The effect of pasture composition on the soil water dynamics beneath native pastures in the high rainfall zone of south-eastern Australia

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Introduction

The adoption of livestock grazing for agriculture has changed the botanical composition of grasslands around the world (e.g. Rusch and Oesterheld 1997) including within the high rainfall zone of southeastern Australia. A loss of perennial and summer-active species has led to the reduction and shift of water use patterns (Dunin et al. 1999) which has been recognised as a major cause of many environmental issues including dryland salinity and soil acidity (Passioura and Ridley 1998). Grazing and increased soil fertility are the main causes for the reduction of initially summer dominant perennials and eventually cool-season perennials from native pastures.

In this study, three native pastures of differing botanical compositions were examined to determine how species composition affects soil moisture use. A range of morphological characteristics such as root depth and distribution, green leaf area index (GLAI) and phenology were observed across time and compared to soil moisture deficits under corresponding pastures.

Materials and methods

The three pastures were located approximately 5 km from one another on commercial farms near Bookham (34° 52’ 34”S, 147° 22’39”E) in the upper region of the Murrumbidgee catchment in south-east Australia. These sites were common in soil type, position on slope, aspect and geology. Soils at these field sites were found to be acidic with moderate to high levels of exchangeable aluminium. The pasture found at each field site varied in botanical composition and have been named according to the photosynthetic pathway of the dominant perennial grass species. The C\(_3\) field site contained *Microlaena stipoides* (C\(_3\)) and *Austrodanthonia* spp. (C\(_3\)); the C\(_3/C_4\) field site was codominated by *Bothriochloa macra* (C\(_4\)), *Microlaena stipoides* (C\(_3\)) and *Austrodanthonia* spp. (C\(_3\)) and the C\(_4\) field site contained almost entirely *Themeda australis* (C\(_4\)). At each field site eight 4 x 4 m plots were established with four randomly sown to an annual ryegrass (*Lolium multiflorum*) control and the other four plots left in their original native state.

Field sites were generally managed with the rest of the paddock, but stock were excluded during ryegrass establishment and when biomass levels dropped below approximately 500 kg DM ha\(^{-1}\). Soil moisture was measured monthly using a neutron moisture meter along with green leaf area index (GLAI), biomass and phenological stage of development. Basal frequency was measured in December 2004 and botanical composition was measured quarterly. In December 2005 following the completion of the study, field sites were sampled to determine root distribution using the core-break method proposed by Smit et al. (2000). Rainfall and temperature loggers were also installed at each field site. Water use by the native pasture at each site is discussed in terms of the difference in soil water deficit (SWDDIFF) compared to the annual ryegrass control. All data was analysed using the linear mixed modelling technique to allow comparisons across time.

Results and discussion

* Austrodanthonia* spp. and *M. stipoides* were dominant across all seasons at the C\(_3\) field site (Figure 1a) comprising on average 32% and 45% of pasture biomass respectively. Annual species comprised a larger proportion of the pasture in winter and spring. At the C\(_3/C_4\) field site (Figure 1b) *B. macra* represented on average 20%, *Austrodanthonia* spp. 19% and *M. stipoides* 30% of the pasture species. During summer and autumn, the pasture was almost exclusively these species though in winter and spring, cool-season annuals appeared. The C\(_4\) field site was very stable in its composition with *T. australis* clearly the dominant species throughout the experimental period (on average 83%). However, in winter and early spring
when *T. australis* was least active, this pasture was surprisingly species rich with other species evident containing *Austrodanthonia spp.*, clovers, some broad-leaf weeds, annual grasses and other small forbs.

Monthly rainfall was well below the long-term median for the district with the autumn break in rainfall not occurring until June in 2004 and 2005. The pattern of available soil water through time when summed to a soil depth of 67.5 cm (maximum depth common for all plots) was found to differ significantly between native and annual treatments at all sites. Soil moisture patterns differed mainly during the dry-down phase of the annual hydrological cycle occurring from summer through to the end of autumn in both years (Figure 2). The maximum soil water deficit achieved by the C₃ pasture occurred in late March (Figure 2a) which was almost two months earlier than the C₃/C₄ and C₄ field sites. In April 2004 the soil water difference (SWDDIFF) between the annual and native treatments pasture was 59 mm.

