Tropical perennial grasses: a productive, hydrologically efficient forage option for the Central West

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Abstract: *Mixed farming systems in the Central West of New South Wales require summer-growing forages that are productive under variable seasonal conditions. Quantitative information on the comparable hydrological performance of tropical perennial grasses with other sown summer-growing forages in this region is limited. This study, conducted at Trangie, compared soil water extraction, herbage production, water use efficiency (WUE) and winter rainfall refill of three tropical perennial grasses—Bambatsi panic (*Panicum coloratum *cv. Bambatsi), digit grass (*Digitaria eriantha *cv. Premier) and panic grass (*Megathyrsus maximus *cv. Gatton)—with lucerne (*Medicago sativa *cv. SARDI-Grazer) and forage sorghum (*Sorghum bicolor *hybrid cv. Banker) over two seasons. Tropical grasses extracted substantial amounts of soil water (73–109 mm) and, in most cases, to depths beyond 1.5 m, with extraction repeated across years. With adequate nutrient supply, they produced both high herbage yields and WUE (17.1–20.8 t DM/ha and 26.6–31.7 kg DM/ha/mm, respectively, in 2020–21), comparable to forage sorghum (18.5 t DM/ha and 28.0 kg DM/ha/mm) and exceeding lucerne (8.4 t DM/ha and 12.4 kg DM/ha/mm). Tropical grasses also achieved high winter rainfall refill efficiencies (24–37%), surpassing lucerne (15%) and, for individual grasses, exceeding the refill achieved during the fallow phase in a forage sorghum system (24%). These results demonstrate that fertilised tropical perennial grasses effectively utilise stored soil water and capture winter rainfall, providing productive, hydrologically efficient forage options for the Central West.*

Key words: mixed farming systems, soil water, rainfall capture, perennial pastures, climate resilience

Introduction

The mixed farming region of Central West New South Wales (NSW) relies on productive summer forage systems to support livestock enterprises. Although annual rainfall is moderate (average 400–600 mm) and slightly summer-dominant (~55% occurs October–March), stored soil water accumulated during winter remains a critical resource for pasture and crop production throughout the highly variable summer period. Therefore, producers in the region have traditionally relied on sown winter-annual legumes (e.g. barrel medic, *Medicago truncatula*), lucerne (*Medicago sativa*), and summer-annual forage crops (e.g. forage sorghum, *Sorghum bicolor*). Interest in tropical perennial grasses (e.g. Bambatsi panic, *Panicum coloratum*; digit grass, *Digitaria eriantha*; panic grass, *Megathyrsus maximus*) has increased substantially over the past decade due to their persistence, responsiveness to summer rainfall and capacity to produce large quantities of forage. Earlier studies at Trangie demonstrated that tropical grasses could achieve high levels of herbage production (McDonald 2003), while more recent work showed their ability to access deep soil water and maintain high water use efficiency under Central West conditions (Toole *et al.* 2019). These characteristics, together with their ability to maintain ground cover (Murphy *et al.* 2019), make tropical perennial grasses an attractive forage option for mixed farming systems.

Research across northern inland NSW has demonstrated that tropical perennial grasses are highly productive and capable of both efficiently using summer rainfall and capturing winter rainfall (Boschma *et al.* 2015; Murphy *et al.* 2019). Tropical grass pastures have also been shown to capture and efficiently store winter rainfall, thereby contributing to favourable hydrological outcomes in pasture systems (Murphy *et al.* 2010, 2022). While these benefits are well documented in more summer-dominant rainfall environments, quantitative information describing the productivity, soil water extraction and winter rainfall refill performance of tropical perennial grasses in the medium-rainfall Central West remains limited.

Forage sorghum remains a common sown option for supplying large quantities of forage during the warmer months, but it requires annual establishment and typically produces forage over a relatively narrow seasonal window. Tropical perennial grasses may offer a perennial alternative that responds to rainfall outside the planting window for forage sorghum, while providing comparable production and water use efficiency, maintaining year-round ground cover and avoiding annual sowing costs. Quantifying their productivity, soil water use and influence on winter soil water refill are therefore important for defining their role within Central West farming systems.

