 weeks, at 5 weeks of age (4 wk–5 wk), and
5. Flooded for 1 week, at 9 weeks of age (1 wk–9 wk).

The plants were watered daily with rainwater when not under flooded conditions. Maximum temperatures in the glasshouse varied between 28 and 34°C. From July 5, 2006, pots in treatments subjected to flooding were placed on plastic trays, at the appropriate time and for the correct duration, in fibreglass tanks filled with rainwater. The water level was maintained at approximately 2 cm above the soil surface of the pots.

Height of the seedlings and leaf number were determined at the beginning of the experiment (when transplanting took place; age of seedlings: 3 weeks), and then every 7 days till the end of the experiment (after 9 weeks; age of seedlings: 12 weeks). Five seedlings from each treatment were harvested at ages of 6, 8, 10 and 12 weeks. Leaf surface area was measured using the 'Image J' scanning program. Seedlings were washed in water, padded dry with tissue paper and fresh weight determined. Dry weight was measured after drying in an oven at 106ºC for 6 hours.

Statistical analysis

Normality of distribution and homogeneity of variance were tested (SPSS data analysis), root dry weight and leaf number were analysed using a one-way analysis of variance (ANOVA) (followed by Dunnett's tests, means compared with control, at $P<0.05$). In those cases where the Dunnett's test detected a significant difference between treatment groups and control ($P < 0.05$), but the calculated F was smaller than the critical value ($P>0.05$), the Null hypothesis that all population means were equal was accepted. A response to flooding was considered as immediate, when a significant difference between two subsequent measurements was determined for the interval during which a particular flooding event occurred.

Root:shoot ratio was calculated to compare possible differences in resource allocation between treatments (root:shoot ratio allows an insight into the balance between the photosynthesising and water and nutrient uptake capabilities of the plant).

Results

Effects of flooding on the number of leaves

Seedlings flooded for 1 week at 4 weeks of age had fewer leaves than the control ($P<0.05$) from the age of 6 weeks until the end of the experiment. For all other treatment groups, leaf number was reduced (compared with the control)($P<0.05$) during or shortly after the flooding event, but at the completion of the experiment no statistically significant differences existed among mean leaf numbers for control and treated plants, although absolute means were different (Figure 1).

Effects of flooding on seedling height

Seedlings flooded for 1 week at 4 weeks of age as well as seedlings flooded for 2 weeks at 5 weeks of age were shorter than control seedlings for the remainder of the experiment ($P<0.05$). Seedlings flooded for 4 weeks at 5 weeks of age were shorter than the control only at the end of the flooding event (at 9 weeks of age), while seedlings flooded for 1 week at 9 weeks of age were shorter than control seedlings from that time but differences were not significant ($P>0.05$) (Figure 2).

