

# Prevalence of anthelmintic resistance on sheep farms in New Zealand

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Part 2a of a series

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## Introduction

The development and spread of internal parasite resistance to anthelmintics continues, as evidenced by submissions to animal health laboratories, practice surveys and field observations.

Farmer drenching practices were surveyed nationally in the early 1980's (Brunsdon, Kissling et al. 1983) and a much smaller postal survey in the mid 1990's and early 2000's (Macchi, Pomroy et al. 1999; Sharma, Pomroy et al. 2005).

Submissions to animal health laboratories over a decade or more have been tabulated and published giving perhaps our strongest indication of the progress in resistance development. The most recent of these reports (McKenna 1998), which was based on a relatively small number of submissions, detected resistance to benzimidazole, levamisole and benzimidazole + levamisole combinations in 66%, 29% and 16% of cases respectively. While these data are undoubtedly open to questions regarding their representation of the greater pool of New Zealand farms, they clearly indicate that resistance has increased substantially since the early survey of Brunsdon et al (Brunsdon, Kissling et al. 1983).

Surveys (Brunsdon, Kissling et al. 1983); (Macchi, Pomroy et al. 1999) have indicated that the number of drench treatments given annually by sheep farmers had changed little over the intervening 15-20 year period. Further, the use of long-acting drench products, which were not available in the 1980's, has now become common place on many farms, leading to the suggestion (Leathwick, Pomroy et al. 2001) that, even though the number of treatments may have remained static, parasite exposure to drenches is likely to have increased with time.

Recently we have seen confirmation of resistance to the macrocyclic lactone (ivermectin) family of drenches occurring in sheep, which marks a significant milestone in that we now have resistance to all the major drench action families. In addition, the recent identification in goats of strains of *Ostertagia circumcincta* and *Trichostrongylus colubriformis* which were highly resistant to a combination of all 3 action families given at higher than normal dose rates, is a cause of concern, especially as these parasites readily infect sheep. The issue of resistance is not limited to just species that infect sheep and goats.

The spectre of resistance was initially highlighted in New Zealand in 1980 (Kemp and Smith 1980). Through the 2 decades since then farmers have been encouraged to drench-test, develop annual drench-family rotations, adopt preventive-drenching practices, use faecal egg counts and trigger drenching, and quarantine management as tactics for reducing the rate of development of resistance on their farm. From time to time the advice has changed, often as new information has become available. The problem is that many farmers perceive elements of conflict in some of the messages and consequently find it easy to defer to continuing their status quo practices and management. The result of this is that farmers' drenching practices have remained largely unchanged for the last 15—20 years while, over the same time period, resistance has gone from being an oddity to being common place. It is now clear that the status quo approach is applying substantial selection pressure for resistance and is therefore unsustainable in the longer term. Much of the technical advice presented to farmers is

based on studies that show short term economic gains from liberal use of anthelmintics. This advice is unbalanced technically due to a dearth of longitudinal studies of long term effects on productivity, animal health and economics.

Australian researchers have generally been more proactive than their New Zealand counterparts at surveying for resistance prevalence. One of these surveys went further in attempting to identify the influence and association of climatic and farm management factors on the development of anthelmintic resistance on sheep farms in Western Australia (Suter, Besier et al. 2004). However, a weakness of this study was that selection of participants was biased favouring farms that had previously submitted a faecal egg count reduction test (FECRT).

This project set out to establish a New Zealand-wide profile of the prevalence and severity of internal parasite resistance across a sample of breeding ewe flocks and to identify common factors associated with the development of resistance. By linking current resistance status with a survey of farming practices this project sought to identify risk factors for those farms which have resistance, data which will complement the results of trial-based research into factors contributing to the development of resistant nematodes. In the sheep study, additional farms with either known or suspected ML resistance were tested and their parasite control practices documented. This was to enable a case-controlled study to be undertaken for the risk factors associated with the occurrence of ML resistance on these farms by comparing them to similar farms without ML resistance.

Combined, both this project and other empirical trials into factors selecting for resistance provide a basis for an extension programme targeting farmers, veterinarians and industry about the situation, risks and strategies that sheep and beef farmer's face.

The objectives of the study were to determine the prevalences of inefficacy to macrocyclic-lactone, albendazole and levamisole in sheep farms in New Zealand using faecal egg count reduction tests and larval cultures.

## **Materials and methods**

### **Farm selection**

The target group was defined as 100 breeding-ewe based flocks with greater than 1000 ewes wintered. A random sample of farms was drawn from the AgriQuality Agribase (Sanson and 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 greater than 1,000 ewes by region.

Sheep farms in all regions of New Zealand, with the exception of South Island High Country farms, were included in the sampling frame. High country South Island farms were excluded since their management is typically extensive and a separate project was investigating similar issues for this enterprise type.

From an initial Agribase sample of 500 farms, a total of 400 farmers were telephoned. Farms were screened for suitability for the survey against criteria of: greater than 1,000 ewes lambing in 2004; access to scales and a facility for weighing lambs; and availability

of lambs in the 3 months post weaning. Where the number of lambs purchased in each of the previous 2 seasons was greater than 25% of the number of own-bred lambs, the farm was excluded.

An additional non-random group of a maximum of 40 sheep farms was targeted on the additional criterion of having a high probability of macrocyclic-lactone resistance. Veterinarians were invited to refer farms for this group, with awareness promoted through correspondence from the New Zealand Veterinary Association, and advice to veterinarians and veterinary practices participating in the project. From 37 farms nominated by veterinarians as highly likely to have macrocyclic-lactone resistance, 32 farms, hereinafter referred to as the purposive group, were enrolled in the study.

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. 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 questionnaire (Appendix 2) were developed for the study. 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.

At either of the two visits to the farm the veterinarian worked with the farmer to complete the questionnaire which examined parasite and farm management practices.

Faecal egg counts were required prior to the faecal egg count reduction test (FECRT) commencing to ensure egg numbers were sufficient to minimise errors in the test. The mean level to enable commencement of the FECRT was specified as 700 epg for lambs.

### **Treatment and analysis**

Treatments involved 60 animals on each farm, with 10 lambs in each treatment. Animals were dosed orally with a syringe at dose rates calculated for individual body weights. Control animals were untreated. Treatment groups and the proprietary names of the treatments employed are listed in Table 1.

**Table 1. Treatment active ingredients and proprietary names**

Active ingredient	Trade name
Control	
Ivermectin full dose	Ivomec
Levamisole	Nilverm
Albendazole	Valbazen
Ivermectin half dose	Ivomec
Levamisole + albendazole	Arrest

Following the initial faecal sample and administration of treatment, a repeat sample was taken 7 to 10 days later. All samples were assessed in the AgResearch, Palmerston North laboratory. All egg counts were carried out using a modified McMaster technique where each egg counted represented 50 eggs per gram (epg).

Larvae were cultured from all control group faecal samples collected post-treatment and from treatment groups where the FECRT was <95%. Where efficacy was determined to be <95%, faecal material was bulked for each of the implicated groups and the untreated control and cultured to provide material for identification of larvae. Larval cultures were only performed on samples taken at the second visit for logistic reasons and larval data collected for the control group were assumed to reflect pre-treatment larval populations for the five treatment groups. Larval culture was undertaken to assess treatment efficacy for *Cooperia*, *Ostertagia*, *Trichostrongylus* and *Haemonchus*.

If the estimated pre-treatment genus epg was <50 epg, larval culture efficacy was not calculated and the result was designated not assessed (NA). Apart from *Nematodirus*, where efficacy was calculated directly from egg counts, the methods used for calculating efficacy are described in the companion "Prevalence of anthelmintic resistance on beef rearing farms in the North Island of New Zealand" section of the report.

## Statistical analysis

All data were recorded in Microsoft Access<sup>®1</sup> databases and Excel spreadsheets and statistical analyses performed in the R statistical package (R Development Core Team, 2005) which was also used with Microsoft Excel to construct figures. All data was examined with descriptive statistics prior to testing for associations between the outcomes of interest with  $\chi^2$  tests for categorical variables. Continuous variables which were not normally distributed were categorised as quartiles. For normally distributed variables a two sample t-test was used to screen continuous variables. As a general rule, variables significant at the  $p < 0.20$  level were entered into the multivariate logistic regression models provided >90% of the farms exhibited that factor. Statistical analysis was performed using Excel<sup>®</sup> and R version 2.2.0 (Team 2005) .

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.

<sup>1</sup> Microsoft Corporation

Prevalences and proportions are displayed wherever possible 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 estimate. Confidence intervals were calculated using the formula from EpiSheet<sup>®</sup> 2002 written by Ken Rothman.

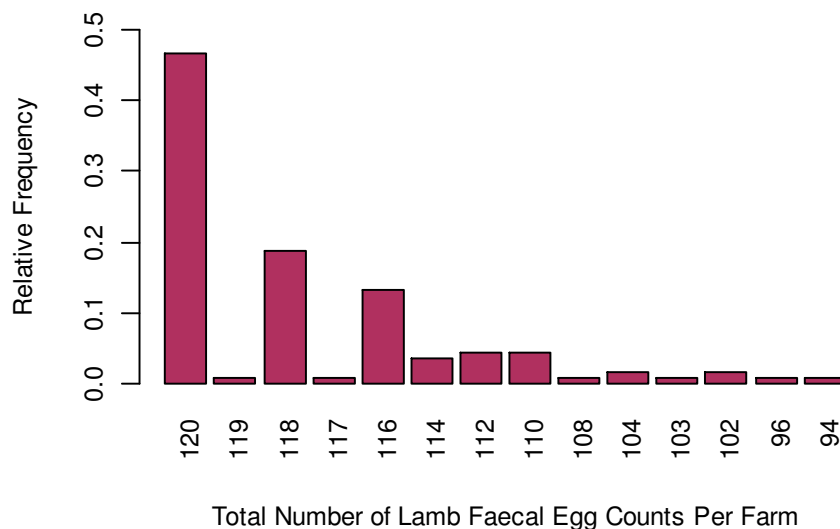
## Results

A total of 80 random selection farms, derived from 119 that met the preconditions set for inclusion, plus 32 purposive selection farms participated in the study. The distributions of participating farms according to their North or South Island location and random or purposive selection criteria are shown in Table 2.

**Table 2. Study population makeup of number of farms aimed for in the study design (target) and numbers of participant farms according to their North or South Island location**

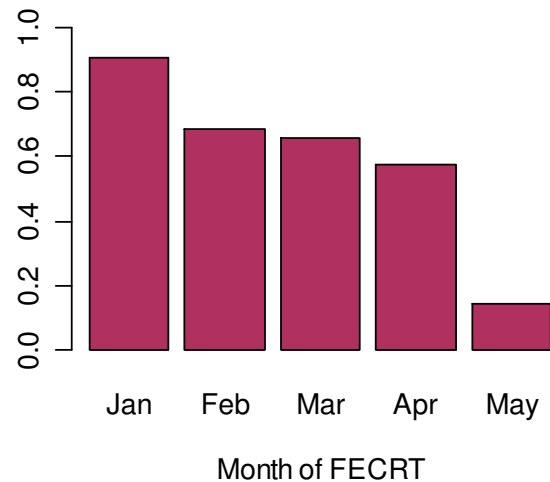
Study Group	Target	Participants	North Island	South Island
Random	100	80	41	39
Purposive	40	32	29	3
Total	140	112	70	42

Full quotas of samples were not submitted for all farms and in some cases there were insufficient faeces for testing. Of a potential 13440 lamb faecal egg counts, viz 120 per farm, 13073 were submitted, equating to about an overall 2.7% sample submission failure rate. About 20% of farms tested submitted fewer than 116 lamb samples with sufficient faeces to enable analysis. The relative frequencies of the number of samples submitted per farm are shown in Figure 1.



**Figure 1. Frequencies of the number of samples submitted per farm**

The pre-treatment group FEC median was 610 epg and the means of the groups ranged from 60 to 6739. Group mean epg's were below the target of 700 epg in 381 (57%) of 672 pre-treatment samples. The effect of month on the proportion of submitted pre-treatment group means that were <700 epg is shown in Figure 2.



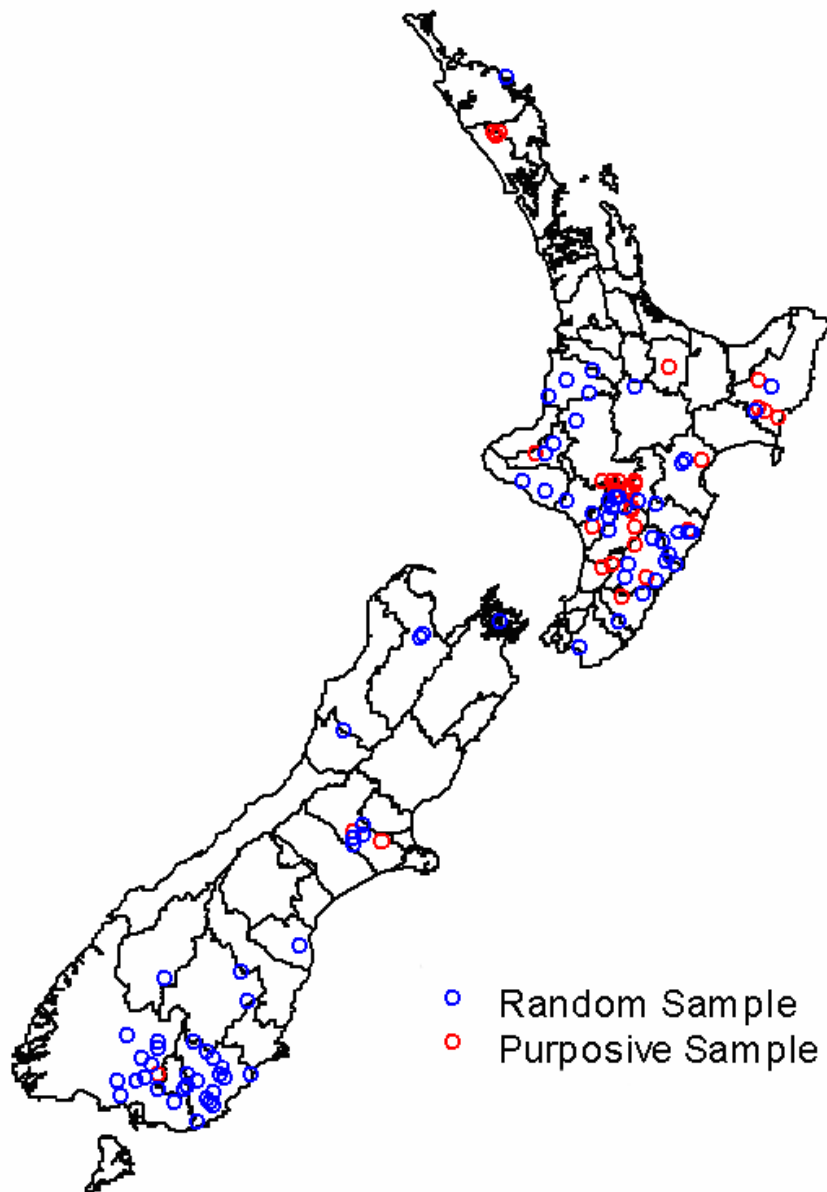
**Figure 2. Proportions of pre-treatment group faecal samples with FEC means <700 for January to May**

## Farm Locations

The locations of the 112 participant farms are shown in Figure 3.



