What is the optimal ratio of digit grass and lucerne in a mixed pasture?

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Abstract: *Tropical perennial grass and legume pasture mixes are productive forage options in northern inland NSW. Optimal sward density (plants/m^2) to efficiently use resources is known to vary with annual rainfall. For the northern inland NSW region, this density for digit grass (*Digitaria eriantha*) ranges between 4 and 9 plants/m^2. Lucerne (*Medicago sativa*) is a favoured companion legume for digit grass, but it can dominate production. Therefore, the aim of this study is to determine the optimal ratio of digit grass and lucerne in a mixed pasture. In spring 2018 a replacement series field experiment, with five treatments comprising different proportions of digit grass and lucerne sown at 8 plants/m^2, was established at the Tamworth Agricultural Institute. Measures of total water use, total herbage production and proportion legume have begun. Early assessments through the hot and dry summer of 2018–19 have indicated that digit grass out-performed lucerne. Data collected over the period 2018–19 to 2021–22 will be used to determine the optimal ratio of grass to legume in this context.*

Key words: water use efficiency, stored soil water

Introduction

Tropical perennial grass pastures have many desirable characteristics as forage in northern inland NSW as they are highly productive, long-lived, and drought tolerant (Boschma *et al*. 2014). Digit grass (*Digitaria eriantha* cv. Premier) is suited to many soils in this region and it has been widely sown as either pure swards or the dominant species in mixes. Recent studies identified that the sward density for optimal production and hydrological performance of a digit grass pasture is 4–9 plants/m^2 (Boschma *et al*. 2019). All highly productive grass pastures require adequate nutrients, particularly nitrogen, to maintain growth (Havilah *et al*. 2006), and grass-legume mixtures are therefore desirable.

Lucerne (*Medicago sativa*) is well suited to this region and earlier studies have investigated the potential of digit grass-lucerne pasture mixes (e.g. Tow 1993). Following on from those studies, a more recent study (Murphy *et al*. 2018) investigated the effects of spatial arrangement on digit grass-lucerne mixes by varying sowing-row configuration (1:1, 3:3 or 6:6 alternating sowing rows of each species) while each species occupied 50% of the overall area sown. Almost regardless of the configuration, lucerne dominated total herbage mass contributing 69–73% of plant dry matter over the four years of the study (Murphy *et al*. 2018). This occurred because lucerne established at a high density and was highly competitive at using stored soil water in spring before the digit grass commenced its growth, and the extent of this competition may have been due to the plant density of lucerne. A more even herbage distribution between the species may have been achieved with a lower plant density of lucerne. Therefore, the challenge is to identify the optimal ratio of digit grass-lucerne to prevent lucerne from out-competing digit grass for stored soil water, yet maintain overall production.

The replacement series experimental technique (de Wit 1960), involving two species sown in differing proportions, is an effective method of studying plant interactions at a constant total density (Boschma *et al*. 2010). The study described here uses five ratios of digit grass-lucerne in replacement series to identify the ratio that provides optimal dry matter production and efficient use of soil water. The study commenced in spring 2018 and will end in autumn 2022. This paper presents findings from the first summer after commencing the experiment.

Methods

Site and spaced plants

The experiment was initiated in spring 2018 at Tamworth Agricultural Institute (31°08’43”S, 150°58’06”E) on a brown Vertosol (Isbell

1996). In the two years prior to initiating the experiment, the site was planted to cover crops of forage oat (*Avena sativa*) and then field pea (*Pisum sativum*) during winter and fallowed during summer to accumulate stored soil water and control weeds.

A replacement series study (de Wit 1960) was designed with five treatments (Table 1). All treatments were established at 8 plants/m^2, but with differing ratios of digit grass and lucerne (vis. 8-0, 6-2, 4-4, 2-6, 0-8 plants/m^2 of digit grass and lucerne, respectively). Each treatment plot, 4 × 4 m, contained 128 plants and was replicated three times in a randomised complete block design. Seedlings of digit grass (cv. Premier) and lucerne (cv. Venus) were grown in a glasshouse as individual tubestock for 4–8 weeks before being transplanted into plots on 13–15 November 2018 in the defined proportions (Fig. 1a). Plots were irrigated on three occasions between 15 and 17 November (totalling 80 mm) to minimise transplant shock. Any sick or dead plants were replaced over the first four weeks. Total rainfall recorded at the Institute's weather station (WaterNSW real-time data; weather station #419113) from transplanting to 1 February 2019 was 156 mm.

