Long-term changes in the biology of a livestock farm system associated with the shift to organic supply

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Abstract

A long-term replicated farm systems study (1997-2005) examined changes in the biology of mixed-livestock systems associated with the shift to organic production. Two farmlets were managed using conventional farm practices (Con) and two low chemical (LC) farmlets complied with the organic production standards of BIO-GRO New Zealand. The Con farmlet had higher (P<0.01) lamb, hogget, 2TH and mixed-aged ewe (P<0.01) performance than the LC farmlet due mainly to differences in the parasite challenge between the two systems. There was no evidence that the use of the Ivermectin® bolus for 8 consecutive years in the Con system led to Ivermectin® drench resistance. Lamb liveweight at weaning was 1.77 kg lower (P<0.001), in LC than in Con. Post-weaning, high parasite burdens (FEC) reduced (P<0.001) LC lamb growth rate. LC systems had smaller 2TH's (P<0.001) and mixed aged ewes (P<0.001) than Con systems, despite similar feeding levels, leading to lower ovulation rate and numbers of lambs born. Lamb mortality rates between lambing and weaning were similar between systems. Until production losses in young stock following weaning in LC systems are reduced, the ability of the organic industry to expand will continue to be constrained. Performance differences between systems did not change over the 9-year trial, suggesting that this study provides a good insight into the relative performance of these two systems at the stocking rate at which they were compared. Pasture composition and production, and soil biophysical and biological characteristics were similar in the two farm systems.

Keywords: low chemical, organic, farm systems Ivermectin®

Introduction

The opportunity for part of the NZ pastoral industry to capture the opportunities available within the rapidly expanding global market for branded natural and organic products has to date not been realised. The inability of the current organic supply base to consistently supply product in the face of a range of production system challenges has been identified as the major impediment to growing this sector (Mackay *et al*. 2002). Chief amongst these are internal parasites. If the vision of the organic sector strategy (MAF 2003), to be recognised internationally as a world leader in organic systems and products delivering $1 billion by 2013, is to be realised, parasitism and other impediments need to be overcome. Currently organic sector sales are over $70 million, with only a very small contribution from the pastoral sector (Manhire 2004). Reaching that target will require major growth in the organics pastoral sector. This paper reports 9 years of data in an on-going, replicated farm systems comparison established in 1997. Changes in animal production and performance, disease status, soil fertility and health and pasture composition associated with a shift from conventional farming practices to a farm operation where chemical use is limited to the treatment of at-risk animals are reported. This study forms part of a wider Natural and Organic research programme in AgResearch designed to underpin the growth of the livestock sector of the industry.

Methods

Description of farmlets

The farm systems comparison was established in 1997. Conventional (Con) and Low-chemical (LC) systems were each replicated twice as self-contained farmlets. The farmlets are located at AgResearch "Ballantrae" Hill Country Research Station in the foothills of the Ruahine Ranges (Lat. Long. 175º50' E, 40º19' S) (Mackay *et al*. 1991). The climate at "Ballantrae" is mild-temperate. Mean monthly soil temperatures at 10 cm depth range between 7.2º and 16.0ºC and mean annual rainfall of 1276 mm is distributed evenly throughout the year (Lambert *et al*. 1983). The farmlets are approximately 18 ha in size (range 17.5-18.9 ha) and have similar topography (moderate to steep hill country) aspects (north-east to north-west) and soil fertility (Olsen P <12-20 µg P/cm^3 soil). Each farmlet is fenced into 18-20 paddocks. The Con and LF farmlets are fertilised annually with the same amount of reactive phosphate rock (RPR) and elemental sulphur. Low-fertility grasses, such as browntop (*Agrostis capillaris*) and sweet vernal (*Anthoxanthum oderatum)* are the dominant (37 to 79%) grass species. Perennial ryegrass (*Lolium perenne*) makes up a small part of the sward (5–8%) and legumes, including white clover (*Trifolium repens)*, comprise 2–21%.

Livestock and management

Each farmlet was stocked at 12 su/ha managed as a closed system. This comprised 90 genetically similar mixed-age ewes (bred for resilience to internal parasites since 1994, Morris *et al*. (2001)), their replacements (30), eight breeding cows, and six rising 1-yr (R1) and 5 R2 heifers. Replacements for the sheep system were bred and reared on the farmlets. The balance of lambs were either sold at weaning or carried through to May.

