Final project report

SmartWorm® App - Case Studies

Contract number 21149-1 SmartWorm® App – Case Studies

Date December 2024

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Project summary

This was a follow up study on the potential of a proprietary software application (SmartWorm®) to reduce the use of anthelmintics under NZ sheep farming conditions. It follows a pilot study completed in 2023, which assessed the potential of SmartWorm® to reduce the use of anthelmintic under New Zealand sheep farming conditions on three farms in the North Island of New Zealand. The current study assessed the application on younger animals and a larger number of NZ commercial farm systems. The application provides a recommendation of whether to drench an animal based on several variables. These include age, weight, expected growth performance and feed details. The SmartWorm® algorithm generates a recommendation in the format of 'red' (administer drench) or 'green' (do not administer drench), in real time.

The key differences of this work relative to the pilot study conducted in 2023 were:

a) conducted at a different time of year (Feb-June as opposed to May-August)
b) younger lambs (6 - 7 months old as opposed to 9 – 10 months old)
c) increased number of sites across the North and South Island (six as opposed to three)
d) different worm species and composition of nematode genera due to seasonal and geographical differences.

The study was conducted on six farms utilising SmartWorm® in a similar but not replicated approach, supported by the local veterinarian. Significant variation in pasture contamination and larval genera present was expected between farms with a potential effect on animal performance.

The animals enrolled were all lambs of mixed sex, grazing various forage types. Useable data was obtained from 6 properties with a total of 3958 lambs with a recorded full dataset.

There were some initial technical difficulties with achieving a commercial speed for automated processing of collecting the eID, recording the weight, making the TST decision and making a correct draft. A majority of these were overcome within the first visit, from which point the processing of the animals through the on-farm automated weighing and drafting equipment occurred at commercial speed.

The SmartWorm® app communicates directly with auto-draft equipment on the farm to sort and draft animals based on their treatment recommendations. It can also allow animals to be identified for manual drafting. There were two groups of lambs on each farm. One group (control) was blanket treated (BT) with an effective anthelmintic for the farm at each monthly yarding. The second group (SmartWorm®) was treated with the same effective anthelmintic (targeted selective treatment dosed, TST-D), or not treated (TST not dosed, TST-ND), based on the TST decision generated by the SmartWorm® app. The BT and SmartWorm® TST lambs were run together throughout the study.

Across the six farms and 3958 lambs, the following were observed:

a) A mean 48% reduction in drench use measured as the number of drench treatments per animal (range 28-57%) in the TST group relative to the BT group
b) The mean Average Daily Gain in live weight (ADG) was 10 gram/day (range 0-19.6 gram/day) lower in the TST group relative to BT group.

This was measured over an average period of 101 days (range 88 – 112).

Rationale & background information

Anthelmintic resistance in internal parasites is a major problem impacting on the productivity of the New Zealand sheep industry. Reducing the amount of drench administered throughout each season is likely to have the biggest impact in slowing the progression of resistance, alongside providing a source of refugia.

To date, there have been no practical commercial tools available in NZ to identify which individuals within a mob require a dose of anthelmintic at the time lambs are treated for internal parasites. SmartWorm® could be a valuable tool to facilitate this. The SmartWorm® app, in conjunction with an eID tag and other farm-pertinent information can identify the animals most likely to require a dose of anthelmintic, on the basis of live weight gain.

This approach is known as targeted selective treatment (TST). The benefits of the TST methodology are:

a) Reduced selection intensity for development of a drench resistant worm population by increasing refugia.

b) Reduced total drench quantity used. Saves unnecessary treatment of animals which do not require it.

Note that SmartWorm® is a proprietary offering that calculates the need or otherwise for treatment with some level of detail for each individual animal, however farmers are also able to instigate TST based on any liveweight gain cut-off that they might choose. Thus, the TST approach has wide application across New Zealand's livestock industries.

In 2023, a pilot study funded by Beef + Lamb New Zealand was carried out on three farms, two in Hawkes Bay and one in the Wairarapa, with varying policies and expected levels of pasture larval contamination. Winter trade lambs (on farm from May-August) of mixed sex were used. There was an average 49% reduction in drench use and an average 327g lower live weight (LW) in the Smartworm(R) group over 90 days.

The current study was undertaken to better understand how a TST programme would perform in younger lambs and in other New Zealand locations.

Objectives

- To assess the effectiveness of the TST methodology using the SmartWorm app for parasite management in lambs under NZ commercial sheep farming conditions from February-May.
- To provide case studies of NZ commercial farm systems utilising eID and/or facial recognition for TST as a means of maintaining parasite control whilst lowering their drench inputs to lambs.