**Figure 3.** Location of random and purposively selected farms that participated in the study



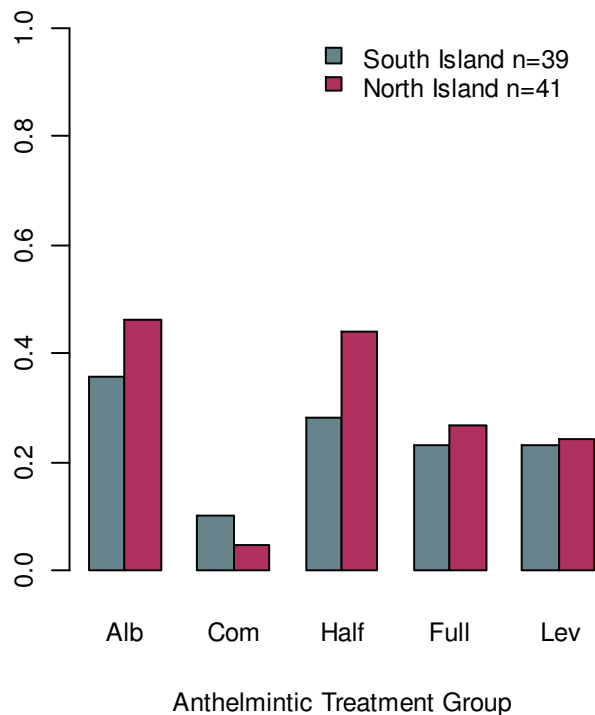
### **Faecal Egg Count Reduction Test**

Faecal egg count reduction tests to assess the efficacy of full and half dose ivermectin, albendazole, levamisole and an albendazole-levamisole combination were performed on all 112 farms.

Overall, 37 (33%, 25, 42) of 112 farms tested had >95% efficacy levels for all anthelmintics tested.

Figure 4 shows no significant difference between the proportions of North and South Island randomly selected farms with <95% efficacy against all anthelmintics tested.

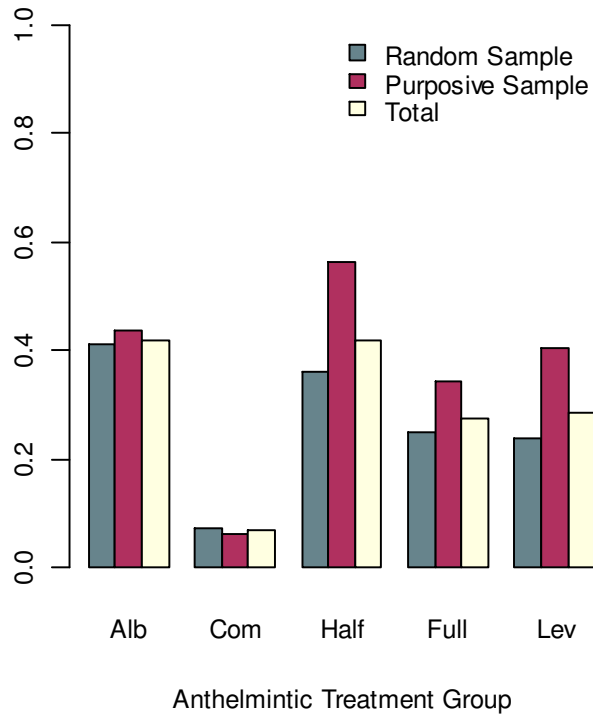
**Figure 4. Proportion of farms with <95% efficacy for each anthelmintic treatment group (Full and Half = full and half dose ivermectin , Lev = levamisole , Alb = albendazole and Com = combination albendazole and levamisole) among North and South Island farms with the Y axis indicating the proportion of farms with <95% efficacy for the anthelmintic treatment**



The various treatment group efficacies for the random and purposively chosen farms categories are shown in Figure 5. Differences can be seen for full and half dose ivermectin and levamisole treatments.

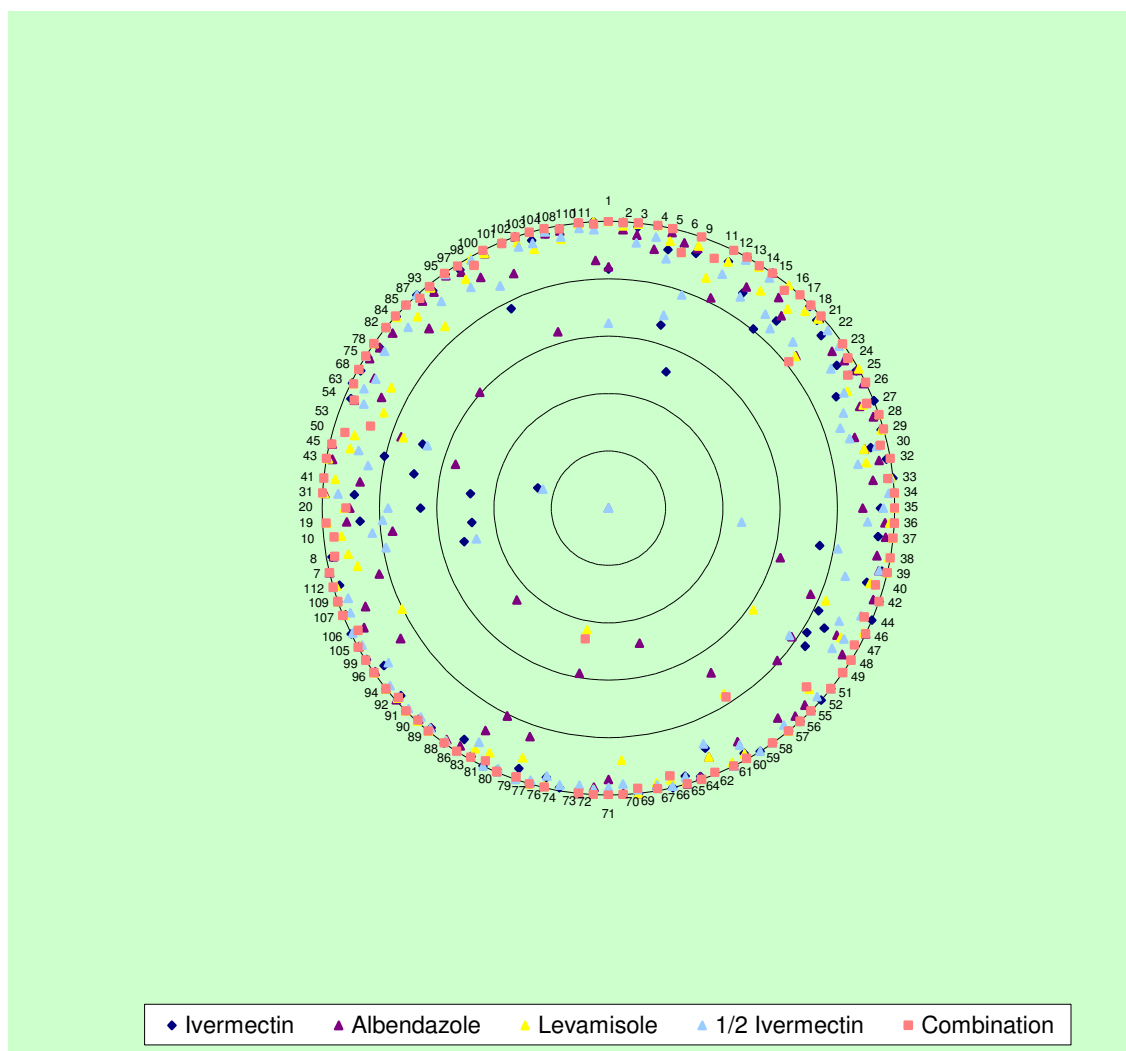
Overall, 29 of 80 (36% 27, 47) randomly selected farms and 8 of 32 (25% 13, 42) purposively selected farms had efficacy levels >95% for all anthelmintic treatments tested. Three farms, one random and two purposively sampled, had efficacy levels <95% for all five anthelmintic treatment groups tested.

**Figure 5. Proportion of farms with <95% efficacy for each anthelmintic treatment group (Full and Half = full and half dose ivermectin ,Lev = levamisole , Alb = albendazole and Com = combination albendazole and levamisole,) among purposively and random selected farms**



Individual farms differed greatly in FECRT efficacy levels calculated for each of the five anthelmintic treatments and the between-farm variation is illustrated in Figure 6.

**Figure 6. Distribution of FECRT efficacies for each of the 112 sheep farms**

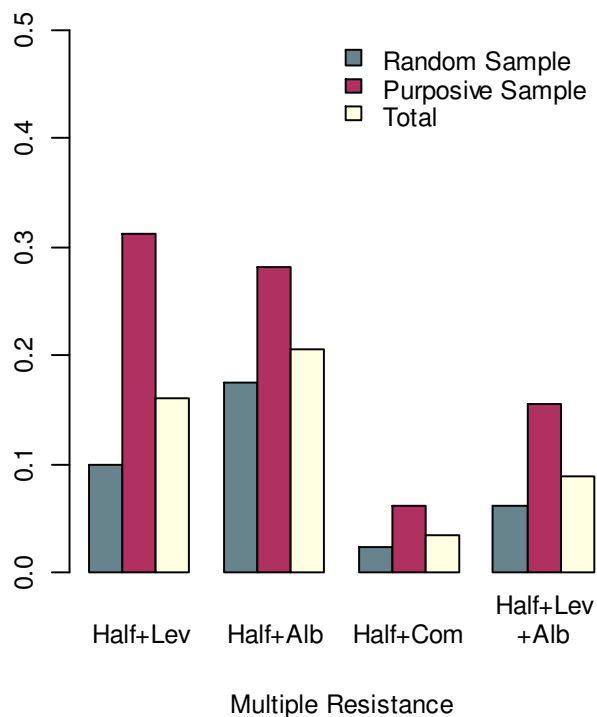


In Figure 6, treatments which achieved 100% efficacy are placed on the circumference, with reducing levels of efficacy indicated by placement towards the centre of the figure, where efficacy is nil.

As an example, on farm 1 efficacy from FECRT's for ivermectin, albendazole, levamisole, half-dose ivermectin and combination treatments were 83%, 84%, 100%, 65% and 100%.

Differences between the purposive and random selection farms in prevalence of resistance to an individual anthelmintic were reflected in the proportion of farms with resistance to more than one anthelmintic treatment. About 30% of purposive farms showed evidence of resistance to both half dose ivermectin and levamisole, or half dose ivermectin and albendazole. The distribution of prevalences of <95% drench efficacy for more than one anthelmintic family in random, purposive and all study farms are shown in Figure 7.

**Figure 7. Prevalences of all farms and random and purposive selected farms with <95% drench efficacy for more than one anthelmintic family**



Efficacy test results for the treatments for the random selection farms are shown in Table 3. Resistance to albendazole was found on 41% (31, 52), to combination albendazole-levamisole treatment on 8% (3, 15), and to both albendazole and half dose ivermectin on 18% (11, 27) of the random selection farms.

An interesting finding was that 18% of farms showed resistance to both albendazole and levamisole when administered separately, yet when administered as a combination treatment, resistance was evident on only 8% of farms, indicating an additive effect on efficacy for the drug combination.

On two farms there was <95% efficacy at full dose ivermectin but >95% efficacy at half dose ivermectin. There is no obvious explanation for this.

**Table 3. Numbers tested (n tested), numbers of failures (n failures) and per cent failures with 95% confidence intervals in brackets of random selection farms with <95% efficacy for all anthelmintic treatments used in the study**

<b>Anthelmintic</b>	<b>n tested</b>	<b>n failures</b>	<b>Per cent failures (95% CI)</b>
Full dose ivermectin	80	20	25 (17, 35)
Half dose ivermectin	80	29	36 (27, 47)
Levamisole	80	19	24 (16, 34)
Albendazole	80	33	41 (31, 52)
Combination	80	6	8 (3, 15)
Full dose ivermectin and levamisole	80	8	10 (5, 19)
Half dose ivermectin and levamisole	80	8	10 (5, 19)
Full dose ivermectin and albendazole	80	10	13 (7, 22)
Half dose ivermectin and albendazole	80	14	18 (11, 27)
Full dose ivermectin and Combination	80	2	3 (1, 9)
Half dose ivermectin and Combination	80	2	3 (1, 9)
Full dose ivermectin, levamisole and albendazole	80	6	8 (3, 15)
Half dose ivermectin, levamisole and albendazole	80	5	6 (3, 14)
Levamisole and albendazole	80	14	18 (11, 27)

Conditional probabilities, defined as the probability that one event will occur given that some other event has occurred, were tested between anthelmintic groups and no dependencies were found, i.e. the probability that a farm had half dose ivermectin resistance was independent of whether that farm had resistance to another drench family.

Efficacy test results for the treatments for the purposive selection farms are shown in Table 4. Resistance to albendazole was found on 44% (26, 62), to combination albendazole-levamisole treatment on 6% (10, 21), and to both albendazole and half dose ivermectin on 19% (7, 36) of the purposive selection farms.