On conventional farmlets, a 100-day Ivermectin® bolus was administered to ewes prior to lambing for control of intestinal parasites. Prior to lambing, ewes were vaccinated with a 7-in-1 vaccine mix for protection against clostridial diseases (*Clostridium chauvoei, C. septicum, C. perfringens, C. tetani and C. novyii*). Lambs received a PK-antitet for protection against C. *perfringens* and *C. tetani* at docking in October and five to seven anthelmintic drenches (21-28 days) from weaning in December until June of the following year. All sheep were spray-dipped (Diflubenzuron®) or pour-on (Cypermethrin®)-treated once or twice a year for protection against ecto-parasites. R1 cattle were treated two to five times with either Ivermectin® or Moxidectin® pour-on or by injection for the control of endo- and ecto-parasites.

Low-chemical farmlets complied with the organic production standards of BIO-GRO New Zealand (BIO-GRO New Zealand 2001), an organic certifier and organic producers' organisation in New Zealand. The standards prohibit the routine use of drenches, vaccines, antibiotics, dips and other chemical remedies unless an individual animal suffers or shows signs of ill thrift. One of the LC farmlets has been registered with BIO-GRO since 1988 and the other since 1997. Animals that required treatment (e.g. 'recovery' drenching) were placed in a designated quarantine paddock for 48 h then returned to the flock or herd. A set of decision rules are used to identify and treat at-risk livestock before their welfare was compromised.

Grazing management was the same on both the Con and LC farmlets. At all times, attempts were made to fully feed young sheep and cattle and lactating animals. Pasture was the only feed used and grazing management was the major tool used for controlling the gastro-intestinal parasite challenge to young sheep and cattle on the LC farmlets.

Each farmlet was managed as two blocks. Ewes grazed year round on one block. During the summer and early autumn (November – March) mixed-aged cows also grazed this block. Weaner cattle grazed in front of the ewes from weaning (in April) until September.

A cattle/hogget block was split into two sub-blocks. Ewe lambs grazed one sub-block from December until September, along with the mixed-aged cows and, from September to March, with the R2 heifers. Ewe lambs grazed regrowth following cattle grazing and vice versa. This sub-block had been grazed in the previous 9 months only by cattle and, prior to this, by older lambs. On the second sub-block older ewes (hogget/ 2TH) grazed from September to March along with the R2 heifers and mixed-aged cows. The reason for splitting was to prevent an accumulation of *Nematodirus* (Mackay *et al*. 1998).

Monitoring

All animals were weighed on a regular basis with young stock weighed monthly in the first 12 months. Wool production was determined in December, March and September; lambing (lambs weaned/ewes mated), scanned lambs, calving (calves born/ cows scanned) percentages, stock deaths and number of stock requiring treatment on the LC farmlet (e.g. recovery drench) were also recorded. From weaning (December), faecal egg count (FEC) samples were taken monthly (10 lambs/ farmlet) to estimate gastro-intestinal tract nematodes based on the number of normal strongylid and *Nematodirus* eggs. Ewes were monitored less frequently. Pasture composition was measured each spring as was soil fertility in four paddocks in each farmlet. A more detailed examination of the biology of the soil was completed in 2003/04.

Analysis

All animal liveweight, performance and FEC data were subjected to a three-way (System, Year, System x Year) analysis of variance (GenStat Committee 2005). Some data required log and rank transformation. A two-way analysis of variance was used to examine the soil and pasture data.

Results and Discussion

Average lamb, 2TH and mixed-age ewe liveweight and parasite burden (measured by FEC) at key times of the year; fleece weight of each sheep class and reproductive performance of ewes for the first 8 years (1997-2003) of this on-going trial are listed in Table 1. All sheep classes had the same liveweight when allocated to farmlets in 1997. A significant difference between treatments in ewe liveweight was found at both mating and weaning. This was in part attributed to the 3.4 kg lower liveweight of the LC 2THs compared to Con 2THs entering the farmlets each year. The lower liveweight of LC ewes at weaning occurred despite fewer lambs weaned in this system. While there were significant differences in ewe liveweight between years, and a significant interaction between farm systems and year, there was no suggestion that ewe performance on the two farm systems was either diverging or converging with time.