Hypothesis:

a) That the use of the SmartWorm® system in conjunction with eID tags or facial recognition can reduce drench inputs without significantly reducing lamb growth performance in a range of commercial farming situations.
b) That the use of SmartWorm® in conjunction with eID tags or facial recognition can enable superior decision making around drench requirements for growing lambs, versus using mob-level faecal egg counts (FECs), achieving equivalent or better animal performance.
c) That the use of eID tags or facial recognition with Smartworm® may highlight that some animals will have poor performance due to factors other than internal parasite burden. Note this work is on-going and is not reported here.

Methodology

Study Design:

This is a comparative study design to determine the outcomes from the regular selective anthelmintic treatment of lambs versus regular 'blanket' treatment of all lambs in the mob, across a variety of farm management systems and forages.

Each enrolled animal was measured serially for live weight (from which ADG was calculated), then the SmartWorm® decision (where applicable) was recorded as drenched or not, along with pregnancy scan outcome (if mated) from February to September 2024.

Sample Size and Determination:

Previous investigations using this approach in lambs in the immediate months after weaning has resulted in an average of around 50% reduction in drench use, varying from 25% to 75% reduction in drench at each drench event. Based on data by Greer et al. (2013) comparing live weight of a TST method group with a control group when adjusted for gender gave a variance of 29 (SD = 5.4). A two-sided T-test using the Equivalence test with a threshold of 0.5kg live weight, sample variances 29 and 29, a significance level of 0.05 and a power of 0.8, requires a replication of 1988 animals for each sample. To demonstrate equivalence with a threshold of 0.6kg live weight, sample variances 29 and 29, a significance level of 0.05 and a power of 0.8, requires a replication of 1381 animals for each sample (Genstat v22.1.0.170).

Notwithstanding the above sample size calculations, it was advised that only 2400 sheep were available for the study. The power analysis was reworked, which indicated that the researchers would be able to demonstrate equivalence with a threshold of 0.62 kg live weight, at a significance level of 0.05 and power of 0.8. It was considered that a difference in mean body weight of 2 kg could be considered biologically significant. As such, this study would have sufficient power to detect such a difference with a reduced **sample size of 1200** sheep in each treatment group across all farms (i.e. on average 200 animals per treatment group on each farm).

Two-sample t test power calculation

n = 1200

delta = 0.6178461

sd = 5.4

sig.level = 0.05

power = 0.8

alternative = two sided

NOTE: n is number in *each* group

Enrolment:

Veterinarians across New Zealand were contacted to be involved, with a geographic spread being identified as a priority. Once the veterinarians registered interest, they were asked to identify a farmer that would be co-operative and motivated and would meet the inclusion criteria.

The starting level of worm contamination on the case study farm was expected to vary across the group and was not measured or managed prior to day 0.

This study was granted ethics approval by the Lincoln University Animal Ethics Committee, application number LUAEC2024-10.

Inclusion criteria:

1. Ewe lambs kept as replacements with flexibility around whether they were to be mated or not.
2. Have eID and drafting facilities.
3. Study to commence between 1st and 29th Feb and conclude by 30th May 2024. Actual start date depended on the farm and worked around their normal operations.
4. The veterinarian had proof that the drench to be used during the study was efficacious by having measured greater than 95% undifferentiated reduction in egg count and greater than 90% reduction by genera via larval differentiation. .
5. Able to weigh lambs every 4 weeks.
6. Flexibility to increase weigh frequency if FECs, larval cultures and animal performance indicate increased risk. . Conversely flexibility to extend drench interval if parasite pressure was considered low. Willingness to continue to provide data over the lifetime performance of the animals where practically possible if required.

On-farm protocol

1. Lambs to be used on each property identified.
2. eID Tags were allocated to all participating animals
3. Randomisation process: Applying eID tags, weighing all animals, using a randomiser to assign animals split evenly by weight. The blanket treated (BT) animals received a colour coded ear tag. While the colour code tag may have introduced bias, this was required to reduce the risk of an animal/mob being drenched inappropriately, e.g. a BT animal not being

treated. Any colour code tag that fell out was replaced. All study animals were managed as one mob until the completion of the study.

