Comparing the water use efficiency of tropical pasture grasses and legumes used in Queensland's mixed farming systems

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Abstract

The integration of tropical pastures in cropping systems can have a number of benefits on the long term viability of farm businesses. Long-term pastures (i.e. >5 years) can be used to rejuvenate marginal cropping soils, whereas shorter term pastures are more likely to be used on more productive soil types in crop-pasture rotations. In this study we report on the soil water use and water use efficiency (WUE) of four pasture species over three growing seasons. A replicated trial was conducted on a brown Vertosol at Roma in Queensland, with two tropical grasses (buffel grass and Rhodes grass) and two tropical legumes (butterfly pea and lablab). Measurements of soil water and ground cover (i.e. radiation interception) were taken at regular intervals with reflectometers, neutron probes and tube solarimeters. The aim of this paper was to compare the efficiency with which these four species use soil water and rainfall to produce biomass. Water use efficiency varied for the four pastures and also from year to year. Over the three years studied, buffel grass was most efficient at converting rainfall to pasture biomass and persisted well during and after the drought. There was no significant difference in WUE between buffel grass and the other pastures in year 1 and 2, but buffel grass had a significantly higher WUE in year 3, after the dry 2006 season where other pastures suffered and did not recover. Data sets obtained from these experiments are being used to validate growth models for these pasture species in APSIM. This study will further our work in the integration and modelling of mixed grain/graze enterprises at the whole farm level.

Keywords

Ley pastures, soil water use, water balance, ground cover

Introduction

Many cropping systems in Queensland are challenged with depleting soil fertility and increasing costs of inputs such as nitrogen fertilisers. The integration of ley pastures in cropping systems could potentially solve some of these issues, while having long term benefits in the sustainability of the farming system. Apart from providing high quality forage for livestock enterprises, long-term pastures can be used to rejuvenate marginal cropping soils, while on the more productive soil types shorter-term pastures might have benefits on cropping rotations. Pastures also provide greater and more permanent ground cover than cropping systems, which reduces soil water losses due to soil evaporation and runoff.

The objective of this study was to compare soil water use, water use efficiency and pasture production of four pasture species. The study illustrates which pasture species were most efficient at converting rainfall to pasture biomass and which provided better soil cover with reduced losses of water.

Materials and Methods

Experimental data for two grass and two legume pasture species was collected from a trial over the 2005-2007 seasons at Roma Research Station Qld. The pastures were planted in a fully randomised block design with three replications (for more details see Lawrence *et al*., 2008 in this volume). The two tropical grasses examined for this WUE study were buffel grass (*Cenchrus ciliaris*) and Rhodes grass (*Chloris gayana* cv. Finecut), and the tropical legumes were Butterfly pea (*Clitoria ternatea* cv. Milgarra) and the annual lablab (*Lablab purpureus* cv.Highworth).

Roma has a subtropical climate with a mean annual rainfall of 595 mm, with about 70% of rain falling in summer. The growing season for these pastures is between October and April. Over the experimental period rainfall variability was high, with the second growing season in 2006 being extremely dry (El Nino year).

Soil at the site is a brown cracking clay or Vertosol over weathered sedimentary rock that originally supported open plains of Mitchell grass (*Astrebla lappacea*). This site had been under annual cereal cropping

for 30+ years. Soil water was measured before sowing and bulk density and drained upper limit (DUL) were determined from a wet pond set up adjacent to the site as described by Dalgliesh and Foale (1998). Soil water measurements of the whole soil profile were made at monthly intervals during the growing season using a neutron probe which was calibrated to volumetric soil water. Soil water in the surface 0.1m was continuously monitored using reflectometers. The crop lower limit (CLL) derived from the lowest volumetric water content (θv) measured for each species (Figure 1). Pastures were established in January 2006 as detailed by Lawrence *et al*. (2008). Prior to planting N and P fertiliser was applied and the plots received 46 mm of irrigation.

