Production, water use and water-use-efficiency of short-term ley legumes in southern Queensland

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Abstract

Ley legumes can have benefits for cropping systems in Australia's subtropics that are increasingly challenged with depleting soil chemical and physical fertility, increasing levels of disease (e.g. crown rot, nematodes), and increasing costs of inputs. The production and water use of a number of summer- and winter-growing forage legumes suited to short-term rotations with crops (1-3 years) was compared at various sites across southern Queensland between 2007 and 2010. We found that annual grass forages (oats and forage sorghum) produced more biomass and had higher water-use-efficiency than the legumes. Lucerne extracted more water from the soil than all other species and had lower water-use-efficiency than other legumes (5.5-9.0 kg DM/mm.ha). The other two perennial species, burgundy bean (*Macroptillium bracteatum*) and sulla (*Hedysarum coronarium*), extracted more water from the soil than the annual species, but this was less than lucerne. Lablab (*Lablab purpureus*) had higher production and WUE than burgundy bean in year 1 but burgundy bean production was similar in subsequent years. Similarly, sulla and snail medic production was variable in year 1 but they responded quickly in their second year (2009) and had higher WUE. Purple vetch was never the most productive legume and production was always less than 2 t DM/ha.

Introduction

Soil fertility in Australia's northern cropping zone is decreasing due to long-term continuous cropping. The use of pasture legumes in these cropping systems is one way to improve levels of soil fertility via inputs of fixed nitrogen, while also providing high quality forage for livestock and diversifying crop rotations (Weston et al. 2000). However, there is often a negative effect on yields of subsequent crops due to depletion of soil water, especially after lucerne (Murray-Prior et al. 2005). Past research has investigated the impacts of lucerne and medic pastures in crop rotations (Hossain *et al*. 1996), but new legume species such as burgundy bean and sulla have since become commercially available (Lloyd et al. 2003; Whitbread et al. 2005). Little information is available on the comparative production, water use and nitrogen benefits of these new species compared with existing legume and forage grass options.

Materials and Methods

Four winter and four summer-growing forages were grown at 4 locations in southern Queensland between 2007 and 2010 (Roma, Chinchilla, Condamine, Toobeah). Winter growing species included forage oats cv. Taipan*,* snail medic *cv. Sava*, sulla cv. Wilpena, and purple vetch cv. Popany*.* Summer growing forages were forage sorghum cv. Sugargraze*,* lucerne cv. UQL-1, burgundy bean cv. Juanita/Cadarga, and lablab cv. Highworth. Oats, forage sorghum, lablab and purple vetch were resown each year on the first opportunity for their respective growing seasons. Other legumes were allowed to perenniate (lucerne, burgundy bean, sulla) or regenerate (snail medic). Each experimental site consisted of summer and winter-growing species separated for ease of management, with 5 x 9 m plots of each species replicated 4 times. Every 6-8 weeks during the growing season, crop biomass cuts were taken from 2 x 0.5 m^2 quadrats in each replicate, to determine accumulated growth of each growing season. Once peak biomass was reached (at end of flowering), the plots were cut to a height of 3-5 cm, biomass removed and allowed to regrow. Soil water content in the top 1.5-2.0 m was monitored with a neutron moisture meter and growing season crop water use was calculated from the change in profile soil water content and the incident rainfall over this period (components of the water losses were not determined). Analysis of variance was conducted using Genstat (VSN International Ltd) for a complete block design. Least significant differences calculated to compare between species within each site.year.

Results and discussion

A range of seasonal conditions were experienced over the experimental period. In general rainfall was above average in summer 07/08 at Chinchilla, winter 08 at Roma, and summer 09/10 at all sites. Other growing seasons had average or below average rainfall.

Amongst the summer growing species, forage sorghum generally produced the most biomass (Table 1). Lablab production was generally more than burgundy bean in its first year, but in subsequent years burgundy bean production was similar to lablab (Table 1). This was often due to variable establishment of burgundy bean (especially evident at Toobeah in 08/09). In its first year lucerne extracted more stored soil water and maintained a drier soil profile than the other species, and hence had higher total water use. Profile soil water content was similar under burgundy bean to lablab and forage sorghum throughout, except in 09/10 where burgundy bean used more water in autumn (Fig. 1). Forage sorghum had much higher WUE than the forage legumes, ranging from 20 to 45 kg DM/mm.ha (Table 1). Lucerne always had the lowest water use efficiency (< 12 kg DM/mm.ha). In all but one situation, lablab had higher WUE than burgundy bean. There was significant variation between years and locations in WUE of lablab (8-30 kg DM/mm.ha) and burgundy bean (7-18 kg DM/mm.ha). In all species, the drier sites at Roma and Condamine generally had lower WUE than at Chinchilla and Toobeah.