4. One to Two days prior to each weigh event, 10 fresh faecal samples collected from the ground from BT animals for individual Faecal Egg Counts.
5. Day 0:
   a. All tagged animals recorded for live weight.
   b. All tagged animals drenched with an effective drench. All animals were assigned to either BT or TST mob after all weights were taken, paired by weight and then randomised to a treatment group using Xcel randomiser.
   c. 10 fresh faecal samples were collected from the ground from the whole mob and sent to Awanui Veterinary for individual FEC and a pooled larval culture.
6. Day 28:
   a. Animals were drafted using the SmartWorm® app. This uses liveweight gain, plus estimates of feed availability and quality along with climate variables and animal size to determine an efficiency value (Worm Rating: WR), on a scale of 1 to 10, with 10 being highly efficient. Treatment thresholds were set at a WR of seven, where any animal with a WR of less than seven received a treatment.
   b. All BT groups were treated with anthelmintic, to the weight of the heaviest live weight recorded in the mob.
   c. All TST-D animals were treated with the same effective anthelmintic as the BT group also to the heaviest liveweight recorded in the mob.
   d. All TST-ND animals were not treated.
   e. 10 fresh faecal samples were collected from the ground from each of the three groups (i.e. 30 samples in total) and sent to Awanui Veterinary for individual FEC and group pooled larval culture.
      i. Note, if larval culture came back with *Haemonchus contortus* present at 20% or greater, consideration was given to bringing the next weigh event forward to 21 days rather than 28 days or change treatment to an anthelmintic product with persistent activity against *H contortus*.
   f. Weigh files (with SmartWorm® decisions) were sent to the project manager by the vet or vet tech the same day of data collection.
7. Every 28 days (or what the veterinarian deemed to be appropriate) for 90 days, 6a – 6f above were repeated.
8. The farmers involved in the study, were asked if they would like to investigate the poor performance in any "non-responder" animals at their cost, at each weigh session. That is those animals that had poor growth rates and the previous drench had not resolved this.

Farms and data

Six farms were represented, with a total of 3,958 lambs.

On five farms, four visits were carried out (V1, V2, V3, V4) with five visits (V5) on one farm.

All lambs were drenched at V1, and animals allocated evenly to groups, one being BT group where all animals were treated at approximately monthly intervals, the other being TST based on the SmartWorm® app at the same intervals (TST-D, TST-ND).

Following cleaning of the data to include only the animals with a full set of data, 3179 complete records remained and were analysed. Of these 1521 were from BT and 1650 from TST groups.

For BT and TST, respectively, Farm A had 186 and 275, Farm B 264 and 261, Farm C 65 and 77, Farm D 285 and 284, Farm E 339 and 339, Farm F 396 and 414 animals.

Analysis was carried out based on the number of treatments administered since V1 (i.e., not including the treatment at V1 where all animals were treated). Where large discrepancies of recorded individual live weights were observed (for example increases of 20 kg over 28 days), data was replaced with estimates of missing values following comparison of antedependence structures and analysis using a restricted maximum likelihood (REML) model for repeated measures (live weight). This occurred on 14 occasions.

Data Summary and Analysis:

This study was granted ethics approval by the Lincoln University Animal Ethics Committee, application number LUAEC2024-10.

Following assessment of antedependence structures, live weight was analysed using a Restricted Maximum Likelihood (REML) for repeated measures with treatment, farm and time as a factor and animal as a random variable.

Overall, there was a time x treatment x farm interaction ($P<0.001$) reflecting similar live weights at the start which then diverged with time between BT and TST groups. There was no treatment x time interaction ($P=0.604$) indicating consistent diversion of live weight on each farm.

Summary performance data for each farm and overall is shown in Table 1 and Figures 1, 2, 3 and 4. Performance data between farms for average daily gain (ADG) and number of treatments was carried out with a general ANOVA blocked for farm. Performance data for mean live weight at V1 and ADG within farm for each number of treatments administered was performed using a general ANOVA with post-hoc comparisons made using a Fishers Unprotected Test at 5%.

Overall, ADG (g/d +/- s.e.m) was 79.9 +/- 0.948 and 69.6 +/- 0.92 for BT and TST, respectively ($P<0.001$). However, this was influenced by three of the six farms having larger differences (Table 1), as shown by statistical analysis showing a treatment x farm interaction ($P<0.001$) reflecting significant reductions in ADG for TST relative to BT on farms B, D and F but not farms A, C and E.

Mean number of treatments administered was 3.26 +/- 0.011 and 1.73 +/- 0.017 ($P<0.001$) for BT and TST, respectively, representing a 48% reduction in the number of treatments administered to TST animals on average. There was no effect of farm on the number of treatments ($P=0.395$) reflecting a consistent reduction in drench use across farms.

