Sheep production and agronomic performance of *Lotus corniculatus* under dryland farming

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Abstract

Lotus corniculatus (lotus) contains condensed tannins (CT; 25–35 g/kg DM), which reduce the microbial degradation of forage protein in the rumen and increase amino acid absorption from the small intestine. In grazing experiments at Palmerston North during the 1990s, sheep grazing *L. corniculatus* had superior wool production, body growth and ovulation rates (OR) relative to sheep grazing lucerne *(Medicago sativa)* or perennial ryegrass *(Lolium perenne)*/white clover *(Tritolium repens)* pasture. Polyethylene glycol (PEG) drenching studies showed that action of CT was responsible for a component of the increases in wool growth and OR, but not body growth, and increased milk yield in lactating ewes.

The 'Massey lotus' programme moved in 2000 to Riverside farm in the Wairarapa, where *L. corniculatus* is more agronomically suited, and its integration into dryland farming systems is being studied. We aim to develop systems that increase animal productivity whilst also reducing chemical input, notably of anthelmintic drenches.

In two experiments conducted over 12 weeks in spring, ewes and lambs grazing *L. corniculatus* without pre-lamb drenching had lower faecal egg counts (FEC) and lower dag scores than ewes and lambs grazing pasture. Also, liveweight gain (+44%), weaning weight (+26%) and wool production (+32%) were greater for lambs grazing lotus. Weaned lambs grazing *L. corniculatus* over 14 weeks in summer grew faster than those grazing pasture (298 cf. 201 g/day) when regularly drenched. Reduction of anthelmintic drenching reduced the growth rates of lambs grazing *L. corniculatus*, but at 228 g/day this was still much faster than those grazing pasture (187 g/day). Lambs grazing *L. corniculatus* with restricted anthelmintic grew slightly faster than regularly drenched lambs grazing pasture.

In addition, ewes mated on *L. corniculatus* had greater ovulation rates, lambing % and weaning % (approximately 25%) than ewes mated on pasture. Lamb weaning weight was unaffected by the ewes grazing *L. corniculatus* during mating, but mortality rate during the period from birth to weaning was lower for lambs that were conceived when their dams were grazing lotus.

Annual (dry matter) production under grazing averaged over two years (2000–2001), was 9.5 t/ha for *L. corniculatus* and 8.6 t/ha for pasture. The percentages of annual production that occurred in spring, summer, autumn and winter were 49, 40, 8 and 4%, respectively, for *L. corniculatus* and 55, 30, 9 and 6%, respectively, for pasture. *L. corniculatus* has potential as a specialist feed in dryland farming systems for use during mating to increase subsequent lambing percentage and to increase lamb growth while reducing anthelmintic use. The result is more lambs being drafted at an earlier age.

Key words: agronomy, body growth, condensed tannins, dry matter yield, *Lotus corniculatus*, reproduction, sheep, withdrawing anthelmintic, wool growth

Introduction

Interest in *Lotus corniculatus* (lotus) arises because of its content of condensed tannins (CT), which have been shown to react with forage protein during chewing to form tannin–protein complexes. These complexes reduce the microbial degradation of protein to ammonia in the rumen (pH 6.0–7.0), yet release the protein under the acid conditions in the abomasum (pH 2.5–3.5) and so have the potential to increase amino acid absorption from the small intestine of ruminants grazing CT-containing forages (Jones & Mangan 1977; Barry & McNabb 1999). Research on this topic during the 1980s focused upon defining the effects of CT upon nutrient supply using indoor studies, whilst in the 1990s field trials of 2–3 months duration were conducted to study the effects of CT upon animal production and animal health (Barry *et al.* 2001).

In 2000, Massey University transferred its nutritional research with *L. corniculatus* from Palmerston North to Riverside Farm, near Masterton in the Wairarapa, to study its integration into dryland farming using a systems approach. *L. corniculatus* is better adapted to dryland regions, where its annual and seasonal production match those of perennial pasture, than regions with high rainfall and heavy, fertile soil. In the high rainfall regions, *L. corniculatus* is less productive than perennial pastures, and is readily outcompeted by pasture species and their weeds, resulting in poor persistence.