Table 1. Summer-growing forages - measured DM production, growing season water use and water-use-efficiency at various sites and seasons in southern Queensland.

	Accumulated DM (t DM/ha)			**Water use during growing period (mm)**			**WUE (kg DM/mm.ha)**		
Growing season	07/08	08/09	09/10	07/08	08/09	09/10	07/08	08/09	09/10
Chinchilla									
Forage sorghum	7.6†?0.4	22.2 ?1.7	14.4 ?1.5	286 ?23	611 ?13	419 ? 54	26.7†	36.2	34.5
Lablab	8.1 ?0.8	8.6 ?0.6	8.0 ?0.6	267 ?15	495 ?10	445 ?79	30.3	17.4	18.0
Lucerne		8.7 ?0.5	1.1†?0.1		711 ?54	448 ?5		12.2	2.5†
Burgundy bean	4.9 ?0.4	9.2 ?0.5	6.2 ?0.2	347 ?24	500 ?15	483 ?32	14.0	18.3	12.8
Roma									
Forage sorghum		9.0 ?0.8	15.4 ?0.6		445 ? 8	542 ? 1		20.2	28.4
Lablab		4.1 ?0.4	4.2 ?0.3		462 ?13	533 ?36		8.9	7.9

Lucerne	4.7 ?0.3	1.4 ?0.2	730 ?14	556 ?13	6.4	2.5
Burgundy bean	3.6 ?0.8	3.7 ?0.2	461 ?20	553 ?21	7.8	6.7
Condamine						
Forage sorghum	13.7 ?1.4		479 ?18	-	28.6	-
Lablab	5.2 ?0.5		458 ?18	-	11.4	-
Lucerne	5.7 ?0.4	1.9 ?0.2	690 ?19	499 ?13	8.3	3.9
Burgundy bean	4.7 ?0.8	4.5 ?0.7	488 ?17	569 ? 3	9.7	7.9
Toobeah						
Forage sorghum	12.0 ?1.6	15.6 ?0.7	263 ?11	389 ?14	40.0	45.3
Lablab	4.6 ?0.4	4.4 ?0.3	268 ?11	374 ? 5	15.0	11.4
Burgundy bean	2.4 ?0.2	4.6 ?0.5	277 ?10	403 ?14	8.1	9.2

† – indicates where biomass growth was not captured in sampling due to senescence or unintentional grazing by stock/feral animals.

Oats was the most productive and water-use-efficient winter-growing species in 2008, however in 2009 it established poorly at all sites and failed at Roma. Purple vetch also established poorly in 2009 at Roma and Condamine. In all years purple vetch produced less than 1.8 t DM/ha, which suggests that pure stands provide limited amounts of grazing. Vetch may be more suited to mixtures with oats or other winter-growing forage grasses.

Production and WUE of snail medic and sulla was quite variable between seasons. Snail medic establishment and production was poor in the first year in 2008 at all sites, but in 2009 (including first year at Toobeah) when good snail medic stands were established, production and WUE was better than oats and vetch (Table 2). First year production of sulla was similar to or greater than other annual legumes in 2008, and during the wet winter and spring in 2008 at Roma, sulla produced nearly as much biomass at oats. Sulla extracted more soil water than other winter-growing annual species, but it did not dry the soil profile as much as lucerne (Fig. 1). Second year WUE of sulla was higher than in year 1 and second year production was better than oats and vetch (which established poorly), but total production levels were limited by the dry seasonal conditions in 2009. In general, adult sulla plants persisted poorly through the summer, with 19-34% of plants surviving.

