Differences in soil water dynamics and herbage production between temperate and tropical pasture species for Central West NSW

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Abstract: *Tropical species have the potential to improve pasture productivity, especially in a changing climate, however little is known of their growth, productivity and persistence in Central West New South Wales. This study compared soil water use, rooting depth, herbage production and water use efficiency (WUE) for peak standing dry matter of six temperate and tropical pasture species established in pure swards. Perennial grass and legume species accessed soil water to depths >1.2 m within 12 months of establishment, while temperate annual legumes generally accessed water to approximately 1 m. Desmanthus (*Desmanthus virgatus*) especially cv. JCU2, barrel medic (*Medicago truncatula*) and woolly pod vetch (*Vicia villosa*) were productive in terms of herbage mass and WUE.*

Key words: extractable soil water, lucerne, *Medicago sativa*, digit grass, *Digitaria eriantha*

Introduction

The mixed farming region of Central West New South Wales (NSW) has medium rainfall (400–600 mm) with aseasonal distribution, but winter rainfall is generally more effective. Sown pastures in this area have traditionally consisted of temperate annual and perennial species, and both *Medicago truncatula* (barrel medic) and *M. sativa* (lucerne) are commonly sown. Over the last two decades there has been development of a range of new temperate annual legumes and cultivars that may be useful in this region. Recently, local producer interest in, and adoption of tropical perennial grasses has increased as these grasses have become widely sown in northern NSW due to their persistence, and ability to respond to summer rainfall and produce large quantities of forage (e.g. Boschma *et al*. 2015). The latest research in northern NSW is investigating the potential of tropical legumes (e.g. *Desmanthus* spp.). These tropical species may benefit pasture productivity, especially in a changing climate, which is predicted to become even more variable (e.g. Howden *et al*. 2008; Cullen *et al*. 2009), however, little is known of their growth, productivity and persistence in Central West NSW.

Information on seasonal soil water dynamics, rooting depths, peak growth periods and water use efficiency (WUE) are fundamental traits to identify diverse forage options and underpin recommendations to producers. A field experiment was conducted to compare the relative performance of pure swards of a number of temperate and tropical pasture species. This paper describes several data sets including herbage production, soil water dynamics, plant rooting depth, water use and WUE.

Methods

A field experiment was conducted on a brown Chromosol soil (Isbell 1996) at the Trangie Agricultural Research Centre (31°59'45"S, 147°56'18"E; elevation 220 m) from spring 2014 to spring 2017. Mean annual rainfall at the site is 493 mm with no distinct seasonality.

The treatments consisted of two cultivars of the tropical legume desmanthus (*D. virgatus*) cvv. JCU2 (www.progardes.com.au) and Marc, three temperate legumes (lucerne cv. Venus, woolly pod vetch (*Vicia villosa*) cv. Haymaker and barrel medic cv. Caliph), tropical digit grass (*Digitaria eriantha*) cv. Premier and a control (bare ground) established in a modified randomised complete block design with three replications (total of 21 plots). The legumes were established by transplanting 6-week old seedlings as spaced plants (9 plants/m^2) into 4 × 4 m plots; tropical legumes were planted in spring 2014 and temperate legumes in autumn 2015. Digit grass had persisted in an established plot sown 16 years prior and was located approximately 100 m from the legume treatments. The legume plots were irrigated as required to ensure establishment of the experiment.

Standing herbage mass (kg DM/ha) in each plot was assessed at approximately 6-week intervals from June 2015 until April 2017 using a modified Ranked Set Sampling method of McIntyre (1952) described by El-Shaarawi and Esterby (1999). In each plot, 12 quadrats (0.5 × 0.5 m) were surveyed; eight of these quadrats were randomly located within 0.5 m of the perimeter of each plot and four were permanently marked in close proximity to a neutron probe access tube in the centre of each plot. Herbage mass in each quadrat was visually scored using a continuous scale (0–5). Plot herbage mass (kg DM/ha) was determined from one of the random quadrats, that represented the median (score = 3), which was cut to 10 mm, and dried at 80°C for 48 hours. Plant dry matter was not harvested or removed from the plots following each herbage mass assessment.

