Prevalence of anthelmintic resistance on beef rearing farms in the North Island of New Zealand

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Introduction

Anthelmintic resistance has generally been noted as principally being an issue for small ruminants whereas in cattle nematodes it is a subject that has been given little attention and often dismissed by those interested in parasitology in this host. There have been no surveys of anthelmintic resistance in cattle in New Zealand (or elsewhere in the world) or of parasite control practices in beef cattle in New Zealand. However, resistant parasites have been noted in cattle parasites in several countries, especially in *Cooperia* spp. Resistance to the macrocyclic lactone (ML) anthelmintics has been noted to be a problem in *Cooperia* spp. in Brazil and Argentina (Anziani, Zimmermann et al. 2001; Fiel, Saumell et al. 2001; Anziani, Suarez et al. 2004) and is present in the UK (Stafford and Coles 1999) and the USA (Gasbarre, Smith et al. 2004). In New Zealand a number of reports have been made commencing in the early 1990s of ML resistance in *Cooperia* (West, Vermunt et al. 1994; Vermunt, West et al. 1995; Watson, Hosking et al. 1995; Vermunt, West et al. 1996; Loveridge, McArthur et al. 2003) to the extent that it was considered to be widespread by the late 1990s. There was some consideration that from the very first introduction of the pour-on formulation of ivermectin for cattle in New Zealand the inefficacy of MLs against this species was already apparent (Bisset, Brunsdon et al. 1990) but if so, this was a situation that was unique to this one study compared to others undertaken elsewhere in the world. It is interesting to note that ML resistance has now been reported in *C. oncophora* (Winterrowd, Pomroy et al. 2003), *C. punctata* (Gasbarre, Smith et al. 2004) and *C. pectinata* (Anziani, Zimmermann et al. 2001). ML resistance has also been reported in *Trichostrongylus longispicularis* in New Zealand (Loveridge, McArthur et al. 2003) and *Haemonchus placei* in Brazil (Rangel, Leite et al. 2005). Of interest is the absence of any reports of ML resistance in *Ostertagia ostertagi* despite ML resistance being reported in deer and noted to be common in closely related species in sheep.

Resistance to benzimidazole (BZ) anthelmintics in cattle has been reported in several species. In Argentina BZ resistance has been reported to *Cooperia punctata*, *Ostertagia ostertagi* and *Haemonchus contortus* (Mejia, Igartua et al. 2003). In Australia there is one report in *Trichostrongylus axei* (Eagleson and Bowie 1986). In New Zealand the first reports were in *Cooperia* spp. (Jackson, Townsend et al. 1987) and later also in *Ostertagia* spp. (Hosking and Watson 1991). In reviews of laboratory submissions McKenna reported several cases where a failure to reduce egg counts suggested resistance in *Cooperia* principally but also in *Ostertagia* and *Trichostrongylus* (McKenna 1991; McKenna 1996). It has subsequently been shown that BZ resistance in *Cooperia oncophora* is controlled by similar changes in the B-tubulin gene to other trichostrongylids (Winterrowd, Pomroy et al. 2003).

There have been fewer cases of resistance reported by cattle nematodes to either levamisole or morantel. Evidence of levamisole resistance in *Ostertagia* was presented in Belgium (Geerts, Brandt et al. 1987) and to morantel in The Netherlands (Borgsteede 1991). The latter report also indicated the isolate expressed cross resistance to levamisole. However, care needs to be taken when interpreting the efficacy of levamisole against *O. ostertagi* as Prichard (Prichard 1983) reviewed the overall efficacy as between 85-95% against adult parasites. Morantel resistance has also been reported in *Haemonchus placei* (Yadav and Verma 1997).

Rapid expansion over the last three decades of intensive bull-beef based cattle systems in New Zealand have seen an increasing reliance on anthelmintics to control gastrointestinal nematodes in this farming system. Although not quantified, there would have also been an increase in anthelmintic use in young cattle in more traditional cow-reared cattle systems. It is not surprising, therefore, that resistant isolates of various species have been reported and with increasing frequency.

This project set out to establish a profile of the prevalence and severity of anthelmintic resistance in trichostrongylid parasites of beef cattle in the North Island to MLs, BZs and levamisole. It was hypothesised that the prevalence may be higher in bull-beef based systems than in traditional cow-reared systems and as the former are more concentrated in the North Island it was considered that restricting the survey to this region would provide a tighter focus for the project. A second aim was to survey farming and nematode control practices on these farms and then evaluate the occurrence of resistance and its severity with these practices to attempt to identify risk factors. The information from this survey will then form the basis for an extension programme targeting both farmers and their veterinarians. It will also identify areas that require further research effort.

Materials and methods

Beef farm selection

The target groups were defined as 50 beef enterprises farming rising yearling bulls through the autumn and winter, and 50 enterprises farming cow-reared rising yearling cattle under moderately intensive grazing management. The latter group involves cow-reared young stock, the introduction of weaners into a grazing system in the autumn at around 6 to 9 months of age, and typically less intensive stocking and grazing systems than occur in bull-beef enterprises. All farms were to be selected from the North Island.

A random selection of beef farms was drawn from the AgriQuality Agribase (Sanson & Pearson, 1997; Sanson, 2000). Regional bias was minimised by ensuring that the regional distribution of farms in the sample was proportionate to the total number of farms with beef cattle by region.

From an initial Agribase random sample of 800 farms, a total of 736 farmers were telephoned. Farms were screened for suitability for the survey against criteria of: farming greater than 60 rising yearling cattle through the summer or autumn; access to scales and a facility for weighing cattle; the period in which these animals are weaned and graze on the farm. Farms where the majority of weaned rising yearling cattle enter the grazing system between 1st January and 28th February were excluded.

Where calves are cow-reared, they will typically enter the enterprise at approximately 6 to 9 months of age and may either be reared on the property or purchased in.

When these criteria were met, the project was described and the farmer was invited to participate. Where the farmer indicated an interest in participating, contact details were confirmed and the name of the veterinarian they would prefer to undertake the survey was obtained.

Details of the project were confirmed in writing with the farmers. Veterinary practices were contacted, the project outlined and a list of the participating farmers nominating them as their preferred practice was provided.

Veterinary practices were required to nominate a project sponsor and key contact. Standard commercial arrangements and protocols were presented to each veterinary practice, which partially recompensed the veterinarian for their input. The project was undertaken with no direct cost to farmers, although they were required to manage stock to facilitate achievement of the pre-treatment egg count, submit faecal samples, and muster and handle stock on at least two occasions.

A standard operating protocol (Appendix 1) and an interview questionnaire (Appendix 2) were developed. Standardised kits containing all drench, sample pottles, syringes, forms, questionnaire and courier materials for the survey were prepared by AgResearch and supplied to veterinarians once the monitor FEC reached the required threshold. Using a standardised kit has the major advantages of ensuring uniformity in drench products used (many tests use product from the same drum) and ensuring that all counts are conducted under the same protocols, usually by the same operator(s).

It was intended that at either of the two visits to the farm the veterinarian would interview the farmer and complete the questionnaire examining parasite and farm management practices.

Treatments and analysis

Faecal egg counts were required prior to the FECRT commencing to ensure egg numbers were sufficient to minimise errors in the test. The specified mean faecal egg count level to enable commencement of the FECRT was 250 epg.

Treatments involved 60 individually identified animals on each farm with 15 cattle in each treatment. These included dosing each animal by its individual weight with a syringe. All anthelmintics were given by the oral route. Control animals were not treated. Treatment groups and the proprietary names of the treatments employed are listed in Table 1.

Table 1. Treatment active ingredients and proprietary names

Treatment group	Proprietary **name**
Control	
Ivermectin	Erase MPC
Levamisole	Levicare
Albendazole	Valbazen

Individually identified faecal samples were collected from all study animals at the first visit when treatments were administered and again 7—10 days later. All samples were tested at the AgResearch Palmerston North laboratory. All egg counts were performed using a modified McMaster technique where each egg counted represented 25 epg.

Where efficacy was determined to be less than 95%, faecal material from the post treatment samples was pooled for each of the implicated groups and the untreated control and cultured to provide stage 3 larvae for identification to genus level.

Three separate formulae for estimation were used and all gave similar results. Unless otherwise stated the formula used in this report is the one commonly known as the Presidente formula. This formula is shown as Equation 1.

Equation 1

$$100 \times \left(1 - \left(\frac{drug\ post-drench\ mean\ epg}{drug\ pre-drench\ mean\ epg}\right) \times \left(\frac{control\ pre-drench\ mean\ epg}{control\ post-drench\ mean\ epg}\right)\right)$$

The formula shown in Equation 2 was used for calculation of drug efficacy for individual genera of parasites

Equation 2

$$1 - \left(\left(\frac{drug\ post-drench\ mean\ epg \times \frac{n\ drug\ test\ larvae}{100}}{drug\ pre-drench\ mean\ epg \times \frac{n\ control\ larvae}{100}}\right) \times \left(\frac{control\ pre-drench\ mean\ epg}{control\ post-drench\ mean\ epg}\right)\right) \times 100$$

Statistical analysis

All data was recorded in Microsoft Access®[1] databases and Excel spreadsheets and statistical analyses performed in Statistix 7®[2] and NCSS®[3]. Microsoft Excel was used to construct some figures.

Box plots were constructed for displaying distributions of continuous variables. In the format used herein, the box encloses the middle half of the data and is bisected by a line at the value for the median. The vertical lines at the top and the bottom of the box indicate the range of "typical" data values. Extreme values are displayed as " " for possible outliers that are values outside the box boundaries by more than 1½ times the size of the box, and " " for probable outliers that are values outside the box boundaries by more than 3 times the size of the box.

