Improving mineral availability for grazing livestock in Australian pasture systems by using plantain and lucerne

Margaret Raeside, Zhongnan Nie and Ralph Behrendt

Department of Primary Industries, PB 105, Hamilton, Vic, Australia, 3300. Email: margaret.raeside@dpi.vic.gov.au

Abstract

Pasture systems in southern Australia are often based on grass/clover mixtures that are dominated by perennial ryegrass (*Lolium perenne* L.) or phalaris (*Phalaris aquatica* L.). The concentrations of some key minerals can be low in these pasture species and grazing livestock can experience a range of dietary mineral imbalances unless supplementary mineral sources are provided. Forage herbs and legumes are generally higher in mineral concentration than temperate grasses. Using herb or legume species in pasture systems could improve mineral availability for grazing livestock.

An experiment was conducted at Hamilton, Victoria, Australia, to compare the mineral concentrations from three pasture species: perennial ryegrass, plantain (*Plantago lanceolata* L.) and lucerne (*Medicago sativa* L.). These three pasture treatments were imposed on 1 ha plots in a randomised complete block design with four replications. The pastures were sown on 2-3rd November 2009. The mineral profile of each pasture species was analysed in April 2011. Analysis of Ca, P, Mg, K, Cl, Na, S, Cu, Mo, Mn, Fe, Zn, Se and Co was conducted by ICP-AES or ICP-MS procedures. The plantain had higher concentrations of Ca, Mg, Cu and Zn than the perennial ryegrass, with the lucerne generally having intermediate concentrations of these minerals. The plantain had higher concentrations of Fe, Na, Cl and S than both the lucerne and perennial ryegrass. The perennial ryegrass had the highest concentrations of Mo, Mn and K. Cobalt concentrations didn’t differ between the pasture species due to a large degree of variability between swards.

Key Words

Perennial pasture, nutritive value, animal nutrition, copper, selenium, condensed tannins.

Introduction

Livestock production in southern Australia is driven by the consumption of high nutritive value forages. Perennial ryegrass and phalaris are the predominant improved pasture species. These temperate grasses can, however, be inherently low in mineral concentrations (Pirhofer-Walzl et al. 2011). Plantain, lucerne, red clover (*Trifolium pratense* L.), white clover (*Trifolium repens* L.) and birdsfoot trefoil (*Lotus corniculatus* L.) all have demonstrably higher mineral concentrations than temperate grasses (Pirhofer-Walzl et al. 2011), but the use of these pasture species in southern Australia is often limited. Even small mineral imbalances have the potential to impact on livestock productivity. In southern Australia, Cu/Mo, K/Mg, Se and Co are some of the most prevalent imbalances (McFarlane et al. 1990). It was hypothesised that the use of plantain or lucerne would improve the mineral availability from pasture systems in southern Australia, relative to the current ‘best practice’ perennial ryegrass system.

Methods

Site description

The experiment was conducted at the Department of Primary Industries research farm at Hamilton, Victoria, Australia (37^{o}50’S, 142^{o}04’E; elevation 200 m). Climatic data was collected from an automated weather station which recorded rainfall every 10 minutes and maximum and minimum air temperatures every hour (at a height of 2 m). The site has a temperate climate with long term (1963-2011) average annual rainfall of 685 mm. Rainfall is winter and spring dominant (July-October are the wettest months) with summer and early autumn (December-April) typically being hot and dry, though large sporadic rainfall events during this time may occur. The long term (1965-2011) average maximum and minimum daily air temperatures in the warmest month (February) are 26^{o}C and 11^{o}C and in the coolest month (July) are 12^{o}C and 4^{o}C. On the day mineral sampling occurred (12th April 2011), the minimum and maximum temperatures were 7.9^{o}C and 15.3^{o}C, with a total of 90 mm of rain falling between the 9th and 11th of April.

Soil pits near the site indicated the geology of the soil was a tertiary/quaternary basalt. The soil mapping unit was a monivae gravelly loam (Northcote 1979). Soil samples collected on 7th October 2009 indicated that the fertility of the top soil (0-10 cm) across the site was in the following range: pH ($H_2$0) 5.6-5.7, P (Olsen) 13-

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19 mg/kg, K (Skene) 99-150 mg/kg and S (KC140) 9-10 mg/kg. Soil mineral concentrations were: Ca (Amm-Acet) 77-81%, Mg (Amm-Acet) 13-17%, Na 2.0-3.2% of cations, Zn (DTPA) 1.1-1.2 mg/kg, Cu (DTPA) 0.24-0.34 mg/kg, Fe (DTPA) 210-390 mg/kg and Mn (DTPA) 11-13 mg/kg.

Experimental treatments and design

Three pasture treatments were imposed on field plots in a randomised complete block design with four replications. The field plots were approximately 1 ha in size (400-600 m long and 16-18 m wide). The pasture treatments were monoculture swards of perennial ryegrass (cv. Banquet II), plantain (cv. Tonic) or lucerne (cv. Stamina GT6). The three different pasture species represent a perennial grass, a legume and a herb and are likely to differ in mineral content (Stewart 1996).