At weaning at 12 weeks of age, lamb liveweight was 1.8 kg lighter on the LC than on the Con farmlets. This

Table 1 Average lamb, two tooth and mixed age ewe liveweight and faecal egg count (FEC) at key times of the year, fleece weights of each sheep class and reproductive performance of ewes for the first 8 years (1997-2003) on conventional (Con) and low chemical (LC) farmlets.

Parameter		Farm System		Significance		
		Con	LC	System	Year	System x Year
Liveweight (kg)						
Ewe	- mating	59.4	54.9	<0.001	0.004	0.020
	- weaning	58.8	54.5	<0.001	0.005	0.310
Lamb	- weaning[1]	22.5	20.8	<0.001	0.003	0.135
	- 32 weeks	34.8	28.5	<0.001	0.182	0.657
Two tooth	- mating	53.5	50.1	0.010	0.056	0.165
Fleece weight (kg)						
Ewe		3.69	3.40	<0.001	<0.001	0.629
Two tooth		2.49	2.33	0.026	<0.001	0.350
Hogget		2.47	1.64	<0.001	<0.001	0.091
Reproductive performance (%)						
Empty rate in ewes[2]		3.50	3.38	0.312	0.014	0.880
Lambs born[3]		140	127	<0.001	0.014	0.575
Lambs weaned		122	104	<0.001	0.171	0.146
Faecal egg count (epg)						
Normal strongylid[4]						
Ewes	- mating	98	250	0.003	0.04	0.560
	- weaning	25	184	<0.001	0.077	0.410
Lambs	- weaning	233	383	<0.001	<0.001	0.002
	- 32 weeks	273	1640	<0.001	0.10	0.095
Two tooth	- mating	376	418	0.383	0.004	0.065
	Nematodirus[5]					
Lambs	- weaning	30	100	<0.001	<0.001	0.001

[6] Lambs were weaned at 12 weeks
[2] Data required log transformation
[3] Lambs are tagged at birth (no docking numbers)
[4] Data required log transformation
[5] Data required log transformation

reflected both the difference in ewe liveweight and the lower FEC in the Con lambs (Table 1). The high FEC (parasite numbers) in the LC lambs was also found in an earlier farm systems study (Mackay *et al*. 1998). In spring 2002, Devantier *et al*. (2004) found large differences in *Nematodirus*, *Ostertagia,* and *Trichostrongylus* in lambs taken from each of these farmlets at 10 weeks of age, housed for 2 weeks and then slaughtered for total gastro-intestinal nematode counts. They calculated the pathogenicity index, based on the system first proposed by Gardiner and Craig (1961) and modified by Gordon (1973), for the lambs on each farmlet and found a score of 1.2 and 5.9 for the Con and LC farming systems, respectively. Any score >2 is considered to be detrimental to growth and animal welfare. The higher liveweight and lower FEC of lambs on Con suggests these animals were benefiting from a lower parasite challenge, although no relationship was found between parasite burden and individual animal liveweight at weaning on each farm system.

Con ewes also had a lower FEC throughout the study (Table 1). This may be attributed to the use of the 100-day Ivermectin® bolus given pre-lambing, especially for FEC measured at weaning. The difference in FEC in ewe lambs between farm systems increased until the autumn (Table 1) at which point there were large differences in liveweight. Devantier *et al*. (2005) found *Haemonchus* and *Ostertagia* in the abomasum and *Trichostrongylus,* and *Cooperia* in the small intestine to be the dominant parasites on the LC farmlets in May 2004. While no relationship was found between parasite burden and animal liveweight at weaning, by May the high parasite burden in lambs on the LC farmlets was associated with reduced liveweight gain. Ewe lambs on Con were drenched between 5-7 times in their first 12 months following weaning, whereas lambs on LC were drenched on average only 1.2 times, with 20% of animals drenched more than twice. When the number of 'recovery drenched' lambs in LC was regressed with time, there was no suggestion that more lambs were being treated as the study progressed. In any one year, the number of lambs treated on one of the LC farmlets varied from 0 to 100%. The inability of ewes on the LC system to reach the same mature liveweight as that found on Con, despite the lower lambing percentage and hence grazing pressure during lambing and spring, suggests the lower lamb growth rates on LC limits the mature body weight of the ewe.

