Managing economic and environmental sustainability with better P nutrition and summer forage legume in rotation with wheat in southern Queensland

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Abstract

A multi-phase legume-wheat cropping system experiment is being carried out in the semi-arid district of Roma, in southwest Queensland, Australia. The split-plot design used 2 rates of phosphorus (P) fertilizer (10 and 40 kg P/ha), applied at 10-15 cm depth, as main plots, and 4 forage legume treatments, sown in mid February 2003, as subplots. The legumes were lucerne *(Medicago sativa),* butterfly pea *(Clitoria ternatea),* burgundy bean *(Macroptilium bracteatum),* lablab *(Lablab purpureus),* together with a summer-fallow control. Spring wheat *(Triticum aestivum* cv. Kennedy) was sown into the legume stubble in early May and was harvested in early October. Soils were sampled during the legume and wheat phases, and analysed for available P and nitrate-N, and water content. Significant P x Legume interactions ($P<0.05$) occurred for legume shoot biomass, and for wheat grain yield. The annual summer forage legume lablab produced the highest shoot dry matter yield of 6.2 t/ha after 2.5 months growth with 40 kg P/ha, production that was significantly greater ($P<0.05$) than the 5.0 t/ha produced with 10 kg P/ha. The following wheat crop yielded 2.7 t grain/ha from the high P lablab, butterfly pea and fallow combinations, a yield that was significantly greater than wheat after lucerne. The annual forage legume-wheat system was able to use much of the summer rainfall water for biomass production. The system was able to maintain continuous surface cover and minimised weed growth in the wheat crop. Valuing the legume shoot biomass as hay or as a ration for cattle live-weight gain indicated that the legume-wheat system, particularly lablab-wheat, can be very profitable.

Media summary

The annual summer forage legume, lablab, provided quality feed for livestock production, increased the use of summer rainfall, provided a ground cover for the effective control of weed and soil erosion, and added adequate amounts of atmospheric N for a subsequent wheat crop.

Key Words

Summer forage legume, lablab, phosphorus, wheat, weed control, soil erosion.

Introduction

The current dryland cropping system in the relatively dry Roma region relies mostly on summer rainfall stored in the soil profile, storage that is achieved by maintaining a weed-free summer fallow using tillage or a combination of herbicides and minimum tillage. This system may lead to poor water use efficiency as well as significant soil erosion losses during episodic rainfall events. The maintenance of a green crop or pasture cover during the summer season could lessen these impacts. Strategically managed and adequately P-fertilized forage legumes can be highly productive under limiting water conditions (Singh et al. 1999). Forage legumes as a cover crop can also replace fertilizer N for the subsequent wheat crop (Dalal et al., 1995; Peoples et al. 1998), minimize soil erosion, maintain soil organic matter and improve soil structure (Smith et al. 1987), reduce weed density and biomass (Fisk et al. 2001; Cheruiyot et al. 2003), and provide quality feed for livestock weight gains. This study evaluated the performance of cropping sequences based on a short-term summer forage legume phase (2-3 months only) followed by a winter wheat crop.

Methods

The experiment was laid out as a split-plot design in 4 replicated blocks, with a factorial combination of 2 P rates as main plots and 4 legume treatments as subplots. The 2 P treatments were low (10 kg P/ha) and high (40 kg P/ha). The 4 legume treatments included lucerne, butterfly pea, burgundy bean and forage lablab (cv. Highworth), together with a summer fallow control plot. Phosphorus was banded at 10-15 cm depth in 33 cm wide row spacing, in the form of mono-ammonium phosphate (MAP) 4 months before the scheduled planting of legumes on 14 October 2002. Urea was also applied to the low-P treatments to match the additional nitrogen added from the increased rate of MAP for the high-P treatment. The forage legumes were planted in 33 cm wide row spacings, on 14 February in 2003. Each plot was 5 m wide and 15 m long. The legumes were grown until the end of April with no pesticide applications for weeds or insect pests. The shoots were harvested at a height of 5 cm on 30 April 2003. The wheat cultivar Kennedy (early maturing) was planted into the legume stubbles and fallow plots on 8 May 2003, at a rate of 60 kg seed/ha and a row spacing of 20 cm. No fertiliser or herbicide applications were undertaken during the wheat phase. The wheat crop matured in early October 2003. A second-year legume phase was planted in mid-October 2003, harvested in February 2004, and followed by a wheat crop planted in May 2004. The data presented in this study are from the first-year legume-wheat phase.

