Digit grass is competitive against desmanthus in grazed mixed pastures during favourable seasons

SP Boschma[A], MA Brennan[A], GD Bevan[A] and WB Badgery[B]

[A]NSW Department of Primary Industries and Regional Development, 4 Marsden Park Rd, Calala, NSW 2340: suzanne.boschma@dpird.nsw.gov.au

[B]NSW Department of Primary Industries and Regional Development, 1447 Forest Road, Orange, NSW 2800

Abstract: *Sown tropical grass pastures have become important for livestock production in northern NSW. The addition of a companion legume is an effective means to enhance pasture quality and productivity over the longer term. The tropical legume desmanthus (*Desmanthus *spp.) is a potential companion, but seed set and seedling regeneration are required to maintain the plant population. A grazing study was conducted to determine the effectiveness of an extended rest period to allow desmanthus seed set and recruitment under both continuous and rotational grazing in a desmanthus (cv. Progardes)–digit grass (*Digitaria eriantha *cv. Premier) pasture. The pasture was established during drought (2018–19) and the experiment conducted from November 2020 to May 2021. High rainfall during the summer growing season resulted in high digit grass growth (up to 15 t DM/ha), producing tall stands with a high proportion of stem that shaded desmanthus plants, which were selectively grazed by sheep. Desmanthus did not set seed during the 75-day rest period and plant frequency declined from an initial low of 5 to 0%, while digit grass frequency increased from 19 to 61% over a 12-month period (October 2020–October 2021). These results indicate that strong competition from digit grass, rather than rest duration alone, constrained desmanthus regrowth, flowering and persistence.*

Key words: competition, persistence, regeneration

Introduction

Research in northern New South Wales (NSW) has shown that tropical pastures are persistent and productive, but nitrogen inputs and appropriate grazing are needed to maintain both pasture quality and quantity (Boschma *et al.* 2012, 2015, 2017). During summer they can have high growth rates, especially following rainfall and in conjunction with good fertility. The current recommendation is to apply 50–100 kg/ha/yr of nitrogen to maintain productivity (Boschma *et al.* 2015; Harris *et al.* 2014). Alternatively, the addition of productive persistent legumes can provide nitrogen.

Desmanthus (*Desmanthus* spp.) has shown potential as a new legume for this region (Boschma *et al.* 2021a, b). It is not as productive as lucerne, however its growth pattern complements tropical grasses growing at the same time of the year (Boschma *et al.* 2021a). This has the advantage of allowing soil water replenishment during the cooler months of the year which supports spring growth (Murphy *et al.* 2022).

Desmanthus is a palatable, short-lived perennial that can set large quantities of hard seed. It also readily recruits seedlings (Cook *et al.* 2020). To achieve long-term persistence in grazed pastures, management that encourages seed set and seedling recruitment will be essential. Grazing management tactics are required to ensure a seed bank is maintained and to encourage seedling recruitment and survival. This fundamental information is required to realise the potential of desmanthus as a companion legume for tropical perennial grasses in NSW.

The objective of this study was to determine the effect of an extended rest on desmanthus seed set and recruitment under both a continuous and rotational grazing system. Our hypothesis was that the extended rest would be essential for desmanthus plants to flower and set seed and for newly recruited seedlings to establish.

Methods

Pasture and site establishment

A mixed pasture of digit grass (*Digitaria eriantha*) cv. Premier and desmanthus cv. Progardes® (southern blend; consisting of a mixture of *D.*

virgatus cv. JCU 2, *D. bicornutus* cv. JCU 4, *D. leptophyllus* cv. JCU 7 and *D. pernambucanus* cv. JCU 9) was sown in a 2 ha paddock with a disk seeder on 20 November 2018. Digit grass was sown at 5 kg/ha coated germinable seed and desmanthus at 2 kg/ha bare seed (50% hard seed, i.e. 1 kg/ha germinable seed) in alternate rows (0.25 m row spacing). The paddock had a brown Chromosol soil and was located at the Tamworth Agricultural Institute near Tamworth (31.146°S, 150.967°E, 405 m above sea level, 638 mm annual average rainfall [AAR]) on the North-West Slopes, NSW (Table 1). Despite poor rainfall, the pasture established, albeit somewhat patchy. Commercial rhizobia for desmanthus was not available at sowing and was applied to the established pasture in November 2019 by sowing sterilised wheat seed coated with rhizobia.