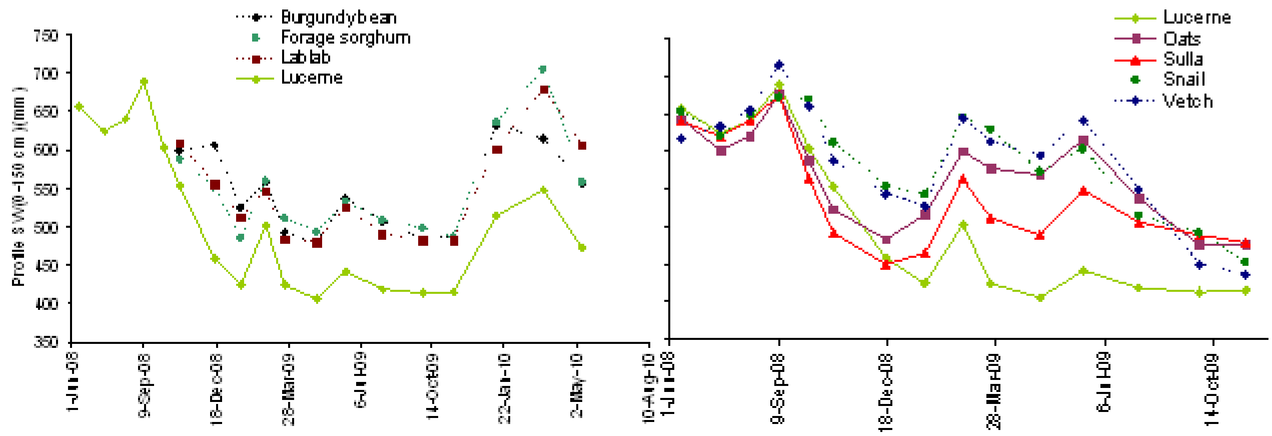

Figure 1. Profile soil water content (0-150 cm) under a 2 year phase of summer- (left) and winter- (right) growing forages at Roma, southern Queensland

Table 2. Winter growing forages - measured DM production, water use, and growing season water-use efficiency, at various sites and seasons across southern Qld.

	Accumulated DM (t DM/ha)		**Water use during growing period (mm)**		**WUE (kg DM/mm)**	
Growing season	08	09	08	09	08	09
Chinchilla						
Oats	3.8 ?0.2	1.1 ?0.2	287 ?24	362 ?30	13.2	3.0
Snail medic	0.8 ?0.1	3.4 ?0.1	260 ?27	370 ?36	2.9	9.2
Purple vetch	1.5 ?0.2	1.4 ?0.1	281 ?15	353 ?10	5.4	4.0
Sulla	1.5 ?0.2	4.0 ?0.5	367 ?29	367 ?38	4.1	10.7
Roma						
Oats	5.1 ?0.4	-	417 ?16	-	12.2	-
Snail medic	0.7[†]?0.2	2.0 ?0.3	356 ?26	242 ?23	2.0[†]	8.3
Purple vetch	1.7 ?0.2	-	366 ?19	-	4.6	-

Sulla	3.4[†]?0.4	1.0 ?0.1	460 ?33	154 ?18	7.4	6.5
Condamine						
Oats	4.9 ?0.4	1.4 ?0.3	281 ?28	260 ? 6	17.4	5.4
Snail medic	1.8 ?0.2	2.9 ?0.4	222 ?15	159 ?11	8.1	18.2
Purple vetch	1.8 ?0.2	0.5 ?0.1	260 ? 7	185 ? 5	6.9	2.7
Sulla	1.0[†]?0.1	1.7 ?0.2	256 ?15	116 ? 5	3.9[†]	14.7
Toobeah						
Oats		1.7 ?0.1		212 ?40		7.9
Snail medic		3.6 ?0.2		209 ?28		17.1
Purple vetch		1.4 ?0.1		258 ?36		5.3
Sulla		1.5 ?0.2		321 ?42		4.7

[†] – indicates where biomass growth was not captured in sampling due to senescence or unintentional grazing by stock/feral animals.

The estimated nitrogen fixation benefit for subsequent crops (1.5% of biomass production) over each phase of forage legumes was 60-130 kg N/ha.yr from lablab, 50-100 kg N/ha.yr from burgundy bean, 40-60 kg N/ha.yr for lucerne, and 20-35 kg N/ha.yr for the winter-growing legumes. In comparison, estimated N losses or requirements to replace N losses (assuming 50% of biomass N was recycled) under oats were 20-120 kg N/ha/yr and 90-220 kg N/ha/yr for forage sorghum. Nitrogen balance was measured in these experiments but is not reported here.

Conclusion

We found that annual forage grasses (oats and forage sorghum) are substantially more productive and water-use-efficient than forage legumes (in terms of DM/mm.ha). The only exception was in the winter of 2009 where the perennial and regenerating species, sulla and snail medic, demonstrated their advantage in utilising early season rain, before annual forage crops could be sown. In forage sorghum, quality and utilisation of biomass for grazing livestock is lower than legumes. However, it is unlikely improved growth rates (per unit biomass) of animals grazing on legume pastures would compensate for the substantially lower biomass production in the legumes. However, in perennial and regenerating species (i.e. sulla, burgundy bean, lucerne, snail medic) growing costs in subsequent years are small compared to species that are resown each year. In addition, if the value of nitrogen inputs is taken into account, forage legumes like burgundy bean and lablab are profitable alternatives to annual forage grasses. Burgundy bean and sulla extracted substantially less soil water less than lucerne. This may be an advantage for their incorporation into cropping systems, as they would not require long fallows to rewet the soil profile prior to resumption of cropping.

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