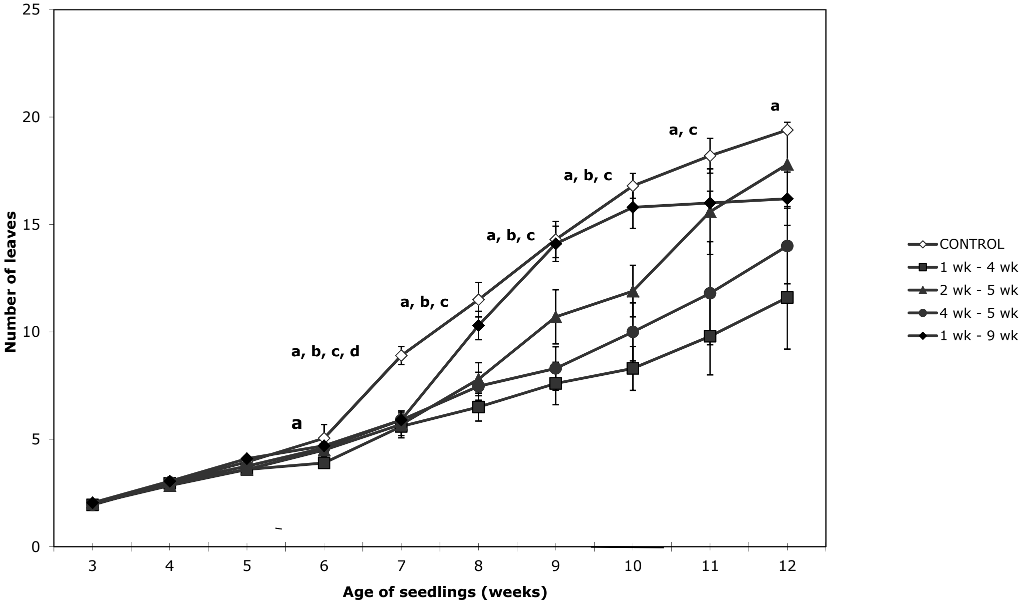

Figure 1. Changes in leaf numbers (mean ± s.e.) to 12 weeks of age of *E. benthamii* seedlings subjected to different periods of flooding (1 week at 4 weeks of age; 2 weeks at 5 weeks of age; 4 weeks at 5 weeks of age; and 1 week at 9 weeks of age). Significant differences between a particular treatment and the controls (Dunnett's tests, $P<0.05$) are indicated by: a (1 wk–4 wk), b (2 wk–5 wk), c (4 wk–5 wk) and d (1 wk–9 wk).

Effects of flooding on leaf area

Seedlings which were 4 weeks of age when flooded for 1 week displayed a significantly ($P<0.05$) smaller leaf area than the controls after 10 and 12 weeks. Leaf area for the other 3 treatment groups was also smaller than controls after flooding, but the differences were not statistically significant (probably due to the large variation among individual responses for both controls and treated groups) (Figure 3).

Effects of flooding on shoot and root dry weight

At the end of the experiment, shoot weight for all flooded seedlings was lower than for controls, but differences were significant ($P<0.05$) only for seedlings, which had been flooded for 1 week at 4 weeks of age and for 2 weeks at 5 weeks of age (Figure 4).

Flooding for 1 week at the age of 4 weeks reduced root weight at the age of 6, 8 and 10 weeks (Figure 5). However, at the end of the experiment, root weights in all flooded treatments did not differ significantly from controls.

Effects of flooding on root:shoot ratio

The average root:shoot ratio increased with time for both flooded and control seedlings, with no consistent differences between treatments.

Discussion

The present study demonstrated that young seedlings of *E. benthamii* were able to survive at least 4 weeks of continuous flooding in coarse sand. However, growth of plants did suffer. In general, flooding reduced leaf number, leaf area, height, dry matter of roots and dry matter of shoots, but the wide variation between plants within treatments often rendered differences non-significant. The study suffered from a lack of adequate replication with only 5 seedlings per treatment being recorded for most observations. Although the large variation in response makes it difficult to quantify the effects on seedling growth, seedlings on all treatments did grow well and survived inundation.

A reduction in resource allocation from below- to above-ground components is a common

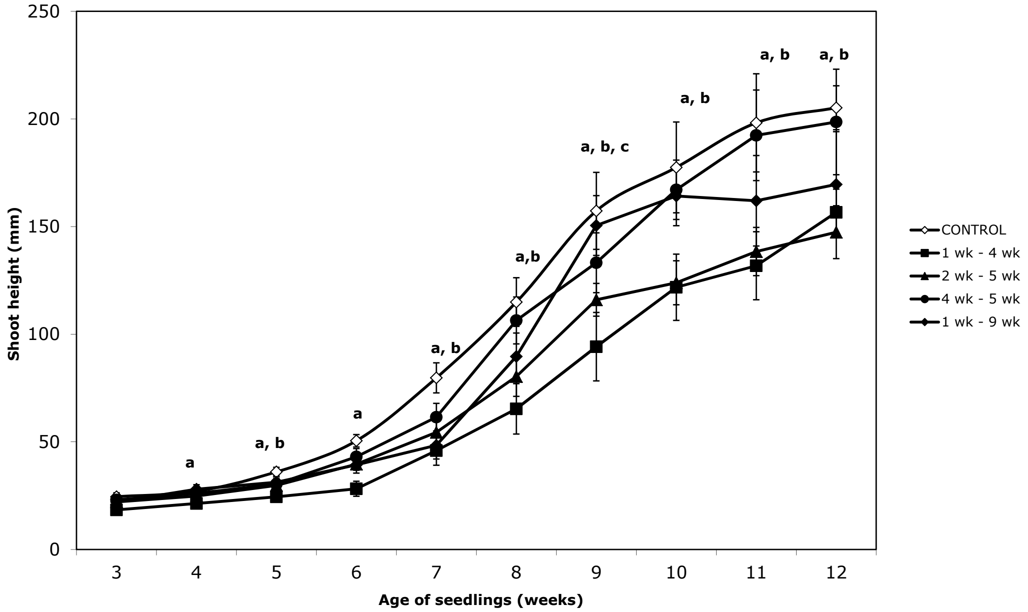

Figure 2. Changes in shoot height (mean ± s.e.) to 12 weeks of age of *E. benthamii* seedlings subjected to different periods of flooding (1 week at 4 weeks of age; 2 weeks at 5 weeks of age; 4 weeks at 5 weeks of age; and 1 week at 9 weeks of age). Significant differences between a particular treatment and the controls (Dunnett's tests, P<0.05) are indicated by: a (1 wk–4 wk), b (2 wk–5 wk), c (4 wk–5 wk) and d (1 wk–9 wk).