We review both the animal and plant production that can be obtained from *L. corniculatus*, with particular emphasis on its performance under dryland farming and its integration into dryland farming systems. Integration of CT-containing forages into grazing systems may well be a research theme for the 2000–2010 era.

Condensed tannins

Condensed tannins are secondary compounds that are found in trace amounts (1–2 mg/kg DM) in the leaves and stems of perennial ryegrass, white clover, red clover and lucerne, where their concentration is too low to affect nutritive value. In contrast, they are found at concentrations of 25–35 g/kg DM in *L. corniculatus* and 75–85 g/kg DM in *L. pedunculatus* (Terrill *et al.* 1992). Recent research has shown that the reactivities of CT differ between forages and depend upon their concentration, molecular weight and molecular structure (Barry & McNabb 1999). The CT in *L. corniculatus* have been the most effective of all the forage CT studied in NZ for increasing amino acid absorption in sheep (Waghorn *et al.* 1987; Min *et al.* 2003). Thus, more grazing trials have been conducted with *L. corniculatus* in NZ in recent years than with any other CT-containing legume.

Grazing studies at Palmerston North

A summary of grazing trials involving *L. corniculatus,* which were conducted at Palmerston North (Massey University and AgResearch Aorangi) during the 1990s, is shown in Tables 1 and 2. These studies were conducted with and without oral supplementation with polyethylene glycol (PEG) (MW 3350), which binds and inactivates CT, in order to deduce the proportion of the lotus effect that is due to CT. In the absence of PEG, both body growth and wool growth were greater for lambs grazing 'Goldie' *L. corniculatus* than for lambs grazing Orangi lucerne. Polyethylene glycol studies showed that the action of CT was responsible for the extra wool grown by lotus-fed lambs but was not responsible for their extra body growth. Lambs grazing lotus and lucerne ate similar amounts of forage, which was not affected by CT in *L. corniculatus*. In similar studies conducted with lactating ewes grazing *L. corniculatus* during spring, responses to PEG supplementation showed that action of CT in mid-lactation increased the secretion of milk and milk protein by 21 and 14% respectively (Wang *et al*. 1996b).

Relative to ewes that were mated on perennial ryegrass-based pasture, mating ewes for 6–8 weeks on *L. corniculatus* increased mean ovulation rate (OR) by 22%, with CT responsible for approximately half of this (Table 2). The responses to CT were larger than this in the two trials where the ewes gained weight during mating, relative to the one trial where a small weight loss occurred during mating. In these three experiments, the ewes mated on *L. corniculatus* continued to graze this for a further 3 weeks after the end of mating.

Grazing studies in the Wairarapa

The first priority for integrating *L.corniculatus* into a whole farming system was to feed ewes during mating, because the period of supplementation is relatively short (6–9 weeks), but the effect produced lasts for the rest of the year. An example of this effect occurred when ewes were mated on *L. corniculatus* during the 2001 autumn, which increased scanning, lambing, docking and weaning percentages (Table 3, Ramíirez-Restrepo *et al.* unpublished). Mating on *L. corniculatus* also reduced lamb mortality between birth and weaning ($P<0.05$), even though no *L. corniculatus* was fed to the ewes after the first trimester of pregnancy. This result is being investigated further in current research.

The second priority for use of *L. corniculatus* in dryland farming was to simultaneously increase spring growth of lambs and reduce the requirements for anthelmintic drench, thus increasing the proportion of lambs drafted before the onset of hot weather in December/January (and hence before the possible onset of drought). Relative to ewes and lambs grazed on spring pasture, grazing ewes and lambs on *L. corniculatus* for 12 weeks during the

Table 1 Voluntary feed intake (VFI), liveweight gain (LWG), carcass gain and wool growth in lambs (Experiments 1, 2 and 3) and dry ewes (Experiment 4) grazing the forage legume *Lotus corniculatus* (27–34 g CT/kg DM) and lucerne (0.3 g total CT/kg DM) during summer.