This study compared the herbage production, soil water extraction, winter rainfall refill and water use efficiency of three tropical perennial grasses with forage sorghum and lucerne over two growing seasons at Trangie in Central West NSW.

Methods

The study was conducted at Trangie Agricultural Research Centre (31°59'40.53"S, 147°56'20.65"E, elevation 215 m above sea level) on a brown Chromosol soil (Isbell 1996). The average annual rainfall in the study area is 496 mm, with 57% falling during the warm season, from October to March. Treatments comprised Bambatsi panic (cv. Bambatsi), digit grass (cv. Premier), panic grass (cv. Gatton), forage sorghum (cv. Banker) and lucerne (cv. SARDI-Grazer) arranged in a randomised complete block design with three replicates (Table 1). The perennial species were sown in November 2019 and allowed to establish, while forage sorghum was sown annually in November 2020 and 2021. All treatments received an annual spring application of single superphosphate (125 kg/ha; 9% phosphorus, 11% sulfur), and the grass treatments received a single application of urea (100 kg/ha; 46% nitrogen [N]).

The experiment was conducted across two growing seasons; 2020–21 (13 August 2020–27 May 2021) and 2021–22 (12 August 2021–17 May 2022). Herbage production (t DM/ha) was assessed using the same method as described in Murphy et al. (2022), and herbage was cut to 50 mm and removed at approximately six-week intervals throughout each growing season. Soil water content was measured every three weeks to a depth of 1.9 m using a neutron moisture meter (CPN 503DR Hydroprobe; Boart Longyear Co., Martinez, CA, USA) calibrated to local conditions (McKenzie *et al.* 1990). Changes in stored soil water (mm, 0.1–1.9 m) were used to estimate effective root depth (m, Murphy and Lodge 2006), maximum extractable water (MEW, mm), winter rainfall refill efficiency (%) and water use efficiency (WUE, kg DM/ha/mm) (Murphy *et al.* 2019). Growing-season WUE was calculated as total herbage production divided by total water use, determined from the soil water balance.

Table 1. Treatments, cultivars and sowing rates (coated seed, kg/ha).

Treatment	Cultivar	Sowing rate (kg/ha)
Bambatsi panic (*Panicum coloratum)*	Bambatsi	4.0
Digit grass (*Digitaria eriantha)*	Premier	10.0
Panic grass (*Megathyrsus maximus)*	Gatton	5.0
Forage sorghum (*Sorghum bicolor* ssp. *bicolor* x *S. bicolor* ssp. *drummondii* hybrid*)*	Banker	9.8
Lucerne (*Medicago sativa)*	SARDI-Grazer	3.5

Results

Seasonal conditions

Both growing seasons received substantially above-average rainfall. For the growing season defined as August–May, total rainfall was 588 mm in 2020–21 and 602 mm in 2021–22, compared with a long-term average of 424 mm. Although rainfall totals were similar, spring temperatures in 2020–21 were warmer (up to 5°C above average), leading to a faster accumulation of growing degree days during the first season. This created more favourable early-season conditions for tropical grass growth in 2020–21 compared to 2021–22.

Soil water extraction

Tropical perennial grasses extracted substantial quantities of soil water during both growing seasons. In 2020–21, MEW ranged from 101 to 109 mm among the three tropical grasses, and values were similar ($P > 0.05$) to those for forage sorghum (101 mm) and lucerne (114 mm) (Table 2). Most extraction occurred within the upper 0.7 m of the profile. Nevertheless, all tropical grasses extracted measurable quantities of water from depths below 1.5 m (Fig. 1). Estimated root depths ranged from 1.52 to 1.69 m and were comparable to forage sorghum and lucerne (Table 2).

In 2021–22, tropical grass MEW ranged from 73 to 109 mm ($P > 0.05$), and again, similar to that of forage sorghum (106 mm, $P > 0.05$) (Table 2). Digit grass, panic grass and forage sorghum extracted more water ($P < 0.05$) than lucerne, and to depths approaching 1.8 m, demonstrating repeated access to deep stored soil water (Fig. 1). Lucerne showed markedly lower extraction in this season, with a total of only 23 mm and to a depth of just 0.45 m.

