

Relationships among faecal egg counts, anti-parasite antibodies and milk yields in an experimental Friesian herd

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Abstract Two studies were carried out to measure variation in faecal nematode egg count (FEC) or serum anti-nematode antibody (Ab) concentration in Friesian cattle, and correlations between these traits and subsequent milk yield traits. In Study 1, FEC and Abs were measured in 9-month-old calves and 21-month-old heifers (1996 and 1995 calf crops, respectively), and correlations with the subsequent first-lactation yield traits were estimated in herds calving in late winter (July/August). In Study 2, Abs were measured in mixed-age cows during lactation in each of four groups (summer, autumn, winter, and spring calving mobs), and correlations were

estimated between Abs and yield in the current lactation. In Study 1, concentrations of the six different Abs (adult and/or third larval stages of four nematode parasite species) were moderately correlated with each other (average correlations of 0.57 in calves and 0.65 in heifers). In Study 2 the average correlation among Abs was 0.74. In Study 1, the average FEC values were 142 and 56 eggs/g in April and June samples collected from calves, and 14 and 28 eggs/g from heifers. Repeatability of FEC over time was moderate in the calves (0.45), but much lower in the heifers (0.13). Correlations between FEC and Ab were low but favourable in sign, averaging –0.24 in calves and –0.12 in heifers, while those between FEC as a juvenile and first-lactation milk or milk-component yields were close to zero, averaging –0.05 for calves and –0.02 for heifers. Correlations between Abs to *Cooperia oncophora* or *Ostertagia* L3 antigens and milk or milk-component yields averaged 0.23 and 0.07, for the two age groups in Study 1, respectively, and 0.06 in Study 2. Correlations between these Abs and liveweight averaged 0.14 for calves and 0.17 for heifers. It is concluded that, under the routine herd management conditions applied, concentrations among all Abs studied were consistently correlated, FEC was repeatable in calves, and those calves with a higher Ab response to *Cooperia oncophora* or *Ostertagia* L3 antigens tended to show slightly higher first-lactation yields.

Keywords nematode parasite; faecal egg count; antibody; dairy cows; milk yield

INTRODUCTION

New Zealand dairy farmers spend around \$14 million annually on anthelmintics to control nematode parasites (Nielsen 1997). Without such measures, the impact of parasitism could be expected to include a substantial reduction in growth rates (and increased mortality) in young stock, leading in turn to reductions in their subsequent milk production, either directly or as a result of failure to conceive (Bisset

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1994). Furthermore, it has been shown that under some circumstances significant losses in milk production can occur as a result of subclinical parasitism in mixed-age dairy cows (Bisset et al. 1987a,b). Studies of nematode parasitism in dairy cows in New Zealand (Bisset et al. 1987b; Morris et al. 2002) and Canada (Guitian et al. 1999) have shown considerable variation in the levels of parasitism from herd to herd, or variable responses from herd to herd following treatment with effective anthelmintic.

Over the last decade, an increasing number of cases of anthelmintic resistance have been reported in cattle in New Zealand. These include a case of ivermectin-resistant *Cooperia* spp. (Vermunt et al. 1995), 19 cases of benzimidazole resistance (McKenna 1996), and 15 cases of resistance (mainly in *Cooperia* spp.) to macrocyclic lactones over 17 farms monitored (Familton et al. 2001). It may be necessary one day to develop methods of managing some New Zealand herds of cattle at pasture in the absence of effective anthelmintics, if greater levels of drench resistance develop. This may be particularly relevant where dairy farmers are being encouraged to drench in-calf or lactating dairy cows using anthelmintic products with nil withholding time. One method may be the genetic approach, utilising the natural ability of some animals to resist high levels of parasitic infection or their effects. Heritable differences in parasite-related traits have been reported in New Zealand, both in dairy cattle (Morris et al. 2002) and in beef cattle (Morris et al. 2003), in all stock classes studied so far. These include: faecal egg count (FEC) in beef calves at 7–10 months of age, and anti-nematode antibody (Ab) concentrations in four stock classes, beef calves, yearling beef heifers, peri-parturient beef cows, and mid-lactation mixed-age dairy cows. Although FEC as a measure of resistance is often believed to be only lowly

repeatable in cattle, this study shows that its use in calves still may have some practical value.