Over the same period, the C₃/C₄ native pasture achieved a SWDDIFF of 67 mm and the C₄ native pasture 85 mm. The end of April 2005 saw the conclusion of the experimental period and again highly significant (though smaller) SWDDIFF values were recorded at all sites (Figure 2). The SWDDIFF at the C₃ field site was 49 mm, the C₃/C₄ field site was 35 mm and the C₄ field site was 79 mm. This is consistent with the findings of Hughes *et al.* (2006) where pastures containing the greatest amount of C₄ perennial species (*T. australis and B. macra*) were found to create the largest soil water deficit.

![Figure 1](image)

**Figure 1** Botanical composition of pastures across the experimental period expressed in terms of biomass

Significant increases in total root population were discovered for the native pasture at the C₃ field site though differences in rooting depth and distribution were not present and only minor differences occurred at the other field sites. Subsoil constraints in the form of shallow bedrock and massively structured B horizons were however present at these sites. Given that SWDDIFF was least at this site, rooting pattern differences were considered only a minor factor affecting SWDDIFF. Much of the difference in soil water use was suspected to be a consequence of seasonal patterns of GLAI. At all field sites peak GLAI for the annual ryegrass treatment was recorded around the beginning of October (Figure 3) with little remaining by February. In comparison, peak GLAI occurred three weeks later in the C₃ native pasture, 5 weeks later in the C₃/C₄ pasture and approximately 10 weeks (2½ months) later in the C₄ native pasture. The length of time that GLAI was retained also differed. Comparing an arbitrary base GLAI of 0.5, the annual treatment retained this level for 3 months at the C₃ and C₃/C₄ field sites and only 2 months at the C₄ field site. The native pastures retained a GLAI of greater than 0.5 for 4 months, > 5 months and 3.5 months at the C₃, C₃/C₄ and C₄ field sites respectively with all native pastures showing a GLAI response to soil moisture in March 2005.
Figure 2 The volumetric soil water content to a depth of 67.5 cm for each pasture across the experimental period. Dashed lines indicate soil water beneath the annual ryegrass and the solid line is represents the native perennial pasture. The grey line indicates the upper limit to plant available water (PAW) as determined from laboratory measured field capacity (FC, -10 kPa). Stars indicate significant differences at twice the standard error.

Annual ryegrass is highly sensitive to aluminium (Rengel and Robinson 1989) and thus growth is likely to be more affected than the better adapted native species endemic to the region. The basal area of native perennial grasses was high at all field sites totalling 0.35, 0.33 and 0.50 m$^2$ m$^{-2}$ for the C$_3$, C$_3$/C$_4$ and C$_4$ sites respectively. It is possible that this also was a major factor affecting soil water deficits.

Figure 3 The green leaf area index (GLAI) of the native pastures (solid line) and the annual pastures (dashed line) for each pasture. Note: GLAI was not collected for annual pasture prior to July 2004. Stars indicate significant differences at twice the standard error.
Conclusions

Native perennial pastures markedly increased water use compared to annual ryegrass in less arable regions of the high rainfall zone, particularly where a large C₄ component was maintained. Drought conditions over the experimental period and the high native perennial grass content of the pastures examined are likely to have resulted in maximum soil water deficits for these pasture types in this region. Soil water deficits of the magnitude found in this study (35-85 mm, average 62 mm across years and pasture comparisons) are likely to reduce soil water deficits and evaporation. The enhancement of native pasture perenniality has the potential to reduce salinity and acidity through the reduction of deep drainage and recharge. Many factors were identified as potentially affecting water use including photosynthetic pathways, GLAI, adaptation to acid soils and basal area. A better understanding of the impact of perennial grass density and the importance of key species for water use and partitioning are necessary to better quantify what pastures of lower native perennial grass content are achieving and where threshold densities of plant abundance are likely to be for management purposes.

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References