**Table 4. Numbers tested (n tested), numbers of failures (n failures) and per cent with 95% confidence intervals in brackets of purposive selection farms with <95% efficacy for all anthelmintic treatments used in the study**

<b>Anthelmintic</b>	<b>n tested</b>	<b>n failures</b>	<b>Per cent (95% CI)</b>
Full dose ivermectin	32	11	34 (19, 53)
Half dose ivermectin	32	18	56 (38, 74)
Levamisole	32	13	41 (24, 59)
Albendazole	32	14	44 (26, 62)
Combination	32	2	6 (1, 21)
Full dose ivermectin and levamisole	32	6	19 (7, 36)
Half dose ivermectin and levamisole	32	10	31 (16, 50)
Full dose ivermectin and albendazole	32	6	19 (7, 36)
Half dose ivermectin and albendazole	32	9	28 (14, 47)
Full dose ivermectin and Combination	32	2	6 (1, 21)
Half dose ivermectin and Combination	32	2	6 (1, 21)
Full dose ivermectin, levamisole and albendazole	32	4	12 (4, 29)
Half dose ivermectin, levamisole and albendazole	32	5	16 (5, 33)
Levamisole and albendazole	32	7	22 (9, 40)

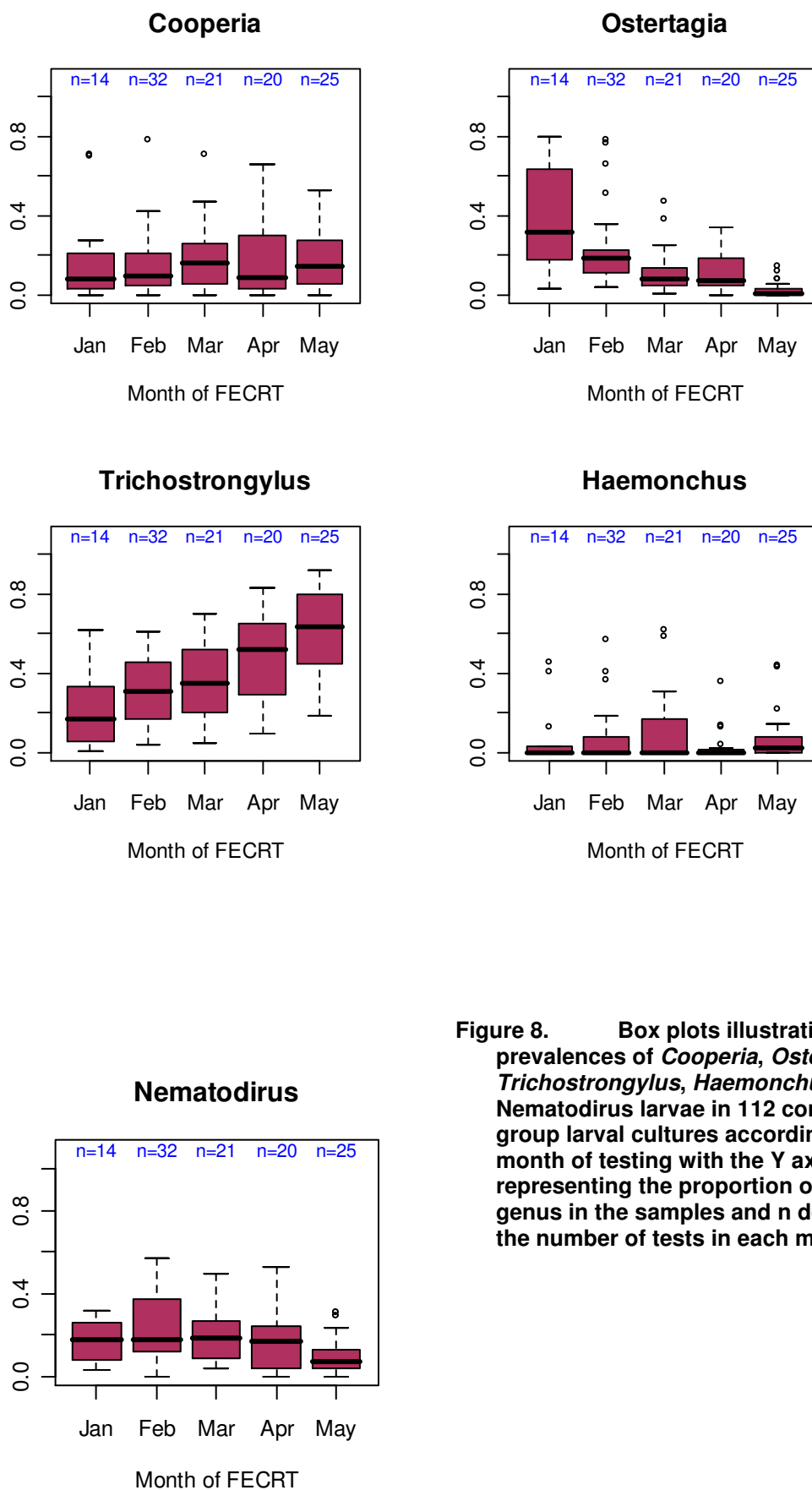
For purposive selection farms, the probability of half dose ivermectin <95% efficacy, given that the farm had levamisole <95% efficacy, was  $10/13 = 0.77$ . This suggests some dependency between levamisole and half dose ivermectin efficacy on the purposively selected farms.

### Month of Testing

Examination of the data for all 112 farms indicated that the month of testing was associated with changes in proportions of nematode genera in the untreated control animals. For the purposes of analysis of that observation, the four FECRTs carried out in December were combined with the January tests and the four FECRTs carried out in June with the May tests.

The proportion of *Ostertagia* present in the controls declined over the period January to May, while *Trichostrongylus* increased as a proportion of the total nematode mix over the same period (Figure 8). The proportions of *Cooperia*, *Haemonchus* and *Nematodirus* remained relatively constant throughout.

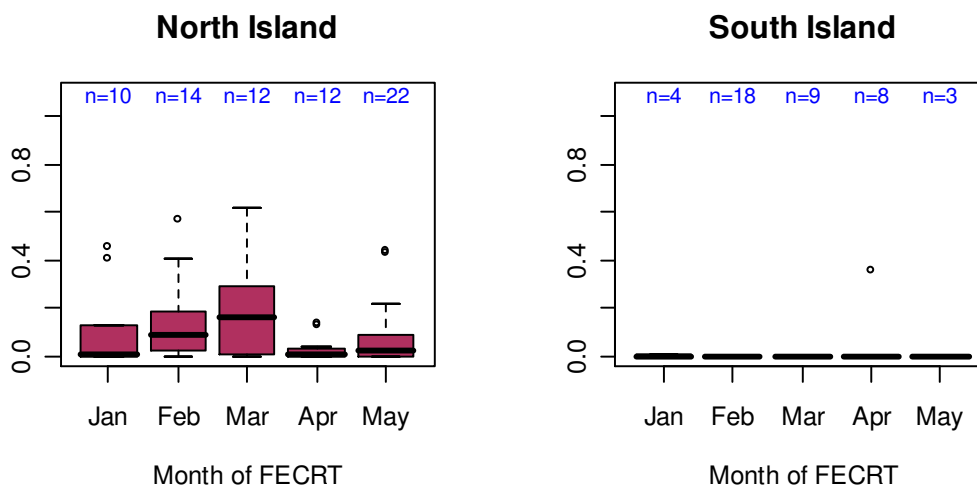
However, as shown in Figure 8, in any one month, there was considerable variation between farms in the composition of the nematode mix, as indicated both by the upper(⌊) and lower(⌋) range of “typical” proportions, and outlier values(°) in the box plots for each genus.



**Figure 8.** Box plots illustrating the prevalences of *Cooperia*, *Ostertagia*, *Trichostrongylus*, *Haemonchus* and *Nematodirus* larvae in 112 control group larval cultures according to the month of testing with the Y axis representing the proportion of each genus in the samples and n denoting the number of tests in each month



For most of the nematode genera, the changes over time are roughly similar for farms in the North and South Islands. The notable exception of *Haemonchus* (Figure 9) suggests that haemonchosis is predominantly a North Island problem. This hypothesis is supported by questionnaire data wherein 7 of 38 random selection North Island farmers and none of 38 South Island farmers gave Barbers pole worm (*Haemonchus*) as their “other” reason for drenching lambs.



**Figure 9.** Box plots showing the temporal distribution of the proportions of *Haemonchus* larvae in control group larval cultures conducted on 42 South Island and 70 North Island study farms.

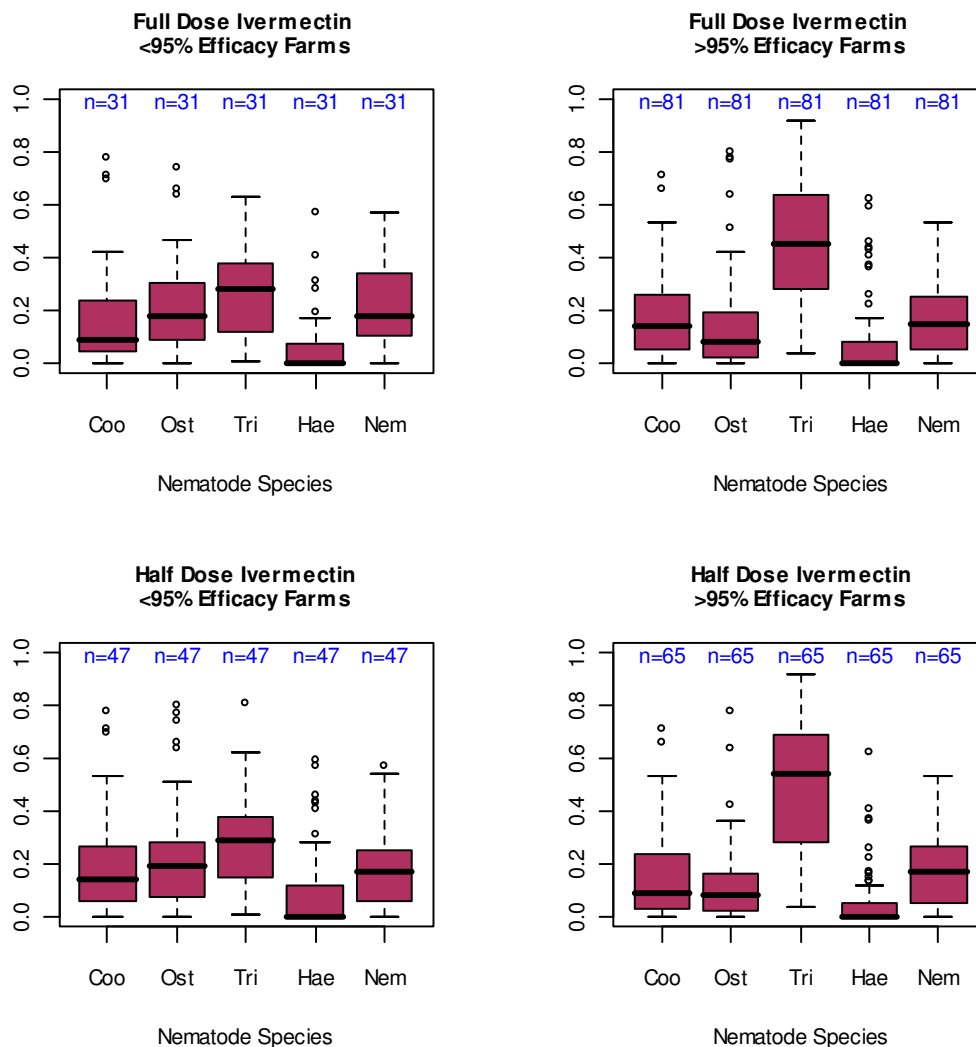
The April outlier for the South Island shown in Figure 9 was located in the Nelson district in the north of the Island.

The profile of efficacy of each anthelmintic treatment group is detailed in Table 5 with the numbers rounded to the nearest whole number. The profiles for albendazole and half dose ivermectin are very similar with the lower quartile of farms achieving less than 90% efficacy on average.

**Table 5.** Descriptive FECRT efficacy statistics results for anthelmintic treatment groups

	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
Full dose ivermectin	26	94	99	93	100	100
Half dose ivermectin	0	90	96	91	99	100
Levamisole	43	94	99	96	100	100
Albendazole	0	89	97	91	99	100
Combination	46	99	100	98	100	100

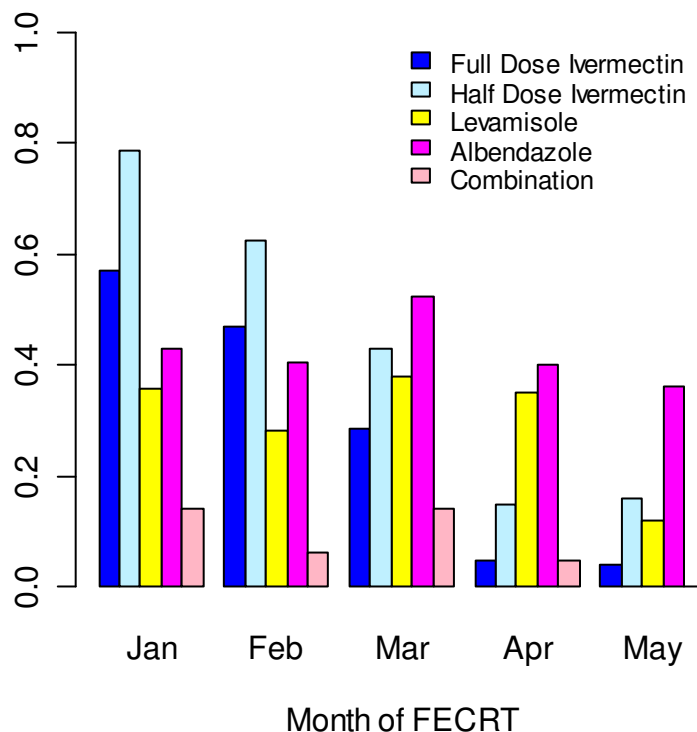
For the levamisole, albendazole and combination treatment groups, the distribution of nematode genera was reasonably similar for farms with <95% efficacy and farms with >95% efficacy. However, there was a marked difference between full and half dose ivermectin (Figure 10). The farms with <95% half and full dose ivermectin efficacy appear to have a greater proportion of *Ostertagia* spp. and a lesser proportion of *Trichostrongylus* spp. in the control group cultures than farms with >95% efficacy.



**Figure 10.** Box plots showing the distribution of nematode genera from <95% and >95% efficacy farms for full and half dose ivermectin treatment groups. The vertical axis is the proportion of each nematode genus in the control group sample, the nematode genera are *Cooperia* (Coo), *Haemonchus* (Hae), *Nematodirus* (Nm), *Ostertagia* (Ost), and *Trichostrongylus* (Tri).