Prevalences and proportions are displayed throughout as point estimates with 95% confidence intervals in brackets. Confidence intervals along with point estimates give an indication of the precision of the effect and the uncertainty about the point estimate. If the confidence intervals are 95%, then we can say in general terms that in 95% of replications of the study the interval will include the true value of the point

[1] Microsoft Corporation
[2] Analytical Systems
[3] Number Cruncher Statistical Systems 2000, Jerry Hintze

estimate. Confidence intervals were calculated using the formula from EpiSheet© 2002 written by Ken Rothman.

Anthelmintic efficacy is expressed either as the percentage reduction in faecal egg count (Equation 1) or the percentage reduction in larvae (Equation 2). As reported by Leathwick et al[4], the generally adopted diagnostic definition of anthelmintic resistance in New Zealand, and that of the World Association for the Advancement for Veterinary Parasitology, is a failure to reduce faecal nematode egg counts (FECs) by at least 95%.

There are inevitably errors associated with the processes of treatment administration, faecal sampling, and faecal egg and larvae counting which should be acknowledged when reporting and interpreting FECRTs and larval culture tests. Accordingly, throughout this report, results have been grouped in the following categories shown in Table 2.

Table 2. Categorisation of the level of reduction in faecal egg count and number of larvae

Level of Reduction	Status
>95% reduction	Susceptible
<95% reduction	Ineffective – standard definition for presence of resistance
90-95% reduction	Suspicious
<90% reduction	Ineffective

[4] Leathwick DM, Pomroy WE, Heath ACG. Anthelmintic Resistance in New Zealand. New Zealand Veterinary J0urnal 49(6), 227-235, 2001

Results

A list of 131 farmers who met the criteria and were interested in participating in the programme was compiled from the 736 farmers with beef cattle who were telephoned. The most frequent reasons precluding suitability were not farming rising yearling cattle, farming less than 60 rising yearling cattle under comparable grazing conditions, or no access to a cattle weighing system.

The project commenced with 50 beef enterprises in April 2004. However, only 15 of these properties were able to achieve the threshold mean pre-FECRT egg count and undertook the test in the period up to the end of August 2004. In 2005 a further 47 farms undertook the test by 30th June.

Faecal egg count reduction test and larval culture data were available for 62 farms and completed questionnaires for 59 of those farms. Although the questionnaires were designed to be administered as interviews by contracted veterinarians, only 37 of the questionnaires appeared to be interview based and the remainder (22) were apparently filled in by farmers.

General description of participant farms

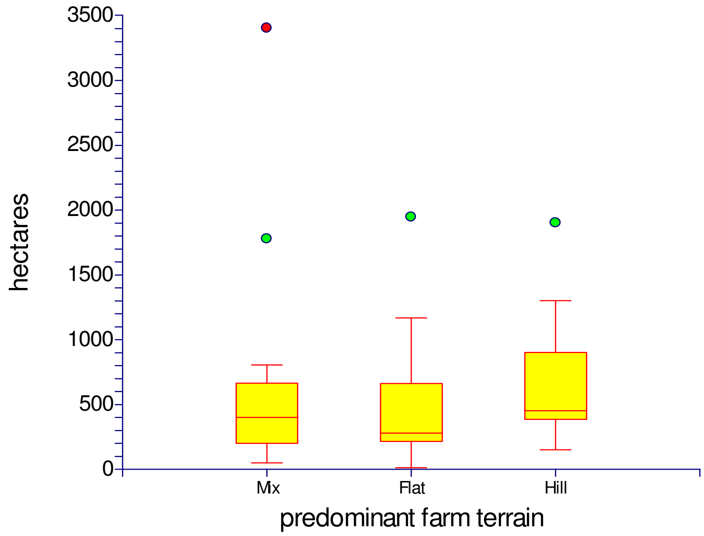
Of the 59 farms for which there were completed questionnaires, 53 nominated beef finishing or stores, 24 nominated beef breeding and one nominated service bull production as one of their four main sources of income as estimated from percentage of gross farm income. Beef finishing or stores was the sole activity on five farms. Five farms had deer, all but 6 farms had sheep, 1 farm produced stud bulls and 3 produced service bulls. Six farms nominated grazing under the questionnaire heading of “other livestock farming”, and of 3 farms that specified dairy grazing, one reared dairy heifers only. Two farms reported cropping as a main source of income.

Two farmers reported no data for numbers of animals reared, 46 reared dairy sourced animals, 38 reared traditional beef animals, 19 reared only dairy animals, 11 reared traditional beef animals only, and 27 reared both types.

Farm size was reported for 59 farms and varied from 13—3,400ha (mean = 592, median = 420). The estimated area for beef finishing or stores was reported for 53 farms and varied from 13—88ha (mean = 217, median = 200).

The dominant terrain in the parts of farms where beef animals were grazed was classified as mainly flat to rolling downlands for 19 farms, more a mixture of flat and hill country for 17 farms, and mainly moderate to steep hill country for 23 farms. Box plots illustrating the distribution of whole farm size for the three categories of terrain are shown in Figure 1 with mild and severe outliers shown as and .

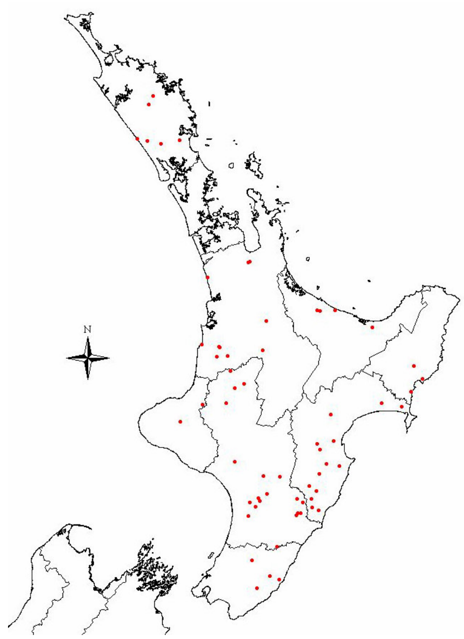
Figure 1. Box plots showing distributions of farm size according to type of terrain classified as Flat (mainly flat to rolling downlands), Mix (more a mixture of flat and hill country) and Hill (mainly moderate to steep hill country)



Only one property had irrigation. The area involved was 50ha and it was grazed by beef animals. A formal program for feed budgeting or pasture recording was used on 10 farms.

The distribution of the approximate locations of the participating farms is shown in Figure 2.

Figure 2. Location of participating beef farms, indicated as



Faecal egg count reduction tests

Faecal egg count reduction tests assessing the efficacy of ivermectin, albendazole and levamisole were performed on the 62 participant study farms. Test results from one farm for ivermectin were discarded due to an error in the way the anthelmintic was administered. The results at cut-offs of <95% and <90% reductions in faecal egg counts are shown in Table 3.

Table 3. Prevalence of inefficacy of ivermectin, albendazole and levamisole at cut-offs of <95% and <90% reduction in faecal egg counts for each and all combinations of the three anthelmintics, ivermectin, albendazole and levamisole, on 62 beef rearing farms

Anthelmintic	efficacy cut-off	n failures	n tested	Prevalence (CIs)
Ivermectin	<95%	56	61	92 (82, 96)
Albendazole	<95%	47	62	76 (64, 85)
Levamisole	<95%	5	62	8 (3, 18)
Iv or A or L	<95%	57	61	93 (84, 97)
Iv and A and L	<95%	5	61	8 (4, 18)
Iv and A	<95%	45	61	74 (62, 83)
Iv and L	<95%	5	61	8 (4, 18)
L and A	<95%	5	62	8 (3, 18)
Ivermectin	<90%	50	61	82 (71, 90)
Albendazole	<90%	37	62	60 (47, 71)
Levamisole	<90%	1	62	2 (0, 9)
Iv or A or L	<90%	51	61	84 (72, 91)
Iv and A and L	<90%	1	61	2 (0, 9)
Iv and A	<90%	35	61	57 (45, 69)
Iv and L	<90%	1	61	2 (0, 9)
L and A	<90%	1	62	2 (0, 9)

Iv = ivermectin; A = albendazole; L = levamisole. n = number, CIs = 95% confidence intervals

Thus for the 62 participating farms, the prevalence of <95% efficacy of ivermectin was 92% (82, 96) and for one or more of the three anthelmintics tested was 93% (84, 97). Levamisole had <95% efficacy on 8% (3, 18) of farms but inefficacy to either levamisole or albendazole was detected on 76% (64, 85) of farms. Only 4 farms showed >95% efficacy for all anthelmintics tested.

Inefficacy with <95% reduction in epg's for all anthelmintics tested was detected on 5 farms 8% (4, 18); for ivermectin and albendazole on 45 farms 74% (62, 83); for ivermectin and levamisole on 5 farms 8% (4, 18); and for albendazole and levamisole on 5 farms 8% (3, 18).

The prevalence of <90% efficacy for ivermectin was 82% (71, 90).

The distributions of inefficacies <95% and <90% in Table 3 are shown in Figures 3 and 4 as point estimates (♦) and 95% confidence intervals (–).