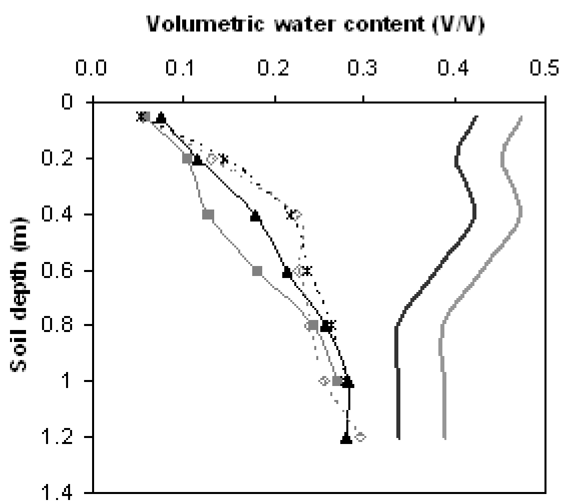

Figure 1. Values of saturated upper limit (—), drained upper limit (—) and crop lower limits for Rhodes grass (■), Buffel grass (▲), Lablab (◊) and Butterfly pea (?), recorded at the experimental site.

Tube solarimeters were used to continuously record radiation interception by each of the four species, while incoming radiation was recorded in an adjacent bare plot. These measurements were later used to derive estimates of ground cover. Pasture biomass was measured throughout the growing season as detailed by Lawrence *et al*. (2008).

WUE (kg/ha/mm) of the pastures was calculated from pasture yield (kg/ha) divided by water use (mm), where water use was calculated as the soil water difference at the start and end of the growing season plus rainfall plus irrigation. Rainfall use efficiency was calculated for the whole experimental period as accumulated pasture production over the three growing seasons divided by accumulated rainfall. Analysis of variance was used to explore differences in treatments using a split plot analysis with year as a subplot treatment (level of significance was 5%).

Results and Discussion

Soil water in the top 0.1m of the soil profile followed a similar pattern for all species, showing its responsiveness to falls of rain and losses through soil evaporation (Figure 2). The two legumes had very similar water use to ???? the top soil layer.

The control or bare plot had the highest soil water (wettest) while Rhodes grass had the lowest total soil water from all the species (Figure 3). The crop lower limit (CLL) of Rhodes grass was lower than all the other pastures indicating a greater capacity to extract more water and dry the soil profile further (Figure 1). By the end of the second growing season, Rhodes grass had completely dried the soil profile. This has important implications for the survival of Rhodes grass, particularly during a drought. A drier soil profile could also affect its capacity to recruit new seedlings, regrow in spring, and even the establishment and success of a following crop in a mixed grazing – cropping rotation.

The two grasses always had higher ground cover than the legumes (Figure 4) and Rhodes grass had the highest cover as it was vigorous and stoloniferous and established more quickly than the other pastures, confirming the findings of Lloyd *et al.* (1983). Ground cover for the legumes started declining in May, whereas the grasses were able to carry over total standing dry matter into the winter. Buffel grass was able to maintain a high level of cover even during the dry year, whereas that of Rhodes grass had severely reduced. The high levels of cover after June 2007 for Rhodes grass (Figure 4) was an artefact caused by weed invasion after survival of Rhodes grass had been severely reduced by the drought.