	Lotus		Lucerne		
	CT Acting	PEG Supplemented	CT Acting	PEG Supplemented	SE
	Experiment 1 (1991–92; 27.9 kg LW[1]; 4.5 kg DM/lamb/day[2])3				
VFI (kg OM/day)	1.76	ND	1.65	ND	0.040
LWG (g/day)	228	ND	183	ND	8.2
Carcass weight (kg)	20.4	ND	17.8	ND	0.82
Fleece weight (kg)	2.78	ND	2.25	ND	0.091
	Experiment 2 (1994–95; 19.3 kg LW; 5.3 kg DM/lamb/day)4				
LWG (g/day)	271	250	ND	ND	8.0
Carcass weight (kg)	21.1	19.8	ND	ND	0.57
Fleece weight (kg)	1.75	1.78	ND	ND	0.067
	Experiment 3 (1992–93); 22.4 kg LW; 2.5 kg DM/lamb/day)5				
Rumen ammonia (mg N/1)	255	370	555	535	–
VFI (kg OM/day)	1.19	1.20	1.32	1.34	0.056
LWG (g/day)	203	188	185	178	5.8
Carcass gain (g/day)	79	75	68	63	2.9
Wool growth (g/day)	12.1	10.9	10.8	10.2	0.39
	Experiment 4 (1995–96; 54.0 kg; 1.3 kg DM/ewe/day)6				
Rumen ammonia (mg N/1)	221	278	ND	ND	8.5
VFI (kg OM/day)	1.23	1.20	ND	ND	0.051
LWG (g/day)	54	67	ND	ND	9.3
Wool growth (g/day)	13.2	11.1	ND	ND	0.66

3 Douglas *et al.* (1995), 4 Douglas *et al* (1999), 5 Wang *et al.* (1996a); 6 Min *et al.* (1998).

CT = condensed tannins, PEG = polythylene glycol, SE = standard error, ND = not determined.

[1] Initial liveweight.

[2] Daily green forage allowance.

spring of 2000 increased lamb growth (258 cf. 189 g/day) and increased weaning weight (36.2 cf. 30.1 kg) (Ramírez-Restrepo *et al.* 2002). This was achieved in the absence of pre-lambing anthelmintic drenching of the ewes; faecal dag scores up to weaning were lower for both ewes and lambs grazing *L. corniculatus* than for their counterparts grazing pasture. Similar results were found when the experiment was repeated in the spring of 2002.

An experiment over the summer of 2002–2003 evaluated the *L. corniculatus* effect on growth of weaned lambs over 14 weeks, relative to comparable lambs grazing perennial ryegrass/white clover pasture. This also examined the possibility of reducing anthelmintic drench input (Figure 1). Lambs grazing each forage were drenched either at 4–week intervals (4 drenches overall; regularly-drenched group) or were given one drench only at day 58, when faecal egg counts (FEC) rose to 1 000 eggs/g (restricted-drench group). Regularly-drenched and restricted-drench lambs grazed separate areas of each forage, under rotational grazing.

There was an interaction between treatment x time ($P<0.001$) because liveweight gain (LWG) throughout

Table 2 The effect of grazing ewes on *Lotus corniculatus* or perennial ryegrass/white clover (pasture), and of supplmentation with polyethylene glycol on maximum ovulation rate, wool production and on liveweight gain.

	Experiment[1]	Pasture	*L. corniculatus*			
		+/– PEG	Supplemented PEG	CT Acting	Legume Effect (%)[2]	CT Effect (%)[3]
(Ovulation rate)						
Min *et al* (1999)	5	1.33	1.46	1.76	9.8	22.6
Luque *et al* (2000)	6	1.45	1.66	1.64	14.5	0
Min *et al* (2001)	7	1.48	1.58	1.79	6.6	14.2
Mean		1.42	1.57	1.73	10.3	12.3
(Clean fleece weight; kg)						
Min *et al.* (1999)	5	1.12	1.31	1.35	17.0	3.6
Luque *et al.* (2000)	6	1.54	1.69	1.73	9.7	2.6
Min *et al.* (2001)	7	1.41	1.61	1.71	14.2	7.1
Mean		1.36	1.54	1.60	13.6	4.4
(Liveweight gain; g/day)						
Min *et al* (1999)	5	12	34	40		
Luque *et al* (2000)	6	-12	-20	-25		
Min *et al* (2001)	7	43	16	22		

PEG = polythylene glycol, CT = condensed tannins.