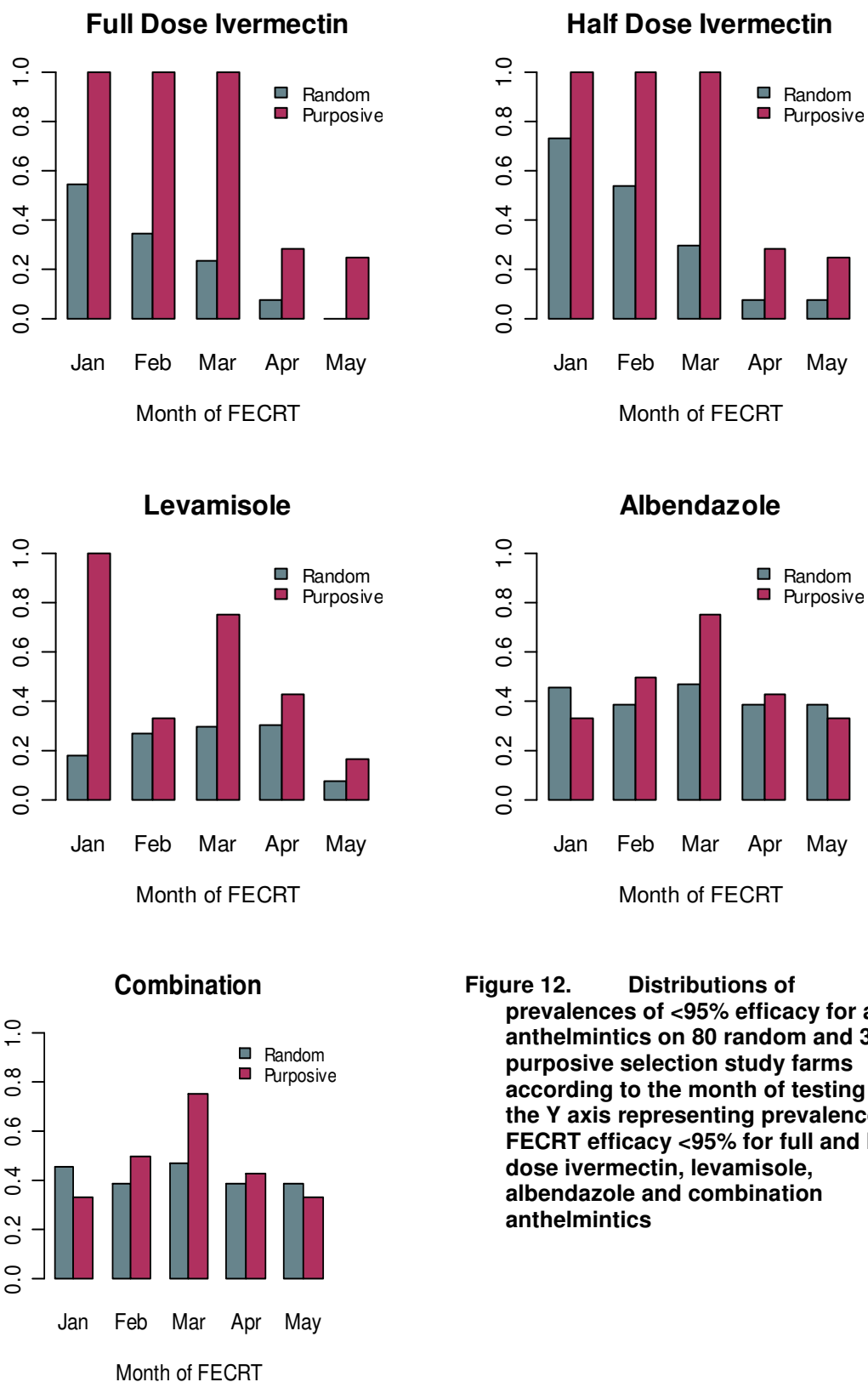
This observation may be due to a changing distribution of the nematode genera over time and strongly suggests that the level of ivermectin resistance observed in this study may be conservative and an underestimate of the true prevalence of resistance.

The changes over time in prevalences of FECRTs with <95% efficacy for all 112 study farms are shown in Figure 11.



**Figure 11. Changes over time in the apparent prevalence of <95% efficacy for FECRTs on 112 study farms for full and half dose ivermectin, levamisole, albendazole and combination anthelmintics. The vertical axis is the proportion of tests per month for each anthelmintic treatment group with <95% efficacy.**

Random and purposively selected farms showed statistically significant different patterns of prevalences of farms with apparent resistance to full and half dose ivermectin over time ( $\chi^2$  test for trend p-value <0.001). Figure 12 illustrates the confounding effect for the purposive or random selection method of farm selection on anthelmintic FECRT results and time of test. The prevalence of resistance to full and half dose ivermectin for random selection farms declined over time but persisted on purposive selection farms during January to March.



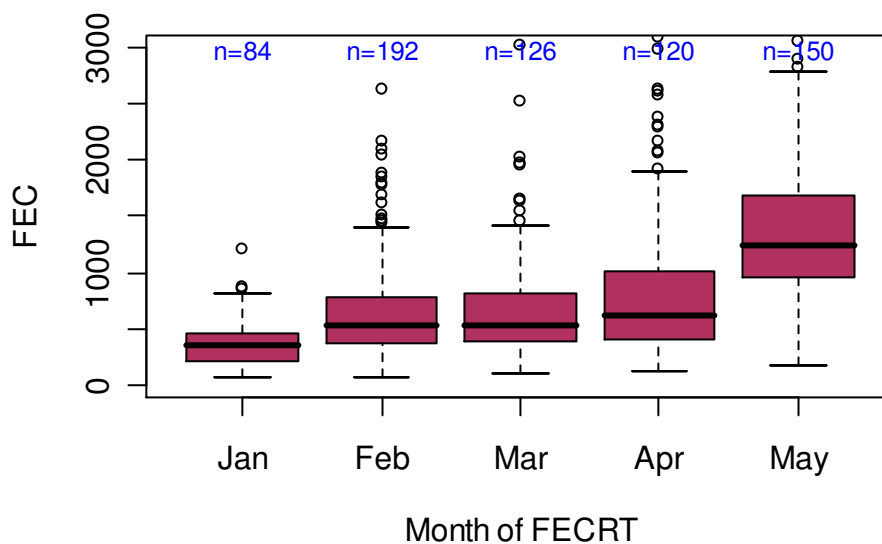
**Figure 12. Distributions of prevalences of <95% efficacy for all anthelmintics on 80 random and 32 purposive selection study farms according to the month of testing with the Y axis representing prevalences of FECRT efficacy <95% for full and half dose ivermectin, levamisole, albendazole and combination anthelmintics**

Purposively selected farms tested between January and March were 3.8 (1.79, 8.06) times more likely to test positive for ivermectin resistance than farms tested later in the year between April and June (Table 6). Whether this finding applies equally to North and South Island farms is unclear since 29 of the purposively selected farms were located in the North Island.

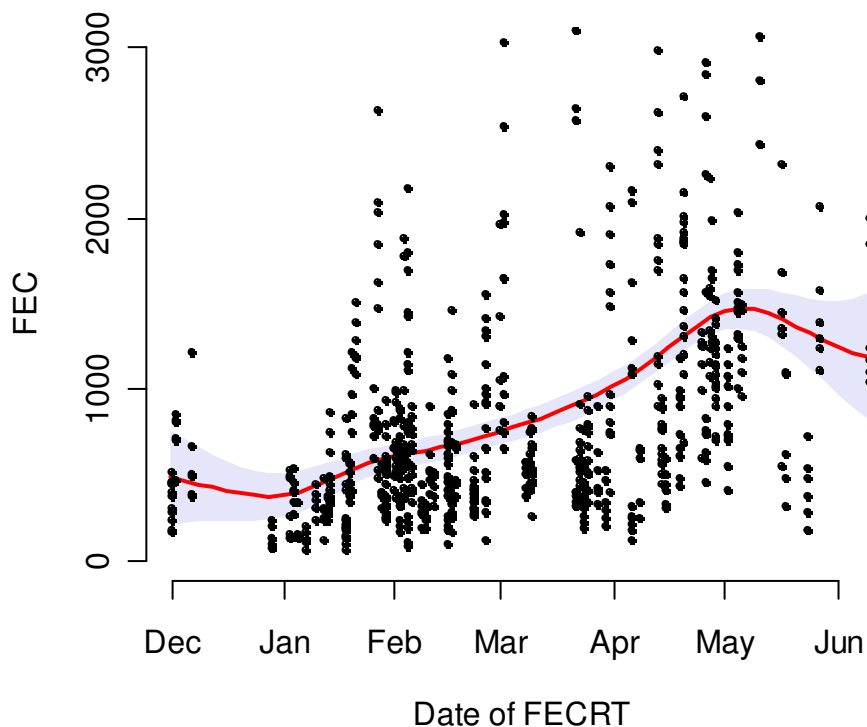
**Table 6. Relationship between number of farms indicating resistance on purposively selected farms and period of testing**

	Period of testing	
	January to March	April to June
Farms with ivermectin resistance detected	13	5
Farms with ivermectin efficacy >95%	0	14

The changes in mean pre-treatment faecal egg counts with date of the FECRT are illustrated in Figures 13 and 14.



**Figure 13. Box plots showing the change in distribution of the mean pre-treatment faecal egg counts with month of testing; n is the number of treatment groups having faecal egg counts completed each month**



**Figure 14.** Scatter plot of the mean faecal egg counts for all pre-treatment groups versus date of FECRT. The shaded area shows the variability around a kernel-smoothed regression line (red line) fitted to the data using a bandwidth of 18days.

The increase in mean faecal egg counts from January to May appears almost linear although both graphs (Figures 13 and 14) illustrate the considerable variability observed about the median faecal egg counts at any particular date (correlation coefficient, 0.44 (0.38, 0.5)).

### Larval culture

It is difficult to calculate precise prevalences of inefficacy for specific drugs and genera since it is not possible to classify the efficacy levels of the not-assessed results and the exclusion of cultures from treatment groups where the FECRT was >95%. Furthermore, the calculation methods produce estimates with wide confidence intervals. For these reasons, the adjusted prevalences levels for genus and treatments in Table 7 are reported as point estimates with a qualitative scale of severity ranging from very low, low, moderate, high and very high in brackets.

Post-treatment control faeces were cultured for all 80 random selection farms and the larval proportions were assumed to represent the pre-test proportions.

**Summary results from larval culture testing (with the exception of Nematodirus where egg count reduction data were used) among 80 random selection farms, according to drug and larval genus. The table reports the number of farms for which the particular genus was estimated to be present at >50 epg in the pre-treatment samples, the number of farms where efficacy was <95%, and quantitative and qualitative estimates of prevalences of resistance**

Drug	Larva genus	n farms with >50epg	n genera with efficacy <95%	Estimated prevalences of resistance
Full Iv	Cooperia	47	3	6% (low)
Full Iv	Ostertagia	52	14	27% (high)
Full Iv	Trichostrongylus	70	2	3% (low)
Full Iv	Haemonchus	24	0	0% (low)
Full Iv	Nematodirus*	27	2	7% (low)
Half Iv	Cooperia	47	11	23% (high)
Half Iv	Ostertagia	52	25	48% (very high)
Half Iv	Trichostrongylus	70	4	6% (low)
Half Iv	Haemonchus	24	0	0% (low)
Half Iv	Nematodirus*	27	13	48% (very high)
Lev	Cooperia	47	0	0% (low)
Lev	Ostertagia	52	11	21% (high)
Lev	Trichostrongylus	70	10	14% (moderate)
Lev	Haemonchus	24	0	0% (low)
Lev	Nematodirus*	27	3	11% (moderate)
Alb	Cooperia	47	10	21% (high)
Alb	Ostertagia	52	21	40% (very high)
Alb	Trichostrongylus	70	15	21% (high)
Alb	Haemonchus	24	2	8% (low)
Alb	Nematodirus*	27	24	89% (very high)
Comb	Cooperia	47	0	0% (low)
Comb	Ostertagia	52	2	4% (low)
Comb	Trichostrongylus	70	4	6% (low)
Comb	Haemonchus	24	0	0% (none)
Comb	Nematodirus*	27	2	7% (low)

Full Iv, full dose ivermectin; Half Iv, half dose ivermectin; Lev, levamisole; Alb, albendazole; Comb, combination

### Table explanation

***n farms with >50 epg*** reports the number of farms where a particular genus was assessed as being present at >50epg in the pre-treatment samples.

***n genera with efficacy <95%*** reports the number of farms for which the genera that were assessed had <95% efficacy on larval culture for a particular anthelmintic treatment.

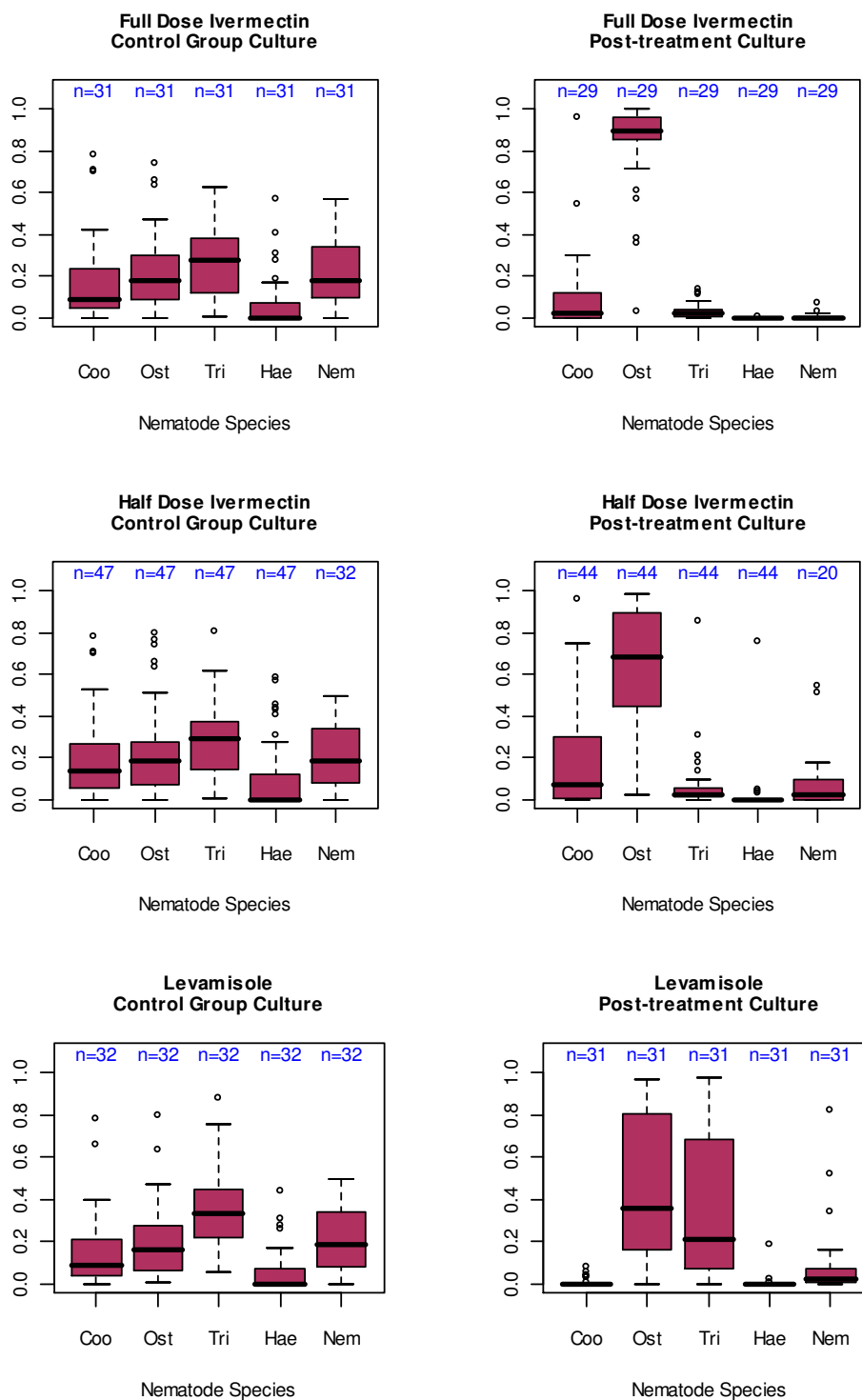
***Estimated prevalences of resistance*** are farm level quantitative and qualitative estimates of the prevalences of resistance for combinations of genus and treatment. The point estimates, shown as percentages, were calculated by dividing the number of farms with efficacy <95% by the number of farms where the genus was assessed to be present at >50 epg in the pre-treatment samples. It underestimates the true level of resistance by an uncertain amount because it ignores farms for which cultures were not done when FECRT efficacy was >95%. Resistance for some genera may have been detected on some of these farms if cultures had been performed.