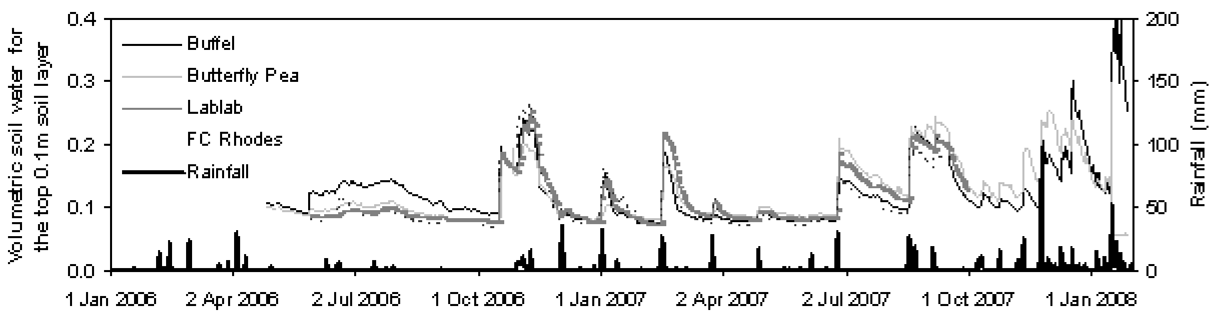

Figure 2 Volumetric soil water in the top 0.1m under buffel grass, Rhodes grass, butterfly pea and lablab pastures and daily rainfall at Roma Research Station. (Note - soil water data for lablab and Rhodes grass are not presented for the 3rd growing season. Numbers for Rhodes grass had been severely reduced after the drought in year 2 and no annual lablab was sown in year 3).

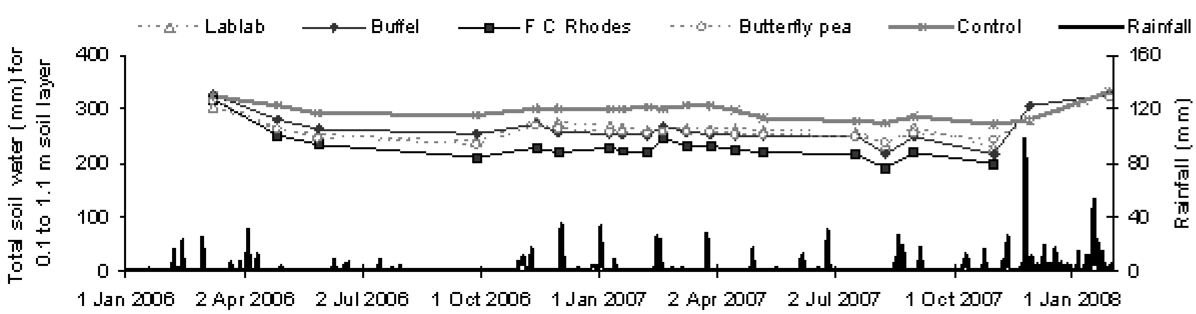

Figure 3 Total soil water for 0.1 - 1.1m soil layers for lablab, buffel grass, Rhodes grass, butterfly pea, and bare ground control (left axis), and daily rainfall (mm) (right axis) at Roma Research Station, Roma Qld.

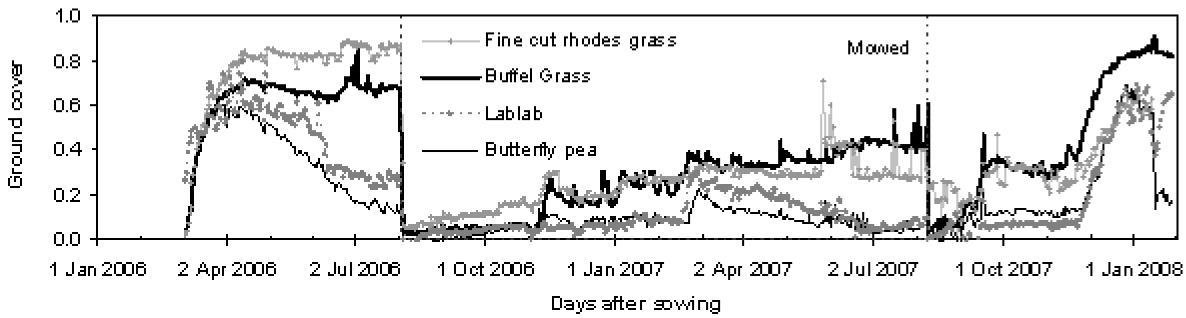

Figure 4 Ground cover for Rhodes grass, buffel grass, butterfly pea and lablab.