The current project was undertaken at Dexcel, Hamilton. In Study 1 with calves and yearlings, we examined the phenotypic relationships of FEC and Ab levels with subsequent first-lactation performance and, in Study 2, the relationship between Ab levels and lactation performance in mixed-age cows. FEC was used as the criterion of resistance in Study 1, but calves were not available for faecal sampling in Study 2.

MATERIALS AND METHODS

Animals

Study 1. Young Friesian females were born on the Hamilton property of Dexcel (formerly the Dairying Research Corporation) in late winter 1995, on its No. 2 and No. 5 farms. These animals were monitored as heifers in their second year of life for FEC and serum Ab levels from April to June 1997. Table 1 shows the faecal- and blood-sampling dates, and the numbers of animals by grazing group (108 animals in total). Liveweights were recorded at 12, 14, and 22 months of age (July 1996, September 1996, and May 1997). Full lactation data were obtained in the first parity in the 1997/98 season.

Additional young Friesian females, born in late winter 1996 at Dexcel's No. 2 and No. 5 farms, were monitored for FEC as calves in their first year of life, immediately before receiving an anthelmintic drench, and for serum Ab levels at 9 and 11 months of age in autumn 1997. Table 1 shows the faecal- and blood-sampling dates, and the numbers of animals by grazing group (38 animals in total). Liveweights were recorded at 12 and 14 months of age. Full

Table 1 Sample collection in April–June 1997 from the No. 2 and No. 5 late-winter calving herds: Study 1.

Year of birth	Source herd	Approx. age ¹ (months)	Grazing group	Number of animals	Faecal sample dates	Blood sample date
1995	No. 2	21	1	63	24 Apr, 9 Jun	3 Jun
	No. 5		2	10	24 Apr, 19 Jun	5 Jun
	No. 5		3	35	29 Apr, 19 Jun	1 May
1996	No. 2	9	4	14	5 Apr, 10 Jun	11 Apr
	No. 2		5	24	14 Apr, 10 Jun	16 Apr
Total				146		

¹Age at first faecal sampling date.

lactation data for these animals were obtained in their first parity in the 1998/99 season.

In both calf crops we were interested in the possibility of carry-over effects from any parasitic challenge during rearing on subsequent lactation performance. The animals from both calf crops experienced routine dairy-herd management conditions in these studies, consisting of year-round grazing, supplemented with silage during periods of pasture shortage. Regular anthelmintic treatment was administered as required: animals were drenched until about 21 months of age, but not as lactating cows.

Study 2. An across-year study was underway at Dexcel's No. 3 herd (Auldlist et al. 1998), evaluating the production of Friesian cows in four separate sub-herds calving in summer, autumn, winter, and spring. One serum sample for Ab was obtained in 1997 for our project from cows in early lactation in each sub-herd ($n = 95$ animals). Table 2 shows the blood sampling dates, carried out between 7 and 29 days after the last cow calved in each group. The milk yield data were taken to the fifth month of lactation (average, 131 days post-partum).

Antibody analyses

Antibody concentrations were analysed using the method reported by Douch et al. (1994), with modifications as described below. Briefly, ELISA plates were coated with infective third stage larval (L3) excretory/secretory antigens of *Cooperia curticei* (Cc), *Cooperia oncophora* (Co), *Ostertagia ostertagi* (Oo) and *Trichostrongylus colubriformis* (Tc), and adult (Ad) somatic antigens of Co and Oo. Plating was done with cultures of pure single-species parasite strains. Serum samples (diluted 1:1000) were added to the wells, and horse-radish peroxidase conjugated Sigma rabbit anti-bovine immunoglobulins (Cat. No. A-5295) at 1:4000 dilution were used with 3, 3', 5, 5'-tetramethylbenzidine and H₂O₂ to detect the bound antibody.