Soil water content and herbage mass

An aluminium access tube was installed in the centre of each plot to a depth of 1.9 m to enable volumetric soil water content to be estimated using a neutron moisture meter calibrated for local soil conditions as per Boschma *et al.* (2019). Soil water content was estimated after transplanting (27 November 2018) and then at 3-week intervals by taking neutron counts over a 16-s period at 0.2 m intervals down the soil profile representing soil layers 0.2 m thick to 1.9 m (i.e. 0.1–0.3, 0.3–0.5,…,1.7–1.9 m). Total stored soil water for the profile (SSW, mm, 0–1.9 m) was calculated by summing values for each layer.

Herbage mass was assessed at 6- and then 9-weeks after transplanting by collecting all herbage above a height of 50 mm in a 1 × 1 m quadrat rotated through two of four locations adjacent to the access tube (e.g. Boschma *et al.* 2019). The herbage of digit grass and lucerne was cut separately and then oven dried at 80°C for 48 hr and plant dry matter (kg DM/ha) determined. After each assessment plots were mown to 50 mm height and the herbage removed.

Changes in soil water content and total herbage production were determined for the period 27 November 2018–1 February 2019. Water use efficiency (WUE, kg DM/ha/mm) of total herbage production was calculated by dividing total dry matter by total water use. Water use was determined by water balance (e.g. Murphy *et al.* 2018; Boschma *et al.* 2019). The least significant difference (l.s.d., $P = 0.05$) was used to identify differences between values of change in profile stored soil water, total water used, total herbage mass and water use efficiency.

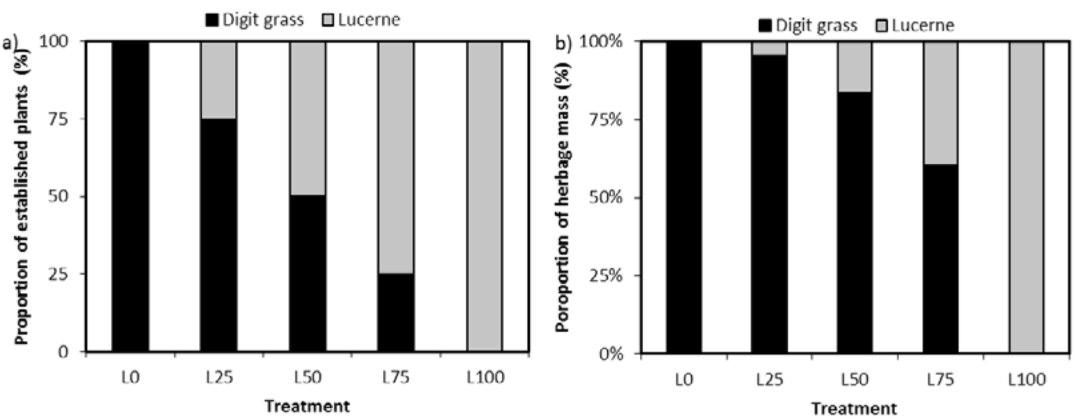

Figure 1. a) Proportions of digit grass and lucerne plants in five treatments established at 8 plants/m^2, and b) proportion of herbage mass (kg DM/ha) of digit grass and lucerne harvested from each of the treatments in summer 2018–19, which illustrates over-yielding of digit grass for this season.

Results

Summer 2018–19 experienced both above average daily temperatures and below average total rainfall. Following the commencement of the experiment, soil water content measures showed extraction to a depth > 1.0 m (Fig. 2), with the treatments extracting 87–103 mm, but differences were not significant ($P > 0.05$). Total water used during the period ranged between 323 and 339 mm for pure lucerne (L100) and pure digit grass (L0), respectively (Table 1).

Digit grass showed superior productivity during summer 2018–19; producing the most herbage of the five treatments as a pure sward (L0, $P < 0.05$, Table 1). It also outperformed its established proportion for the three treatments containing both species, e.g. digit grass represented 84% of total herbage in L50 (Table 1, Fig. 1). Total herbage production declined as the proportion of lucerne increased, with pure lucerne (L100) producing less ($P < 0.05$) than all other treatments (Table 1). Water use efficiency of total herbage production similarly declined from 11.5 to 4.9 kg DM/ha/mm with pure digit grass and lucerne plots having the highest and lowest ($P < 0.05$) efficiencies, respectively (Table 1).