Gross margins were also calculated from legume and wheat crops after subtracting the increased costs involved in applying P fertilisers. Legume gross margins were calculated on the basis of its value as hay, or its value as a hay supplement in producing live-weight gain in beef cattle. The value of the legume hay was valued at A$3 per 20 kg bale, allowing for (1) a lowest selling price in the district for lucerne hay of A$5 for a 20 kg bale in a high rainfall year and (2) a poor marketing infrastructure for lablab hay. Assumed losses in hay making were 25% of the shoot dry matter. The value of the legume hay for cattle live-weight gain was based on a 1 kg gain resulting from the ingestion of 7 kg legume hay, with a 25% dry matter loss in the feeding process. Each kg of live-weight gain was valued at A$1.50/kg, with the current market price though being between A$1.70 and A$1.90/kg. The gross margin for the wheat crop after the legume phase was based on a wheat grain price of $170 t/ha. The gross margin for a standard wheat crop grown using district practices was calculated at A$294/ha. District practice involves the use of 3-4 herbicide applications to control summer weed growth during the fallow phase costing about $50/ha for the herbicide application. It should be noted that no fertiliser N or herbicide or P fertiliser were applied to the wheat crop following legumes in this experiment.

Results

Lablab produced the highest shoot dry matter yields of between 5 and 6 t/ha in the 2.5 month growth period from February to April 2003 (Figure 1). This yield was about 4 times that of the perennial legume lucerne, which was healthy and produced up to 1.7 t shoot dry matter/ha in this short time; a successful crop of lucerne produces between 5 and 6 t/ha shoot dry matter annually in this region. On this soil, where the initial soil P value was 15 mg P/kg soil (Colwell P) for 0-10 cm depth, the legumes responded to the higher rate of P. A substantial residual effect of the high rate of P fertiliser occurred with the shoot biomass of wheat (+ 15%) and the grain yield at maturity (Figure 2). The grain yield was highest for the high-P butterfly, lablab and fallow plots (Figure 2). The residual effect of the high-P rate was further extended to the third crop in a row, the second phase of legumes (data not presented).

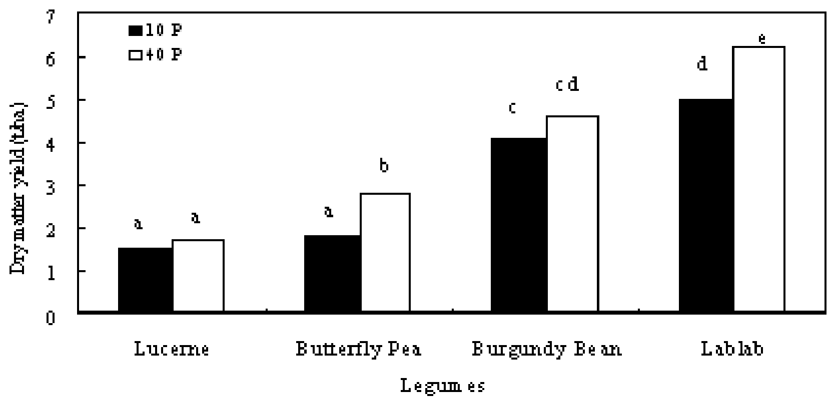

Figure 1. Effect of deep P applied at low (10 kg P/ha) and high (40 kg P/ha) rates on the shoot dry matter yield of legumes at the end of April 2003. Same letter/s indicate no significant difference

An unexpected result was the very low weed population and weed growth in the open between the wheat rows in the lablab plots (Photograph 1), due apparently to the ground cover of lablab in the previous season. The weed growth up until September 2003 was 0.8, 2.3, 3.7, and 5.0 t/ha for the lablab, burgundy bean, butterfly pea and fallow plots respectively.