Table 1. Soil characteristics (0–10 cm) of the grazing experimental site at Tamworth.

Soil characteristic	Value
pH ($CaCl_2$, 0–10 cm)	5.2
Total nitrogen (%)	0.2
Sulfur (KCl40, mg/kg)	20
Phosphorus (Colwell, mg/kg)	45
Organic carbon (%)	1.8
Potassium (cmol(+)/kg)	1.1

Fences were erected in 2019 to create plots (15 x 10 m) for an experiment consisting of four treatments with three replicates. The plots within each replicate were side by side, with a laneway running between replicates. Fences were constructed to allow sheep to communally graze with gates that could be closed to exclude grazing as required. An additional area was also incorporated into each communal grazing area to provide addition pasture for livestock. The total experimental area was 0.6 ha. The experiment was due to commence in spring 2019 but delayed due to the ongoing drought. The pasture was flail mown and the herbage removed from the plots in August and October 2020 to reset the pasture for the experiment.

Treatment details

The desmanthus grazing study was conducted November 2020–May 2021. There were four treatments in a 2x2 factorial: two grazing system treatments (continuous and rotational) and two rest periods (nil and extended). The extended rest period was to provide an opportunity for desmanthus to set seed and/or seedlings to regenerate and anticipated to be 8–12 weeks. The treatments are listed in Table 2. The grazing systems were implemented using an open communal grazing design (Kemp *et al.* 2000).

Table 2. Grazing treatments imposed in the desmanthus-digit grass grazing experiment.

ID	Treatment
T1	Continuously grazed (nil opportunity for seed set or seedling regeneration)
T2	Treatment 1 with a rest period to allow set seed/seedling regeneration. Rest period triggered by significant rainfall during the growing season
T3	Rotationally grazed with high stock numbers then rested until desmanthus regrew to minimum 0.25 m height
T4	Treatment 3 with an additional rest period to allow for seed set/seedling regeneration

Six-month old Merino wether lambs were placed on the plots on 4 November 2020. Sheep remained on the continuously grazed plots (T1) until 4 May 2021; a total of 181 days. The two rotationally grazed treatments were grazed three times during the growing season for a total of 42 and 32 days for the T3 and T4 treatments respectively. The extended rest periods in T2 and T4 were for 72 and 77 days (~11 weeks), respectively, during December 2020–February 2021.

The stocking rate was varied using a put-and-take method whereby sheep numbers were adjusted to match the pasture growth rate and maintain green herbage mass suitable for livestock production (≥0.8 t dry matter (DM)/ha green leaf). Therefore, stocking rates were increased when pasture growth rates increased and reduced when they declined. Stocking rates for each communal grazing system area were adjusted independently. The number of sheep on the continuous grazed plots ranged from 2 to 13 (8–64 sheep/ha) over the growing season. On the rotationally grazed plots, sheep numbers ranged 9 to 92 (up to 452 sheep/ha) to provide heavy stocking for short duration to graze digit grass without extended overgrazing of desmanthus.

It was noted that pasture height (>1 m tall) and high digit grass stem density restricted sheep access, particularly in the plots that had been rested for seed set. To encourage sheep to move through the tall pasture, tracks were cut (~0.5 m wide with pasture shortened to ~0.3 m high) down the middle of all plots using a whipper snipper in late January 2021.

Sheep were vaccinated with 5 in 1 for clostridial diseases prior to commencing grazing. Sheep were drenched with monepantel (25 mg/ml a.i.) and moxidectin (20 g/L a.i.) on 4 November 2020 and derquantel (10 g/ml a.i.) + abamectin (1 mg/ml a.i.) on 18 February 2021 to control internal parasites. The lambs were crutched on 8 March 2021 and backlined on 29 March 2021 with cryomazine (60 g/L a.i.) as a preventative against fly strike.

Data collection

Herbage production was assessed every 1–3 weeks; before plots were opened or closed (rest periods or rotational grazing), or there was a change in green herbage mass availability. Dry matter was assessed using a calibration score technique (Boschma *et al*. 2021a). Each plot was divided into six strata providing six assessments per plot. The calibration quadrats (n = 15) were cut to 10 mm and material sorted into desmanthus, digit grass and other. Digit grass was the major component of the pasture and a subset of grass samples were sorted into green leaf, green stem, dead leaf and dead stem to better estimate what was available for the sheep. All samples were dried at 80°C for 48 h then weighed. Dried sample weights were regressed against scores and scores converted to kg DM/ha.