Discussion

The data sets described in this paper provide a unique snapshot of the early development of these digit grass-lucerne pastures. While the assessed growth period was just 67 days, it has revealed some surprising insights. The soil water content data show that extraction took place in all treatments to depths of at least 1.0 m, which indicate that the drying front progressed downwards at a rate of ~15 mm/day (i.e. 1000 mm divided by 67 days). Despite all treatments using similar amounts of soil water from the profile, there were large differences among values of herbage mass, which translated directly to significant differences in WUE.

The replacement series experimental approach (de Wit 1960) offers an effective method to study the competition between two species sown in a pasture sward (Boschma *et al.* 2010). The data presented here, obviously, are for only a short period following establishment and so only represent initial interactions. It is clear, however, that for this short period, neither species

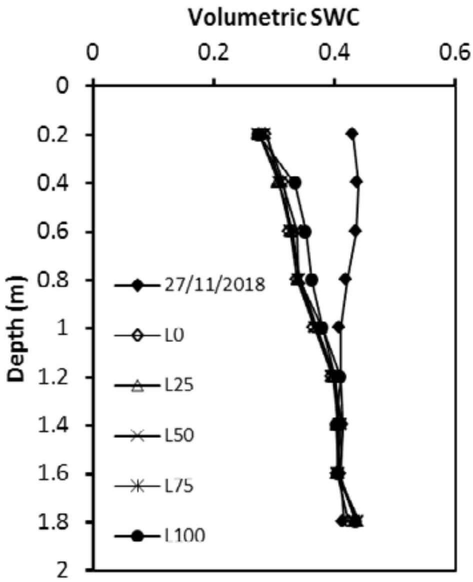

Figure 2. Changes in volumetric soil water content (SWC) of digit grass and lucerne treatments established at increasing proportion of lucerne from 27 November 2018 (mean of all treatments) to 1 February 2019.

Table 1. Effect of digit grass-lucerne treatments on change in stored soil water (SSW, mm), total water used (mm), herbage produced (kg DM/ha) and water use efficiency (WUE, kg DM/ha/mm) for the period 17 November 2018 –1 February 2019.

Treatment	Plants/m²		Rainfall + Irrigation (mm)	Change in SSW (mm)	Total water used (mm)	Herbage (kg DM/ha)	WUE (kg DM/ha/mm)
	digit grass	lucerne					
L0	8	0	236	103	339	3904	11.5
L25	6	2	236	101	337	3590	10.6
L50	4	4	236	97	333	3218	9.7
L75	2	6	236	101	337	2674	7.9
L100	0	8	236	87	323	1596	4.9
l.s.d. $P = 0.05$			–	NS	NS	794.8	2.06

contributed to total herbage mass in direct proportion to its ratio in the mixture, with digit grass over-yielding and lucerne under-yielding. This outcome may be due to a couple of factors.

The tropical grass appeared to be unaffected by the hot and dry summer compared to the temperate legume. The high daily maximum temperatures experienced (mean maximum of 34.9°C) were above the reported optimum for lucerne growth (25–30°C; Moot *et al.* 2008), but within the reported range for growth of digit grass (25–40°C; Whitney and Green 1969). In the comparatively cooler autumn and in subsequent seasons the lucerne component of these mixtures may well perform more strongly as seen in earlier experiments (Murphy *et al.* 2019), where lucerne was shown to begin strong growth earlier in spring than digit grass.

Spring is known to be a less favourable time for sowing lucerne pastures and in a grass-legume mixture, sowing time can have a long-lasting impact on performance (S. Boschma pers. comm.). For such pastures, established plant density, and therefore subsequent production will tend to be dominated by the species sown closest to its preferred time of year, which in this experiment, was digit grass. In a previous experiment, where conditions for establishment were more suited to lucerne, it established well and subsequently dominated early spring growth, utilised soil moisture stored during winter, and so tended to dominate the stand through time, contributing 69–73% of herbage mass (Murphy *et al.* 2018).

The low WUE values for L100 and L75 (i.e. plant ratios dominated by lucerne) clearly articulate the relative underperformance in this establishment phase of these treatments compared with those having a high ratio of digit grass. It appears that WUE will be an ideal parameter to describe the effects of competition for soil water in these mixtures, as all treatments have had and will receive equal rainfall. This study will continue until the end of autumn 2022 and so provide data across seasons and years that will define the optimal ratio of digit grass and lucerne in mixed pastures in northern inland NSW.

Acknowledgments

We appreciate technical support provided by Geoff Bevan and Brad Jenkins. This study is funded by NSW Department of Primary Industries and the Meat & Livestock Australia Donor Company as part of the Livestock Productivity Partnership.

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