Figure 3. Prevalence of inefficacy of ivermectin (Iv), albendazole (A) and levamisole (L) at cut-offs of <95% reduction in faecal egg counts on 62 beef rearing farms for each and all combinations of the three anthelmintics

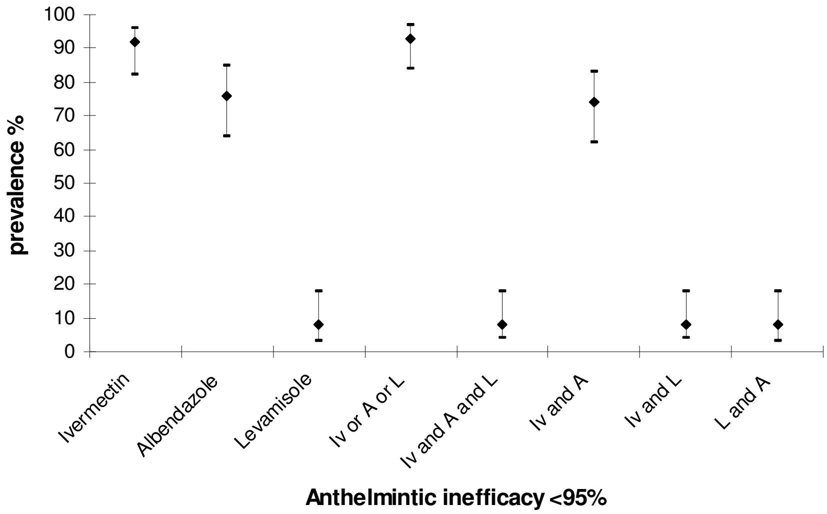
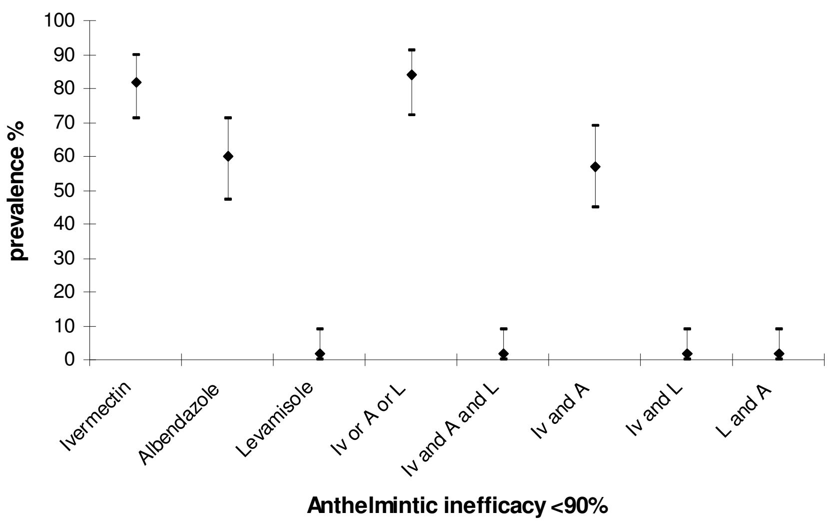
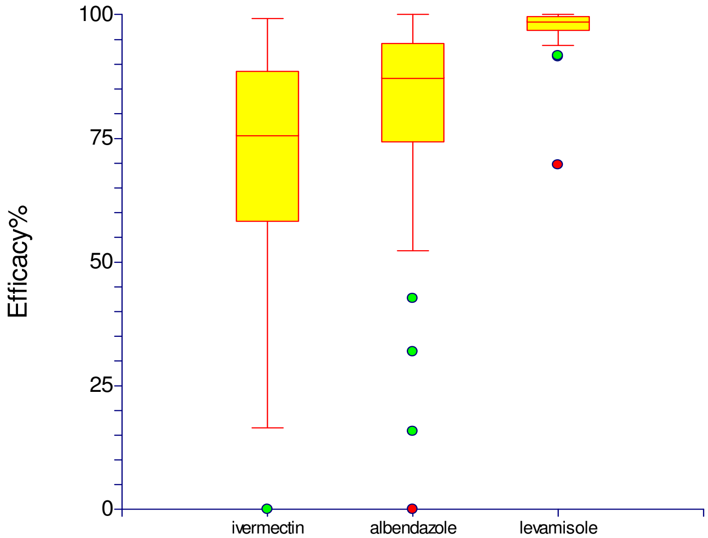


Figure 4. Prevalence of inefficacy of ivermectin (Iv), albendazole (A) and levamisole (L) at cut-offs of <90% reduction in faecal egg counts on 62 beef rearing farms for each and all combinations of the three anthelmintics



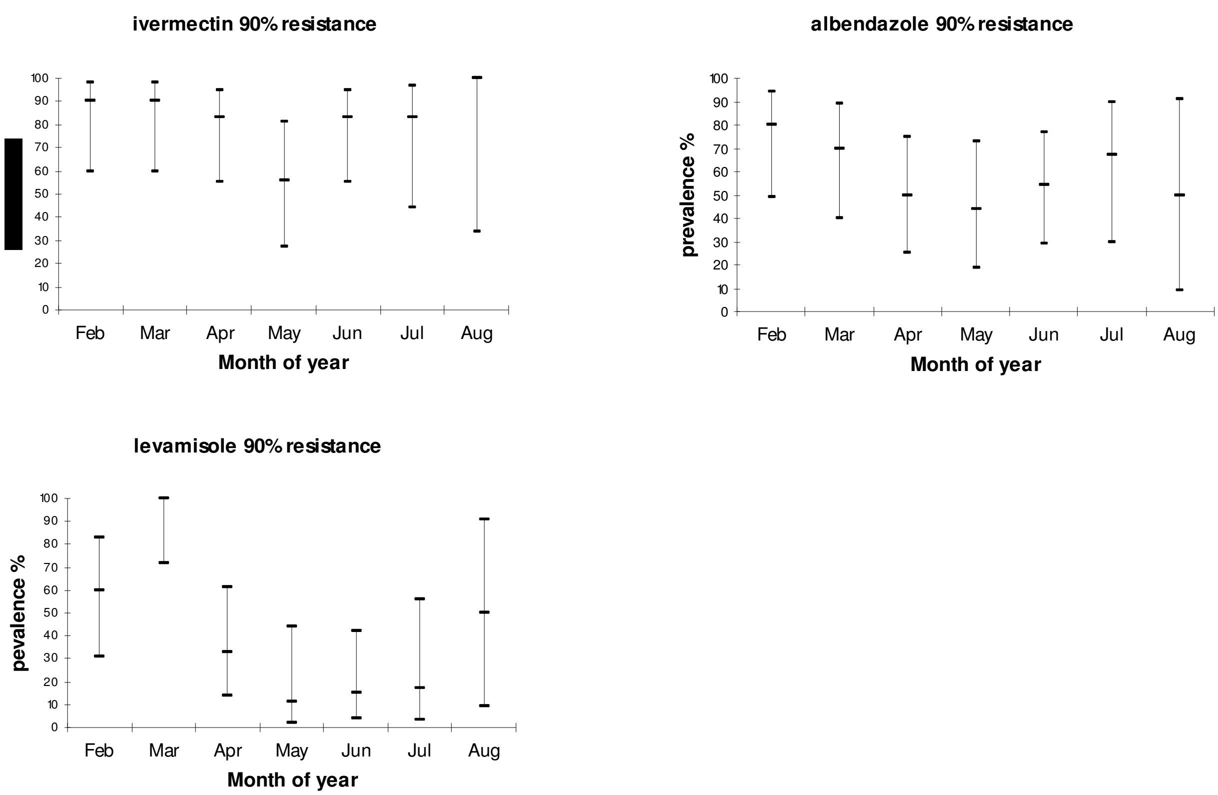
The distributions of the point estimates of efficacy summarized in Table 3 for each anthelmintic are displayed in box plots in Figure 5.

Figure 5. Distribution of efficacy estimates as percentage reduction in FECRTs for ivermectin, albendazole and levamisole on 62 beef rearing enterprises



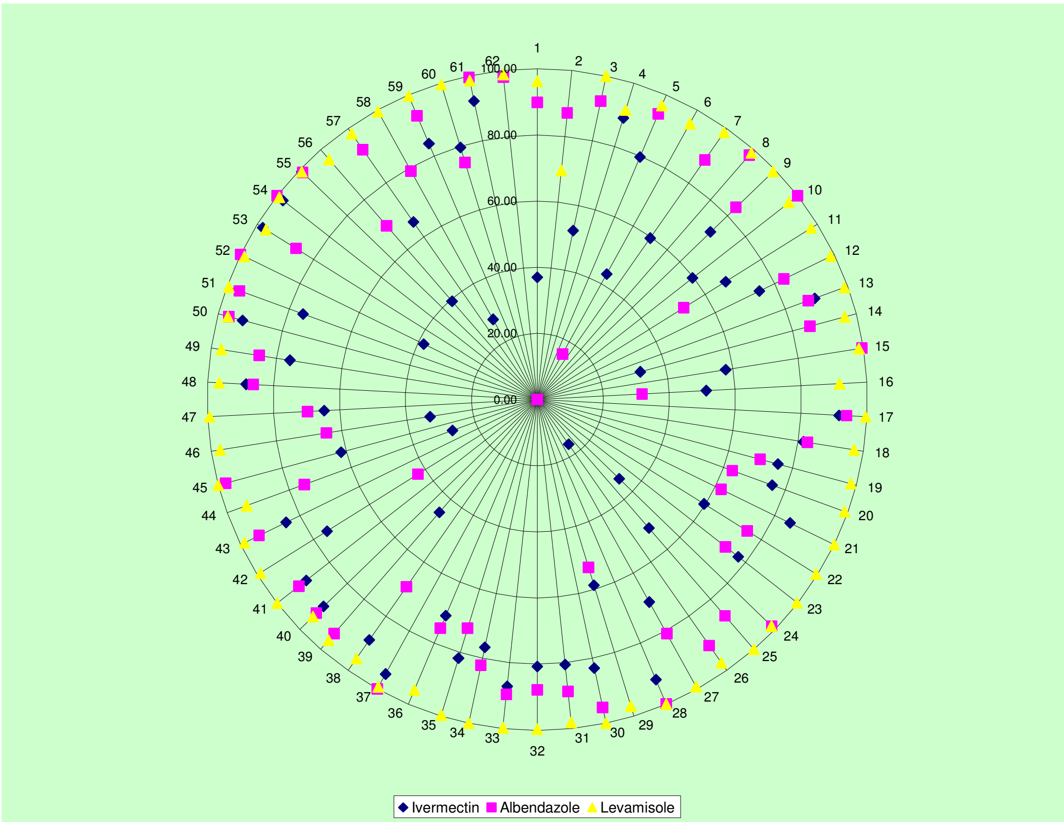
There was no significant difference in prevalences of inefficacy between months of the year but the data indicate a trend towards a decrease about May. It should be kept in mind that the numbers processed per month were low and the confidence intervals about the point estimates are large. The 15 tests that were processed in 2004 were allocated to the corresponding months of the following year for the purposes of analysis. The monthly prevalences and 95% confidence intervals of inefficacy based on a 90% reduction cut-off for ivermectin, albendazole and levamisole are shown in Figure 6.