The herbage mass data were used to determine stocking rates with the aim to maintain at least ~800 kg DM/ha of green leaf. Stock numbers were determined using the calculation:

Number of sheep = (S-R+G*T)/(DMI*30)

Where S was the average standing green herbage mass of the treatment before grazing (kg DM/ha), R was the residual herbage mass (kg DM/ha), G was the estimated pasture growth rate (kg DM/ha/d), T was the time period for grazing (days), and DMI was the dry matter intake (kg DM/hd/d) and set at 1.5 kg DM/hd/d.

Pasture persistence of desmanthus and digit grass was assessed using frequency of occurrence (Brown 1954) at the start of the experiment (October 2020) and again in October 2021. Frequency was assessed using 1 m2 grid consisting of 100 cells (each 0.1 x 0.1 m) in four fixed locations in each plot. The number of cells containing the base of desmanthus and digit grass were recorded. Actual and long-term average (LTA) month rainfall data were sourced from a local Bureau of Meteorology site (055325).

Results

Rainfall

Rainfall was below average 2018–19 (50% of the LTA) during pasture establishment, but above average (139% LTA) January 2020–October 2020 (Fig. 1). During the desmanthus-digit grass grazing experiment (November 2020–April 2021) total rainfall was 543 mm (143% LTA); rainfall far exceeding the monthly average in December 2020 and March 2021 (Fig. 1).

Pasture growth and rest periods

There was ~2000 kg DM/ha pasture on all treatments when the experiment commenced on 4 November 2020 (Fig. 2). Desmanthus was preferentially grazed by the sheep. Within 2 weeks of grazing commencing, the sheep had grazed all desmanthus plants to 10 mm. On the continuously grazed plots, desmanthus plants remained short for the entire growing season. Desmanthus regrowth was slow in the rotationally grazed treatments taking up to 7 weeks to regrow to 0.25 m height.

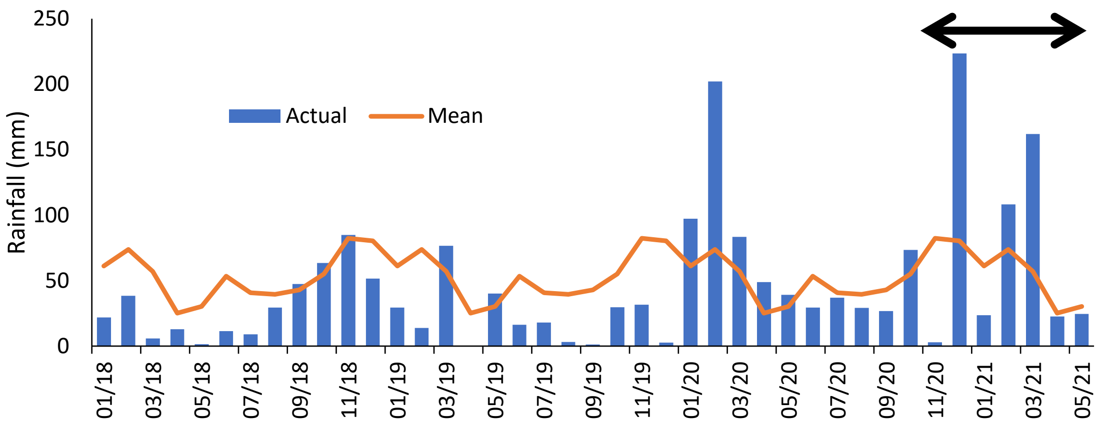

Figure 1. Actual and long-term average (mean) monthly rainfall (mm) at Tamworth, January 2018–April 2021. The black arrow indicates the experimental period. Data are from Bureau of Meteorology station 55325 (1992–2022).