The data indicate significant problems with *Ostertagia* resistance to all action families, with *Cooperia* resistance to ivermectin, with *Trichostrongylus* resistance to levamisole and resistance among all genera to albendazole. A qualitative assessment of efficacy of the combination treatment is particularly difficult because of the very few larval cultures performed for that treatment.

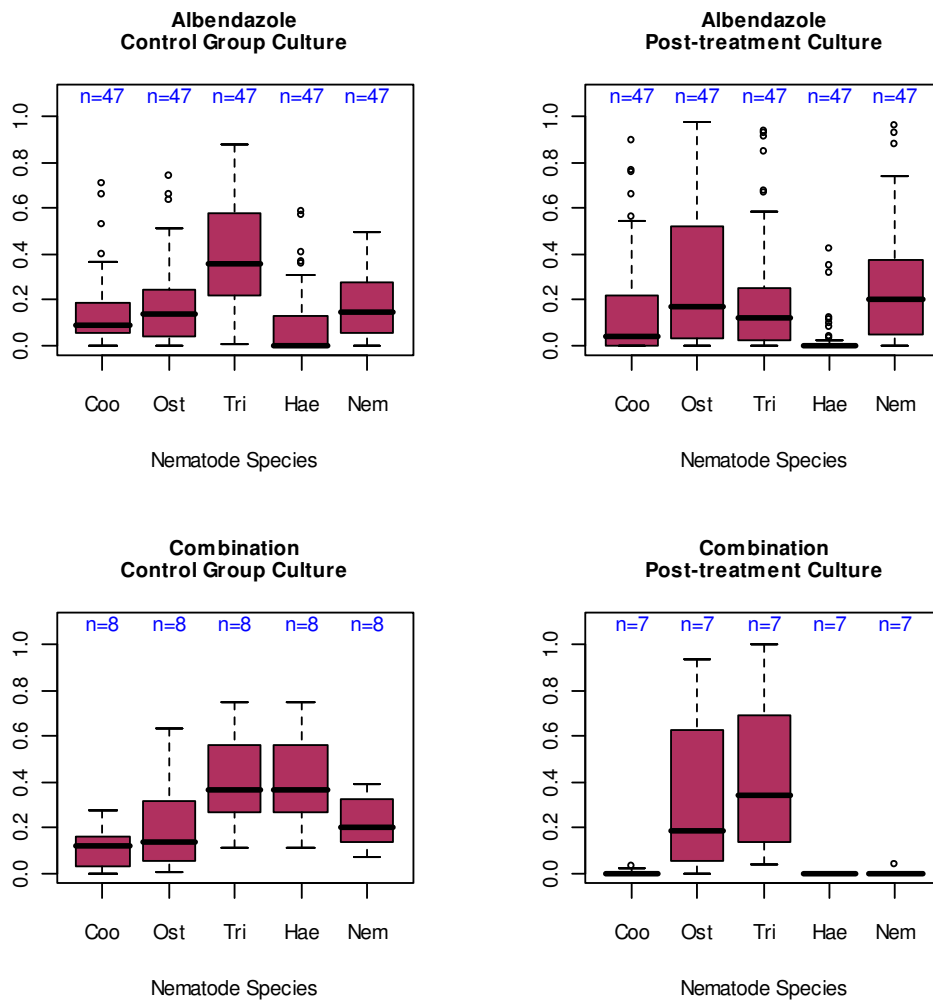
Figures 15 and 16 compare nematode distributions from the control samples from all 112 farms with those for the treatment samples, whenever the anthelmintic treatment achieved efficacy of less than 95%. This provides compelling evidence about which nematode genera are expressing resistance to particular anthelmintic treatment groups.

The distributions of anthelmintic efficacy levels for *Cooperia*, *Ostertagia*, *Trichostrongylus* and *Haemonchus* species for treatment groups where efficacy was <95% and the sample was processed are shown in Figure 17.

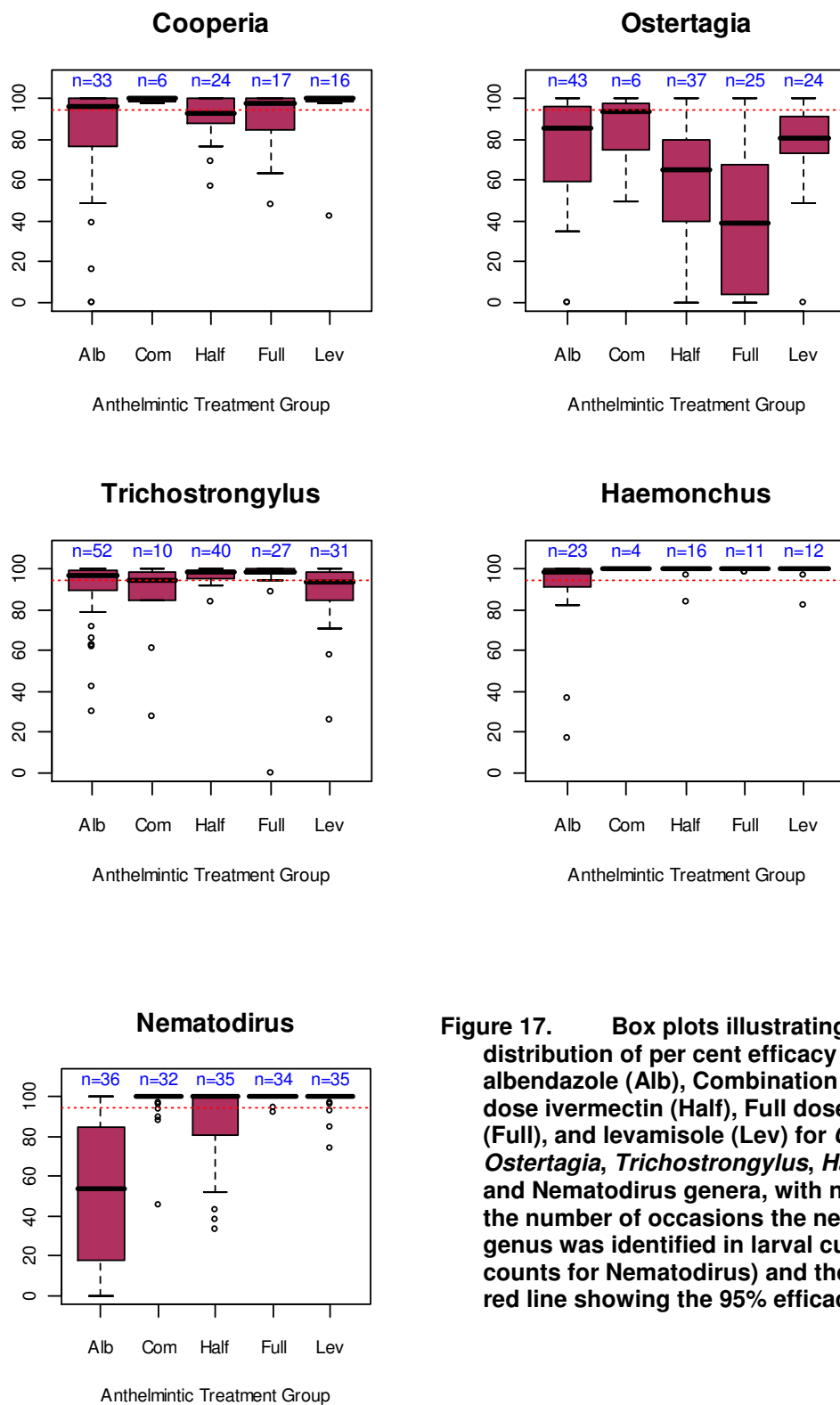




**Figure 15.** Box plots showing the changes in pre and post-treatment distributions of nematode genera on random and purposive selection farms for full dose ivermectin, half dose ivermectin and levamisole treatment groups where efficacy was <95%, and with n indicating the number of larval cultures performed.



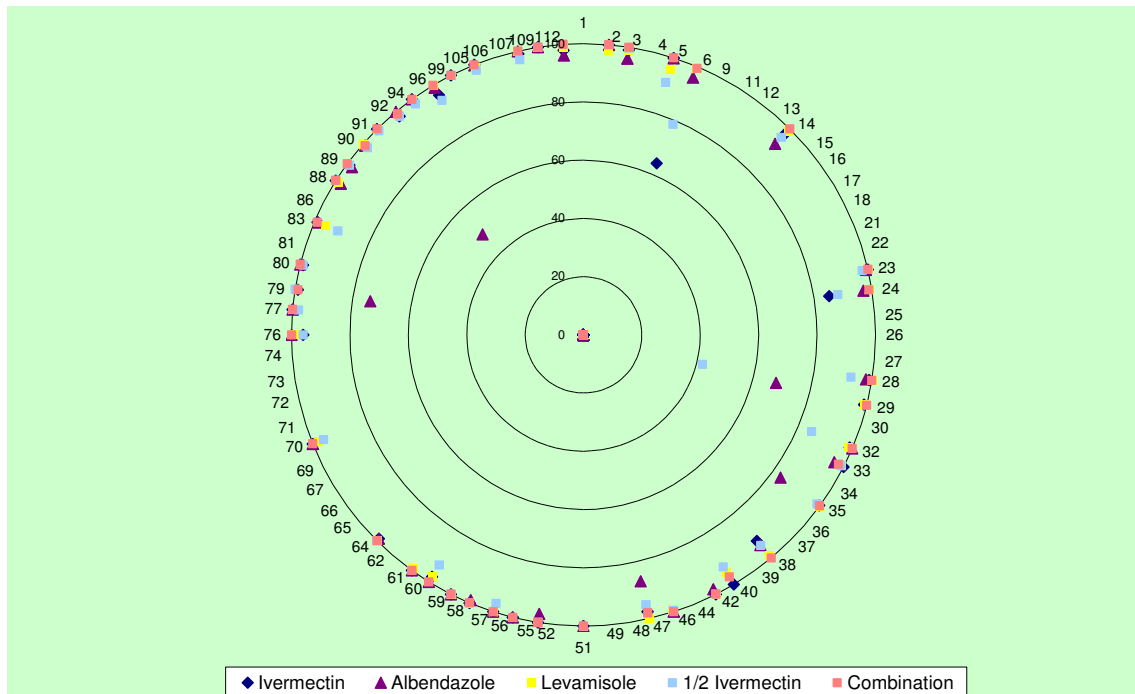
**Figure 16.** Box plots showing pre and post treatment distributions of nematode genera for albendazole and combination treatment groups with less than 95% anthelmintic efficacy, and with n indicating the number of larval cultures performed



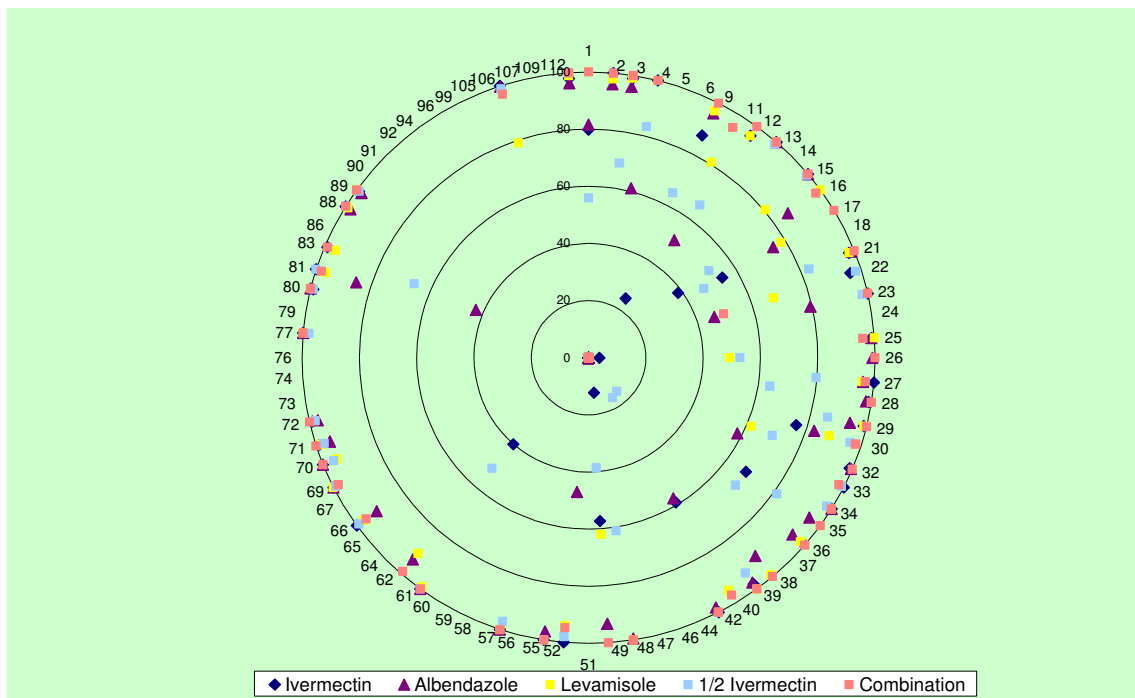
**Figure 17.** Box plots illustrating the distribution of per cent efficacy of albendazole (Alb), Combination (Com), Half dose ivermectin (Half), Full dose ivermectin (Full), and levamisole (Lev) for *Cooperia*, *Ostertagia*, *Trichostrongylus*, *Haemonchus* and *Nematodirus* genera, with n indicating the number of occasions the nematode genus was identified in larval cultures (egg counts for *Nematodirus*) and the dashed red line showing the 95% efficacy cut point.