Absorbance of the resultant colour reaction was determined at 450 and 630 nm using a dual wavelength plate reader. Each serum sample was assayed in triplicate and results were expressed as mean absorbance in optical density units. Standard serum samples were included in each ELISA plate and results were corrected multiplicatively to each standard, both between plates within any one assay run, and between assay runs. The coefficients of variation within and between ELISA tests were $3.32 \pm 0.86\%$ and $7.0 \pm 3.6\%$, respectively.

As Oo L3 was the only cattle antigen available to analyse the earliest sera, the sheep antigens Tc L3 and Cc L3 were chosen as being likely to cross-react with *T. axei* L3, and Co L3, respectively. With these three antigens showing promising results, Oo Ad, Co L3, and Co Ad antigens were produced subsequently and used for all sera.

Egg counts

Faecal samples were counted for FEC using a modified McMaster method (Whitlock 1948), in which each worm egg counted represented 100 eggs/g of faeces.

Data analysis

Both the FEC and antibody data were analysed after transformation to natural logarithms ($\log_e(\text{FEC} + 100)$ in the case of FEC). In both studies, least squares models (SAS 1995) were set up to take account of the different treatments experienced by the groups of calves, heifers or cows. In addition, Study 1 included effects of grazing group, and a covariate for date of birth. Yields of milk, fat, and protein in Study 1 were analysed fitting herd, with date of calving as a covariate. Least squares analyses used in Study 2 included effects for sub-herd, age of cow, and a covariate for date of calving within sub-herd. After adjustment for fixed effects, correlations (R) were calculated in both studies between milk

Table 2 Sample collection in 1997 from the No. 3 herds calving in different seasons: Study 2.

Calving mob 1997	Number of cows	Calving date range	Blood sample date	Post-calving range (days) at blood sampling time
Summer	22	6 Jan–12 Mar	10 Apr	29–94
Autumn	27	7 Apr–11 Jun	18 Jun	7–72
Winter	14	23 Jun–1 Aug	12 Aug	11–50
Spring	32	7 Oct–24 Nov	18 Dec	24–72
Total	95			

production traits and FEC or Ab. In Study 1, correlations between FEC or Ab and liveweight were also calculated.

RESULTS

Study 1

Table 3 shows the average FECs for the 1995-born heifers and 1996-born calves at their first and second FEC sampling times. Values were low in the heifers (14 and 28 eggs/g, respectively, with 70 and 58% zero counts, respectively), whereas they were somewhat higher in the calves (142 and 56 eggs/g, respectively, with 2 and 50% zero counts, respectively). In all cases the Ab levels were higher in the heifers than in the calves, by 17–31% for Abs to L3 antigens and by 10–11% for Abs to adult stages.

Table 4 shows phenotypic correlations among production traits and antibody/parasite traits for the calves and heifers. The repeatability of FEC over sampling times was higher in the calves (0.45) than in the heifers (0.13), probably reflecting higher means for FEC in the calves. The average of correlations among Ab measurements was 0.57 in the calves (range 0.18–0.94) and 0.65 in the heifers (range 0.52–0.81). It is acknowledged that there must

be some cross-reactivity, particularly in responses to the L3 and Ad antigens of a single nematode species (i.e., for both the Co and Oo species), but these correlations were not the highest among different antibody responses.

Averages of correlations between FEC and Ab were -0.24 in the calves (range -0.59 to 0.13), compared with -0.12 in the heifers (range -0.22 to -0.01). Correlations between FEC and milk or milk-component yields averaged -0.05 (range -0.18 to 0.03) for calves and -0.02 (range -0.13 to 0.11) for heifers, whilst corresponding correlations between Ab and milk or milk-component yields averaged 0.18 (range 0.07 – 0.27) and 0.06 (range -0.01 to 0.13), respectively. Restricting the Abs to Co and Oo L3 antigens only, correlations with milk or milk-component yields were 0.23 (range 0.16 – 0.27) in the calves and 0.07 (range 0.01 – 0.10) in the heifers. Correlations between the two FEC measurements and the liveweight taken near the time of the faecal samples averaged 0.08 in the calves (range -0.07 to 0.22), and 0.06 in the heifers (range -0.07 and 0.19). Correlations between Abs to Co and Oo L3 antigens and the same liveweights as above averaged 0.14 for the calves (range 0.10 – 0.17) and 0.17 for the heifers (range 0.14 – 0.20). Not shown in the table were correlations of each trait with September (14-month) weights for both age groups. For the calves, the

Table 3 Raw means and phenotypic standard deviations (SD) for each trait: all parasite/antibody traits are geometric means, with SDs in \log_e units. (o.d., optical density unit.)