[1] Initial liveweight was 54, 60 and 53 kg in Experiments 5, 6 and 7, respectively.

[2] Calculated as: $\frac{(L.\ corniculatus\ \text{PEG} - \text{Pasture}) \times 100}{\text{Pasture}}$

[3] Calculated as: $\frac{(L.\ corniculatus\ \text{CT Acting} - \text{Lotus PEG}) \times 100}{\text{Pasture}}$

Table 3 The effect of mating on *Lotus corniculatus* in 2001 on the reproductive performance (% ewes mated) of ewes on Massey University dryland farm in the Wairarapa. The period of grazing on lotus was 9 weeks from 13 February to 16 April 2002 (rams were introduced on 15 February and removed on 16 April).

	L. corniculatus	Pasture	Significance
Scanning (%)	179	170	*
Lambing (%)	175	159	*
Docking (%)	159	130	*
Weaning (%)	155	123	*
Birth weight (kg)	5.5	5.5	NS
Weaning weight (kg)	32.1	32.3	NS
Fleece weight (kg)	3.1	2.9	**
Lamb mortality:			
Lambing to weaning (%)	11.4	22.6	*

Ramíerz-Restrepo *et al.* unpublished.

NS non-significant.

* (P<0.05).

** (P<0.01).

the entire experiment was higher for regularly-drenched than restricted-drench lambs grazing *L. corniculatus* (298 cf. 228 g/day; $P<0.001$), whereas for lambs grazing pasture, LWG was similar for both groups (201 cf. 187 g/day). LWG of lotus restricted-drench lambs was also higher than either pasture group. Final liveweight after 95 days was 7.0 kg greater ($P<0.001$) for regularly- drenched than restricted-drench lambs grazing *L. corniculatus* (57.2 cf. 50.1 kg), but was similar ($P<0.82$) for both drench groups grazing pasture (47.8 cf. 47.5 kg). Final liveweight of *L. corniculatus* restricted-drench lambs was 2.6 kg heavier ($P<0.005$) than that of pasture restricted-drench lambs and 2.4 kg greater than that of pasture regularly-drenched lambs ($P<0.054$).

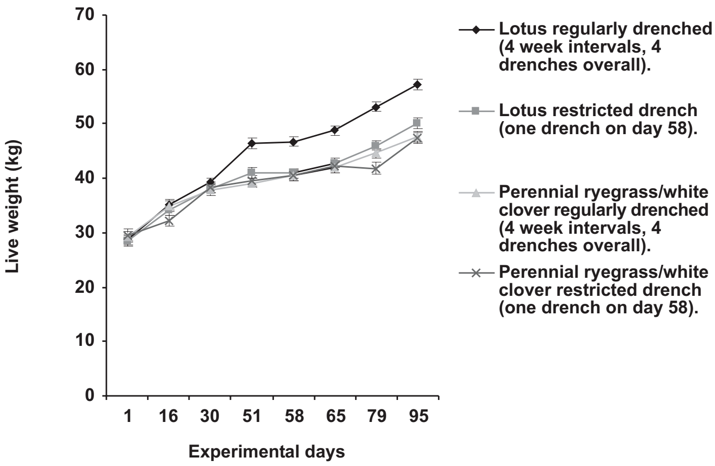

Figure 1 The effect of withdrawing anthelmintic drench upon the growth of weaned lambs grazing *Lotus corniculatus* or perennial ryegrass-based pasture for 95 days over the 2002/2003 summer at Riverside Farm, Masterton, Wairarapa. Green DM allowance was 6.5 kg/lamb/day for all treatments. The experiment commenced on 18 November 2002 and concluded on 21 February 2003. (Ramírez-Restrepo *et al.* unpublished). SEM for the four treatments ranged from 0.92 to 1.00 kg.

These results show growth in the regularly drenched *L. corniculatus* lambs approached the Sheep Industry target of 400 g/day during the first month. Under field conditions, the CT in *L. corniculatus* did not seem to be particularly effective for counteracting parasites, as both undrenched groups required drenching on day 58 when faecal egg counts exceeded 1 000/g for both groups. However, restricted-drench, lotus-fed lambs grew at higher rates under a parasite challenge, probably due in part to better protein absorption from the action of CT.