Site establishment and management

The pastures were direct drilled on 2-3rd November 2009 using a conventional disc drill. The sowing depth for all species was approximately 3 cm, with open drill rows. The site was rolled after sowing with a rubber-tyre roller. Sowing rates were 27 kg/ha for the perennial ryegrass, 6.2 kg/ha for the plantain and 11.4 kg/ha for the lucerne. All treatments were sown with 100 kg/ha mono-ammonium phosphate (MAP) (10%N, 22%P, 0%K, 2%S with 0.05%Mo). On 7th July 2010, 50 kg/ha of MAP was applied (10%N, 22%P, 0%K and 2%S). On 15th March 2011, 267 kg/ha of a superphosphate/urea mixed fertiliser (6.9%N, 7.5%P, 0%K, 9.3%S, 16.1% Ca) was applied to all plots. Weed control was conducted prior to and during the experiment to ensure that the swards consisted predominantly of the sown species. The plots were rotationally grazed by weaner lambs over the March-May period in 2011.

Measurements

Pasture mineral concentrations were analysed by Symbio Alliance (Eight Mile Plains, Qld, Australia). Referencing methods for the mineral analysis were ICP-AES for macro elements (Ca, P, Mg, K, Na, Cl and S) and ICP-MS for trace elements (Cu, Mo, Mn, Fe, Zn, Se and Co). The mineral concentration of the pastures was analysed prior to grazing on 12th April 2011, when the average herbage mass was 3.0-4.5 t DM/ha for most plots. The lucerne and plantain were flowering at the time of harvest and the perennial ryegrass was as the three leaf stage. Samples were collected by walking in a zig-zag manner across the plot, stopping every five paces to collect a handful of herbage at ground level using hand-held shears to give a total sample size of approximately 2 kg per plot. This sample was mixed thoroughly and a subsample dissected into green and dead material. The green portion was dried at 65^{o}C for 48 hours and then ground through a 1 mm sieve. The samples were not washed and, when possible, were kept iced/refrigerated between harvesting and drying. Presented mineral concentrations are the sum total in all above-ground plant parts (leaf and pseudostem in the perennial ryegrass; leaf, reproductive stem and seed head in the plantain and leaf and stem in the lucerne). All mineral concentrations are in mg/kg.

Statistical analysis

Differences in mineral concentrations between the perennial ryegrass, plantain and lucerne were determined using Fisher's protected least significant difference (LSD, P=0.05) (Steel and Torrie 1980). Each mineral element was analysed separately. The statistical package used was GenStat® Release 13 VSN International, Hemel Hempstead, UK.

Results

Mineral concentrations for perennial ryegrass, plantain and lucerne are shown in Table 1. The pasture species showed significant differences in all mineral concentrations except for Co.

Macro-minerals

Ca concentrations between the plantain and the lucerne did not differ significantly, but both these species had higher Ca concentrations than the perennial ryegrass. The plantain had higher concentrations of Mg than the perennial ryegrass and higher concentrations of Na, Cl and S than the lucerne and perennial ryegrass. The perennial ryegrass had the highest K concentrations.

Trace elements

The plantain had higher Cu concentrations than the perennial ryegrass (7.58 mg/kg in the plantain vs. 4.27 mg/kg in the perennial ryegrass), with Cu concentrations in the lucerne being similar to the perennial ryegrass. There was, however, a large degree of variation in the Cu concentrations of the lucerne, ranging from 2.85-6.00 mg/kg between the individual lucerne swards. The perennial ryegrass had the highest concentrations of Mo and Mn. The concentrations of Mo and Mn did not differ significantly between the plantain and lucerne. The plantain had the highest concentrations of Fe and Se and also had higher concentrations of Zn than the perennial ryegrass. Zn concentrations in the lucerne were generally intermediate of the plantain and perennial ryegrass. The large LSD for Co is due to a large degree of variation in Co concentration in the plantain and lucerne swards. Co concentrations in the perennial ryegrass were consistently in the range of 0.09-0.14 mg/kg, whereas plantain ranged from 0.05-0.96 mg/kg and lucerne from 0.30-0.63 mg/kg.