There was an adverse event on one farm (Farm F) at V4 that was reported to the Lincoln University Animal Ethics Committee. Study lambs were visually identified by the farmer to not be performing well and looking ill-thrifty. Before treatment could be made three animals died, one from each of the treatment groups at the previous visit (BT, TST-ND and TST-D). The cause of death could not be confirmed as post-mortems were not carried out, but it was suspected to be a result of an acute parasite challenge, possibly Haemonchosis, as cultures at the previous visit showed 25% *H. contortus.* Due to a clerical error, previous FEC results were delayed but did show several animals with a very high FEC. All of these high FEC individuals were in the TST drenched group, but it is suspected that prior to being drenched in the previous visit they had already deposited a large amount of larval contamination on pasture.

Table 1: Overall farm performance data, ADG (g per d) and number of treatments for Blanket Treatment (BT) and SmartWorm® targeted specific treatment (TST) for each farm (A to F).

		Count	ADG (g per d)	s.e.m.	No of drenches	s.e.m.
Farm A	*BT*	186	78.6	2.40	3.00	0.00
	TST	275	73.3	2.05	1.27	0.04
	% reduction		6.7		57.7*	
Farm B	*BT*	261	55.0	2.98	3.00	0.00
	TST	264	45.5	2.99	1.94	0.04
	% reduction		17.3*		35.2*	
Farm C	*BT*	65	57.9	2.69	3.00	0.00
	TST	77	57.9	2.86	2.16	0.07
	% reduction		0.0		28.1	
Farm D	*BT*	285	106.7	1.36	3.00	0.00
	TST	284	96.3	1.39	1.44	0.04
	% reduction		9.7*		52.1*	
Farm E	*BT*	333	94.3	1.73	3.00	0.00
	TST	339	90.1	1.70	1.61	0.03
	% reduction		4.4		46.4*	
Farm F	*BT*	396	69.2	0.95	4.00	0.00
	TST	414	49.6	1.04	2.14	0.03
	% reduction		28.3*		46.6*	

Note: * indicated significance at the 5% threshold (P<0.05). S.e.m = standard error of the mean.

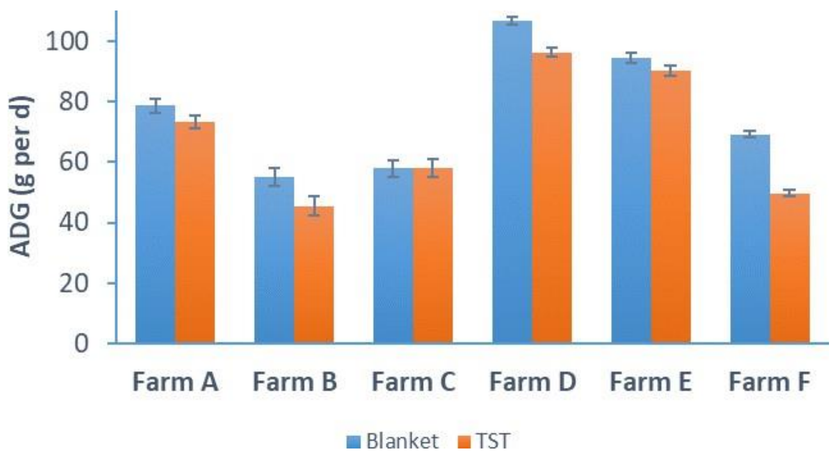

Figure 1: Average daily gain (ADG; g per d) over the entire period for Blanket and TST animals for Farms A to F. Error bars represent the standard error of the mean (s.e.m).

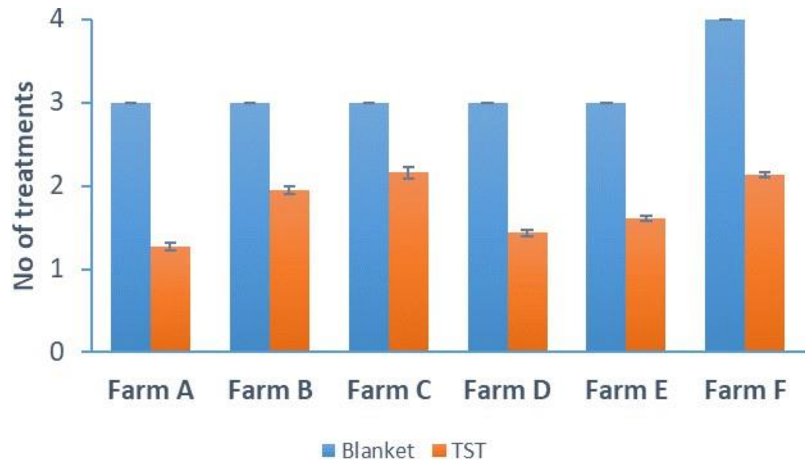

Figure 2: Mean number of treatments administered over the entire period for Blanket and TST animals for Farms A to F. Error bars represent the standard error of the mean (s.e.m).

