NUTRITIONAL STUDIES ON *LOTUS CORNICULATUS* CONTAINING CONDENSED TANNINS TO INCREASE REPRODUCTIVE RATE AND LAMB GROWTH UNDER COMMERCIAL DRYLAND FARMING CONDITIONS

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Carlos Alberto Ramírez-Restrepo

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DECLARATION

The studies presented in this thesis were completed by the author whilst a Postgraduate student in the Institute of Veterinary, Animal and Biomedical Science, Massey University, Palmerston North, New Zealand. I hereby affirm that the content of this thesis is original research conducted by the author. All views and conclusions are the sole responsibility of the author. All references to previous work are included in the References section of each chapter. Any assistance received during the preparation of this thesis has been acknowledged.

I certify that the content of this thesis has not already been submitted for any degree and is note being currently submitted for any other degree. I certify that to the best of my knowledge any help received in preparing this thesis, and all sources of materials used, have been acknowledged in the thesis.

Carlos Alberto Ramírez-Restrepo
PhD candidate

Professor T. N. Barry
Chief Supervisor

Dr. P.D. Kemp
Co-supervisor

Dr. W. C. McNabb
Co-supervisor

N. M. Shadbolt
Co-supervisor

T. G. Harvey
Co-supervisor

ABSTRACT

Five rotational grazing experiments were carried out at Massey University's Riverside farm, in the Wairarapa, on the East Coast of the Southern North Island, New Zealand, to compare the effects of feeding *Lotus corniculatus* L. (birdsfoot trefoil; cv. Grasslands Goldie) or perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) dominant pasture upon sheep year round productivity. These studies also investigated under grazing, seasonal and annual net herbage accumulation rate and seasonal dynamics of undisturbed (i.e. non-grazed) net herbage accumulation rate of *L. corniculatus* relative to that of grass-dominant pasture. Aspects of *in vivo* digestibility of dry matter (DMD), organic matter (OMD), digestible organic matter in the dry matter (DOMD) and metabolisable energy (ME) concentration of *L. corniculatus* at different stages of maturity over the spring, summer and autumn were investigated in three indoor digestion trials.

1. Two field experiments (Chapter 2) were conducted during spring to assess the effects of grazing mixed age undrenched ewes on *L. corniculatus* (n = 50) or pasture (n = 50) and their lambs (mainly twins) on live weight (LW), wool production, faecal nematode egg count (FEC) and dag score. In Experiment 1 (18 October 2000 to 21 January 2001) and Experiment 2 (3 October 2001 to 2 January 2002) both forages were fed *ad libitum.* Total condensed tannin (CT) concentration in the diet selected was 24 to 27 g CT/kg DM for *L. corniculatus* and 1.4 to 1.5 g CT/kg DM for pasture. The LW gain, weaning LW and wool production were consistently greater (P < 0.001) for lambs grazing *L. corniculatus*, in either

Experiment 1 (258 vs. 189 g/day; 36.1 vs. 30.1kg; 1.17 vs. 0.98 kg) and in Experiment 2 (247 vs. 162 g/day; 31.8 vs. 24.1kg; 1.17 vs. 0.81 kg), respectively. Ewe and lamb dag scores were strongly and positively correlated with dag weight ($P < 0.001$) and generally increased with time in sheep grazing pasture, whilst grazing on *L. corniculatus* consistently reduced dag score. FEC in ewes grazing pasture showed a post-parturient rise (PPR) following lambing, whilst ewes grazing *L. corniculatus* had a reduced PPR in FEC. Up to day 70, FEC in lambs grazing *L. corniculatus* was lower than that for lambs grazing pasture, but between day 70 and the end of both experiments (approximately day 90), FEC in lambs grazing *L. corniculatus* increased to similar values as for pasture-fed lambs. FEC was not correlated with dag score or dag weight in ewes or lambs grazing pasture, but these indices were weakly and positively correlated in ewes and lambs grazing *L. corniculatus*, suggesting that lowering FEC on *L. corniculatus* also reduced dag formation.

It was concluded that under dryland farming conditions, the use of *L. corniculatus* during the spring/early summer lactation period can increase lamb LWT and wool production, whilst eliminating the need for pre-lambing anthelmintic drenching and probably reducing the amount of insecticide needed to control flystrike. These effects compared to pasture are probably due to higher digestibilty, higher ME concentration, higher voluntary feed intake (VFI), and to the effect of CT in reducing rumen protein degradability and controlling internal parasites in sheep grazing *L. corniculatus*. The absence of endophyte in *L. corniculatus* may have also have contributed to these effects.