Table 1. Pre-grazing mineral concentrations (mg/kg) of perennial ryegrass, plantain and lucerne on 12th April 2011, with LSD's for comparing means between pasture species. Dietary requirements (mg/kg) for a 40 kg lamb growing at 100 g/day are shown (Standing Committee on Agriculture: Ruminants Subcommittee 1990)

Mineral	Perennial ryegrass	Plantain	Lucerne	LSD (P=0.05)	Approximate requirement of a 40 kg lamb growing at 100 g/day
			Macro-mineral concentrations (mg/kg)		
Ca	3017	16605	12151	5629.5	2900
P	3553	2753	2437	923.7	2000
Mg	1973	3169	2579	968.0	1200
K	28567	16084	15715	8578.9	5000
Na	4260	8143	1651	3775.5	700-900
Cl	17033	38234	10901	10569.9	800-1000
S	2830	4153	2223	1208.6	2500-3100
			Trace element concentrations (mg/kg)		
Cu	4.27	7.58	4.96	3.02	5.5
Mo	0.94	0.40	0.38	0.20	0.2-2.0
Mn	85.20	44.51	31.94	29.99	15-20
Fe	65.63	161.08	86.88	68.20	30-40
Zn	18.67	37.89	25.83	13.37	14-24
Se	0.11	0.18	0.09	0.04	>0.03
Co	0.11	0.49	0.46	0.44	0.11-0.50

Discussion

Perennial ryegrass pastures in this research had Cu concentrations below the dietary requirement of 5.5 mg/kg for a 40 kg lamb (Standing Committee on Agriculture: Ruminants Subcommittee 1990) and also had higher Mo concentrations than the other pasture species. Previous research has suggested that Cu deficiency can affect up to 11% of sheep and 13% of cattle in Victoria, as indicated from liver, kidney and muscle analysis (Langlands et al. 1987) and can represent a major economic loss to livestock systems due to ill thrift, poor liveweight gains and animal death, particularly among lambs. It is also known that Mo and S concentrations outside the range of 0.2-2.0 mg Mo/kg and 1000-3000 mg S/kg affect Cu absorption in sheep (Weber et al. 1978) and cattle (Mylrea 1958). This occurs because the intake of high levels of Mo by ruminants can decrease the activity of sulphur-based enzyme reactions, which leads to the formation of insoluble Cu compounds which are physiologically unavailable. The low Cu and high Mo concentrations in the perennial ryegrass may result in Cu deficiency in livestock, with unpublished autopsy results from the DPI Hamilton farm indicating that Cu deficiency has affected lambs on the property. The use of plantain in pasture systems may provide an improved dietary source of Cu, without increase Mo intake.

The concentrations of Zn and Fe were within or above the dietary requirements for a 40 kg lamb (Standing Committee on Agriculture: Ruminants Subcommittee 1990). These minerals are important in southern Australian pasture systems because they can also interfere with Cu absorption (Dick 1954). For Zn and Fe to interfere with Cu absorption, their respective concentrations need to exceed 100 mg Zn/kg or 500 mg Fe/kg (Standing Committee on Agriculture: Ruminants Subcommittee 1990), which are well below the levels reported from the tested pastures.

There are a number of cations and anions which are required to maintain osmotic pressure and acid:base equilibrium. The most important of these are Cl, K and Na. All of these elements had concentrations well above the dietary requirements for a 40 kg lamb (Standing Committee on Agriculture: Ruminants Subcommittee 1990). K, in particular, is an important cation in south west Victoria because, if present at high concentrations, it can interfere with Mg absorption in livestock (Tomas and Potter 1976). Previous research has shown that K concentrations of perennial ryegrass in south west Victoria are generally 3-4% DM (Walsh and Birrell 1987), which is consistent with the findings reported in this study. At this level, K is unlikely to impact on Mg absorption. Pastures containing high levels of Mg, such as plantain, may effectively prevent Mg deficiency in livestock. For example, hypomagnesaemia is rarely reported on tropical grasses which tend to have higher Mg concentrations than temperate species (Minson and Norton 1982).

Ca concentrations in the plantain and lucerne were four to five times higher than the perennial ryegrass and were well above the dietary requirements of a 40 kg lamb. The dietary Ca requirement of a dairy cow is approximately 14500 mg/kg for a jersey and 11500 mg/kg for a Friesian to balance Ca losses in milk (Standing Committee on Agriculture: Ruminants Subcommittee 1990). Only the plantain had sufficient Ca concentration to meet this requirement. The use of plantain in grazing systems may, therefore, improve the Ca homeostasis of lactating animals due to the species high Ca concentration and high anionic levels, especially Cl.

Conclusion

This research has suggested that perennial ryegrass may not adequately meet the mineral requirements of grazing livestock. Cu imbalances, in particular, may occur on perennial ryegrass due to low Cu concentrations and high Mo concentrations. Plantain had high levels of the key minerals Cu, Fe, Zn, Se, Ca and Mg, while also having low levels of other minerals which can cause problems if present in high concentrations, namely Mo and K. Plantain may, therefore, be an effective dietary mineral source for grazing livestock, especially for lactating animals due to its high Ca and Mg concentrations and anionic levels. This research was, however, only conducted on one sampling date and during a rainy period. Further research is needed to determine pasture mineral concentrations throughout the year. Furthermore, this has been an agronomy based study, with mineral absorption in the animal not considered. Further research is needed to determine if minerals present in the pastures are in an animal available form and how this affects animal production and carcass eating quality.

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