Trait	No. 2 and No. 5 herds: Study 1				No. 3 herd: Study 2				
	1995-born		1996-born		Summer	Autumn	Winter	Spring	SD ¹
	Mean	SD	Mean	SD					
Milk yield ² (litre)	3011	441	3085	434	1977	1872	2651	2409	287
Fat yield (kg)	136	17.2	143	20	93.0	82.8	117	103	12.6
Protein yield (kg)	102	13.6	105	14.5	64.0	63.7	89.7	75.1	9.02
FEC1 (eggs/g)	14	0.21	142	0.71					
FEC2 (eggs/g)	28	0.34	56	0.48					
CoL3 (o.d.)	1.91	0.19	1.46	0.24	1.80	1.66	1.65	2.85	0.24
CoAd (o.d.)	1.17	0.22	1.06	0.26	1.09	1.11	1.03	1.51	0.22
OoL3 (o.d.)	1.80	0.17	1.37	0.26	1.69	1.63	1.51	3.05	0.24
OoAd (o.d.)	1.40	0.18	1.26	0.18	1.31	1.59	1.29	2.28	0.17
CcL3 (o.d.)	1.71	0.22	1.35	0.22	1.60	1.71	1.47		0.28
TcL3 (o.d.)	1.93	0.18	1.65	0.24	2.12	2.11	1.91		0.25
12-month wt (kg)	254	18	278	18					
14-month wt (kg)	269	21	308	18					
22-month wt (kg)	452	32							

¹Average SD from the four seasonal herds.

²Study 2: yields to mid lactation (average, 131 days).

Table 4 Phenotypic correlations among parasite/antibody traits, lactation yield traits and liveweight (recorded at 12 or 22 months of age) in Study 1: 1995-born heifers and 1996-born calves. (For the heifer and calf data, correlations with absolute values > 0.19 and > 0.32 are significant ($P < 0.05$), respectively.)

	Milk yield	Fat yield	Protein yield	FEC1	FEC2	CoL3	CoAd	OoL3	OoAd	CcL3	TcL3
1995-born heifers											
Fat yield	0.70										
Protein yield	0.90	0.84									
FEC1	0.01	0.11	0.07								
FEC2	-0.08	-0.13	-0.07	0.13							
CoL3	0.02	0.09	0.01	-0.11	-0.18						
CoAd	0.08	0.03	0.06	-0.19	-0.08	0.64					
OoL3	0.10	0.07	0.10	-0.01	-0.14	0.74	0.59				
OoAd	0.06	0.03	-0.01	-0.22	-0.12	0.55	0.60	0.52			
CcL3	0.12	0.13	0.10	-0.10	-0.16	0.79	0.63	0.71	0.52		
TcL3	0.02	0.05	-0.00	-0.02	-0.14	0.81	0.55	0.79	0.56	0.79	
22-month live wt	0.16	0.35	0.21	0.19	-0.07	0.14	0.00	0.20	0.11	0.07	0.04
1996-born calves											
Fat yield	0.82										
Protein yield	0.92	0.87									
FEC1	0.03	-0.18	-0.01								
FEC2	-0.05	-0.02	-0.09	0.45							
CoL3	0.27	0.23	0.16	-0.48	-0.24						
CoAd	0.27	0.22	0.21	-0.29	-0.24	0.71					
OoL3	0.27	0.26	0.18	-0.59	-0.25	0.94	0.70				
OoAd	0.21	0.21	0.17	-0.27	-0.16	0.81	0.75	0.70			
CcL3	0.07	0.07	0.09	0.00	0.13	0.28	0.22	0.18	0.39		
TcL3	0.12	0.12	0.11	-0.29	-0.19	0.75	0.36	0.67	0.60	0.50	
12-month live wt	-0.12	0.11	-0.09	-0.07	0.22	0.10	0.13	0.17	0.08	-0.10	0.03

Table 5 Phenotypic correlations among antibody and yield traits in Study 2. (Correlations with absolute values > 0.20 are significant ($P < 0.05$).)