Point estimates of efficacies for individual farms for full and half dose ivermectin, albendazole, levamisole and combination treatments against *Cooperia*, *Ostertagia*, *Trichostrongylus*, *Haemonchus* and *Nematodirus* genera are shown in Figures 19 to 23.

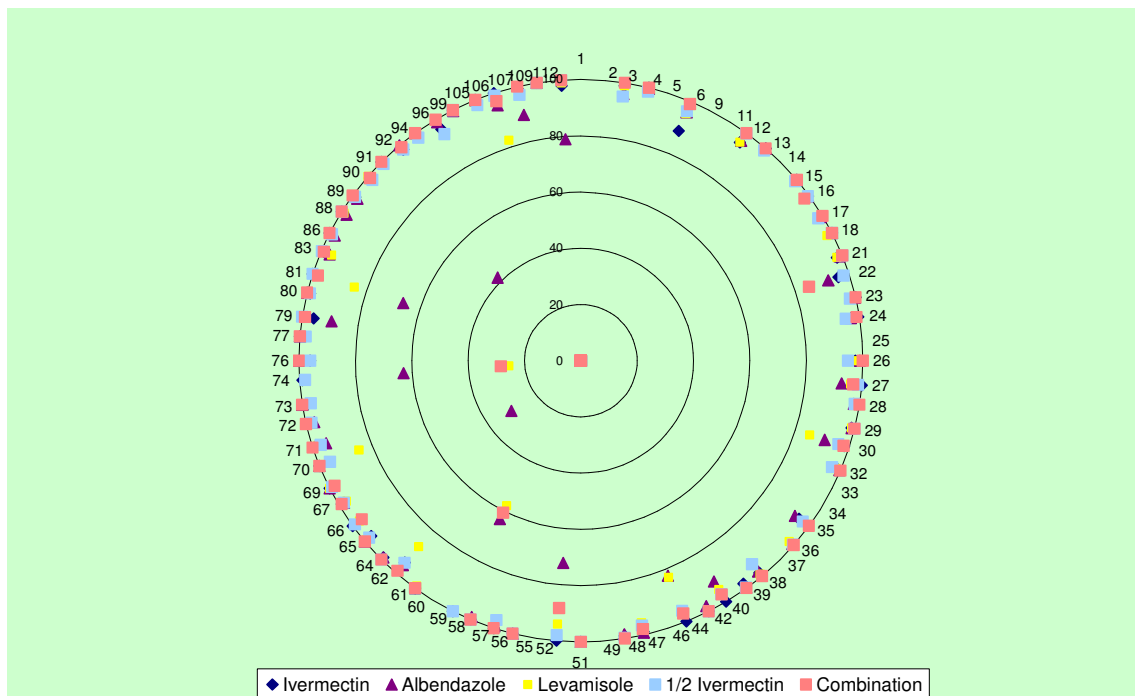
**Figure 18. Individual farm efficacy for full and half dose ivermectin, albendazole, levamisole and combination treatments against *Cooperia* spp.**



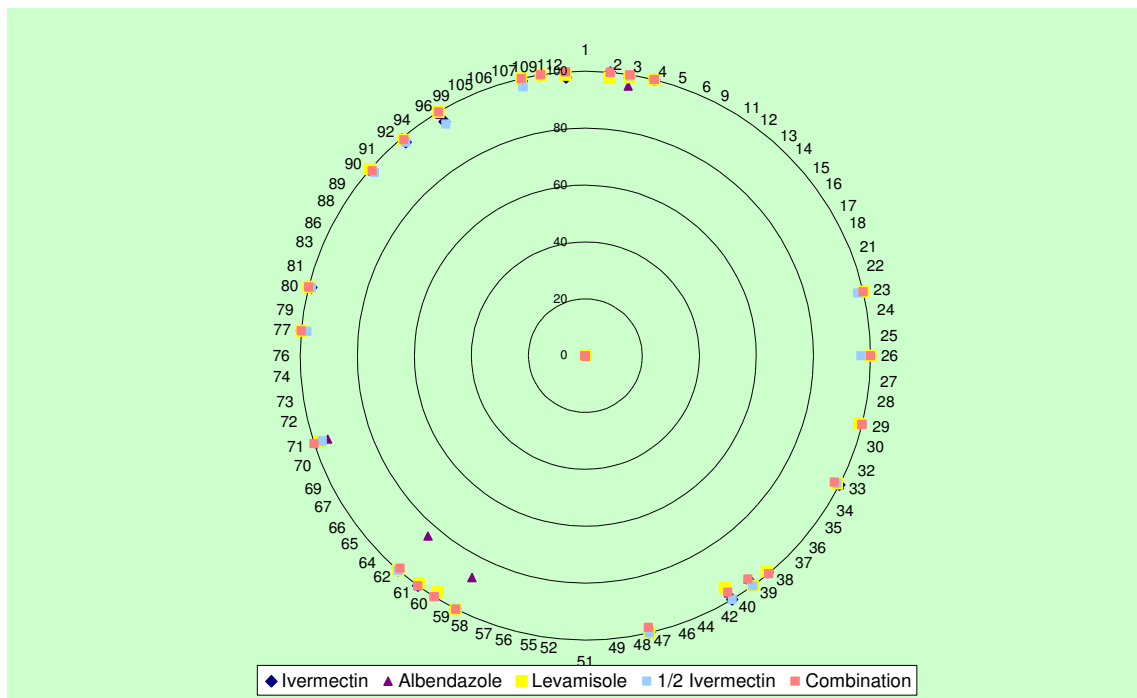
**Figure 19. Individual farm efficacy for full and half dose ivermectin, albendazole, levamisole and combination treatments against *Ostertagia* spp.**



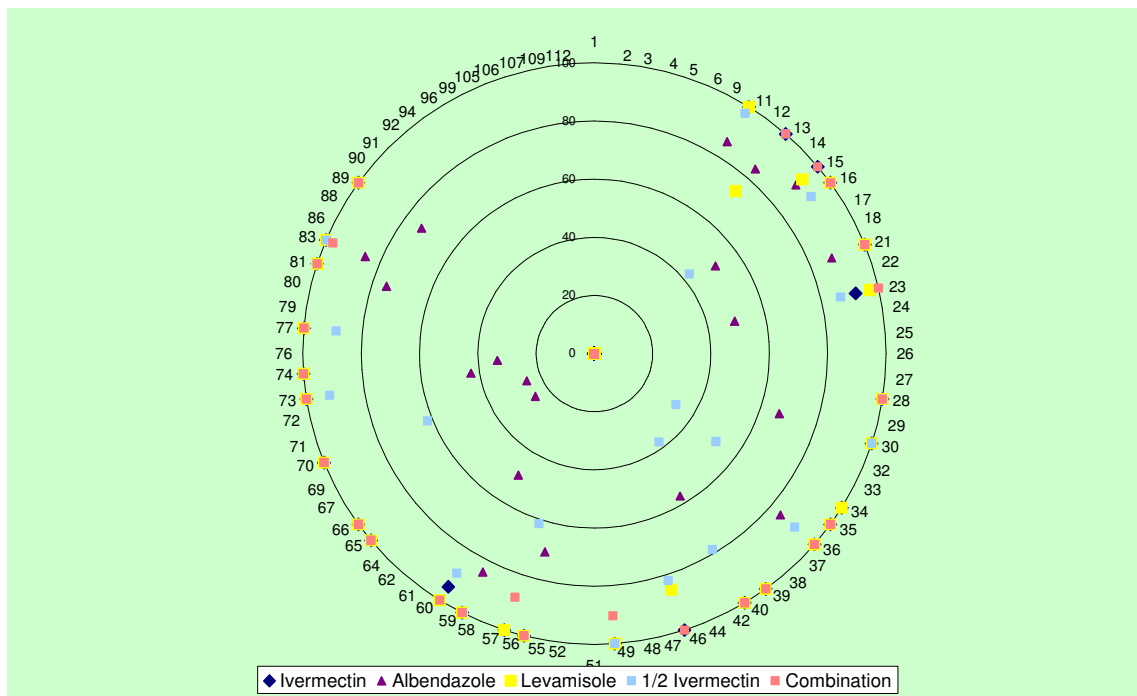
**Figure 20. Individual farm efficacy for full and half dose ivermectin, albendazole, levamisole and combination treatments against *Trichostrongylus* spp.**



**Figure 21. Individual farm efficacy for full and half dose ivermectin, albendazole, levamisole and combination treatments against *Haemonchus* spp.**



**Figure 22. Individual farm efficacy for full and half dose ivermectin, albendazole, levamisole and combination treatments against *Nematodirus* spp.**



## Temporal nature of resistance to ivermectin

The data in Table 8 shows a trend for an increasing percentage of drench failures with increasing proportions of *Ostertagia* in control samples.

**Table 7. Showing the change in proportion of drench treatments with <95% efficacy as the prevalence of *Ostertagia* in the pre-treatment control sample changes**

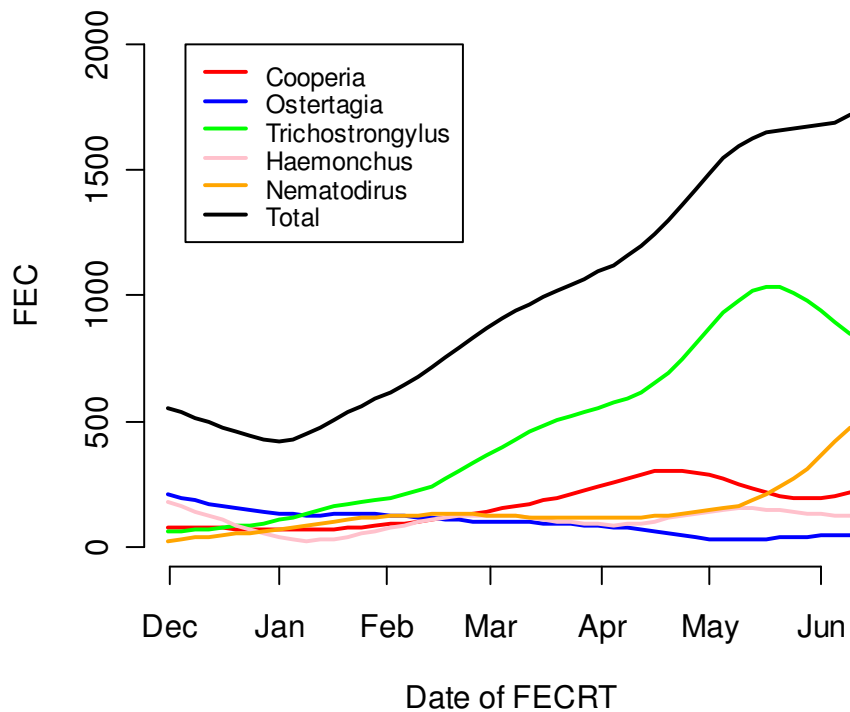
Treatment group	Efficacy	<i>Ostertagia</i> prevalence (number of samples)			
		0—5%	5—10%	10—20%	>20%
Full dose ivermectin	<95%	14 (6, 29)	22 (9, 45)	36 (21, 54)	40 (25, 58)
Half dose ivermectin	<95%	28 (16, 44)	33 (16, 56)	43 (27, 61)	63 (46, 78)
Levamisole	<95%	19 (10, 35)	28 (12, 51)	25 (13, 43)	43 (27, 61)
Albendazole	<95%	39 (25, 55)	22 (9, 45)	43 (27, 61)	57 (39, 73)
Combination	<95%	6 (2, 18)	11 (3, 33)	4 (1, 18)	10 (3, 26)
Number of samples		36	18	28	30

Table 9 shows that as the pre-treatment FEC increases the percentage of drench failures decreases for most drenches.

**Table 8. Showing the change in proportion of drench treatments with <95% efficacy as the mean pre-treatment faecal egg count changes**

Treatment group	Efficacy	Mean pre-treatment faecal egg count			
		0—300	300—600	600—1000	>1000
Full dose ivermectin	<95%	42%	32%	25%	17%
Half dose ivermectin	<95%	49%	45%	25%	33%
Levamisole	<95%	50%	30%	29%	16%
Albendazole	<95%	40%	39%	42%	48%
Combination	<95%	11%	5%	9%	7%

Figure 18 shows that the count of *Ostertagia* eggs in the faecal samples fell relatively slowly over time whereas the count of *Trichostrongylus* climbed dramatically. It is hypothesised that although *Ostertagia* are nearly always present in faecal samples, their influence on the FECRT is largely lost unless testing is completed before mid-March. A potential property of the Presidente formula is the return of favourable results for FECRTs when the pre-treatment FEC is high and the predominant nematode, *viz* *Trichostrongylus*, is 100% sensitive to the test anthelmintic. Put simply, in order to hear the *Ostertagia* signal, one needs to “tune-in” before mid-March.



**Figure 23.** Kernel smoothed regression lines showing the mean count of each nematode genus in the control group samples, the bandwidth used is 18 days.