2. During 2001 and 2002 (Chapter 3), grazing trials from February to November were conducted for 279 days (Experiments 1) and 285 days (Experiment 2), to compare the effects of grazing shorn mixed age Romney ewes in light condition on *L. corniculatus* versus pasture during the mating period (9 weeks, Experiment 1) and 11 weeks (Experiment 2). In Experiment 2, the length of time (days) that ewes need to graze *L. corniculatus* before mating to maximise reproductive performance was also investigated. Common objectives in both Experiments were to measure forage feeding effects on ewe wool production and LW of their lambs at weaning.

In Experiment 1, groups of ewes (n = 100) were fed on either *L. corniculatus* or pasture at a herbage allowance of 1.8 kg green DM/ewe/day for the first three weeks of feeding and increased to *ad libitum* (2.3 kg green DM/ewe/day) during the mating period for two cycles. In Experiment 2, groups of 75 ewes grazed *L. corniculatus* for 42, 21, 10 and 0 days before a synchronised oestrus, with pasture being grazed for the balance of the 42 days. All *L. corniculatus* groups continued grazing *L. corniculatus* for a further 5 weeks. Feed allowance was initially 2.0 kg green DM/ewe/day, increased to 2.3 kg green DM/ewe/day during the mating period over the two cycles. At the end of *L. corniculatus* feeding in both experiments the groups were combined and grazed on pasture until weaning. Total CT concentration in the diet selected was 18 to 29 g CT/kg DM for *L. corniculatus*, with only trace amounts in pasture.

In Experiment 1 mating ewes on *L. corniculatus* compared to pasture increased number of lambs born and lambs weaned per ewe lambing by 16 and 32% units respectively ($P < 0.05$), due to more multiple and less single births ($P = 0.06$) and to reduced lamb mortality ($P < 0.05$) between birth and weaning. In Experiment 2, increasing the numbers of days of grazing *L. corniculatus* before ovulation (0, 10, 21, 42 days) linearly increased ovulation rate ($P < 0.05$), lambs born and lamb weaned by up to 16% units, but had no effect upon lamb mortality. Mating ewes on *L. corniculatus* increased wool production ($P < 0.01$) and fibre length ($P < 0.05$) in Experiment 1 but not in Experiment 2. Grazing *L. corniculatus* had no effect on lamb birth weight and only small positive effects on weaning LW.

It was concluded that, under commercial dryland farming conditions, the use of *L. corniculatus* during the mating season in late summer/autumn can be used to increase reproductive efficiency and wool production, with the largest responses in years with exceptionally dry autumn periods. These effects are probably due to the higher digestibility and ME concentration of *L. corniculatus* than pasture and to the CT in *L. corniculatus* reducing rumen protein degradability and leading to greater essential amino acid (EAA) absorption from the small intestine. Effects of forage CT upon the uterine microenvironment at the time of conception, implantation and early foetal growth, need to be investigated in future studies. It is also suggested that effects of mating on *L. corniculatus* upon lamb mortality between birth and weaning should be further investigated with ewe numbers/treatment increased from 100 to 350.

3. During the summer of 2002/2003, another grazing trial (Chapter 4: 95 days) compared the effects of grazing *L. corniculatus* and pasture on LW and the dynamics of nematode parasite infection in Suffolk x Romney weaned lambs fed *ad libitum*. Half of the lambs (n = 30) grazing either *L. corniculatus* or pasture received oral anthelmintic at the start and at monthly intervals (regular-drenched groups), whilst the remaining 30 lambs in each treatment only received oral anthelmintic when mean faecal nematode egg counts (FECs) exceed 1,000 eggs/g wet faeces (trigger-drenched groups), which occurred on day 58 only for both groups. Trigger and regular-drench lambs grazed separate areas. Total CT concentration in the diet selected was 40 to 31 g CT/kg DM for *L. corniculatus*, with only trace amounts in pasture.