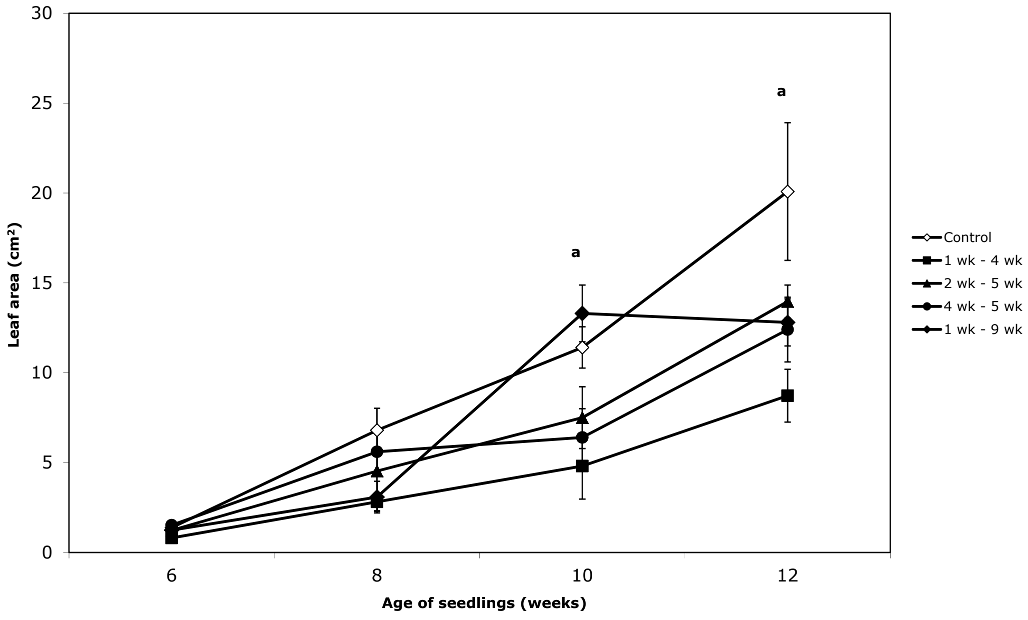

Figure 3. Changes in leaf area (mean ± s.e.) from 6 to 12 weeks of age of *E. benthamii* seedlings subjected to different periods of flooding (1 week at 4 weeks of age; 2 weeks at 5 weeks of age; 4 weeks at 5 weeks of age; and 1 week at 9 weeks of age). Significant differences between a particular treatment and the controls (Dunnett's tests, P<0.05) are indicated by: a (1 wk–4 wk), b (2 wk–5 wk), c (4 wk–5 wk) and d (1 wk–9 wk).