## Discussion

Anthelmintic resistance in sheep involving albendazole and *Haemonchus* in New Zealand was first recorded in 1979 (Vlassoff and Kettle 1980). Since then it has been confirmed many times in case reports from practices and diagnostic laboratories (Middelberg and McKenna 1983; McKenna and Seifert 1985; Pomroy, Charleston et al. 1985; West, Pomroy et al. 1989; West and Probert 1989; McKenna 1994; McKenna, Allan et al. 1995; Leathwick, Moen et al. 2000; Hughes, McKenna et al. 2004; Hughes and McKenna 2005), from a practice based survey (Hughes, McKenna et al. 2005), and in prevalence studies (Kettle, Vlassoff et al. 1981; Kemp and Smith 1982; Kettle, Vlassoff et al. 1982). Leathwick *et al* (Leathwick, Pomroy et al. 2001) commented in a review of anthelmintic resistance that despite no formal surveys having been conducted for 20 years, there was little doubt that resistance is now common in sheep in New Zealand. The objective of this study was to provide updated estimates of prevalences of inefficacy to macrocyclic-lactone, albendazole and levamisole in sheep farms in New Zealand using faecal egg count reduction tests and larval cultures.

The target numbers for the study of 100 random selection and 40 purposive selection farms nominated by veterinarians on the basis of a past diagnosis of resistance was not achieved for a variety of reasons which included failure to meet threshold faecal egg count levels for the random selection farms and insufficient recent or current case farms reported. The 80 random selection study farms were randomly selected from throughout the country, and apart from the exclusion of fine wool breeds, are considered to be reasonably representative of the national population of sheep breeding farms, despite an unknown degree of bias from exclusion due to failure to meet entry criteria or threshold FEC's. Larval cultures were only undertaken when the FECRT was less than 95%. These biases are likely to make the prevalences of resistance reported here conservative estimates.

The FECRT identified high levels of inefficacy in random selection farms to all drug families with 25% (17, 35) of farms showing <95% efficacy for full dose ivermectin, 36% (27, 47) for half dose ivermectin, 24% (16, 34) for levamisole and 41% (31, 52) for albendazole. The combination drench containing albendazole and levamisole performed reasonably well with only 8% (3, 15) of farms showing < 95% efficacy. Levels of inefficacy in the purposive group tended to be higher although the confidence intervals around the point estimates for both groups of farms show lack of statistical significance for that issue at the 95% level.

These results contrast with those of previous prevalence studies conducted in the early 1980's. Resistance as measured by an *in vitro* egg-hatch technique found evidence of thiabendazole resistance in *Haemonchus contortus* and *Trichostrongylus* spp. on 11 of 50 randomly selected North Island properties (Kemp and Smith 1982) equating to a prevalence of 21.2% (12, 34). Because a different method for assessing resistance was used their results are not directly comparable to those reported here. However, the *in vitro* technique is generally considered to be useful for early detection of resistance (Taylor, Hunt et al. 2002) and the Kemp and Smith study provided that warning.

The combined results for the early North and South Island studies (Kettle, Vlassoff et al. 1981; Kettle, Vlassoff et al. 1982) showed less than 90% efficacy to thiabendazole on 6 (7% [3, 14]) farms and less than 90% efficacy to levamisole on 6 farms from the same

study. Thiabendazole was first used in New Zealand about 1962, levamisole about 1970 and ivermectin around 1980. Other features of note in the early studies were the relatively narrow range of the mean faecal egg count reduction for thiabendazole (lowest 87%) and for levamisole (72%), the high proportion of occasions where efficacy was 100%, and the presence of dual resistance to thiabendazole and levamisole on only 2 farms. The results from the 1980 studies and the present one clearly demonstrate a significant increase in the prevalence of resistance over time. The differences may have been influenced to some degree by the timing of the early studies which were later for the North Island and Nelson region study (April to mid-June) (Kettle, Vlassoff et al. 1981) than for the South Island study (beginning of March to end of first week in June, 1981) (Kettle, Vlassoff et al. 1982).

The results from this study are disturbing and indicate the extent of anthelmintic resistance on sheep farms. While 29 of 80 (36% 27, 47) randomly selected farms and 8 of 32 (25% 13, 42) purposively selected farms had efficacy levels >95% for all anthelmintic treatments tested, it should be kept in mind that FECRT results of greater than 95% efficacy give no cause for complacency on the farms where they occur, as the FECRT does not give a direct measure of the prevalence of resistant alleles. It is generally considered that the prevalence of resistant alleles will be high when the FECRT is less than 95%. On the other hand, the result for 29 of the random selection farms having efficacy levels greater than 95% is encouraging. The relatively higher efficacy of combination drenches probably reflects the distribution of resistance to a particular anthelmintic amongst the population and the chance that an individual worm will be resistant to two anthelmintic action groups.

There is a perception among some veterinarians that resistance is less common in the South Island than in the North Island. This study suggests some difference although the validity of that finding has to be considered in relation to the relatively small sample sizes for each Island. The perception may have come from the early 1980's prevalence studies where fewer South island farms were affected although the prevalences recorded then were not significantly different. It is difficult to advance any plausible hypothesis for differences based on geographical location unless there were marked differences in agro-pastoral zones such as would occur between arid and high rainfall zones.

This study supports general experience that *Haemonchus* is predominantly a North Island problem. There was a marked difference in the proportions of *Haemonchus* larvae cultured from control samples between the two Islands and it was significant that the only outlier in the South Island data was from a farm in the Nelson region in the northern part of the South Island.

Not all purposive selection farms showed evidence of resistance as measured by less than 95% efficacy in the FECRT and it may be that as yet unidentified factors may influence the persistence of resistance at farm level from year to year. On the other hand, given that the original diagnosis was correct, any apparent changes in resistance status could be due to effects of changing makeup of worm burden genera, and faecal egg counts over time as was demonstrated in this study.

Farms with less than 95% efficacy to half and full dose ivermectin apparently had greater proportions of *Ostertagia* spp. and lesser proportions of *Trichostrongylus* spp. in the control larval cultures. Furthermore, purposive selected farms were about four times

more likely (Relative Risk 3.8 [1.79, 8.06]) to test positive between January and March than farms tested later in the year between April and June. Despite considerable variability around median egg counts, faecal egg counts rose almost linearly from December to June. A model of efficacy to half dose ivermectin (less than 95% efficacy) indicated that the probability of inefficacy decreased over time (December to June) and as the proportion of *Trichostrongylus* larvae in control group faecal samples increased.

Despite the uncertainties in the precision of FECRT's, the study points to significant problems with *Ostertagia* resistance to all action families, with *Cooperia* resistance to ivomec, with *Trichostrongylus* resistance to levamisole and resistance among all genera to albendazole.

Decision making about which course of action to follow when faced with a case of drench resistance is not simple. The FECRT and larval cultures are far from perfect tests and it is strongly recommended that the raw data always be examined along with summary estimates of efficacy. Faecal egg count reduction tests and larval cultures are now routine tests for sheep farms and decision making should be based on as much evidence as is possible. It should be remembered that a test is only valid for the genus of nematode that is present at the time of the test. In this study, the prevalence of drench failures to full dose ivermectin dropped from 46% prior to mid-March to 6% post mid-March. If the genus of interest is not present then a retest should be done at a time when it is likely to be present.

## Acknowledgements

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

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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, Kevin Lawrence and John Moffat who have nurtured and developed this project to completion. In particular, acknowledgement must be made of Ron Jackson and Kevin Lawrence for their dedication in both data analysis and report writing.

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## Appendix 1 Protocol for lamb 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 lamb is an animal born since 1 July 2004.

### 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 70-80 well grown lambs of even body weight that have not been treated with a long-acting drench and have not been drenched for at least 28, but preferably 35 days.
- Run as one mob close to the yards for easy availability until all samples have been collected.
- 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. To reduce the cost of this screening, it would be appropriate to make a composite sample and determine the mean count. When the mean is reached, a check should be undertaken with 10 samples to ensure all have eggs present.**
- When the average egg count (FEC) reaches at least 700 **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.

### 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 should suffice as a check weight.

- Bring lambs 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 lambs need to be individually identified, and a record kept of the tag, live weight, treatment and dose volume for each lamb. A set of six different coloured tags is provided in the kit, together with applicator pliers which need to be returned with samples. A form is supplied for this data. Please double check this data as you proceed – it is easy to transpose numbers. Treatments have been allocated colours to facilitate ease of dosing, animal and sample identification.
 

1.	Ivomec full dose	– Pink
2.	Nilverm	– Yellow
3.	Valbazen	– Blue
4.	½ dose Ivomec	– Green
5.	Arrest	– Orange
6.	control	– Red
- Work on one group at a time.
  - a rectal faecal sample first and if a sample is obtained, tag lambs (or record existing numbers ensuring no duplicates)
  - b you may choose to mark the lambs according to the treatment group to make drafting for re-sampling easier
  - c weigh and record the weight and tag number of each lamb
  - d check chart for the correct dose volume and record this for each lamb – a look-up chart will be supplied with drench volumes required for each liveweight.
  - e **all treatments are to be provided orally** - administer the correct dose volume for each lamb carefully
- Rectal faecal samples need to be taken from each lamb. 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 lambs. **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 5 grams for pre-samples and a ½ pottle, or more if possible, 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 lamb **orally** at the dose rate recommended for its individual liveweight from the dose rate chart included. Use the syringes provided and a clean syringe for each drench type.

- Treatment groups

Group / Active	COLOUR	TREATMENT	No OF LAMBS
1 ivermectin	Pink	Ivomec	10
2 levamisole	Yellow	Nilverm	10
3 albendazole	Blue	Valbazen	10
4 ½ dose ivermectin	Green	Ivomec	10
5 levamisole + albendazole combination	Orange	Arrest	10
6 nil	Red	Control	10

- All the lambs in the test can be run as one mob 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.**
- **For post-drench sampling, draft lambs into the treatment groups. This enables collecting samples from only one group at a time and minimises the risk of cross-contaminating faecal material.**
- After post-drench sampling, drench all lambs with the product currently being used by the farmer and return them to the mob.
- 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 Sheep Farm Questionnaire

### SHEEP ANTHELMINTIC RESISTANCE STUDY

Thank you for agreeing to participate in this study of anthelmintic resistance in sheep. This study comprises the sheep 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 sheep 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 100 randomly selected sheep systems throughout New Zealand.
- To ascertain farmers' parasite and livestock management practices and identify factors that may be associated with anthelmintic resistance, and report findings by September 2005.
- 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 genus 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, Dannevirke.  
Phone: 06 374 4046; Fax: 06 374 4045

E-mail: [tonyrhodes@clear.net.nz](mailto:tonyrhodes@clear.net.nz)



## 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	

Please note that the generic term 'drench' used in this survey includes controlled release capsules, pour-ons and injections as well as liquid by mouth.

### 1. FARM DETAILS

1.1. What is your main property's average annual rainfall?	mm or	inches
--	-------	--------

1.2. For how long have you farmed this property?	years
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	<b>Hectares</b> (1 hectare = 2.5 acres)
1.3. What is the total size of your farming operation?	
1.4. What is the effective area of your farming operation (i.e. land available for cropping or grazing)?	
1.5. Approximately what area of your pasture is renewed each year?	

1.6. How would you best describe the breed make-up of the ewe flock you farm?	
1.7. What is the average micron of the main adult flock?	micron

<b>1.8. What are your farm's 4 main sources of income? (e.g. wool, prime lambs, beef, dairy, forestry, trading, deer)</b>		
<b>i</b>		
<b>ii</b>		<b>As estimated from percentage of gross farm income</b>
<b>iii</b>		
<b>iv</b>		

<b>What are the approximate areas of the farm devoted to:</b>	<b>Hectares</b>			
<b>1.9. Sheep farming?</b>				
<b>1.10. Beef farming?</b>				
<b>1.18. Is irrigation used on your farm?</b>	<b>Yes</b>		<b>No</b>	
<b>1.19. If yes what area of the farm is irrigated?</b>	<b>Ha</b>			
<b>1.20. Were lambs grazed on the irrigated land?</b>	<b>Yes</b>		<b>No</b>	
<b>1.21. What is the main farming activity on the irrigated land?</b>				
<b>1.14. Arable cropping?</b>				
<b>1.15. Horticulture?</b>				
<b>1.16. Forestry?</b>				
<b>1.17. Conservation?</b>				

### Farm terrain

<b>2.1. What is the dominant terrain in the parts of the farm where the sheep are grazed?</b>		
<b>Mainly flat to rolling downlands</b>		<b>Please tick ✓ only one box</b>
<b>Mainly moderate to steep hill country</b>		
<b>More a mixture of both flat and hill country</b>		

### 3. Pasture recording and feed budgeting

<b>3.1. Do you use a formal feed budgeting or pasture recording system?</b>	<b>Yes</b>		<b>No</b>	
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3.2. If yes, please give the name or type of system you use.

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#### 4. LIVESTOCK ON THE FARM AT OR ABOUT 30 JUNE 2004

On 30 June 2004, how many of each type of sheep were on your farm?	Number
4.1. Two-tooth and Mixed Age ewes put to the Ram (Dec2003-May 2004)	
4.2. Ewe Hoggets put to the ram (Dec2003-May 2004)	
4.3. Ewe Hoggets NOT put to the ram	
4.4. Ram and wether hoggets	
4.5. Rams (2 tooth and over)	
4.6. Wethers (2 tooth and over)	
4.7. Total sheep	

On 30 June 2004, how many of each type of beef cattle were on your farm?	Number
4.8. Beef cows & heifers (breeding) 2yrs & over	
4.9. Beef cows & heifers (breeding) 1-2yrs old	
4.10. Beef cows & heifers (not for breeding) 2yrs & over	
4.11. Beef cows & heifers (not for breeding) 1-2yrs old	
4.12. Beef heifers (rising 1 year old) and calves	
4.13. Steers 2 yrs old and over	
4.14. Steers 1-2 yrs old	
4.15. Steers (under 1 year)	
4.16. Beef non-breeding bulls 2yrs & over (R3)	
4.17. Beef non-breeding bulls 1-2yrs old (R2)	
4.18. Beef non-breeding bulls (under 1 year) (R1)	
4.19. Beef breeding bulls (all ages)	

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

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

4.30. If there are no farmed goats on the farm now, have you ever in your farm tenure farmed goats on this property?	Yes		No	
4.31. If yes, when was the last year goat were farmed?				