Winter rainfall refill

All treatments accumulated soil water during winter (21–100 mm), when evaporative demand was low, and rainfall effectiveness was higher. During winter 2021, tropical grass refill efficiencies ranged from 24 to 37% (43–65 mm refill), compared with only 15% (21 mm) for lucerne. Infiltration depths ranged from 0.73 to 1.46 m for the tropical grasses, but 0.42 m for lucerne. Forage sorghum had a refill efficiency of 24%, but the highest total refill amount at 84 mm ($P < 0.05$) and the deepest infiltration at 1.61 m, attributable to the longer fallow period between crops. In contrast, lucerne had the lowest refill at 21 mm ($P < 0.05$) and the shallowest infiltration depth of 0.42 m.

Table 2. Maximum extractable water (MEW, mm) for treatments in different soil profile layers (upper 0.1–0.7 m, middle 0.7–1.3 m, lower 1.3–1.9 m and total 0.1–1.9 m), during the 2020–21 (13 August 2020–27 May 2021) and 2021–22 (12 August 2021–17 May 2022) growing seasons, together with the estimated plant root depth (m). Treatment values within a profile layer and growing season with the same letter are not significantly different ($P < 0.05$).

		Maximum extractable water (mm)				Root depth (m)
Season	**Treatment**	**0.1–0.7 m**	**0.7–1.3 m**	**1.3–1.9 m**	**0.1–1.9 m**	
2020-21	Bambatsi panic	72a	29a	9ab	109a	1.68
	Digit grass	65a	31a	8ab	104a	1.69
	Panic grass	74a	25a	2a	101a	1.52
	Lucerne	61a	32a	21b	114a	1.80
	Forage sorghum	57a	31a	13ab	101a	1.69
2021-22	Bambatsi panic	54a	11ab	8a	73ab	1.06
	Digit grass	51a	28a	11a	91a	1.77
	Panic grass	65a	29a	16a	109a	1.80
	Lucerne	20b	3b	0a	23b	0.45
	Forage sorghum	62a	30a	14a	106a	1.78