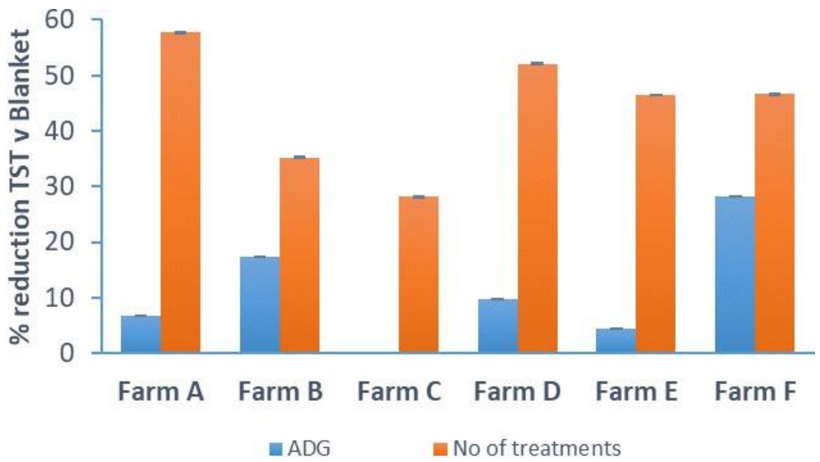

Figure 3: Percent reduction of average daily gain (ADG; g per d) and number of treatments administered over the entire period for TST animals relative to Blanket animals on each Farm (A to F).