Figure 6. Monthly prevalences and 95% confidence intervals of inefficacy based on a 90% reduction cut-off for ivermectin, albendazole and levamisole



Individual farms differed greatly in the level of efficacy indicated for each of the anthelmintic treatments based on the FECRT and that variation is displayed in Figure 7.

Figure 7. Distribution of efficacies, based on FECRT, calculated for each of the 62 beef rearing farms



In Figure 7, treatments which achieved 100% efficacy are placed on the circumference, with reducing levels of efficacy indicated by placement towards the centre of the figure, where efficacy is nil.

As an example, farm 3 recorded efficacies of 52% for ivermectin, 92% for albendazole and 100% for levamisole. In comparison, farm 43 recorded efficacies of 85% for ivermectin, 94% for albendazole and 99% for levamisole.

Larval culture

Larvae were cultured from post treatment faecal samples for all control groups and treatment groups when that treatment achieved <95% efficacy based on FEC. Larval culture data for the control group samples collected at the post-treatment visit were assumed to reflect pre-treatment larval populations for the three treatment groups.

Larval culture efficacy was not calculated and the result was designated not assessed (NA) if the estimated pre-treatment genera epg was <25 epg. Hence it was difficult to calculate precise prevalences of inefficacy for specific drugs and genera since it was not possible to classify the efficacy levels of the not-assessed results. It should also be kept in mind that the calculation methods produce estimates with wide confidence intervals. For these reasons prevalences in Table 4 are classified on a broad scale of severity ranging from very low, low, moderate, high and very high.

Table 4. Distributions of genera from larval cultures according to drug treatment, where n NA, n <90%, and n <95% = number not assessed, number < 90% and number < 95%, and prevalence of <95% reduction is ranked from very low to very high for the 62 study farms

Drug	Genera	n NA	n <95%	n <90%	Prevalence <95%
Ivermectin	*Cooperia*	6	56	52	very high
Ivermectin	*Ostertagia*	21	5	1	moderate
Ivermectin	*Trichostrongylus*	44	1	1	low
Albendazole	*Cooperia*	15	46	37	very high
Albendazole	*Ostertagia*	27	16	11	high
Albendazole	*Trichostrongylus*	47	3	1	low
Levamisole	*Cooperia*	58	0	0	very low
Levamisole	*Ostertagia*	58	4	4	low
Levamisole	*Trichostrongylus*	62	0	0	very low

n NA = number not assessed

The results of larval culture efficacy tests for *Cooperia*, *Ostertagia* and *Trichostrongylus* larvae at cut-offs of <95% and <90% reduction in larval cultures are shown in Tables 5, 6 and 7. Inefficacy to ivermectin or albendazole or levamisole means one or more of the three treatments failed.

Table 5. Prevalence of inefficacy of ivermectin, albendazole and levamisole at cut-offs of <95% and <90% reduction in *Cooperia* spp. larvae for each and all combinations of the three anthelmintics on 62 beef rearing farms when larvae were present in sufficient numbers to give a valid test

Anthelmintic	efficacy cut-off	n failures	n tested	Prevalence (CIs)
Ivermectin	<95%	56	56	100 (94, 100)
Albendazole	<95%	46	47	98 (89, 100)
Levamisole	<95%	0	4	0 (0, 49)
Iv or A or L	<95%	57	57	100 (94, 100)
Iv and A and L	<95%	0	3	0 (0, 56)
Iv and A	<95%	44	45	98 (88, 100)
Iv and L	<95%	0	3	0 (0, 56)
L and A	<95%	0	4	0 (0, 49)
Ivermectin	<90%	53	56	95 (85, 98)
Albendazole	<90%	37	47	79 (65, 88)
Levamisole	<90%	0	4	0 (0, 49)
Iv or A or L	<90%	54	57	95 (86, 98)
Iv and A and L	<90%	0	3	0 (0, 56)
Iv and A	<90%	35	45	78 (64, 87)
Iv and L	<90%	0	3	0 (0, 56)
L and A	<90%	0	4	0 (0, 49)

Iv = ivermectin; A = albendazole; L = levamisole. n = number, CIs = 95% confidence intervals

Table 6. Prevalence of inefficacy of ivermectin, albendazole and levamisole at cut-offs of <95% and <90% reduction in *Ostertagia* spp. larvae for each and all combinations of the three anthelmintics on 62 beef rearing farms when larvae were present in sufficient numbers to give a valid test

Anthelmintic	efficacy cut-off	n failures	n tested	Prevalence (CIs)
Ivermectin	<95%	5	41	12 (5, 26)
Albendazole	<95%	16	35	46 (30, 62)
Levamisole	<95%	4	4	100 (51, 100)
Iv or A or L	<95%	19	42	45 (31, 60)
Iv and A and L	<95%	0	3	0 (0, 56)
Iv and A	<95%	1	33	3 (1, 15)
Iv and L	<95%	1	3	33 (6, 79)
L and A	<95%	1	4	25 (5, 70)
Ivermectin	<90%	1	41	2 (0, 13)
Albendazole	<90%	11	35	31 (19, 48)
Levamisole	<90%	4	4	100 (51, 100)
Iv or A or L	<90%	11	42	26 (15, 41)
Iv and A and L	<90%	0	3	0 (0, 56)
Iv and A	<90%	0	33	0 (0, 10)
Iv and L	<90%	0	3	0 (0, 56)
L and A	<90%	3	4	75 (30, 95)

Iv = ivermectin; A = albendazole; L = levamisole. n = number, CIs = 95% confidence intervals

Table 7. Prevalence of inefficacy of ivermectin, albendazole and levamisole at cut-offs of <95% and <90% reduction in *Trichostrongylus* spp. larvae for each and all combinations of the three anthelmintics on 62 beef rearing farms when larvae were present in sufficient numbers to give a valid test

Anthelmintic	efficacy cut-off	n failures	n tested	Prevalence (CIs)
Ivermectin	<95%	1	18	6 (1, 26)
Albendazole	<95%	3	15	20 (7, 45)
Levamisole	<95%		0	
Iv or A or L	<95%	4	20	20 (8, 42)
Iv and A and L	<95%		0	
Iv and A	<95%	0	13	0 (0, 23)
Iv and L	<95%		0	
L and A	<95%		0	
Ivermectin	<90%	1	18	6 (1, 26)
Albendazole	<90%	1	15	7 (1, 30)
Levamisole	<90%		0	
Iv or A or L	<90%	2	20	10 (3, 30)
Iv and A and L	<90%	0	0	
Iv and A	<90%	0	13	0 (0, 23)
Iv and L	<90%		0	
L and A	<90%		0	

Iv = ivermectin; A = albendazole; L = levamisole. n = number, CIs = 95% confidence intervals

On any individual farm it is most likely that the farmer is attempting to manage a mix of parasites at any one time. It is also most unlikely that the farmer will be aware of the mix and proportion of parasites present when an anthelmintic treatment is administered.

The prevalence of farms with resistance to more than one genus is shown in Table 8. The prevalence of <95% efficacy of ivermectin against both *Cooperia* and *Ostertagia* was 12% on the 41 farms on which efficacy of ivermectin was evaluated by larval culture for both genera. Albendazole was tested for these particular genera on 35 farms and was less than 95% effective on 46%.

Of the 33 farms where the efficacies of both ivermectin and albendazole were evaluated against *Cooperia* and *Ostertagia* by larval culture, 3% had efficacies less than 95% against both genera. Occurrence of multiple genus anthelmintic resistance compounds the complexity of on-farm decision making.

Table 8. Prevalence of inefficacy (<95%) for combinations of genera and anthelmintic families.

Anthelmintic		***Cooperia* and *Ostertagia***	***Cooperia* and *Trichostrongylus***	***Ostertagia* and *Trichostrongylus***	***Cooperia* and *Ostertagia* and *Trichostrongylus***
Ivermectin (Iv)	n failures	5	1	0	0
	n tested	41	18	14	14
	Prevalence	**12 (5, 26)**	**6 (1, 26)**	**0 (0, 22)**	**0 (0, 22)**
Albendazole (A)	n failures	16	3	2	2
	n tested	35	15	13	13
	Prevalence	**46 (30, 62)**	**20 (7, 45)**	**15 (4, 42)**	**15 (4, 42)**
Levamisole (L)	n failures	0			
	n tested	4	0	0	0
	Prevalence	**0 (0, 49)**			
Iv and A and L	n failures	0			
	n tested	4	0	0	0
	Prevalence	**0 (0, 49)**			
Iv and A	n failures	1	0	0	0
	n tested	33	14	12	12
	Prevalence	**3 (1, 15)**	**0 (0, 22)**	**0 (0, 24)**	**0 (0, 24)**
Iv and L	n failures	0			
	n tested	4	0	0	0
	Prevalence	**0 (0, 49)**			
L and A	n failures	0			
	n tested	4	0	0	0
	Prevalence	**0 (0, 49)**			

The distributions of the efficacy values for the larval cultures for the three genera and three anthelmintics tested are shown in Figures 8, 9 and 10. The number of data points used in the box plots in Figures 9 and 10 is shown as the numbers at the end of each X-axis anthelmintic identifier. The distributions should be only considered as indicative of trends since the point estimates are relatively crude and in some instances based on few data points.