	Milk yield	Fat yield	Protein yield	CoL3	CoAd	OoL3	OoAd	CcL3
Fat yield	0.64							
Protein yield	0.90	0.77						
CoL3	-0.02	0.07	0.09					
CoAd	-0.04	0.00	0.05	0.71				
OoL3	-0.03	0.12	0.10	0.90	0.70			
OoAd	-0.02	0.00	0.12	0.62	0.61	0.55		
CcL3	-0.04	-0.00	0.07	0.90	0.67	0.78	0.79	
TcL3	0.02	0.07	0.11	0.83	0.66	0.82	0.66	0.87

correlation of 12- and 14-month weights was high (0.92), and correlations of parasite/antibody traits were similar with 12-month weight to those with 14-month weight. For the heifers, correlations were slightly higher for parasite/antibody traits with 12- or 14-month weights than with 22-month weight; the averages of correlations with 12-month weight were 0.09 for FEC, and 0.20 for Ab.

Study 2

Table 5 shows the phenotypic correlations among antibody and yield traits in the four sub-herds combined. Correlations among the Ab measurements averaged 0.74 (range 0.55–0.90), slightly higher than those in Study 1. Correlations between Ab and milk or milk-component yields were low (average 0.04, range –0.04 to 0.12); correlations between the Abs to Co and Oo L3 antigens and milk or milk-component yields were also low (average 0.06, range –0.03 to 0.12).

DISCUSSION

Study 1

Although sample sizes in the present study were too small for heritabilities to be estimated, our previous work on nematode parasites in cattle have shown that FEC and Ab levels are heritable traits in young stock and in peri-parturient females (Morris et al. 2003). Phenotypic correlation estimates among production and parasite/antibody traits in the present study were obtained from animals run under routine (i.e., non-experimental) dairy-herd management procedures, typical for young heifer replacement stock in New Zealand.

The repeatability estimate for FEC in dairy calves in this study ($R = 0.45$, $P < 0.05$; Table 4) was somewhat higher than that found in grazing beef calves in an earlier study ($R = 0.21 \pm 0.08$; Morris et al. 1992). However, the repeatability estimate for FEC in heifers ($R = 0.13$; Table 4) was considerably lower than for the calves. We suspect that the repeatability of FEC is higher when the mean FEC of the group is higher, although there were too few classes of cattle in Study 1 for a robust test of this. It is often believed that the repeatability of FEC in cattle, especially in older cattle, is lower than in lambs. In our corresponding records of FEC in lambs, we found a repeatability of 0.42 ± 0.01 (Morris et al. 2000), very similar to the value for calves here. Using log-transformed data (as in the present analyses and in our cited publications), or cube root-transformed data,

may increase the repeatability estimate relative to using untransformed values.

Although repeated samples of blood were not taken in this study to provide estimates of repeatability for Ab, estimates in beef cattle between successive Ab samples taken from animals within an age class (Morris et al. 2003) were 0.40 in calves (4–9 months of age), 0.48 in yearlings (11–20 months of age) and 0.35 in peri-partum cows. In the beef cattle, phenotypic correlations among the six different Abs averaged 0.61 in calves, while the corresponding estimates in the present study were similar at 0.57 in calves and 0.65 in heifers.

The phenotypic correlations of FEC with subsequent milk or milk-component yields in Study 1 were close to zero, averaging –0.05 in calves and –0.02 in heifers. Corresponding studies in New Zealand Romney lambs in a selection experiment to change FEC (Morris et al. 2000) revealed unfavourable correlations between FEC and production traits (post-weaning gain, 7-month weight, yearling greasy fleece weight). However, in a large study with Australian Merino lambs (Eady et al. 1998) the genetic correlation between FEC and liveweight (at weaning, 10 months, and 16 months) was favourable in direction (averaging –0.21), whilst the genetic correlation between FEC and greasy fleece weight (at 10, 16, and 21 months of age) was unfavourable (averaging 0.15).