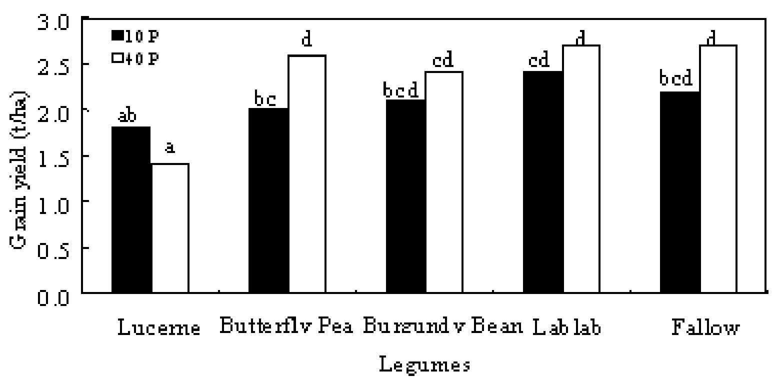

Figure 2: The effects of legumes and deep P, applied at low (10 kg P/ha) and high (40 kg P/ha) rates in October 2002, on the grain yield of the following wheat crop harvested in October 2003. Same letter/s indicate no significant difference

Photograph 1. The photograph on the left is showing the weed population (naturalized burr medic) between two wheat strips in a plot which was fallowed previously, compared with virtually no weeds in the plot (on the right) previously planted to lablab.