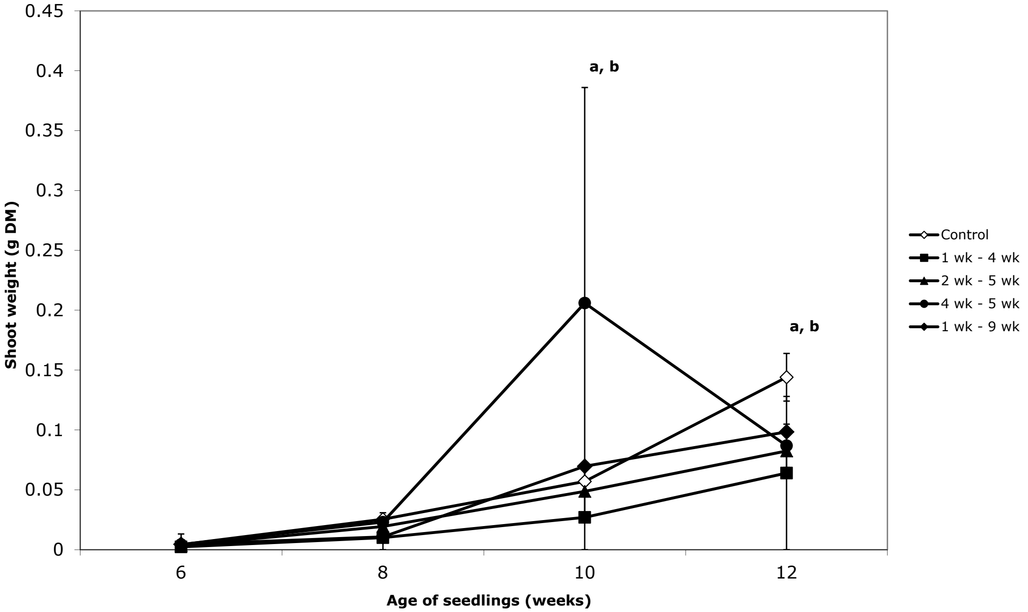

Figure 4. Changes in dry shoot weight (mean ± s.e.) from 6 to 12 weeks of age of *E. benthamii* seedlings subjected to different periods of flooding (1 week at 4 weeks of age; 2 weeks at 5 weeks of age; 4 weeks at 5 weeks of age; and 1 week at 9 weeks of age). Significant differences between a particular treatment and the controls (Dunnett's tests, $P<0.05$) are indicated by: a (1 wk–4 wk), b (2 wk–5 wk), c (4 wk–5 wk) and d (1 wk–9 wk).

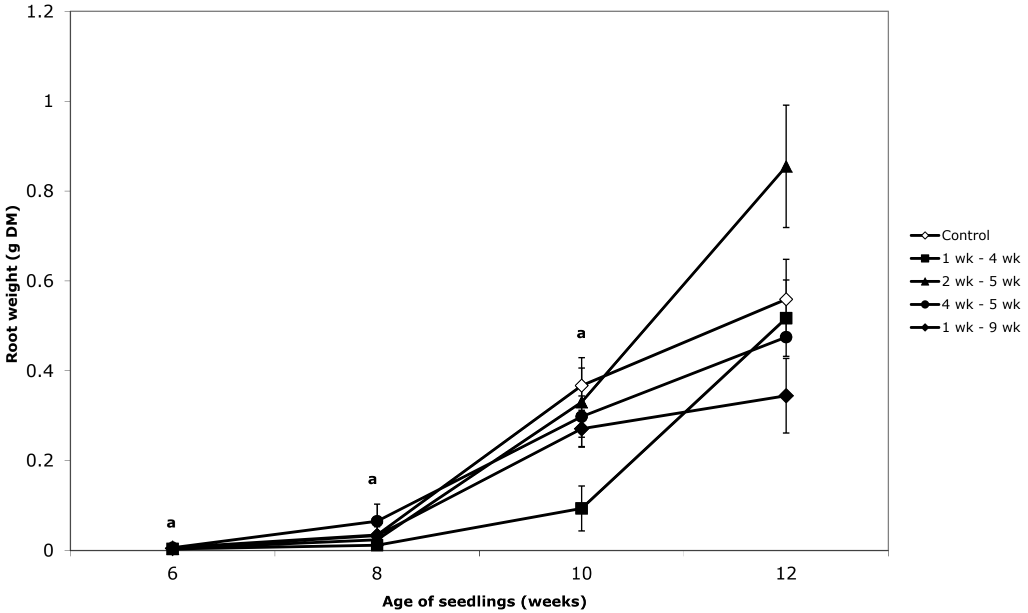

Figure 5. Changes in dry root weight (mean ± s.e.) of *E. benthamii* seedlings subjected to different periods of flooding (1 week at 4 weeks of age; 2 weeks at 5 weeks of age; 4 weeks at 5 weeks of age; and 1 week at 9 weeks of age). Significant differences between a particular treatment and the controls (Dunnett's tests, $P<0.05$) are indicated by: a (1 wk–4 wk), b (2 wk–5 wk), c (4 wk–5 wk) and d (1 wk–9 wk).

response of grasses to transient flooding or waterlogging (Naidoo and Naidoo 1992; Rubio and Lavado 1999), since flooding induces root decay and affects root formation and branching (Kozlowski 1997; Drew 1997). Taxa sensitive to flooding can therefore show dramatic decreases in root:shoot ratio. However, a decrease or a small increase in root:shoot ratio can usually be observed for flood-tolerant species in response to flooding (Rubio and Lavado 1999). Flooding had no significant effect on root:shoot ratio of the flood-tolerant, perennial grass *Panicum decompositum* (Geurts *et al.* 2005). During the present study, the root:shoot ratio steadily increased (from first to last harvest) for both flooded and control seedlings of *E. benthamii* mainly owing to enhanced root weight. Further research, especially anatomical studies, is required to reveal whether new root material was produced and/or root length increased (we did not measure root length), and/or adventitious roots formed during the experimental period.