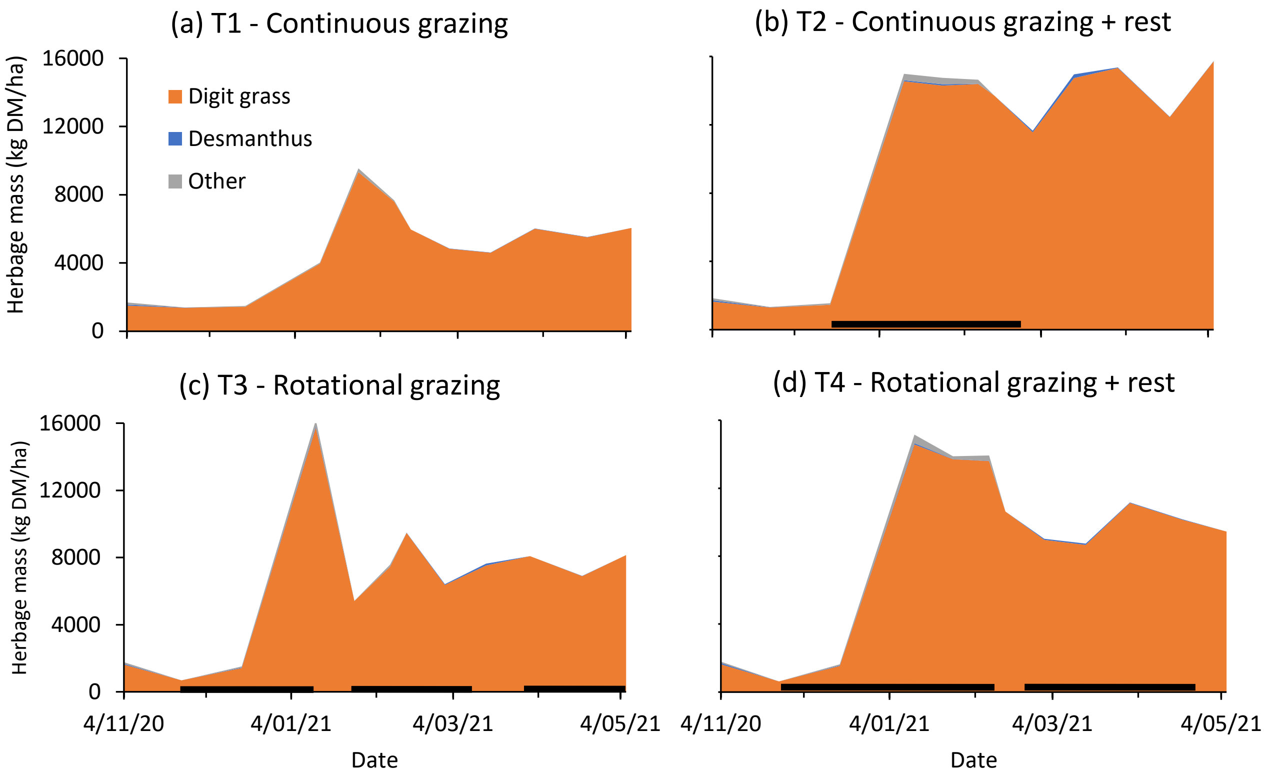

Figure 2. Herbage mass (kg DM/ha) in the desmanthus-digit grass grazing experiment during the 2020–21 growing season for (a) Continuous grazing (T1), (b) Continuous grazing with rest period (T2), (c) Rotational grazing (T3), and (d) Rotational grazing with rest period (T4). Periods when sheep were not grazing the plots are shown by black bars on each figure.

Stocking rate matched pasture growth relatively well throughout November and December (Fig. 2). Rainfall over the Christmas–January period resulted in strong pasture growth. Reduced ability to conduct pasture assessments and adjust stocking rates during this period resulted in digit grass growth greatly exceeding animal intake. Over this 4-week period, herbage mass on the continuously grazed plots rose from 1.5 t DM ha to an average 9.5 t DM/ha (with green leaf declining from 35% to average 12% and green stem increasing from 65 to 88%). From this time until the end of the growing season, the proportion of stem in all four treatments continued to increase (Fig. 2).

During the rest period in both T2 and T4, digit grass growth was extensive and flowering stems grew to >1 m height and the pasture herbage mass estimated to be 14–16 t DM/ha (Fig. 2). Desmanthus was shorter and had comparatively slow growth compared to digit grass.

Desmanthus and digit grass persistence

Average frequencies of occurrence of digit grass and desmanthus at the commencement of the experiment were 19 and 5% respectively. The frequency of desmanthus was lower than preferred, but the experiment continued as planned. Twelve months later, the frequency of digit grass had increased to an average of 61%. Desmanthus failed to persist, with a plant frequency of 0% in all fixed quadrats, although some plants were noted outside the assessment areas (data not shown).