Figure 8. Distribution of 56 ivermectin, 47 albendazole and 4 levamisole *Cooperia* larval culture efficacy values

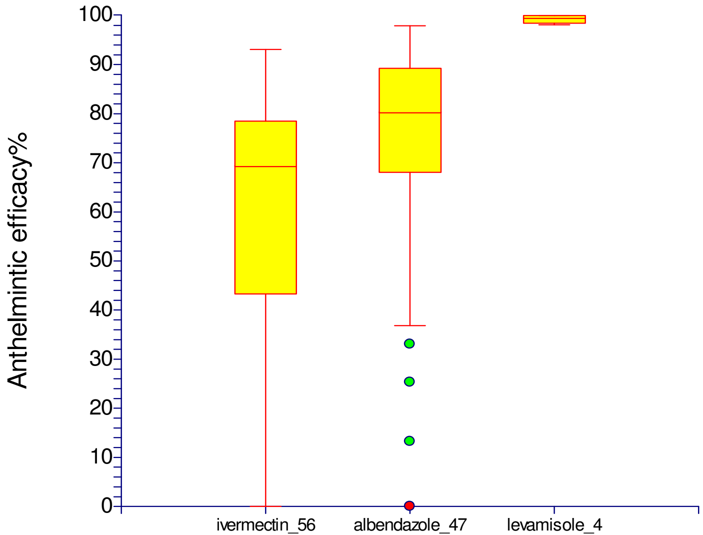


Figure 9. Distribution of 41 ivermectin, 35 albendazole and 4 levamisole *Ostertagia* larval culture efficacy values

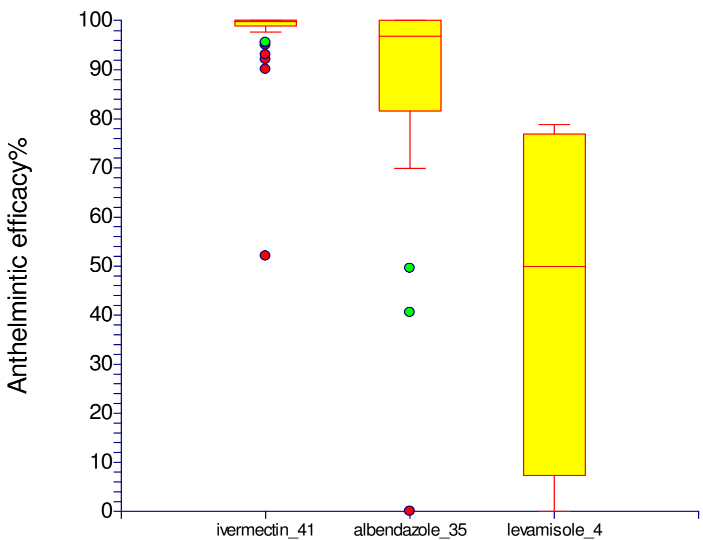
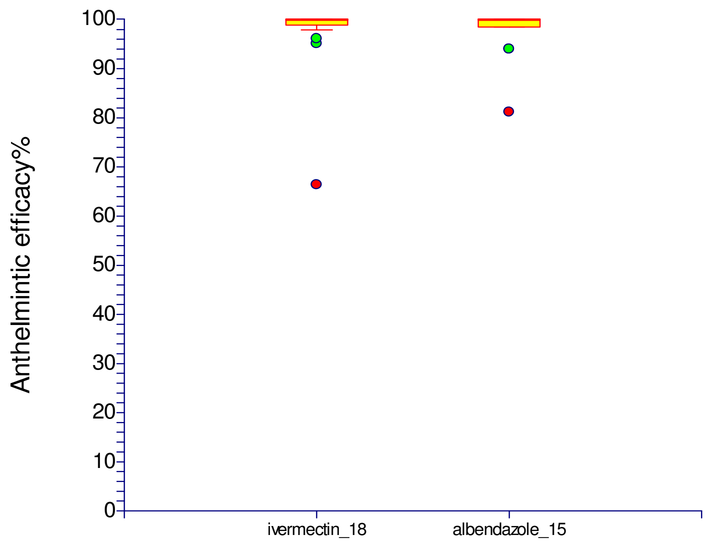


Figure 10. Distribution of 18 ivermectin and 5 albendazole *Trichostrongylus* larval culture efficacy values

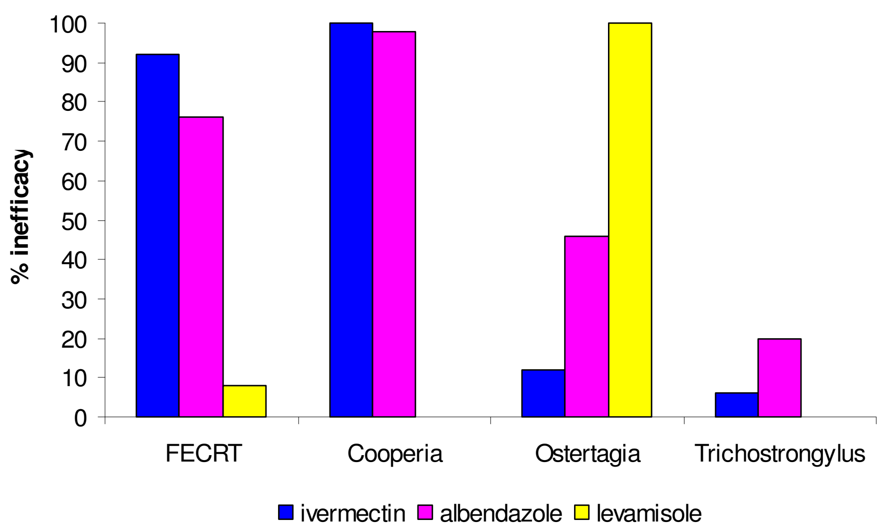


These figures suggest:

- relatively high efficacies of ivermectin and albendazole against *Trichostrongylus*, and for the most part, with the exception of three outliers, consistency of these treatments against this genus;
- a relatively consistent efficacy of levamisole against *Cooperia*, albeit for only four cultures;
- large variation in the efficacy of ivermectin against *Cooperia*;
- for the most part, relatively high efficacies of ivermectin and albendazole against *Ostertagia* but presence of some outliers that are cause for concern.

In this survey, the FECRT indicated a high prevalence of drench failure to ivermectin and albendazole. However, the nature of that resistance, and the prevalence of multiple resistance can only be fully assessed when larval culture is undertaken in conjunction with the FECRT, Figure 11. The reported prevalences of resistance to *Ostertagia* and *Trichostrongylus* most likely overestimate the true prevalences, due to the high level of *Cooperia* in many samples and the decision to culture only treatments where FECRT efficacy was <95%.

Figure 11. Proportion of farms with less than 95% efficacy on FECRT and with less than 95% efficacy on larval culture by genus, subject to the genus being present at the time of testing



Discussion

Previous reports of anthelmintic resistance in New Zealand (McKenna 1991; McKenna 1996) (West and Probert 1989; Vermunt, West et al. 1996) relied on case data and were important in drawing attention to the condition but provided no clear indication of the prevalence of resistance in cattle. This study focused on enterprises rearing yearling beef animals since that age group of animals were the most likely to be affected with detectable parasitism caused by the three nematode genera considered most important *viz. Cooperia, Ostertagia and Trichostrongylus*.

The study farms were randomly selected from a comprehensive list of North Island beef cattle farms held in the AgriQuality Agribase and are considered to be reasonably representative of beef rearing enterprises throughout the country. The choice of the North Island was influenced by a perception that the risks for developing resistance for beef rearing enterprises would be largely independent of location, as risks for development of resistance were considered *a priori* to be related to general farming practices, such as stocking density and frequency of anthelmintic use for that class of animals, rather than geographical location.

It is highly likely that specialised enterprises engaged in rearing young dairy replacement animals are exposed to similar risks for development of resistance as are intensive beef rearing operations. It would be prudent therefore to consider the results from this study to also apply to dairy rearing enterprises because of similar grazing and anthelmintic treatment management practices. However, it would be advisable to test that hypothesis with an independent study on dairy rearing units and gain further insights into the nature of resistance and anthelmintic use in cattle.

Among all beef farmers contacted, a common feature was the significant number of farms which met the criteria for inclusion, but the farmer was not interested in participating in the study. Many said that they were not interested in assessing the efficacy of anthelmintics on their farm, some indicated they had already "done it", while others simply declined the offer to participate. In contrast, other farmers were very enthusiastic and positive about the opportunity to learn more about the situation on their farm. Enterprises where only older cattle were farmed were excluded from the study, because immunity, as exemplified by *Cooperia* spp, is usually developed by 12 to 18 months of age and faecal egg counts are almost invariably too low for faecal egg count reduction testing.

Although the survey farms were randomly selected, the results are biased to an unknown degree by the exclusion of farms that did not meet the required threshold of 250 eggs per gram (Appendix I). The likely effect of this bias would be to inflate the true prevalence by an uncertain amount.

The FECRT identified a high prevalence of inefficacy, with 94% (85, 97) of farms recording resistance to at least one of the treatments. The prevalence of resistance was very high for both ivermectin (92% [82, 97]) and albendazole (76% [64, 85]), and low for levamisole (8% [3, 18]). Inefficacy to either levamisole or albendazole was detected on 76% (64, 85) of farms. Only 4 farms showed >95% efficacy to all anthelmintics tested and although the sample size for that group is too small for inferences to be made, further detailed investigations of circumstances on those farms are warranted for generation of hypotheses that might explain their freedom from resistance.

Larval culture was employed to give insights into the nature of the resistance and provide quantitative and qualitative estimates for particular genera and drugs. The study farms demonstrated a very high prevalence of inefficacy of ivermectin and albendazole for *Cooperia*. The situation for levamisole and *Cooperia* is less certain because of the few farms evaluated and the relatively small data set, but the available evidence suggests reasonable efficacy.