The reduction in leaf area in response to flooding in seedlings of *E. benthamii* agrees with reductions observed in other grass species (Jackson and Drew 1984; Baruch 1994; Dias-Filho and Carvalho 2000; Geurts *et al.* 2005).

The flood tolerance of many other native Australian grass species has yet to be examined. Among the native grasses, which are considered to be tolerant of flooding, are *Agrostis avenacea*, *Amphibromus nervosus* and species of the genera *Austrostipa* and *Eragrostis* (Water and Rivers Commission 2003). Seedlings of *Panicum decompositum*, another perennial grass that occurs in the Fortescue Valley floodplain, are able to survive 4 weeks of flooding (Geurts *et al.* 2005).

Tolerance to flooding and the ability to withstand harsh climatic and soil conditions make *E. benthamii* a suitable choice for the rehabilitation of degraded rangelands, in particular arid-zone floodplains.

References

Archer, K.A. and Robinson, G.G. (1988) Agronomic potential of native grass species on the Northern Tablelands of New South Wales. II. Nutritive value. *Australian Journal of Agricultural Research,* **39**, 425–436.

Baker, K.F. (1957) The UC system for producing healthy container grown plants. *California Agriculture Experiment Station Manual* 23.

Baruch, Z. (1994) Responses to drought and flooding in tropical forage grasses. I. Biomass allocation, leaf growth and mineral nutrients. *Plant and Soil*, **164**, 87–96.

Dias-Filho, M.B and Carvalho, C.J.R. (2000) Physiological and morphological responses of *Brachiaria* spp. to flooding. *Pesquisa Agropecuaria Brasileira*, **35** (10), 1959–1966.

Drew, M. (1997) Oxygen deficiency and root metabolism: injury and acclimation under hypoxia and anoxia. *Annual Review of Plant Biology,* **48**, 223–250.

Geurts, C., Fox, J.E.D., Luong, T. and Cox, M.C. (2005) Flood tolerance of *Panicum decompositum*: Effects on seedling biomass. *Tropical Grasslands,* **39**, 160–170.

Jackson, M.B. and Drew, M. (1984) Effects of flooding on the growth and metabolism of herbaceous plants. In: Kozlowski, T.T. (ed.) *Flooding and plant growth*. pp. 47–182. (Academic Press Inc.: London, UK).

Kercher, S.M. and Zedler, J.B. (2004) Flood tolerance in wetland angiosperms: a comparison of invasive and non-invasive species. *Aquatic Botany*, **80**, 89–102.

Kozlowski, T.T. (1997) Responses of woody plants to flooding and salinity. *Tree Physiology Monograph*, **1**, 1–28.

Lazarides, M. (1995) The Genus *Eriachne*. *Australian Systematic Botany,* **8**, 355–452.

Lazarides, M., van den Borre, A. and Willer, C.M. (2005) *Eriachne*. In: Mallett, K. (ed.) *Flora of Australia*. Vol. 44B, Poaceae 3. pp. 132–174. (CSIRO: Melbourne).

Lodge, G.M. (1981) Establishment of warm- and cool-season native perennial grasses on the north-west slopes of New South Wales. II. Establishment and seedling survival in the field. *Australian Journal of Botany*, **29**, 121–133.

Lodge, G.M. and Whalley, R.D.B. (1981) Establishment of warm- and cool-season native perennial grasses on the north-west slopes of New South Wales. I. Dormancy and germination. *Australian Journal of Botany,* **29**, 111–119.

Naidoo, G. and Naidoo, S. (1992) Waterlogging responses of *Sporobolus virginicus* (L.) Kunth. *Oecologia*, **90**, 445–450.

Payne, A.L. and Mitchell, A.A. (2002) An assessment of the impact of Opthalmia Dam on the floodplain of the Fortescue River on Ethel Creek and Roy Hill Stations. pp. 1–69. *Technical report 124. Western Australia Department of Agriculture, Perth, Australia.*

Robinson, G.G. and Archer, K.A. (1988) Agronomic potential of native grass species on the Northern Tablelands of New South Wales. I. Growth and herbage production. *Australian Journal of Agricultural Research,* **39** (3), 415–423.

Rubio, G. and Lavado, R.S. (1999) Acquisition and allocation of resources in two waterlogging-tolerant grasses. *New Phytologist,* **143** (3), 539–546.

Setter, T.L. and Waters, I. (2003) Review of prospects for germplasm improvement for water-logging tolerance in wheat, barley and oats. *Plant and Soil*, **253**, 1–34.

Water and Rivers Commission (2003) Revegetating with native grasses in the Avon catchment. *Water notes WN 31. Water and Rivers Commission, Perth, WA.*

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