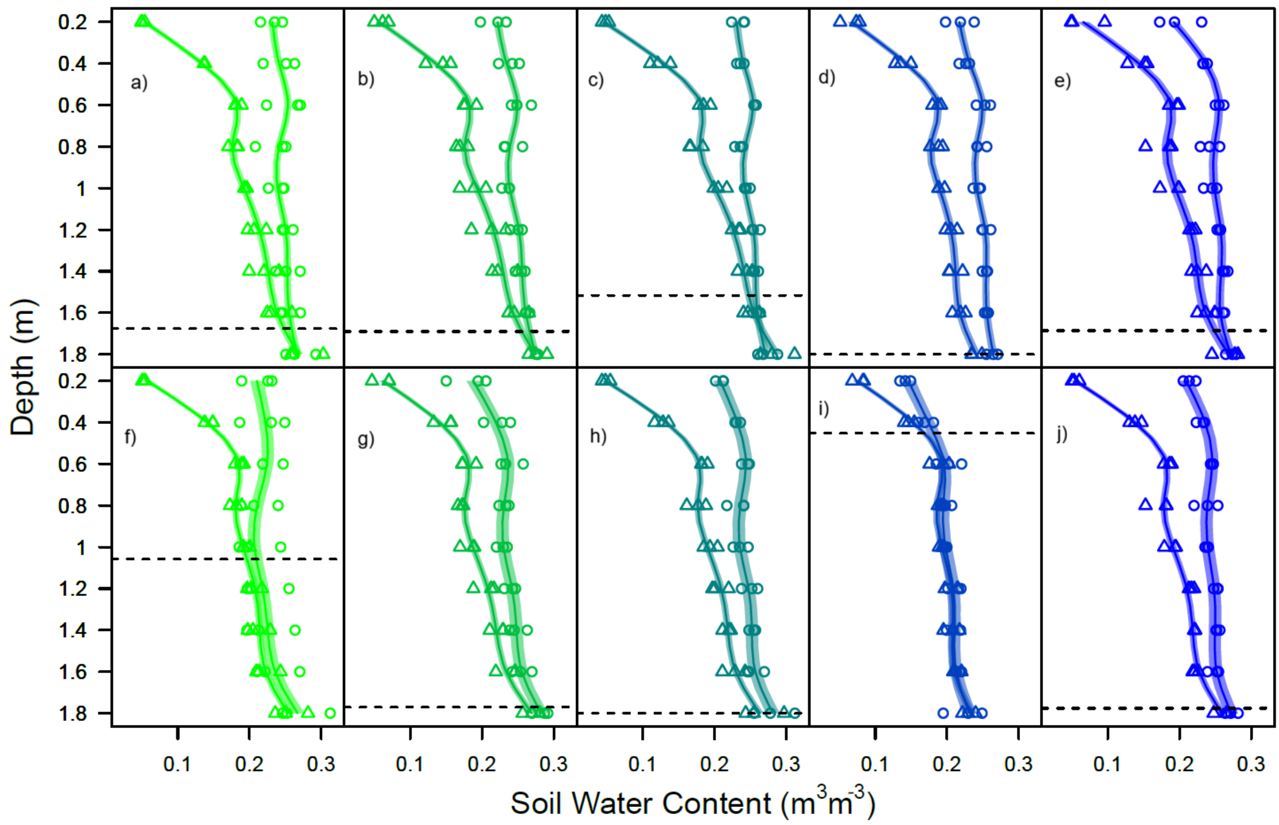

Figure 1. Maximum extractable water (mm) in 2020–21 (upper row) and 2021–22 (lower row) for Bambatsi panic (a, f), digit grass (b, g), panic grass (c, h), lucerne (d, i) and forage sorghum (e, j). Plot maximum (○) and minimum (Δ) soil water content (m³/m³) for each treatment are shown. Solid lines represent predicted soil water content, and the shaded area represents the standard error of the prediction. The dashed line represents maximum root depth.

Measurement of winter rainfall refill in 2022 was truncated because the experiment concluded in mid-May. However, the tropical grass treatments again demonstrated the ability to capture a substantial proportion of the rainfall (i.e. 39–49%) and replenish profile soil water (79–100 mm refill), while lucerne captured slightly less (32% and replenished 66 mm), but the differences were not significant (P > 0.05). Infiltration depths ranged from 1.16 to 1.79 m for the tropical grasses, and 1.07 m for lucerne.

Herbage production and water use efficiency

Herbage production varied markedly between the two seasons. During 2020–21, tropical perennial grasses produced between 17.1 and 20.8 t DM/ha, equivalent to forage sorghum (18.5 t DM/ha, P > 0.05) and substantially greater than lucerne (8.4 t DM/ha, P < 0.05) (Table 3). Water use efficiencies for tropical grasses ranged from 26.6–31.7 kg DM/ha/mm and 28.0 kg DM/ha/mm for forage sorghum (P > 0.05), whereas lucerne achieved only 12.4 kg DM/ha/mm (P < 0.05) (Table 3).

Production for the tropical perennial grasses declined sharply in 2021–22, ranging from 3.7 to 5.5 t DM/ha (P > 0.05), while forage sorghum and lucerne produced 9.6 t DM/ha and 11.7 t DM/ha (P < 0.05), respectively (Table 3). Consequently, WUE for the perennial grasses also declined to 5.4–8.5 kg DM/ha/mm (P > 0.05), compared with 14.4 and 17.9 kg DM/ha/mm for forage sorghum and lucerne (P < 0.05).

Table 3. Herbage production (kg DM/ha) and components of the water balance used to calculate water use efficiency (WUE, kg DM/ha/mm) for treatments during the 2020–21 (13 August 2020–27 May 2021) and 2021–22 (12 August 2021–17 May 2022) growing seasons. Water balance components are growing-season rainfall (mm), change in profile-stored soil water (mm), and total water used (mm). Treatment values within a growing season with the same letter are not significantly different ($P < 0.05$).