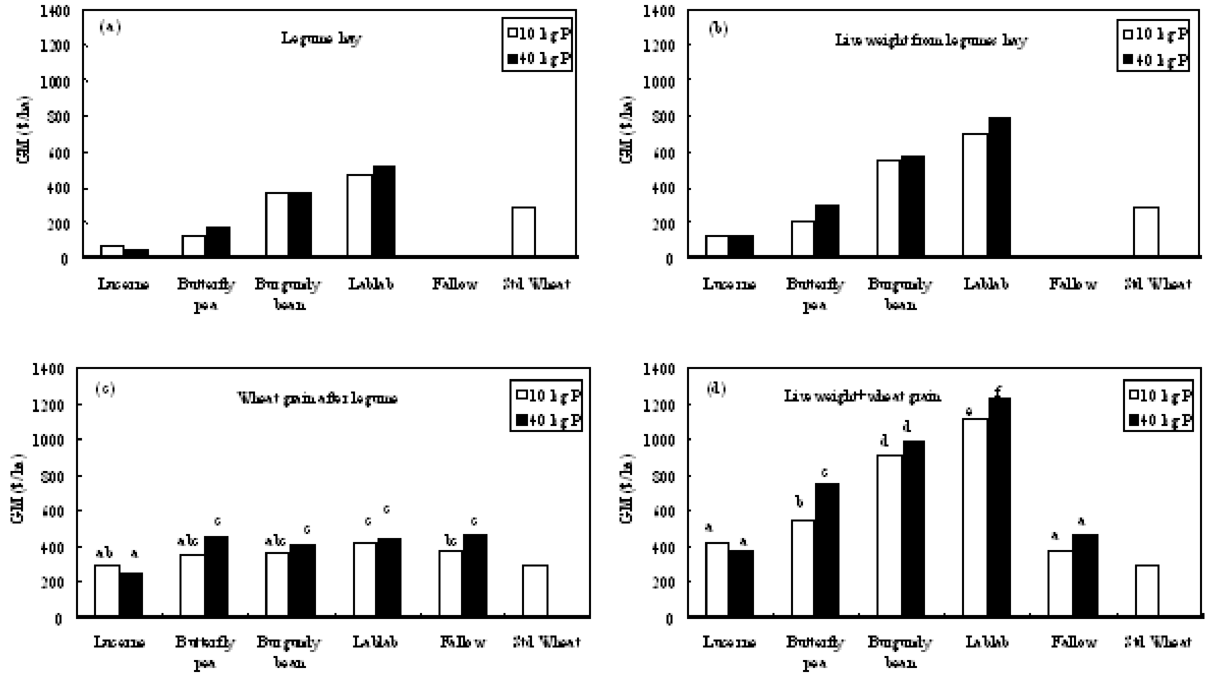

Figure 3. Estimated gross margins ($/ha) for legume-wheat or fallow-wheat rotation sequences with 10 and 40 kg P/ha applied, and the average fallow-wheat (std wheat) gross margin for the district. Gross margins estimated for the legume hay (a), beef live-weight gain from hay (b), wheat grain yield (c), and beef live-weight gain plus wheat grain yields (d). Same letter/s indicate no significant difference

The gross margins analysis, based on forage legume hay production from the legume phase, highlighted the benefits of the summer forage legume-wheat system, in particular lablab-wheat, compared with the standard wheat practice (Figure 3). The main effect gross margin mean, based on hay production, was almost A$500/ha for lablab, which was significantly higher ($P<0.001$) than that for burgundy bean (A$370), butterfly bean (A$150) or lucerne (A$60) (Figure 3a). These differences were a direct reflection of the greater shoot biomass produced by lablab after 2.5 months of growth (Figure 1). When the legume hay was fed to increase steer liveweight, estimated gross margins for the legume phase increased by about a further A$200/ha for lablab and burgundy bean (Figure 3b). The combination of the wheat and beef gross margins resulted in very profitable systems for the lablab and burgundy bean-wheat cropping systems (Figure 3d).

Discussion

The results demonstrated the potential value of legumes and additional P fertiliser in developing improved sustainable cropping practices in SW Queensland. A satisfying feature of the summer forage legume-wheat system was its potential ability to use *in situ* practically all of the water that fell as rain in summer, compared with the summer fallow-wheat system. The high seeding rates, narrow row spacings and the early sowing date for subsequent wheat crop ensured that the wheat canopy would close rapidly, thus resulting in a continuous ground cover and a better water use efficiency due to less early season evaporation (Eastham et al. 1999). The legume-wheat system is likely to reduce runoff, soil erosion, deep drainage and movement of chemicals and nutrients. A potential concern is that the utilisation of the summer rainfall by the legumes might raise concerns about less soil water being stored in the profile prior to the sowing of the wheat crop. In this study, a short-term (2-3 months) legume phase was able to produce substantial amounts of forage dry matter, without greatly influencing the quantity of stored water compared with the fallow plots (data not presented). The fallow plots lost 50% of the plant available water without producing any income-generating biomass.

A further benefit from the system, particularly with lablab, comes from its ability to readily establish in soil that is subject to rapid drying. Land managers in the region have experienced many failures in establishing grass, grass plus legumes or lucerne pastures in this environment (Belloti et al. 1991), as the small-seeded grass and lucerne must be sown close to the soil surface. The soil in which they are sown is therefore subject to rapid drying and establishment failures are common. On the other hand, lablab has a large seed size and it can be sown as deep as 10-15 cm if necessary. The lablab-wheat system successfully suppressed the weeds without the use of herbicides. This effect needs further investigation. It may due to a combination of factors, such as the rapid canopy closure and the high growth rate of lablab impacting on the germination of weed seed. Competition for water and nutrients is a less likely cause, since the weed suppression effect was seen following the lablab phase. There may also be some allelopathic effects, which were suspected in another study with lablab (Cheruiyot et al. 2003).

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