A 'half strength drench test' with Ivermectin (0.1 mg/kg), conducted on lambs in February 2005 and ewes in August 2005, prior to lambing, achieved a 100 and 98.9% reduction in FEC, respectively, suggesting that there had been no build up in resistance to Ivermectin on either of the Con farmlets. The lambs used in the drench test had an average FEC of 83 epg (range 0-800 epg) with their cultures dominated by *Ostertagia* and *Trichostrongylus,* prior to the drench test. The ewes used in the drench test had an average FEC of 440 epg (range 150-1050 epg) with the cultures dominated by *Cooperia.* It should be noted that in this study the ewe lambs are drenched and removed from the ewe block to the hogget/cattle block where they remain as a 2TH till mating. The lamb block is grazed only occasionally by the mixed aged ewes.

While there was no difference in the number of 'empty' ewes between treatments, there was a difference in the number of lambs born, reflecting the heavier ewe liveweight on Con at mating, which would increase the ovulation rate (Smith & Knight 1998). Little difference between treatments was found in lamb mortality rate to weaning (18.6 and 22.9% for Con and LC, respectively), despite the use of a pre-lambing and docking vaccinations in the Con system. Industry mortality rates in lowland systems for single, twin and triplet lambs from birth to 1 day-after-birth (tagging) are approximately 7%, 9% and 17%, respectively (J. Everett-Hincks pers. comm. 2006), with an additional mortality of 1-2% for single- and 5% for triplets, from tagging to 3 weeks of age. The losses in the present study were approximately twice those rates, reflecting the additional challenges faced by a lamb in a hill country environment (Knight *et al*. 1989). There was no indication that the difference in reproductive performance between the two farm systems changed with time, suggesting that the difference reported in this study provides a good insight into the relative performance of these two systems at the stocking rate at which they have been compared.

Both farm systems receive annual inputs of RPR/elemental S to provide a moderate fertility level with Olsen P values of 14 and 19 on Con and LC, respectively (Table 2). The lower P status of the Con farm system might reflect in part the higher production levels driving higher maintenance P requirements on theses farmlets. The most probable explanation is paddock to paddock variation. Parfitt *et al*. (2004) found, in a separate study, that a number of the biological properties (e.g. N mineralisation rates, microbial pools) and communities (numbers of bacteria and fungi feeding nematodes and earthworms) of the soils of an LC system could be fitted along the same ecological gradient as a conventionally farmed legume-based pasture system, suggesting that both the biology and organic matter decomposition cycle of the two systems were similar. In the current study, pastures on both systems had very similar compositions, including the dead matter content in late spring (November) of 2005 (Table 2), providing additional evidence that after 8 years under an organic management regime the two farm systems had similar pasture production and feed quality. Management of a range of undesirable woody plant species (gorse, manuka) is an ongoing challenge within the LC farmlets

Table 2 Selected soil properties and pasture composition of conventional and low chemical farm systems sampled in spring 2005.

Year 2005 (Spring)	Con	LC	Significance
Soil properties			
Organic matter content (%)	9.05	9.80	0.54
pH	5.35	5.35	1.00
Olsen P	14.5	19.5	0.43
$S\text{-}SO_4$	12.0	10.5	0.21
Organic S	6.0	6.0	1.00
Mg^{++}	27.5	28.5	0.90
Ca^{++}	4.5	5.0	0.50
K^{+}	8.0	10.5	0.61
Na^{+}	5.25	5.25	1.00
Pasture composition (% DM)			
HF[1] grass	50.8	47.4	0.59
LF[1] grass	31.8	35.4	0.17
Legume	3.36	3.06	0.62
Other species	2.10	1.07	0.70
Dead matter	11.9	13.0	0.79

[1]High- and low-fertility species

Conclusions

This study represents a world first; a long-term replicated farm systems study examining the changes in the biology of legume-based, mixed-livestock systems associated with the shift to organic production. Until options are found to limit the production loss in young stock in the months following weaning in the LC system, the ability of the organic industry to expand will continue to be constrained. There was no suggestion that the difference in the performance of the two systems was either diverging or converging.

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