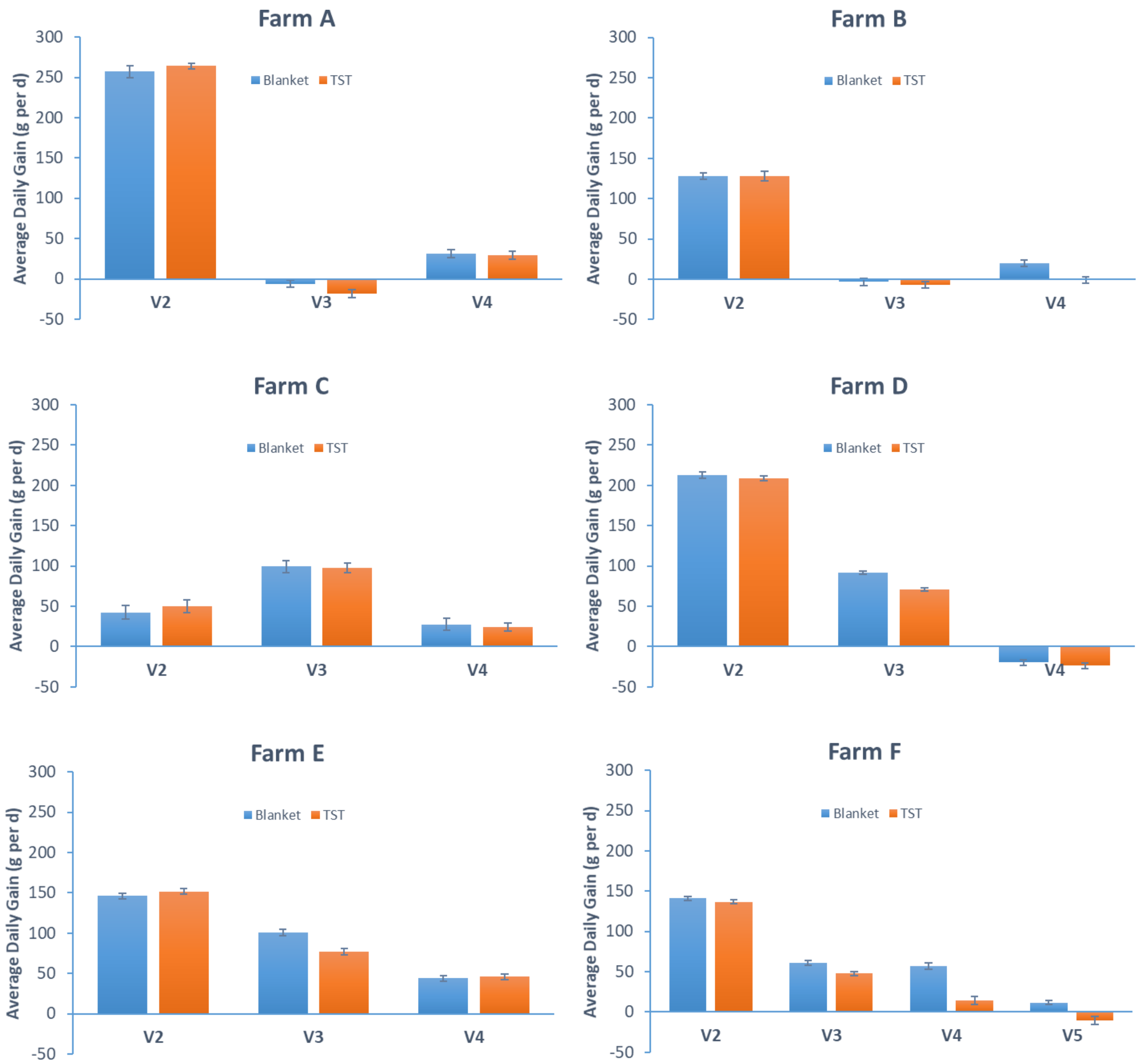

Figure 4: Average daily gain (ADG; g per d) for Blanket and TST animals for the previous period at each weighing event (V2 to V5) for each Farm (A to F). Error bars represent the standard error of the mean (s.e.m).

Anthelmintic treatments

The proportion of TST animals treated at each visit for each farm is given in Figure 5. The proportion treated on each ranged from 0.14 on Farm A at V2, to 0.99 on Farm C at V4. In general, the proportion treated followed a pattern of a lesser proportion requiring treatment if a large proportion was treated at the previous visit, and vice versa.

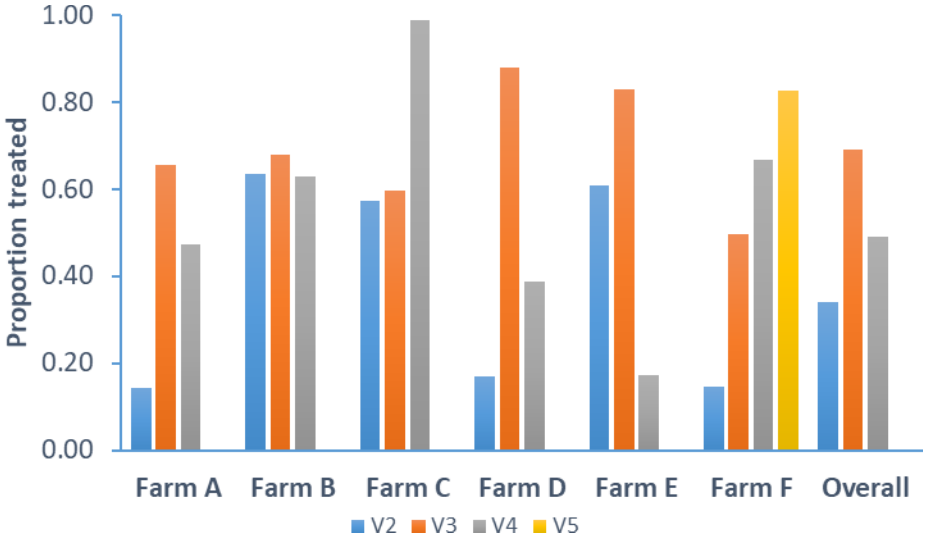

Figure 5: Proportion of TST animals treated at each weighing event (V2 to V5) for each Farm (A to F) and overall for all TST animals across all farms.

The distribution of treatment administered to TST animals is shown in Figure 6. Overall, the treatment frequency was normally distributed with a small proportion of animals requiring zero or three or more treatments and a majority receiving either one or two treatments. Only one animal (from Farm F) received four treatments.