## 5. Sheep Trading

5.1. Do you graze any sheep away from your main farm?	Yes		No	
---	-----	--	----	--

5.2. How many sheep moved OFF your farm between 1 Jan 2004 and 31 Dec 2004?		
Stock class	Sold	Grazed away
Cull ewes		
Cull wethers		
Cull rams		
Prime lambs		
Store lambs		
Hoggets		
Total sheep sold/grazed off		

5.3. Did you sell more or fewer sheep between 1 Jan 2004 and 31 Dec 2004 than you usually do? Answer the same if it was within 10% of your usual sales policy.		
More	The same	Fewer

5.4. If you answered yes to question 5.1. Do you quarantine drench your own sheep when they return from grazing away to your main farm?			
Never	Sometimes	Often	Always

5.1. Do you use graze sheep from another farmer on your main farm?	Yes		No	
--	-----	--	----	--

5.5. How many sheep were moved ONTO your property between 1 Jan 2004 and 31 Dec 2004?		
Stock class	Purchased	Grazed onto your farm
Cast for age ewes (one year ewes)		
Replacement ewe lambs		
Replacement ewe hoggets		
Replacement two-tooths		
Store lambs		
Others (please specify)		
Total sheep purchased/grazed on		

5.6. Did you purchase more or fewer sheep between 1 Jan 2004 and 31 Dec 2004 than you usually do? Answer the same if it was within 10% of your usual purchase policy.		
More	The same	Fewer

5.7. Do you use High Country Summer Pasture?		Yes	No
5.8. If yes what class of stock grazes the High Country?			

## 6. Management of Lambs

6.1. What were the scanning and weaning results for the 2004 mating season?			
Stock class	Empty%	Scanning%	Weaning%
Hoggets mated			
Two-tooths			
MA ewes			
Total flock			
If separate results are not available please use brackets to group classes together			

6.2. Do you use split mating?		Yes	No

6.4. How many lambs were docked on your farm this season?			
6.3. When did tupping commence this season?			
Mob ID	Tupping date	Ewe breed	Ram breed

6.5. Do you wean lambs onto the same paddocks each year?			
Never	Sometimes	Often	Always

6.6. What system of grazing management do you mostly use for your lambs in the FIRST TWO MONTHS after weaning? Please tick ✓ one box	Daily shifts	
	Shifts every 2—10 days	
	Shifts at intervals of longer than 10 days	
	Set stocking	

6.7. What proportion of this season's lambs (BORN 2004) did you wean onto paddocks not grazed by lambing ewes since 1 <sup>st</sup> June 2004?			
None	Less than half	More than half	All

6.7. Unless you ticked none, how long (on average) after weaning did it take before the lambs were put on a pasture previously grazed by ewes and lambs? Please tick ✓ one box	Between 0—1 month	
	About 1—2 months	
	About 2—3 months	
	More than 3 months or does not apply	

6.8. Do you use mixed grazing on your farm?			
Never	Sometimes	Often	Always

6.9. Do you graze ewes on pastures between periods of lamb grazing?			
Never	Sometimes	Often	Always

6.10. Do you graze cattle/deer on pastures between periods of lamb grazing?			
Never	Sometimes	Often	Always

6.11. For last season's lambs (BORN 2003) did you make hay, baylage, silage or another crop on land subsequently grazed by lambs?	Yes		No	
---	-----	--	----	--

6.12. If yes what size of area?	Hectares
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6.13. What proportion of your farm was or will be grazed by lambs between 1 July 2004 and 30 June 2005?			
Less than $\frac{1}{4}$	Between $\frac{1}{4}$ & $\frac{1}{2}$	Between $\frac{1}{2}$ & $\frac{3}{4}$	Greater than $\frac{3}{4}$

6.14. When did you sell last season's lambs? Include both farm born and bought in lambs.		
Full date or just month	No of lambs sold	Ave. dead weight
/ /		
/ /		
/ /		
/ /		
/ /		
/ /		
/ /		
/ /		

## 7. Drenching policies and procedures

If you never purchase in sheep, other than replacement rams, please tick box and go to question 7.8.

7.1. Do you drench newly purchased or introduced sheep soon after arrival on your farm i.e. give a quarantine drench?			
Never	Sometimes	Often	Always

If answer "Never" go to question 7.4.

e.g. Albendazole® Oxfen® Rycoben® Valbazen V	e.g. Levicare® Nilvax® Nilverm®	e.g. Ivomec® Cydectin® Eweguard® Genesis® Vetdectin®	e.g. Arrest® Leviben® Scanda® Valbazen combo	e.g. Triton®
--	--	---	--	-----------------

7.3. If you ticked more than one drench family how often do you give these products together
--



as quarantine drench?			
Never	Sometimes	Often	Always

7.4. If you use one or more ML products as part (or all) of a quarantine drench which do you use? You may circle more than one product.			
Cydectin ®	Eweguard ®	Genesis ®	Ivomec ®
Paramectin ®	Vetdectin ®	Rycomectin ®	Bomectin ®
Noromectin ®	Other (please specify)		

7.5. How long have you been using quarantine drenches? Please tick box.			
1 to 3 years	4 to 6 years	7 to 9 years	10 years and over

7.6. Did you use ML products as part of (or all) of your quarantine drenching in this period?			
Never	Sometimes	Often	Always

If answer "Never" go to question 7.8.

7.7. Which ML product did you use then? You may circle more than one product if required.			
Cydectin ®	Eweguard ®	Genesis ®	Ivomec ®
Paramectin ®	Vetdectin ®	Rycomectin ®	Bomectin ®
Noromectin ®	Other (please specify)		

7.8. If you changed drench families between last season (2003-2004) to this season (2004-2005), please give the reason(s): (you may tick more than one box)	
The previous drench did not appear to work	
A vet recommended that you change to a different drench	
A person other than a vet recommended that you change	
It was part of a planned drench family rotation	
The new drench saved money	
The new drench had an attractive promotion	
Other	Specify

7.9. Do you intend to use the same drench family next season?		
Yes	No	Don't know

7.10. Given a choice do you usually buy drench with added minerals?			
Never	Sometimes	Often	Always

## LAMBS

7.11. How do you assess the level of parasitism in your lambs/hoggets? (You may tick more than one box)			
FEC	Condition score	Growth rate	Dags
Scouring	Other (please specify)		

7.12. Do you use pre-weaning drenches in your lambs? Please tick one box.			
Never	Sometimes	Often	Always

7.13. On how many occasions, between 1 July 2003 and 30 June 2004, were last season's lambs/hoggets (born in 2003) drenched?	
--	--

7.14. Please specify the commercial names of the drenches you used on your lambs/hoggets?			
July to Sept 2003	Oct to Dec 2003	Jan to March 2004	April to June 2004

7.15. When do you drench your lambs/hoggets? (You may tick more than one box)	
You follow a 5-6 drench programme, drenching every 3 to 4 weeks from weaning regardless of the weather or other factors	
You monitor with FEC and drench when counts are high	
You drench the lambs when they show signs of scouring or illthrift	
You drench the lambs regularly (~ monthly) throughout their first year	
You drench the lambs regularly during the period of greatest risk *	
Other *	

<b>If you ticked options with * please could you briefly explain your decision making process.</b>

<b>7.16. After drenching do you return the lambs back to the same paddock they came from? Tick only one box please</b>			
<b>Never</b>	<b>Sometimes</b>	<b>Often</b>	<b>Always</b>

<b>7.17. Of the lambs that do not return to the same paddock where do they go? Please tick an entry for each row.</b>				
<b>Pasture re-growth from an earlier grazing with lambs</b>	<b>Never</b>	<b>Sometimes</b>	<b>Often</b>	<b>Always</b>
<b>Pasture re-growth from an earlier grazing with another class of stock</b>	<b>Never</b>	<b>Sometimes</b>	<b>Often</b>	<b>Always</b>
<b>Specify stock class/es</b>				
<b>New pasture</b>	<b>Never</b>	<b>Sometimes</b>	<b>Often</b>	<b>Always</b>
<b>Crop</b>	<b>Never</b>	<b>Sometimes</b>	<b>Often</b>	<b>Always</b>
<b>Other*</b>	<b>Never</b>	<b>Sometimes</b>	<b>Often</b>	<b>Always</b>
<b>*Please specify</b>				

## TWO-TOOTHES

<b>7.18. How many times (on average) did you drench your two-tooths between 1 year of age and mating in Dec 2003-May 2004? Please tick one box.</b>				
<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>Over 3</b>

<b>7.19. If you did drench your two-tooths between 1 year of age and mating in Dec 2003-May 2004, what was the reason? (You may tick more than one option)</b>	
<b>High FEC</b>	
<b>Dags</b>	
<b>Poor condition</b>	
<b>Following a predetermined drench programme</b>	
<b>Other</b>	<b>Please specify</b>

## EWES

7.19. How many times (on average) did you drench your ewes between 1 July 2003 and 30 June 2004? Please tick only one box.				
0	1	2 to 3	4 to 5	Over 5

7.20. When do you usually drench your ewes? Please tick one box on each row.			
	Always	Sometimes	Never
Before mating			
Before lambing			
At tailing/docking			

7.21. If you use a pre-lambing drench can you record the product(s) used for each of the last five years? (commercial name)	
2004	
2003	
2002	
2001	
2000	

7.22. If you do drench your ewes at other times to those specified in question 7.21., for what reason do you drench them? (You may tick more than one option)	
High FEC	
Dags	
Poor condition	
Following a predetermined drench programme	
Other	Please specify

7.23. Have you ever used controlled release capsules on your farm?			
Yes		No	
If you answered No go to question 7.25			

7.24. If you used controlled release capsules please circle the product(s)		
Product	Stock class given to	Number of years used
Ivomec Maximiser (adult)		
Ivomec Maximiser (lamb)		
Extender/Proftril		

<b>7.25. Do you use FEC to monitor the number of worms present in your sheep?</b>		
<b>Yes</b>	<b>No</b>	<b>If you answered No go to question 7.29.</b>

<b>7.26. In which year did you first start using faecal egg counts?</b>	
<b>7.27. Between 1 July 2003 and 30 June 2004 on how many occasions was FEC carried out on your farm?</b>	

<b>7.28. Who performed the faecal egg count? You may tick more than one box.</b>		
<b>Vet</b>	<b>Yourself</b>	<b>Other Specify</b>

<b>7.29. In the last twelve months have you had a severe parasitic problem in your sheep which resulted in weight loss and deaths?</b>	<b>Yes</b>		<b>No</b>	
--	------------	--	-----------	--

<b>7.30. If you answered 'yes' to question 7.29 please could you give the stock class and month.</b>			
<b>Stock class</b>		<b>Month</b>	

<b>7.31. When drenching your sheep, how often do you check the volume of drench delivered by your gun/applicator? Please tick only one box</b>			
<b>Never, you rely on the gun being accurate</b>			
<b>Sometimes before you start drenching</b>			
<b>Always before you start drenching</b>			
<b>Both before you start and when you finish drenching</b>			
<b>Every</b>		<b>Sheep/lambs drenched (enter number)</b>	

<b>7.32. Do you routinely check the seal integrity of your gun before use? Please tick box</b>	<b>Yes</b>		<b>No</b>	
--	------------	--	-----------	--

<b>7.33. Before drenching a mob of sheep, what weight do you use to calculate the drench dose? Please tick one box.</b>			
<b>The average weight of the heaviest group of animals in the mob</b>			
<b>The average weight of all sheep in the mob</b>			
<b>The heaviest individual in the mob</b>			
<b>Each individual animal's weight</b>			
<b>Other</b>		<b>Please specify</b>	

7.34. Before drenching a mob of sheep how did you estimate their body weight?			
Scales			
By eye appraisal			
By weigh band			
Other		Please specify	

7.35. When drenching a mob of sheep do you drench the whole mob every time?			
Never	Sometimes	Often	Always

7.36. Have you previously ever tested for drench resistance in SHEEP on your farm?		
Yes	No	Don't know

7.37. 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 diagnosed in SHEEP				Drench family (i.e. white, clear, combination, ML)	Parasite species (if known)
	Yes		No		to	
	Yes		No		to	
	Yes		No		to	
	Yes		No		to	

7.33. How was the last test carried out? (Please tick only one box)	
Faecal samples were collected after drenching the sheep (drench check)	
Faecal samples were collected before and after drenching the sheep (drench test)	
Don't know	

7.34. Who performed this test?	
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## 8. Records (for completion by interviewer)

8.1. What type of information records were used/present for the interview? Please specify	
--	--

8.2 For each of the question categories please indicate whether records or an estimate was used to give the answer. Please tick one answer per row.		
Question category	Records	Estimate
Stock numbers on 30 June 2004		
Sheep trading numbers		
Empty, Scanning and Weaning numbers		
Lamb sales		
Current drench usage		
Historical drench usage		
Resistance test results		

## 9. Farmer's Opinions

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

No problem	<input type="checkbox"/>	Please tick one
Low	<input type="checkbox"/>	
Moderate	<input type="checkbox"/>	
High	<input type="checkbox"/>	

9.2. Please list what you consider are the three most important animal health problems on your SHEEP farm. Please rank the order with 1 as the most important.

	Priority ranking
	1
	2
	3

9.3. Do you believe drench resistance is a problem for the sheep industry of New Zealand?  
Please tick only one box.

Yes it is a serious problem today	<input type="checkbox"/>
Yes, it is a problem, but not a serious one	<input type="checkbox"/>
Not yet, but will be in the next 5 years	<input type="checkbox"/>
Not yet, but will be in the next 10 years	<input type="checkbox"/>
No, it is unlikely to ever be a problem	<input type="checkbox"/>

	Definitely	Possibly	No	Don't know
From farmers	drench resistance requires action (please tick one box from each row)			

From drench manufacturers				
From MAF				
From private vets				
Other*				
*Please specify				

9.5. From which sources do YOU obtain your information on worm control in sheep? Please tick and rank the three most important to you (1, 2, 3)			
Farm consultant	Field days	Farming journals	Veterinarians
Neighbour	Television	MAF	Stock agents
Internet	Radio	Seminars	Discussion groups
Other, please specify.			

9.6. Please tick the methods used on your farm for prevention or control of drench resistance in SHEEP. In addition please 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 within the same season	
Change drug action families each year or every second year	
Treat lambs regularly every 4 to 6 weeks to keep worm populations suppressed	
Treat only when faecal egg counts indicate a problem	
Treat only when sheep are not doing well or are scouring	
Use combination drenches	
Use generous doses of drench	
Use other stock classes in the grazing rotation to clean up pastures	
Follow lambs with older animals or other stock classes as part of the grazing strategy	
Integrate crop or hay/silage making with grazing management	
Use quarantine treatment when buying in new batches of animals	
Use feed budgeting to keep animals growing to their potential	
Use mineral supplements	
Follow advice of veterinarians and advisors	
Pasture renewal and/or cropping as part of the grazing feeding system	
Other (please specify)	
Other (please specify)	



**9.7. 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.**

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<b>Name of interviewer</b>	
----------------------------	--

<b>Date</b>	
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