Soil water content was estimated at 3-week intervals using a neutron moisture meter (CPN 503DR Hydroprobe; Boart Longyear Co., Martinez, CA, USA) calibrated for local conditions, in an aluminium access tube installed to 1.2 m depth in the centre of each plot. Maximum extractable soil water (MEW, mm) by the treatments was calculated from the greatest decline in stored soil water within the growing season of each species. The growing season was defined as a period when a species commenced regrowth until peak standing herbage mass was achieved. The duration of the growth period varied for each species and year (Table 1). Growth periods for lucerne were shorter and occurred at varying times of the year according to the availability of soil water. Plant rooting

Table 1. Length of the growing season (duration, weeks) and the maximum extractable soil water (MEW, mm), plant root depth (m), rainfall (mm), total water used (mm), herbage mass production (kg DM/ha) and water use efficiency (WUE, kg/DM/ha/mm) for each defined season for the treatments during the three experimental years.

Treatment	Duration (weeks)	MEW (mm)	Root depth (m)	Rainfall (mm)	Total water used (mm)	Herbage mass (kg DM/ha)	WUE (kg DM/ha/mm)
				2014–15			
Digit grass	–	–	–	–	–	–	–
Desmanthus cv. JCU2	32	61	>1.20	362	355	1861	5.2
Desmanthus cv. Marc	32	69	>1.20	362	354	2022	5.7
Lucerne	27	–	–	251	293	1271	4.3
Barrel medic	23	–	–	174	225	4279	19.0
Woolly pod vetch	22	–	–	174	224	4040	18.0
l.s.d., *P* = 0.05	–	*4.6*	–	–	*17.7*	*742.0*	*2.96*
				2015–16			
Digit grass	31	89	>1.20	283	366	1694	4.6
Desmanthus cv. JCU2	29	71	>1.20	283	336	4356	13.0
Desmanthus cv. Marc	29	74	>1.20	283	340	3093	9.1
Lucerne	11	70	>1.20	250	197	1572	8.0
Barrel medic	20	70	1.15	416	397	3909	9.8
Woolly pod vetch	20	59	0.92	416	412	3655	8.9
l.s.d., *P* = 0.05	–	*17.4*	–	–	*16.1*	*1208.6*	*3.46*
				2016–17			
Digit grass	27	137	>1.20	297	358	1878	5.2
Desmanthus cv. JCU2	27	85	>1.20	297	353	10622	30.1
Desmanthus cv. Marc	27	86	>1.20	297	358	3565	10.0
Lucerne	6	84	>1.20	65	119	3649	30.7
Barrel medic	–	53	0.92	–	–	–	–
Woolly pod vetch	–	52	0.85	–	–	–	–
l.s.d., *P* = 0.05	–	*8.4*	–	–	*22.0*	*3003.4*	*9.82*

depth was determined from changes in profile soil water content (Murphy and Lodge 2006). Peak herbage mass was divided by total water used (change in stored soil water plus rainfall; automatic weather station located 1 km from experimental site) to determine WUE (kg DM/ha/mm) for each treatment and growing season.

Results

Monthly rainfall during the experimental period was highly variable, with rainfall over the warmer months and in winter and spring of 2016 higher than long-term median. Highest mean maximum and lowest mean minimum daily temperatures were recorded in February (34.9–37.2°C cf. 32.4°C LTA) and July (2.9–4.3°C cf. 3.2°C LTA), respectively. Total frost occurrence (≤2°C) was 38- and 35-d in 2015 and 2016 (cf. 37.7-d LTA), respectively, which frosted all tropical species.

Treatment values of MEW significantly differed ($P < 0.05$) in each year of the experiment. During the 2014–15 growing season desmanthus cv. Marc (69 mm) extracted more water than cv. JCU2 (61 mm) (Table 1). During the 2015–16 and 2016–17 growing season, digit grass extracted the most water and the annual legumes the least (Table 1). The other perennial species (i.e. desmanthus and lucerne) were intermediate. Plant rooting depth of the perennial species was always >1.2 m, while rooting depth for the annual legumes was <1.0 m, with exception of barrel medic in 2016 which had a rooting depth of 1.15 m (Table 1).