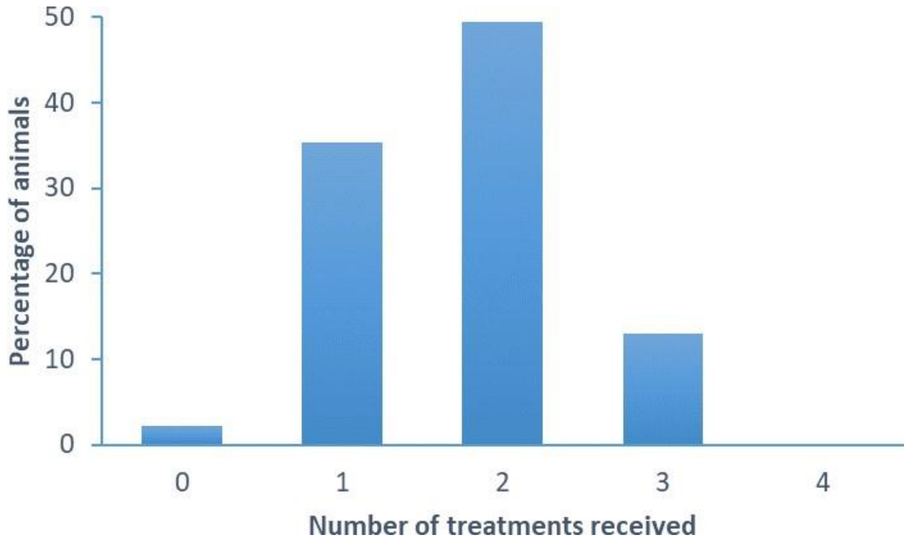

Figure 6: Distribution of treatments administered across all TST animals across all farms.

Animal performance relative to anthelmintic treatment is given in Figure 7. As expected ADG was influenced by the number of treatments with those receiving fewer treatments having a greater ADG. This presumably reflects the nature of the decision model where animals with lower growth rates are likely to be identified as requiring treatment. Of note, those that received 0 or 1 treatments performed better than the average of the BT group, possibly indicating greater resilience or early onset of immunity in this subset of the population.

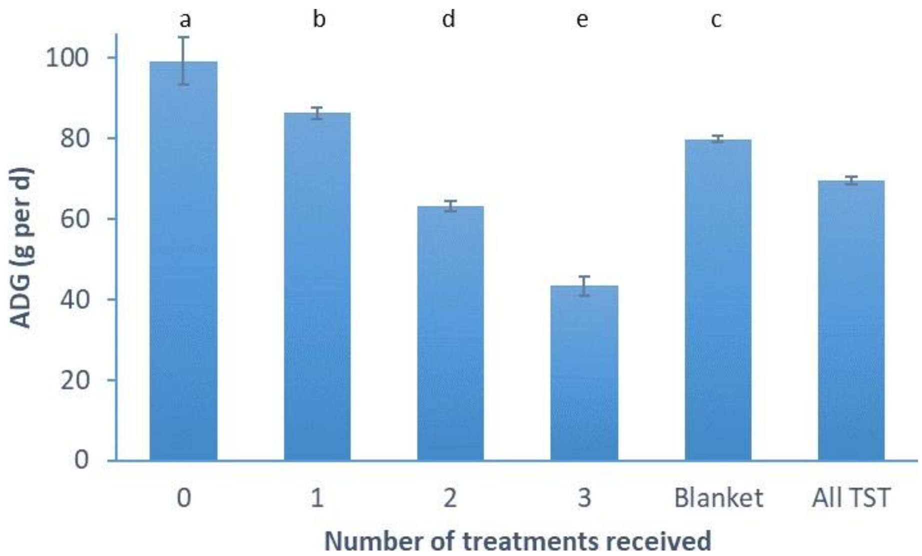

Figure 7: Average daily gain (ADG; g per d) over the entire period for all farms relative to the number of treatments administered to TST animals and BT. The letters above each column represent statistical differences (P<0.05). Error bars represent the standard error of the mean (s.e.m).

Within farm performance analysis is given in Table 2. The number of treatments was influenced by V1 live weight with a general trend that those who received fewer treatments were initially lighter. This may reflect a bias in the model against heavier animals where expected levels of production are over-estimated or may reflect an element of catch-up growth in those initially lighter.

Table 2: Within farm performance comparisons for initial live weight (WT) at V1 and ADG relative to the number of treatments administered for BT and TST for each farm (Farm A to F). Within farm, initial WT and ADG with different superscripts (a to d) were significantly different (P<0.05).