During the 11-week rest period, seedling regeneration of both desmanthus and digit grass was noted, however, while digit grass set seed during this period, desmanthus did not. Seedling recruitment of digit grass occurred in all treatments.

Discussion

We hypothesised that an extended rest period would be essential for desmanthus plants to flower and set seed, and for newly recruited seedlings to establish sufficiently to withstand grazing. Contrary to this, desmanthus plants failed to set seed and there was negligible seedling recruitment during the extended rest period. Furthermore, desmanthus failed to persist under all treatments. These results indicate that the duration of the rest period alone was insufficient to support desmanthus persistence and that other factors, particularly extreme competition from digit grass, constrained regeneration and survival.

The poor persistence of desmanthus observed in this study was unexpected and contrasts with findings from an earlier study that highlighted its superior persistence (Boschma *et al.* 2021a,b). Notably, the earlier study was conducted largely during and following drought conditions. Desmanthus is recognised as a legume adapted to semi-arid rangeland environments in northern Australia (Gardiner 2016), where annual rainfall is lower (250–500 mm AAR) and grass density and growth potential are typically reduced relative to higher rainfall regions. In those environments, the prolific seeding and hard-seeded characteristics of desmanthus are well suited to supporting persistence. While these traits would also be advantageous in higher rainfall environments, we suggest that they were insufficient to overcome the competitive pressures imposed by digit grass in our study. In support of this suggestion, desmanthus has recently failed to persist in a commercial mixed pasture in the Boggabri area on the North-West Slopes (~600 mm AAR; 60% falling October–March), yet is persisting in a pasture with low grass population in the Mungindi area of North-West NSW (~500 mm AAR; 64% October–March) (JW McLachlan, pers. comm.). These observations suggest that competition intensity, rather than rainfall alone, may be a critical determinant of desmanthus persistence.

The competitiveness of digit grass relative to desmanthus was clearly demonstrated in this study. Digit grass exhibited higher growth rates and proved to be highly competitive against desmanthus, with this difference exacerbated by the favourable season for growth. On the North-West Slopes, digit grass also commences spring growth earlier than desmanthus, enabling it to gain first and largely uninhibited access to mineralised nitrogen and soil water stored over the winter period. This slow regrowth of desmanthus in spring is an important limitation. Desmanthus growth recommences from the crown because frost kills all growth points on the stems. In contrast, digit grass resumes growth earlier and with higher growth rates. Additionally, at the time of this study, the pasture was likely still in the high-growth phase commonly observed during the first 2–3 years following establishment, when soil nitrate and water resources are readily available. Being post-drought, mineralisation may also have elevated soil nitrogen levels, further favouring strong early grass growth. High rainfall during the growing season compounded these effects, creating conditions ideal for digit grass dominance.

The extended rest period proved insufficient for Progardes desmanthus to regrow, flower and set seed in the mixed pasture. In contrast, digit grass was able to set seed within this period. This was possibly in part due to digit grass having substantially higher herbage mass than desmanthus at the commencement of the rest period (i.e. ~1300 cf. <100 kg DM/ha). These observations highlight the inherent growth and phenological advantages of digit grass under the conditions of this study.

In northern NSW, early flowering and rapid pod development appear to be important traits for desmanthus persistence. The lack of seed set during the ~11-week rest period may have been influenced by the later-maturing cultivars with slow pod development. Among commercially available cultivars in Australia, cv. Marc is the earliest flowering and has demonstrated persistence in previous studies (Boschma *et al.* 2021a,b). It also produces large quantities of seed that mature quickly and recruit readily (Graham *et al.* 1991; Cox 1998; Cook *et al.* 2020). However, cv. Marc has disadvantages, including a short growth habit (maximum 0.6 m; Cook *et al.* 2020) and high susceptibility to alfalfa mosaic virus, which markedly reduces productivity of infected plants (van Leur *et al.* 2019; Murphy *et al.* 2022). For these reasons, cv. Progardes was used in the present study. Each cultivar within the Progardes mix was selected as the earliest flowering of its species among the JCU suite and, while also susceptible to alfalfa mosaic virus, these cultivars have been observed to succumb more slowly and appear to experience less growth reduction (Boschma and Brennan, unpublished data).