In contrast to FEC, the correlations of calf Abs with subsequent milk or milk-component yields tended to be positive (favourable), particularly in the case of the predominant Co and Oo L3 antigens (Table 4), where correlations averaged 0.23 in calves and 0.07 in heifers. (Corresponding correlations of autumn weight with Ab levels in Romney lambs averaged only 0.05; Douch et al. 1995). This suggests that in calves there may be a favourable association between a calf's ability to mount a strong anti-nematode antibody response and her subsequent milk yield.

Phenotypic correlations of FEC with liveweights were generally close to zero (average $R = 0.08$ from calves and 0.06 from heifers), while those for Abs to Co and Oo L3 antigens with liveweights were slightly higher and favourable (average $R = 0.14$ from calves and 0.17 from heifers). These results were consistent with the beef cattle data reported by Morris et al. (2003) where phenotypic correlations were: FEC \times yearling weight (0.02), Ab \times yearling weight (0.13), but in both cases the genetic correlation estimates were considerably higher (0.34 and 0.29, respectively) than the phenotypic correlations.

Study 2

The phenotypic correlations of Ab traits with milk or milk-component traits in Study 2 were all small (Table 5), although the milk traits were highly correlated among themselves, as expected. The Abs were also highly correlated amongst themselves, as also reported by Agneessens et al. (2000) in a Belgian study, with a high correlation ($R = 0.72$) between Abs to adult *Cooperia* and *Ostertagia* species, and by Morris et al. (2002) in a New Zealand study with grazing dairy cows, where four of the same six Abs as in the present study had a similar high correlation (average $R = 0.81$). Bisset et al. (1987a,b) have also investigated responses in lactating New Zealand dairy cows to anthelmintic treatment in the dry period. Overall there was a small but significant milk production response, and the level of response was significantly affected by calf-drenching practice on the farm. There is also wide variation from herd to herd in the anti-parasite Ab levels in milk from cows at pasture (Guitian et al. (1999) in Canadian herds; Morris et al. (2002) in New Zealand herds), but our Study 2 suggests that lactation yields within a herd were not associated with antibody levels to nematode challenge.

There were considerable differences in yields to mid lactation between herds calving in the four seasons (Table 3), reflecting the extent to which feed supply matched nutritional demand. In all cases, the Abs were highest in the spring-calving cows, which perhaps indicates the better ability of nematodes to challenge mature peri-parturient animals when calving occurs in October/November, i.e., considerably later than the conventional time for the great majority of New Zealand dairy herds (July/August calving). An alternative viewpoint is that nutritional supply to the cow was associated (across treatments) with challenge level and host response.

CONCLUSIONS

From Study 1, FEC was repeatable in calves ($R = 0.45$), and it was negatively correlated with Ab level (average $R = -0.24$). Ab levels to different nematode antigens were consistently correlated with each other; this was found in both studies, encompassing three classes of dairy stock. Calves with stronger immune responses (to *Cooperia* and *Ostertagia* L3 nematode antigens) tended to show slightly higher subsequent lactation yields (average $R = 0.23$) and they were heavier as yearlings ($R = 0.14$). In contrast, there was little correlation between the Abs

from 21-month heifers and their first-lactation production (Study 1), or between the Abs from mixed-aged cows and their current-lactation production (Study 2). As seen earlier, the relationships of FEC or Ab with production in cattle may be different from those in New Zealand Romney sheep.

From the above cattle data, together with the corresponding genetic parameters available from other studies in New Zealand cattle, it is concluded that there is scope for improving dairy-cow productivity in grazing herds by reducing the levels of nematode parasitism in calves. Genetic selection to reduce FEC and increase Ab levels is one approach to achieve this. Based on experiences in sheep (Morris et al. (2000) in New Zealand; Woolaston & Piper (1996) in Australia), and direct experience with FEC selection in beef cattle in Australia (Esdale et al. 1986), it would probably be successful. However, there would be an opportunity cost in terms of lower rates of progress for other dairy traits selected at the same time, and the final decision would need to be an economic one.

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