Regular-drenched lambs grazing *L. corniculatus* had significantly higher LW gain (298 g/day) and carcass weight gain (133 g/day) than all the other groups, whilst trigger-drenched lambs grazing *L. corniculatus* had significantly greater LW gain (228 g/day) and carcass gain (99 g/day) than regular-drenched (200; 66 g/day) and trigger-drenched (187; 63 g/day) lambs grazing pasture. Carcass fatness was significantly lower for trigger-drenched lambs than for regular-drenched lambs, when fed either *L. corniculatus* or pasture. Dag score was consistently lower for regular-drenched lambs grazing *L. corniculatus* than pasture; trigger-drenched lambs showed similar effects up to day 48, with no differences between the two groups thereafter. Regular anthelmintic treatment maintained FECs at low values, while parasitised lambs on *L. corniculatus* tended to have higher FECs than pasture-fed lambs. Relative to trigger-drenched lambs that grazed pasture, grazing

trigger-drenched lambs on *L. corniculatus* had significantly reduced worm burdens of *Haemochus contortus*, *Teladosargia spp.*, *Nematodirus spp.* and *Cooperia spp.* at slaughter, but greater burdens of *Trichostrongylus spp.*, *Chabertia ovina*, *Oesophagostonum spp.* and *Trichuris ovis* were present in *L. corniculatus*-fed lambs.

It was concluded that grazing *L. corniculatus* under dryland farming conditions compared to pasture can increase LW gain of weaned lambs, whilst reducing reliance on anthelmintic drenches to control parasites. These effects are probably due to increased protein supply from the action of CT enabling the lambs to have a higher LW gain when carrying a parasite burden, and to *L. corniculatus* better maintaining its high ME value under drought conditions. Using *L. corniculatus* to finish weaned lambs without anthelmintic drenches for a seven-week period is proposed.

4. A three-year study (Chapter 5; November 2000 to October 2003) was conducted to compare, under grazing conditions, seasonal and annual grazed net herbage accumulation rate and seasonal dynamics of undisturbed (i.e. non-grazed) net herbage accumulation rate of *L. corniculatus* relative to grass-dominant pasture. Prediction equations to estimate standing DM in *L. corniculatus* and pasture from the rising plate meter (RPM) and sward surface height were also generated.

L. corniculatus and pasture growing in a moderate fertility and low-pH soil (pH 5.35) accumulated similar total herbage masses (24.3 vs. 24.1 t DM/ha) over the 3-year period, with the DM production being greater for *L. corniculatus* than for

pasture during 2000–2001, producing more DM during summer/autumn drought conditions. The net herbage accumulation rate from undisturbed areas of *L. corniculatus* and pasture were similar in spring, summer and autumn. Seasonal variation in the calibration regressions fitted to estimate herbage mass of *L. corniculatus* non-destructively, suggested a combination of destructive and non-destructive methods are needed to assess herbage mass. It was concluded that *L. corniculatus* has the potential to increase the performance of a pasture-based sheep dryland farming system due to its ability to grow in acidic soils, its tolerance of drought conditions during summer/autumn and its seasonality of feed supply.

5. Three digestion experiments involving cryptorchid weaned lambs were conducted for 14 days over the spring, summer and autumn to determine changes in *in vivo* digestibility of DM, OM, digestible OM in the DM and ME concentration of *L. corniculatus* at different stages of maturity. *In vivo* digestibility samples were then used as standards to investigate if the enzymatic *in vitro* system of Roughan and Holland (1977) could predict OMD and DOMD of CT-containing *L. corniculatus.* Digestibility of *L. corniculatus* declined as it matured, but the rate of decline was much less than occurs for temperate grasses and for white clover. It was concluded that the *in vitro* enzymatic system of Roughan and Holland (1977) can be used to predict OMD and DOMD of *L. corniculatus*, provided a standard curve involving *in vivo* data generated with *L. corniculatus* is used. Using a standard curve with *in vivo* data from pasture led to bias which increased at lower OMD values. Reasons for the consistent differences between *L. corniculatus* and

pasture standard curves are discussed, including possible effects of residual bound CT in lowering *in vitro* digestibility.

From this series of experiments, this study is the first to report that relative to conventional perennial ryegrass/white clover, mating ewes on *L. corniculatus* under grazing conditions may reduce post-natal lamb mortality. It is also the first study to show that grazing sheep on *L. corniculatus* can maintain productivity during spring and summer with reduced dependence on anthelmintic drench input. It is concluded that whole farm modelling, mechanical harvesting and conservation strategies, selection of *L. corniculatus* germplasm for creeping-type plants more suited to grazing and the integration of new crops containing secondary compounds, such as chicory, should be considered to support major advances in sustainable dryland sheep farming systems.

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