Resistance in multiple parasite genera to albendazole on the same farm was demonstrated on about one in every two farms for *Ostertagia* and *Cooperia*, and one in five farms for *Trichostrongylus* and *Cooperia*. With ivermectin it was on about one in eight farms for *Cooperia* and *Ostertagia*. Ivermectin and levamisole inefficacy in *Ostertagia* appears to be an emerging issue, with *Ostertagia* being the genus resistant to levamisole on all four farms that were evaluated by culture for this drug.

The prevalence of resistance by both *Cooperia* and *Ostertagia* to albendazole on the same farm was high, at 35% of farms tested. Approximately one farm in five demonstrated resistance to multiple parasite genera; *Cooperia* and *Trichostrongylus* to albendazole; and about the same for *Cooperia* and *Ostertagia* to Ivermectin.

It is significant that resistance to multiple anthelmintic families was demonstrated by both *Cooperia* and *Ostertagia* against both ivermectin and albendazole on one farm (3% prevalence).

Although resistance to macrocyclic-lactone in *Cooperia* spp (West, Vermunt et al. 1994; Vermunt, West et al. 1996) and benzimidazole resistance in *Cooperia* and *Ostertagia* spp (Hosking, Watson et al. 1996; McKenna 1996) is known to occur in cattle in New Zealand, macrocyclic-lactone resistance in *Ostertagia* has not been previously reported in peer reviewed literature in this country or elsewhere. The indication from this study of ivermectin resistance in *Trichostrongylus* on one farm, and in particular in *Ostertagia* on five farms, is a disturbing finding, given the high pathogenicity of *Ostertagia* in cattle. Further investigations to validate the findings on these farms are warranted, given the impact that macrocyclic-lactone resistance in *Ostertagia* spp would have for cattle rearing enterprises.

A prior hypothesis that intensive bull beef farming systems were more likely to exhibit resistance than traditional cow-calf properties where weaners were retained for further development could not be tested because of a high prevalence of purchasing yearling or 2-year-olds animals for rearing among the cow-calf study farms. The study showed no apparent difference in the prevalence of resistance between the two farming systems represented in the survey.

The study gives guidance to farmers and their advisors when planning parasite management strategies and points to the need to carefully consider the likelihood of single and multiple drug resistance and how best to detect it before embarking on a program. There is wide acceptance among farmers and veterinarians that faecal egg counts in sheep provide a reasonable assessment of the number of worms in the host. The reason that the case for cattle FEC's is not as well accepted is probably because of unreliable associations between worm burdens and egg counts in mature cattle. However, the procedure is recommended for young cattle where the association is considered to be stronger and of diagnostic value (McKenna 1997; Familton 2001).

Acknowledgements

This project was only able to be undertaken as a result of the commitment and financial support of the Sustainable Farming Fund, Meat & Wool New Zealand and Schering Plough Animal Health Ltd.

Wrightson and Allflex supported the project through the provision of animal identification systems.

Assistance with the supply of anthelmintic was provided by Merial, Ancare and Schering Plough Animal Health.

The field work was supported by veterinarians in practice throughout New Zealand who willingly found time during a busy period of the year to plan and undertake the work with farmers.

The farmers who were initially contacted by phone and who agreed to participate in the survey must be acknowledged for their willingness to support an initiative that has established important benchmarks for the whole industry. These farmers worked through the inconvenience of screening sampling as well as the management inconvenience of testing through what were, at times, challenging climatic conditions.

AgriQuality provided a random selection of farms for initial contact from AgriBase.

The staff at AgResearch, Palmerston North, planned and undertook the tasks of creating, managing and receiving all the kits and samples. They undertook all the faecal egg counting, and in conjunction with staff from Massey University carried out all the larval counts. In addition, AgResearch completed all sample and initial data analysis.

The management and support team including Bill Pomroy, Dave Leathwick, Dave West, Tania Waghorn, Ron Jackson and John Moffat who have nurtured and developed this project to completion. In particular, acknowledgement must be made of Ron Jackson for his dedication in both data analysis and report writing.

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Appendix 1 Protocol for Cattle Faecal Nematode Egg Count Reduction Test

Please read carefully - it is important that all farms in this national survey use the same methods. Our definition of a rising yearling is an animal born since 1 July 2004.

1. Pre-FECRT Screening Protocol

- Discuss with the farmer the options for which sex group/mob of animals will be used and consider previous drench and grazing management in determining when to undertake the test.
- Select 60-70 well grown calves/rising yearling cattle of even body weight that have not been drenched for at least 35, but preferably 42 days.
- Run as one mob close to the yards for easy availability.
- Collect 10 fresh faecal samples, off the ground will do, and submit to the veterinarian in the Practice supervising the survey for analysis to determine the level of infection. You may choose to analyse these samples in your Practice or any other convenient laboratory. **Sample containers for this are not included in the kit**. This step may need to be repeated until the threshold is reached. **If in doubt, contact us to review the options.**
- When the average egg count (FEC) reaches at least **250 eggs per gram** the FECRT can proceed. At this point you will need to contact AgResearch in Palmerston North and they will send out the test kit – **phone Rebecca Alexander or Anne-Maree Oliver on (06) 351 8105**.

2. FECRT Protocol – note all treatments are to be administered orally

Please sample Mondays to Wednesdays only. Samples put on the courier on a Thursday or Friday often don't arrive at the lab until the following Monday. Monday is the day of choice for the pre-drench samples because this makes it easier to organise a post-drench sample at 7-10 days (without working weekends).

- Check that the farmer's scales are working. Your own weight in working clothes plus the farmer should suffice as check weights.
- Bring calves/rising yearlings in fresh off pasture. Unless there are obvious reasons, assume that mustering and yarding will generate a random order of animals. This will allow each treatment to be administered sequentially.
- All calves need to be individually identified, and a record kept of the tag, live weight, treatment and dose volume for each calf. A form is supplied for this data. Please double check this data as you proceed – it is easy to transpose numbers.
- Work on one group at a time.
  - *a* draft into treatment
  - *b* tag calves (or record existing numbers ensuring no duplicates)
  - *c* rectal faecal sample
  - *d* weigh and record weight
  - *e* check chart for dose volume and record this – a look-up chart will be supplied with drench volumes required for each liveweight.
  - *f* **all treatments are to be provided orally** - administer the correct dose volume carefully
- Rectal faecal samples are taken from each calf. Each container needs to be uniquely identified. **Label both pottle and lid with tag number and treatment group** using the marker pens supplied.

Samples **must** be obtained from all calves. **Re-sample non-givers at the end, or after lunch**. This is extremely important, as missed animals will downgrade the value of the test.

- A faecal sample must be 8 grams for pre-samples, and a full pottle (approximately) for the post drench sample to allow for egg count and culture. **The quantity is important as it becomes a major problem if there is insufficient faeces to enable cultures to be completed**.

- Treat each calf **orally** at the dose rate recommended for its liveweight from the dose rate chart included. Use the syringes provided and a clean syringe for each drench type.

- Treatment groups

Group / Active	TREATMENT	No OF CALVES
1 ivermectin	Erase MPC	15
2 levamasole	Levicare	15
3 albendazole	Valbazen	15
4 nil	Control	15

- Calves will be run together for a further 7-10 days (**being a Monday to Wednesday**) before post-drenching rectal faecal samples will be taken**. Remember to get plenty of faeces for this sample**. **Remember to label lids and pottles.**

- After post-drench sampling, drench the previously untreated calves and return all animals to the herd.

- All samples must be kept cool, but not frozen, and couriered **overnight** to the laboratory. Any samples unable to be sent immediately should be refrigerated until they are couriered (don't leave on the front seat of the vehicle in the sun).

Errors to be aware of (we've seen them all)

- ***Drench not administered orally***
- ***Pre samples not sent***
- ***Use only the drenches provided – not your own selection***
- ***Calves drenched to the heaviest of the group, not their individual liveweight - in some groups the liveweight range was exceeded by over 100kg***
- ***Calves undrenched - either missed drenching or spat the drench out***
- ***Calves with no faecal sample***
- ***Not enough faeces for culturing***
- ***Poorly identified samples***
- ***Samples sitting at the courier depot over the weekend***

Appendix 2 Beef Farm Questionnaire

CATTLE ANTHELMINTIC RESISTANCE STUDY

Thank you for agreeing to participate in this study of anthelmintic resistance in cattle. This study comprises the cattle component of a wider study of anthelmintic resistance in sheep and cattle.

There are good reasons for improving our understanding of anthelmintic resistance:

- The incidence of resistance appears to be increasing in intensive bull-beef based cattle systems;
- Anthelmintic resistance is likely to be adversely affecting productivity;
- The options for managing parasite resistance are somewhat limited;
- Farmers are uncertain about the effects of resistance;
- Farmers are uncertain about the most effective strategies for dealing with its emergence.

The objectives of the study are:

- To identify and report on the prevalence of anthelmintic resistance across 50 randomly selected beef systems that are farming rising yearling bulls through the autumn and winter, and 50 randomly selected beef systems farming cow-reared rising yearlings under moderately intensive grazing systems.
- To ascertain farmers' parasite and livestock management practices and identify factors that may be associated with anthelmintic resistance, and report findings by September 2004.
- To contribute to farmers' awareness and understanding of the implications of various management practices on their parasite control strategies and options.

This study is part of a wider project involving both sheep and cattle to establish a New Zealand-wide profile of the status of internal parasite resistance and which will also attempt to identify common factors associated with the development of resistance. By linking current resistance status with a survey of farming practices this project aims to identify characteristics of those farms which have resistance, data which will complement the results of trial-based research into the rate of development of resistant nematodes.