Agronomy of *Lotus corniculatus* in the Wairarapa

The annual and seasonal DM production of *L. corniculatus* at Riverside Farm near Masterton has been similar to that of perennial ryegrass and white clover pasture. The annual production of *L. corniculatus* and perennial ryegrass in 2000–2001 were 9 53 and 8 640 kg DM/ha, respectively, (Ramírez-Restrepo unpublished) and they had similar patterns of seasonal production. The mean seasonal percentage production in spring, summer, autumn and winter was 49, 40, 8 and 4% for *L. corniculatus* and 55, 30, 9 and 6% for perennial ryegrass/white clover pasture. The *L. corniculatus* has remained productive and persistent for three years, in contrast to *L. corniculatus* grown on heavy soil in the Manawatu that failed to persist beyond two years without regular use of herbicide.

Successful establishment of *L. corniculatus* in the experimental programme has been achieved by the use of at least 20 kg/ha of coated seed, to obtain rapid ground cover and minimise weed invasion, and sowing in either late February, early March, or in spring. In addition, sowing depth must be no greater than 10 mm, which although possible by direct drilling, is easier to manage with a roller drill. The only establishment failure in the programme resulted from the one occasion direct drilling was used, which resulted in the seed being sown too deep.

Early weed control of *L. corniculatus* with Preside (a.i. flumetsulam) has been successful, with Gallant (a.i. haloxyfop) used to remove invading grasses, and either Sencor (a.i. metribuzin) or a clean up with a paraquat/diquat herbicide used in late winter (August). A paraquat/diquat herbicide is cheaper but delays spring growth. Thistles have proved to be a problem in established *L. corniculatus* stands due to the history of the paddocks, but have been cheaply and effectively controlled by boom wick application of glyphosate. Pre-emergent herbicides have not been used in the experimental programme.

The regrowth after grazing of *L. corniculatus* is from both primary shoots from the crown and from secondary shoots on primary shoots that are on the ground. Regrowth is slow if the prostrate primary shoots are grazed (Ayala 2001). First grazing of *L. corniculatus* occurred after the network of primary shoots along the ground established and the sward was at least 0.10 m tall (Ayala 2001). Grazing management in spring was a monthly rotation, with sheep in each break for one week. Pre-grazing herbage mass in spring was approximately 3 500 kg DM/ha, or 15–20 cm tall, and the post-grazing herbage mass was 2 000 kg DM/ha, or 10–15 cm. In summer, the pre- and post-grazing mass was 2 000 and 900 kg DM/ha, respectively. There were typically eight grazings per year on *L. corniculatus* (Restrepo-Ramirez *et al.* unpublished).

Apparent intake of the sheep on *L. corniculatus* has been greater than those sheep on the perennial ryegrass/white clover treatment, notably in spring, which suggests that *L. corniculatus* will be grazed harder by *ad lib*-fed sheep than perennial ryegrass/white clover unless the post-grazing herbage mass is controlled. Sheep were observed to mainly eat the leaves of *L. corniculatus* under lax grazing, but when pushed they ate the stems. As was also reported by Ayala (2001), grazing that removed a substantial proportion of the prostrate primary shoots severely delayed regrowth and encouraged weed ingression.

Conclusion

Following effective establishment, our stands of *L. corniculatus* have thus far lasted for 3 years in the Wairarapa. They have out-yielded normal pasture by about 10% and have greater summer production.

From the results obtained to date, the first priority for using *L. corniculatus* in dryland farming is to increase lambing percentage and weaning percentage, as 6–9 weeks of feeding during mating is all that is necessary to increase whole year productivity.

A second priority is to feed *L .corniculatus* to lactating ewes and their lambs during spring, to increase lamb weaning weight and hence the proportion of lambs drafted early. This can be achieved whilst also eliminating pre-lambing anthelmintic drenching. The third priority for use of *L .corniculatus* under dryland farming is to increase the growth of weaned lambs over summer. However, for maximum growth rates, regular anthelmintic drenching proved necessary, though the growth rates of reduced drench lambs grazing *Lotus* still exceeded that of regularly drenched lambs grazing pasture.

These results show that *L .corniculatus* has potential as a specialist feed in dryland farming systems.

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