There was a significant interaction in WUE between the different pastures from year to year. In terms of production per unit of available water, the WUE of lablab was significantly higher than the other pasture species in year 1 (Table 1). However lablab is an annual and therefore most likely to produce higher evaporative losses when the pasture establishment phases are considered. The WUE of lablab compares well with derived WUE values from Hill et al. (2006) of 9 kg/ha/mm at Emerald and 17 kg/ha/mm at Gayndah and Moree. Butterfly pea had the lowest WUE, probably because it was not well adapted in this subtropical environment. Therefore we did not expect good production or efficiency from the butterfly pea at Roma. We did however expect to see greater differences in WUE between the legumes with C3 photosynthetic pathways and the tropical grasses with C4 pathways, as reported by Tow (1993).

Buffel grass was the most persistent and drought tolerant species, producing the highest pasture growth (reported by Lawrence *et al*. 2008) and maintaining high cover even in the dry year. There was no significant difference in WUE between buffel grass and the other pastures in year 1 and 2, but buffel grass had a significantly higher WUE in year 3. Rhodes grass did not recover from the drought in year 2 as well as buffel grass. Lloyd *et al.* (1983) also found poor persistence by Rhodes grass under dry conditions on clay soils.

Table 1 Water use efficiency and rainfall use efficiency during the growing season for four buffel grass, Rhodes grass, butterfly pea and lablab pastures

Efficiency (kg/ha/mm)	Growing season	Start date	End date	Rainfall (mm)	Buffel grass	Rhodes grass	Butterfly pea	Lablab[*]
	year 1	31 Jan 06	27 Apr 06	132	9.8	8.5	6.7	14.4
WUE	year 2	28 Sep 06	8 May 07	171	6.5	5.3	5.2	5.9
	year 3	31 Aug 07	30 Jan 08	501	9.7	5.4	2.1	-

Rainfall Use Efficiency	all	31 Jan 06	30 Jan 08	1095	6.5	5.0	3.0	-

* Lablab was not resown in year 3.

The WUE of buffel was close to 10 kg/ha/mm during years 1 and 3, whereas it was 6.5 kg/ha/mm in the dry year. Rhodes grass had a WUE of 8.5 kg/ha/mm in year 1, but after the drought it was around 5 kg/ha/mm. These values are not different from values determined elsewhere. McCown *et al.* (1972) reported WUE values of 20 kg/ha/mm for nitrogen fertilized buffel grass in north Queensland. The WUE of unfertilised native pastures, Rhodes grass and buffel grass from approximately 100 GUNSYND sites in Queensland (Day *et al.* 1997) ranged from 2 to 10 kg/ha/mm, with an average of 4 kg/ha/mm. Tow *et al.* (1993) reported the range of WUE of another sub-tropical grass, Digit grass (*Digitaria eriantha*), and lucerne (*Medicago sativa*) on solodic soils of the far-north slopes of New South Wales with values of 8 kg/ha/mm to 16 kg/ha/mm for Digit grass, and of 17 kg/ha/mm to 31 kg/ha/mm for lucerne.

The rainfall use efficiency of buffel grass was 6.5 kg/ha/mm over the whole experimental period. Henzell *et al.* (1975) measured the rainfall use efficiency of buffel grass on a duplex soil at the Narayen Research Station in southern Queensland as 3.2 kg/ha/mm during a very dry season (October to April 1969).

Conclusion

In this study we report the WUE of four tropical pasture species over three growing seasons. WUE varied for the pastures and also from year to year. Over the three years studied, buffel grass was most efficient at converting rainfall to pasture biomass and persisted well during and after the drought. Buffel grass also provided better soil cover with reduced losses of water. Different species had contrasting capacities to dry the soil profile which might create issues in regards to regrowth, seedling recruitment and for soil water replenishment during the transition between the pasture and cropping phases. Data sets obtained from these experiments are being used to validate growth models in APSIM which will further our work in the integration and modelling of mixed grain/graze enterprises.

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