Combined, both this project and other trials will provide substantial evidence to farmers about the situation, risks and strategies that sheep and specialist beef farmer's face.

Resistance will be assessed with a faecal egg count reduction test. Faecal samples from treatments indicating resistance will be cultured to identify the species involved. Determination of the level of resistance will be correlated with survey data for each farm to identify likely risk factors . On each property on which the faecal egg count reduction test is completed, a survey of current and historic parasite management practices will be undertaken.

This project is funded by Meat and Wool Innovation and the Sustainable Farming Fund. It is a joint project involving scientists from Wrightson, AgResearch, and IVABS, Massey University.

Confidentiality of information supplied

We give an undertaking that all information will be treated by us as strictly confidential. No information will be used in any way that could reasonably be expected to identify any individual farm or herd.

Project leader for further details:
Tony Rhodes, Wrightson, PO Box 184, Dannevirke.
Phone: 06 901 4506; Fax: 06 901 4506
E-mail: tonyrhodes@wrightson.co.nz

MEAT & WOOL NEW ZEALAND

Sustainable Farming Fund
www.maf.govt.nz/sff

FARMER CONTACT DETAILS

Contact person's name			
Farm address			
Number and road name			
Locality			
Nearest town/city			
Phone No		Mobile phone	
Fax No		E-mail	

FARM DETAILS

What are the farm's 4 main sources of income? (e.g. beef finishing or stores, beef breeding, sheep, dairy)

I	
ii	
iii	
iv	

As estimated from percentage of gross farm income

LAND AREA OF THE FARM AND USAGE. What are the approximate areas of the farm devoted to	Hectares (1 hectare = 2.5 acres)
Beef finishing or stores?	
Sheep and beef farming other than finishing/stores?	
Dairying?	
Deer farming?	
Other livestock farming?	
Arable cropping?	
Horticulture?	

IRRIGATION: During the year ended 30 June 2004		
What area of the farm was irrigated?		Hectares
Was beef finishing carried out on irrigated land?		
What was the main activity on the irrigated land?		

Farm terrain

What is the dominant terrain in the parts of the farm where the bull beef or traditional beef animals are grazed?

Mainly flat to rolling downlands		Please tick one
Mainly moderate to steep hill country		
More a mixture of both flat and hill country		

Pasture recording and feed budgeting

Do you use a formal feed budgeting or pasture recording system?	Yes		No	

If yes, please give the name or type of system you use.

LIVESTOCK ON THE FARM AT OR ABOUT 30 JUNE 2004

BEEF CATTLE: On or about 30 June 2004, how many of each type of beef cattle were on your farm?	Number
Beef cows & heifers (breeding) 2yrs & over	
Beef cows & heifers (breeding) 1-2yrs old	
Beef cows & heifers (not for breeding) 2yrs & over	
Beef cows & heifers (not for breeding) 1-2yrs old	
Beef heifers (rising 1 year old) and calves	
Steers 2 yrs old and over	
Steers 1-2 yrs old	
Steers (under 1 year)	
Beef non-breeding bulls 2yrs & over (R3)	
Beef non-breeding bulls 1-2yrs old (R2)	
Beef non-breeding bulls (under 1 year) (R1)	
Beef breeding bulls (all ages)	

DAIRY CATTLE: On 30 June 2004, how many of each type of dairy cattle were on your farm?	Number
Dairy heifers (rising 1 year) and heifer calves	
Dairy cows & heifers (over 1 year) in milk or in calf	
Dairy cows & heifers (over 1 year) not in milk or in calf	
Dairy bulls to be used for dairy breeding	
Bobby calves on the farm	

SHEEP: On 30 June 2004, how many of each type of sheep were on your farm?	Number
Ewes (2 tooth and over) put to Ram (Dec-May 2004)	
Ewe Hoggets	
Ram and wether hoggets	
Rams (2 tooth and over)	
Wethers (2 tooth and over)	

OTHER LIVESTOCK: On 30 June 2004, how many of each other types of livestock were on your farm?	Number	
Deer over 1 year		
Deer under 1 year		
Goats over 1 year (do not include feral goats)		
Goats under 1 year (do not include feral goats)		Other livestock types
Other livestock (please specify the type or types)		

DAIRY-SOURCED BEEF ANIMALS

At what age or ages do you purchase your dairy beef animals?

As bobby calves?	Yes		No	
As weaned calves?	Yes		No	

Please specify the number of dairy beef animals purchased, their average age, sex, and month of purchase for the current batch of animals that were born in 2003.

	July03	Aug03	Sep03	Oct03	Nov03	Dec03	Jan04	Feb04	Mar04	Apr04	May04	Jun04
Number purchased												
Age												
Sex (M, F, Mixed)												

DAIRY BEEF purchasing pattern over time
Was this pattern of buying much the same as your general pattern of buying for dairy sourced calves over the past 5 seasons?

2002—2003 season	Yes		No	
2001—2002 season	Yes		No	
2000—2001 season	Yes		No	
1999—2000 season	Yes		No	
1998—1999 season	Yes		No	

TRADITIONAL BEEF REARING

Please specify the number of traditional beef animals either purchased or weaned from the home beef herd , their average age, sex, and month of purchase for the current batch of animals that were born in late winter—spring—early summer period of 2003

	Dec03	Jan04	Feb04	Mar04	Apr04	May04	Jun04	Jly04
Number purchased or weaned								
Age (months)								
Sex (M, F, Mixed)								

TRADITIONAL BEEF purchasing or weaning pattern over time.
Was this pattern of buying or weaning much the same as your general pattern of buying or weaning for traditional beef sourced weaners over the past 5 seasons?

2002—2003 season	Yes		No	
2001—2002 season	Yes		No	
2000—2001 season	Yes		No	
1999—2000 season	Yes		No	
1998—1999 season	Yes		No	

TRADING PATTERNS

What is the average age at which you sell your bull beef or traditional beef animals?		months
For how many years have you been farming traditional beef cattle or dairy bull beef animals for sale as stores or finished beef at about 16—30 months of		years

Please indicate the pattern of sales of store or finished bull beef or traditional beef animals that were born in late winter—spring—early summer period of 2002 by specifying the date or month of sale and average live weight.

Full date or month	No. sold	Av. weight	Full date or month	No. sold	Av. weight
/ /200			/ /200		
/ /200			/ /200		
/ /200			/ /200		
/ /200			/ /200		
/ /200			/ /200		

/ /200			/ /200		

Pattern of sales of bull beef or traditional beef animals either as stores or finished animals **Was this pattern of sales much the same as your general pattern of sales for bull beef or traditional beef animals over the past 5 seasons?**	Born 2002	Yes		No	
	Born 2001	Yes		No	
	Born 2000	Yes		No	
	Born 1999	Yes		No	
	Born 1998	Yes		No	

What is the general breed makeup of the young cattle that you are grazing for finishing or taking through for sale as stores? Please which ever applies	Friesian	
	Dairy cross (e.g. Friesian Hereford cross)	
	Traditional straight bred beef (e.g. Angus, Hereford etc)	
	Traditional cross (e.g. Angus Hereford cross)	
	Exotic cross (e.g. Hereford Charolais cross)	
	Exotic (e.g. Charolais, Simmental, Main Anjou)	

SUMMER—AUTUMN and AUTUMN—WINTER GRAZING MANAGEMENT

What system of grazing management for your BULL BEEF calves do you mostly use in their FIRST SUMMER—AUTUMN PERIOD after weaning? You may tick more than one box	Daily shifts	
	Shifts every 2—10 days	
	Shifts at intervals of longer than 10 days	
	Set stocking	

What system do you mostly use thereafter for your BULL BEEF calves in the LATE AUTUMN—WINTER PERIOD when pasture length is shorter? You may tick more than one box	Daily shifts	
	Shifts every 2—10 days	
	Shifts at intervals of longer than 10 days	
	Set stocking	

What system of grazing management do you mostly use for your TRADITIONAL BEEF weaners in their FIRST AUTUMN—WINTER PERIOD after weaning? You may tick more than one box	Daily shifts	
	Shifts every 2—10 days	
	Shifts at intervals of longer than 10 days	
	Set stocking	

What sort of programme do you follow for integrating sheep or older cattle in your grazing management of your bull beef or traditional beef? Please tick whichever applies	Planned integration that you try to follow	
	Random integration – i.e. only if circumstances suit	
	Don't integrate at all	

<u>BULL BEEF rotation with sheep or older cattle</u> **In the period from November to March, how long on average do you usually take before you put your BULL BEEF calves onto a pasture that was last grazed by sheep or cattle older than 1 year?** Please tick whichever applies You may tick more than one box	Between 0—1 month	
	Between 1—2 months	
	Between 2—3 months	
	More than 3 months or does not apply	
	Co-graze with sheep continuously during this period	
	Co-graze with sheep occasionally during this period	
	Co-graze with older cattle continuously during this period	
	Co-graze with older cattle occasionally during this period	

If you co-graze your BULL BEEF with sheep during the period from November to March, approximately what ratio of sheep stock units to dairy beef do you use?

	Sheep		Cattle	Sheep/cattle stock unit ratio

Calculate 55kg ewe = 1 su; Breeding beef cow = 5 su; Growing heifers/steers/bulls = 4.6 su

In the period from April to the end of September, how long on average do you usually take before you put your yearling beef animals (either BULL BEEF or TRADITIONAL BEEF animals less than 15 months-old) onto a pasture that was last grazed by sheep or cattle older than 1 year? Please tick whichever applies. You may tick more than one box	Between 0—1 month	
	About 1—2 months	
	About 2—3 months	
	More than 3 months or does not apply	
	Co-graze with sheep continuously during this period	
	Co-graze with sheep occasionally during this period	
	Co-graze with older cattle continuously during this period	
	Co-graze with older cattle occasionally during this period	

If you co-graze your yearling beef animals (i.e. either BULL BEEF or TRADITIONAL BEEF animals less than 15 months-old) with sheep during the period from April to September, approximately what ratio of sheep stock units bull beef do you use?