Season	Treatment	Herbage production (kg DM/ha)	Rainfall (mm)	Change in stored soil water (0.1–1.9 m, mm)	Total water used (mm)	WUE (kg DM/ha/mm)
2020-21	Bambatsi panic	20762a	567	-88	655	31.7a
	Digit Grass	17383a		-86	653	26.6a
	Panic grass	17148a		-73	640	26.8a
	Lucerne	8390b		-110	677	12.4b
	Forage sorghum	18494a		-94	661	28.0a
2021-22	Bambatsi panic	4462a	722	49	673	6.6ab
	Digit Grass	5491ab		79	643	8.5ab
	Panic grass	3749a		32	690	5.4a
	Lucerne	11742c		65	657	17.9c
	Forage sorghum	9557bc		57	665	14.4bc

Discussion

This study demonstrates that tropical perennial grasses can serve as productive, hydrologically efficient summer-growing forage options in Central West NSW. During the first growing season, all three tropical grasses achieved herbage production and water use efficiencies equivalent to those of forage sorghum, which remains the benchmark summer forage crop in many mixed farming systems. In contrast to forage sorghum, perennial grasses persist across seasons and maintain ground cover, allowing soil water to be replenished in winter and forage production to commence before forage sorghum does, without the need to re-sow each year.

A notable feature of the tropical grasses was their ability to repeatedly access deep stored soil water. Root depths commonly exceeded 1.5 m, and notable extraction occurred from below 1.3 m in both years. Having access to stored soil water acts as a buffer during periods of unreliable early-summer rainfall, which is crucial for mixed farming systems in areas such as the Central West, where rainfall is only slightly summer-dominant. Similar responses have been reported previously in northern NSW and indicate that these species can maintain production from a combination of growing-season rainfall and stored water accumulated during winter. This aspect provides resilience in variable-rainfall environments, supporting persistence, and potentially enhancing soil structure and hydrological efficiency (Banks *et al*. 2020).

The winter refill results are equally important from a system perspective. Although tropical grasses extracted substantial quantities of soil water during summer, their frosted state in winter reduced their water use and allowed a substantial proportion of winter rainfall to replenish the profile soil water. Refill efficiency values approached those of an extended fallow period of forage sorghum. They also commonly exceeded those of lucerne, which maintained green leaf and continued to transpire even though winter growth rates were low. This finding indicates that tropical perennial grass pastures are not only effective users of stored soil water, but they also allow soil water to replenish during the non-growing season.

For environments with a less summer-dominant rainfall pattern, this is a distinct system advantage.

The substantial decline in tropical grass production during the second season was unlikely to be driven by soil water availability because reserves were replenished by winter profile refill, clear extraction patterns were evident, and seasonal rainfall was above average. A more likely explanation is that soil nutrient availability became limiting following the high herbage production achieved in 2020–21. The tropical grasses produced 17–21 t DM/ha during the first year, and the annual application of 46 kg N/ha was unlikely to replace the quantity of nitrogen removed in harvested herbage. Earlier studies have reported strong responses of tropical perennial grasses to nitrogen supply (Boschma *et al.* 2017), and the present results reinforce the importance of maintaining good soil fertility where high productivity is anticipated. Access to soil water alone is insufficient to drive production.

Overall, the results suggest that tropical perennial grasses have the potential to replace or complement annual forage sorghum in Central West mixed farming systems. Their combination of high productivity, deep-profile soil water use, winter rainfall capture and perenniality provides a compelling option for increasing forage supply while maintaining hydrological efficiency in a variable climate.

Conclusions

Tropical perennial grasses extracted substantial quantities of soil water (73–109 mm) and repeatedly accessed water from depths greater than 1.5 m. When nutrient supply was adequate, they produced 17–21 t DM/ha and achieved water use efficiencies (26.6–31.7 kg DM/ha/mm) equivalent to those of forage sorghum. Despite substantial summer water use, tropical grasses replenished soil water reserves efficiently during winter, achieving winter rainfall refill efficiencies of 24–49%, exceeding those of lucerne and being comparable to forage sorghum systems. These findings indicate that tropical perennial grasses have the potential to replace or complement annual forage sorghum in Central West NSW, providing a productive, persistent and hydrologically efficient summer-growing forage option for mixed farming systems.

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