Poor seasonal conditions following establishment, combined with the presence of later-maturing desmanthus cultivars, may have collectively resulted in reduced seed set and the development of a low soil seed bank, contributing to poor desmanthus regeneration in our study. Additionally, the soil pH at the site was lower than optimal for desmanthus, which may have further reduced its resilience to stresses such as competition and grazing. Winter slashing may also have influenced persistence. Slashing large, frosted desmanthus plants with woody stems in late winter may have been detrimental, as broken crowns were observed in some plants. This physical damage may have increased vulnerability to infection and reduced subsequent survival.

Poor flowering and seed set were potentially exacerbated by shading arising from the high herbage mass and height of digit grass (14–16 t DM/ha). Although shade tolerance varies among *Desmanthus* species, with some able to tolerate moderate shading (e.g. *D. pernambucanus*), they are generally reported to perform best under full light conditions (Cook *et al.* 2020). The combination of shading, late cultivar maturity, and intense competition likely constrained flowering and pod development during the rest period.

There is potential for the competitive balance between digit grass and desmanthus to be partly manipulated at pasture establishment. For example, reducing the sowing rate of digit grass while increasing the sowing rate of desmanthus (e.g. to 0.5 and 4 kg/ha germinable bare seed equivalent, respectively) could allow desmanthus to establish at higher plant densities and set more seed early, thereby building a larger soil seed bank. Although digit grass would likely thicken over time, as evidenced by plant frequency tripling during the 12-months surrounding the study period, this process may be slowed due to increased competition from a larger desmanthus population. While such strategies may assist establishment, they are unlikely to support long-term persistence of desmanthus once digit grass exceeds a threshold plant density and ongoing recruitment becomes restricted. An alternative option may be to sow desmanthus with grasses that exhibit slower spring growth and do not readily recruit from seed, such as Bambatsi panic (*Panicum coloratum*) or panic grass (*Megathyrsus maximus*).

The purpose of a rest period influences both its timing and duration. In this study, the rest period commenced in December to capitalise on rainfall and to facilitate seedling establishment. While logical in this situation, the timing may have been too early for later-maturing cultivars. In earlier studies on the North-West Slopes, pastures were rested from autumn (Boschma *et al.* 2021a). Although desmanthus can flower and seedlings regenerate from November/December through to the end of the growing season (SP Boschma, unpublished data), resting during autumn may allow seed set and pod maturation before frosts in May while maximising grazing opportunities through summer. However, this strategy carries risks, as poor late summer–autumn rainfall may limit seed set, particularly for cultivars requiring extended pod development. It also does not protect seedlings that germinate after earlier rainfall events, although seedling recruitment has been reported to be higher in grazed pastures (Burrows and Porter 1993).

Desmanthus is highly palatable, and sheep are more proficient at selective grazing than cattle. Additionally, taller pastures are generally better suited to cattle grazing systems (Graham 2017). In studies examining the response of D. *virgatus* to varying defoliation heights and regrowth intervals, frequent close defoliation reduced branching, productivity and persistence, whereas light frequent defoliation (every 2 weeks maintaining a stubble height of 1 m) resulted in superior persistence (Trujillo *et al.* 1996). In grazed systems, this could be achieved using short periods of grazing with high stocking rates of livestock which show less selectivity. In our study, the grass and legume were sown in alternate rows to increase spatial separation and potentially reduce competition. However, this configuration may also encourage livestock—particularly sheep—tracking along rows and selectively grazing desmanthus. Collectively, these findings suggest that digit grass–desmanthus pastures may be better suited to cattle grazing than sheep, as the stocking rates required to maintain pasture masses suitable for sheep (≤1600 kg DM/ha; Graham 2017) are unlikely to support adequate desmanthus regrowth and persistence.

Conclusions

This study demonstrated that digit grass is highly competitive against desmanthus, restricting regrowth and flowering. The failure of desmanthus to persist under an extended rest period appeared to be primarily due competition with digit grass rather than by rest duration alone. Manipulating the sowing rates of desmanthus and digit grass may assist establishment and contribute to maintaining higher desmanthus plant populations. Alternatively, sowing desmanthus with a shorter-season tropical grass may reduce competitive pressure, particularly during early spring when desmanthus growth rates are low. The high growth rates of digit grass relative to desmanthus also complicated grazing management, especially in sheep-grazed systems.

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