	Sheep		Cattle	Sheep/cattle stock unit ratio

Do you graze your weaner cattle in front of ewe mobs over winter?	Yes		No	

If your answer to Question 8.9 is Yes, what ratio of sheep stock units do you use?

	Sheep		Cattle	Sheep/cattle stock unit ratio

Calculate 55kg ewe = 1 su; Breeding beef cow = 5 su; Growing heifers/steers/bulls = 4.6 su

Are sheep or deer, or cattle older than 18 months grazed on pastures in between their use for grazing beef for finishing or stores between weaning and 12 months of age? Please tick whichever applies	Never	
	Occasionally	
	Often	
	Always	

For cattle born in late winter and spring of 2003, did you make hay, haylage, silage or another crop on land before the cattle grazed it? Note: crops include annual rye grass or a newly sown pasture	Yes		No	

If yes to question 8.11, what size of area?		hectares

Do you follow a programme of pasture renewal or cropping on land used for growing out bull beef or traditional beef animals in their first year?	Yes		No	

On average what percentage of land used for growing out bull beef or traditional beef animals would be renewed annually?		per cent

What proportion of your farm was grazed or will be grazed by cattle under 12 months of age between 1 July 2003 and 30 June 2004? Please tick whichever applies	Less than ¼	
	Between ¼ and ½	
	Between ½ and ¾	
	Greater than 3/4	

DRENCHING POLICY AND PROCEDURES

What general treatment programme for internal parasites do you have for your cattle? You may tick more than one box	I have a planned programme which I follow	
	I treat them straight after I purchase them	
	Rely wholly or partially on faecal egg counts (FEC)	
	Poor growth rate, condition or condition score	
	Signs of parasites such as scouring or dirty hocks	
	Gut feeling	
	Other (specify)	

Do you routinely weigh your cattle that you are rearing for finishing or stores?	Yes		No	

On average, how often do you weigh your fattening cattle?	every		weeks

If you do faecal egg counts, who does the counts? Please tick whichever applies	Vet	
	Yourself	
	Other	

How many drenches do you normally give to your beef calves between September and March?	

How many drenches do you normally give to your beef weaners between April and September?	

Please specify the commercial names of the worm drenches, pourons, or injectables that you have used or will use on your young cattle that were born in late winter – spring of 2003.

July—Sept 03	Oct—Dec03	Jan—March04	April—June04

Do you routinely drench your traditional beef calves at marking?	Yes		No	

Do you routinely treat your traditional beef cows and cattle over 2 years old?	Yes		No	

Do you routinely treat your rising 2 years old in-calf heifers (R2s) before calving?	Yes		No	

If Yes to question 9.9, what product do you use and when do you treat animals over 2 years old?

Product/s		Time/s for treatment	

What is the earliest age at which you routinely treat your dairy sourced calves?		weeks

<u>ONE</u> season ago. Please list the commercial worm treatments (drenches, pourons and injectibles) that you used most on the cattle born in late winter – spring 2002.

<u>TWO</u> seasons ago. Please list the commercial worm treatments (drenches, pourons and injectibles) that you used most on the cattle born in late winter – spring 2001.

<u>THREE</u> seasons ago. Please list the commercial worm treatments (drenches, pourons and injectibles) that you used most on the cattle born in late winter – spring 2000.

<u>FOUR</u> seasons ago. Please list the commercial worm treatments (drenches, pourons and injectibles) that you used most on the cattle born in late winter – spring 1999.

If you changed treatments between last season (2002—2003) and this season (2002—2004), please give the reason(s): You may tick more than one box

The previous drench did not appear to work	
A veterinarian recommended that you change to a different treatment	
A person other than a veterinarian recommended that you change	
It was part of a planned drench family rotation	
The new drench was cheaper	
Other. Explain	

Do you return the young cattle to the same paddock after treatment? Please tick whichever applies	Never	
	Occasionally	
	Often	
	Always	

For the cattle that do not return to the same paddock, where do they go? Please tick whichever applies	Pasture re-growth from earlier grazing with calves	
	Pasture re-growth from another class of stock	
	Specify class/es	
	New pasture	
	Crop	
	Other	

How many times (on average) did you treat your 1 to 2 year-old cattle last season? Please tick one.

Zero	Once	Twice	Three times	More than three

If you treated your 1 to 2 year-old cattle, was it because: Please tick whichever	Their egg counts were too high?	
	They were scouring	
	Followed a programme of treating at set times	
	Other: specify	

When treating your cattle for worms, how often do you check the volume of the drug delivered by the applicator or gun? Please tick whichever	Occasionally before you start treatments		
	You rely on the applicator/gun being accurate		
	Always before starting		
	Before starting and again when finished		
	Every		(approximate number) of animals

Do you routinely check the seal integrity of your gun before use?	Yes		No	

The last time you treated a mob of cattle less than one-year-old, how did you estimate their body weight?	Scales?	
	Eye appraisal?	
	Weighband a sample?	
	Other: specify	

The last time you treated a mob of cattle less than one-year-old, what weight did you base the dose rate on?	The average weight in the mob	
	The heaviest individual in the mob	
	The individual animal's weight	
	Other:specify	

Have you ever tested for drench resistance in CATTLE on this farm?	Yes		No	

If Yes, please fill in below the year(s) when the test was carried out, the results of the test, the products (if any) to which resistance was diagnosed and the resistant parasite species identified.

Year	Resistance CATTLE					Products	Parasite spp
	Yes		No		to		
	Yes		No		to		
	Yes		No		to		
	Yes		No		to		

Have you ever tested for drench resistance in SHEEP on this farm?	Yes		No	

If Yes, please fill in below the year(s) when the test was carried out, the results of the test, the products (if any) to which resistance was diagnosed and the resistant parasite species identified.

Year	Resistance SHEEP					Products	Parasite spp
	Yes		No		to		
	Yes		No		to		
	Yes		No		to		
	Yes		No		to		

How was the last test carried out? Please tick whichever applies		
	Faecal samples collected only after treatment (drench check)	
	Samples collected before and after treatment (drench test)	
	Don't know	

Who performed the test?	

FARMER OPINIONS

How do you rate drench resistance as a CATTLE animal health problem on your farm?

No problem		Please tick one
Low		
Moderate		
High		

How do you rate drench resistance as a SHEEP animal health problem on your farm?

A minor nuisance		Please tick one
Neither a minor nuisance nor a serious problem		
A serious problem		

Do you believe drench resistance is a problem for the CATTLE industry? Please tick whichever applies		
	Yes, it is a serious problem now	
	Yes, it is a problem now, but not a serious one	
	Not yet, but will be in the next 5 years	
	Not yet, but will be in the next 10 years	
	No, it is unlikely it will ever be a problem	

Do you believe drench resistance is a problem for the SHEEP industry?		
	Yes, it is a serious problem now	
	Yes, it is a problem now, but not a serious one	
	Not yet, but will be in the next 5 years	

	Not yet, but will be in the next 10 years	
	No, it is unlikely it will ever be a problem	

How long do you consider a grass pasture must be spelled over the summer autumn period before if becomes "safe"?		weeks

Please list what you consider are the three most important disease or production limiting factors for CATTLE rearing and finishing operations. Order by ranking with 1 indicating the most important.

	Priority
	1
	2
	3

Management methods practised on this farm to prevent or control drench resistance in CATTLE

Please tick the methods used on this farm for prevention or control of drench resistance in CATTLE. Mark the three main methods relied on with 1, 2 and 3 to indicate the methods given the top priority, next highest and third highest. Please mark any that you consider useless with an X. Specify any other methods used that are not included in this list.

METHOD	Priority rank
Change drug action families frequently	
Change drug action families regularly each year or every second year	
Treat regularly every 4 to 6 weeks to keep worm populations suppressed	
Treat only when faecal egg counts indicate a problem	
Treat only when cattle are not doing well or are scouring	
Use combination drugs	
Use generous doses of drench	
Use sheep in the grazing rotation to clean up pastures	
Follow young cattle with older animals or sheep as part of the grazing strategy	
Integrate crop or hay/silage making with grazing management	
Operate an all-in all-out system for bull beef or traditional beef	
Use quarantine treatment when buying in new batches of animals	
Use feed budgeting to keep animals growing to their potential	
Follow advice of veterinarians and advisors	
Pasture renewal and/or cropping as part of the grazing feeding system	
Other	
Other	

Thank you for taking the time to fill in this questionnaire. Please make any comments about anthelmintic resistance that you feel may be useful to us. We value your opinions and would like to hear from you.

RECORDS

What type of information records were used/present for the interview?	Please specify:

Please tick □ whichever applies	Records	Precise estimate	Estimate	Bias
Section 4. Livestock on the farm at 30 June 2004				
Section 5.2 Purchasing pattern for bull beef animals				
Section 6.1 Purchasing pattern for traditional beef animals				
Section 6.5 Pattern of sales of finished animals (stores or prime)				
Section 8.5 Number of treatments between Sept and March				
Section 8.6 Number of treatments between April and Sept				
Section 8.7 Timing and identification of treatments				
Section 8.11 Treatments for last season				
Section 8.12 Treatments for two seasons ago				
Section 8.13 Treatments for three seasons ago				
Section 8.14 Treatments for four seasons ago				
Section 8.18 Number of treatments for 1 to 2-year-olds last year				
Section 8.25 Resistance test results for cattle				
Section 8.27 Resistance test results for sheep				

Name of interviewer	
Date	

Codes for use in the interview:

Answer refusal	9
Don't know	8
Biased or best guess estimate	5

Note: The term “drench” applies to any anthelmintic treatment whether given as an injectable, orally or as a pour-on.

The term “feral goats” applies to goats that are uncontrolled.