Total water use by treatments differed ($P < 0.05$) in each year of the experiment. In two of the three years, lucerne had the lowest total water use (197 and 119 mm, 2015–16 and 2016–17, respectively) due to its short growing season compared to the other species (Table 1). During the 2014–15 growing season the perennial species used more water than the annual legumes ($P < 0.05$), but in 2015–16 the reverse occurred due to double the amount of rainfall that occurred during the growing season of the annual legumes (416 cf. 174 mm).

Among the tropical species, desmanthus cv. JCU2 had greater herbage mass and digit grass the least. The productivity of the desmanthus cultivars increased with each year of the experiment and was associated with recruitment (I. Toole, pers. comm.). Within the temperate species, the annual legumes were more productive than lucerne (Table 1) resulting in lucerne having significantly lower WUE; c. 25% of that for the annual legumes during the 2014–15 growing season. Data values for the 2015–16 growing season were less straight forward. The annual legumes had the highest total water use, but their herbage masses were intermediate to the desmanthus cultivars, resulting in WUE for the annual legumes and desmanthus cv. Marc being similar, but significantly less than desmanthus cv. JCU2 (Table 1). Digit grass had low herbage mass, resulting in the lowest WUE values (Table 1).

Discussion

The perennial species accessed soil water below 1.2 m, the depth of the access tubes, while the temperate annual species extracted water to a maximum depth of 1.15 m. The values for the perennial species broadly align with those from a range of studies conducted at Tamworth in northern NSW; vis. digit grass 1.0–1.3 m (Murphy *et al*. 2019), lucerne 1.2–1.6 m (Murphy *et al*. 2017, 2019) and desmanthus 1.4–1.8 m (Murphy *et al*. 2018). The values for the annual legumes were shallower than that found at Tamworth for subterranean clover (*Trifolium subterraneum*); vis. rooting depth of 1.2–1.4 m (S. Murphy, unpub. data). The ability of the perennial species to extract the soil water to depths >1.2 m indicates the importance of deep profile soil water for these species in this environment. Unfortunately, the total amount of soil water extracted was not quantified as the access tubes were too shallow (1.2 m).

No previous studies have examined the potential productivity of desmanthus in Central West NSW (medium rainfall environment). Herbage production of both cultivars of desmanthus increased each year that the study was conducted with cv. JCU2 producing more herbage with greater WUE than cv. Marc. Cultivar JCU2, one of a composite of five cultivars blended and sold as cv. Progardes (https://www.progardes.com.

au), also performed well on a brown Chromosol soil in northern NSW (Boschma *et al*. 2018a). Both desmanthus cultivars were selected for central and northern Queensland where rainfall is more summer dominant and frosts are fewer and less severe.

Both barrel medic and woolly pod vetch were productive legumes in this study, producing >3500 kg DM/ha each growing season in these non-defoliated stands. Both of these legumes also showed superior productivity and persistence compared to 14 other temperate annual legume species and cultivars in a co-located study (Boschma *et al*. 2018b). Both legumes were evaluated throughout the Central West decades ago and reported to have potential (e.g. Brownlee 1985; Meakins 1972), although only barrel medic is still widely sown. Lucerne productivity, both herbage mass and WUE, was underestimated in this study as it needs to be grazed to continue growth. In a five year study conducted at Trangie, lucerne cv. Trifecta grazed by sheep produced up to 4.9 t DM/ha per year (Bowman *et al*. 2002).

Digit grass reported only modest herbage production in this study; far below that reported in other studies. This is likely due to the stand not being defoliated and the growing season limited to 27–32 weeks as opposed to up to eight months (pending rainfall) and the fertility regime prior to the experiment. The digit grass stand was about 16 years old at the commencement of the experiment and had not received fertiliser for some years. Subsequently, digit grass showed consistently low rates of WUE (<5.5 kg DM/ha/mm); less than those reported for fertilised stands in northern NSW (33–34 kg DM/ha/mm [Murphy *et al*. 2019] and 6.5–11.4 kg DM/ha/mm [Boschma *et al*. 2019]).

This experiment has shown that in this medium rainfall environment the perennial species tested accessed soil water to depths of up to 1.2 m within 12 months of establishment, while temperate annual legumes generally accessed water down to about 1 m. Desmanthus was productive, especially cv. JCU 2, and increased productivity as the stand thickened. Similarly, barrel medic and woolly pod vetch were equally productive in these ungrazed stands.

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