Farm	Treatment	No Treatments	Count	Initial WT	s.e.m.		ADG (g per d)	s.e.m.	
Farm A	*BT*	*3*	186	34.6	0.3	abc	78.6	2.4	ac
	TST	*0*	26	33.7	0.9	a	92.6	6.5	d
		1	159	33.8	0.4	ab	76.6	2.6	ac
		2	80	35.5	0.5	ac	61.9	3.7	a
		3	10	33.8	1.5	a	61.2	10.4	a
Farm	**Treatment**	**No Treatments**	**Count**	**Initial WT**	**s.e.m.**		**ADG (g per d)**	**s.e.m.**	
Farm B	*BT*	*3*	264	40.9	0.3	ac	55.0	3.0	c
	TST	*0*	1	32.5	4.7	a	125.0	48.3	bd
		1	72	38.7	0.6	a	70.0	5.7	d
		2	129	41.5	0.4	acd	39.8	4.3	ab
		3	59	42.8	0.6	d	26.5	6.3	a
Farm	**Treatment**	**No Treatments**	**Count**	**Initial WT**	**s.e.m.**		**ADG (g per d)**	**s.e.m.**	
Farm C	*BT*	*3*	65	38.9	0.5	b	57.9	2.7	b
	TST	*1*	12	35.1	1.2	a	81.0	6.3	c
		2	41	38.7	0.7	b	60.9	3.4	b
		3	24	41.7	0.9	c	41.3	1.4	a
Farm	**Treatment**	**No Treatments**	**Count**	**Initial WT**	**s.e.m.**		**ADG (g per d)**	**s.e.m.**	
Farm D	*BT*	*3*	285	31.5	0.1	a	106.7	1.4	c
	TST	*0*	10	31.6	0.5	ab	114.2	7.3	c
		1	152	31.5	0.1	a	104.0	1.9	c
		2	110	31.5	0.2	a	87.8	2.2	b
		3	12	32.5	0.5	b	57.8	6.7	a
Farm	**Treatment**	**No Treatments**	**Count**	**Initial WT**	**s.e.m.**		**ADG (g per d)**	**s.e.m.**	
Farm E	*BT*	*3*	333	38.0	0.15	b	94.3	1.7	b
	TST	*1*	133	37.0	0.23	a	99.3	2.7	b
		2	206	38.8	0.19	c	84.2	2.2	a
Farm	**Treatment**	**No Treatments**	**Count**	**Initial WT**	**s.e.m.**		**ADG (g per d)**	**s.e.m.**	
Farm F	*BT*	*4*	396	29.6	0.18	b	69.2	0.95	a
	TST	*1*	55	28.4	0.47	a	56.0	2.56	a
		2	249	29.6	0.22	b	48.1	1.20	ab
		3	109	30.7	0.33	c	49.7	1.82	ab
		4	1	34.5			48.1		

Response to treatment

Treatment threshold was based on a worm rating (WR) of 7, below which TST animals were treated. Response to treatment, as calculated by the % increase in WR in the period post- treatment relative to their WR at the time of treatment for all animals that were treated, including both TST and BT groups is given in Figure 8. Overall, a greater % increase was observed in those with a lower WR at treatment while those with a WR above 8 typically decreased in WR in the period following treatment.

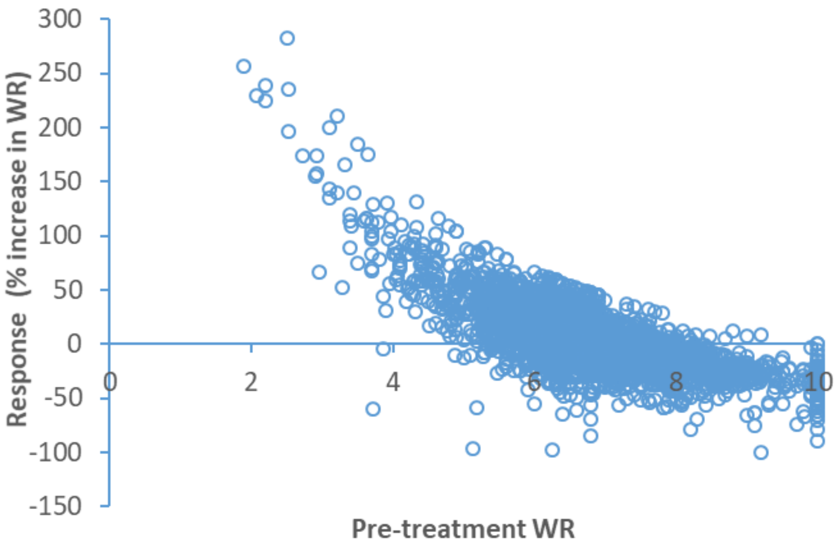

Figure 8: Response to treatment (% increase in WR) relative to the WR at the time of treatment for all animals treated (from TST and Blanket) during the study period.

Receiver Operator Characteristic (ROC) analysis was performed to determine the suitability of the WR threshold (Figure 9). ROC analysis revealed an area under the curve of 0.85 which indicated excellent discrimination between true positives and false negatives. NB. An area under the curve of 1.0 reflects perfect discrimination and 0.5 no discrimination.

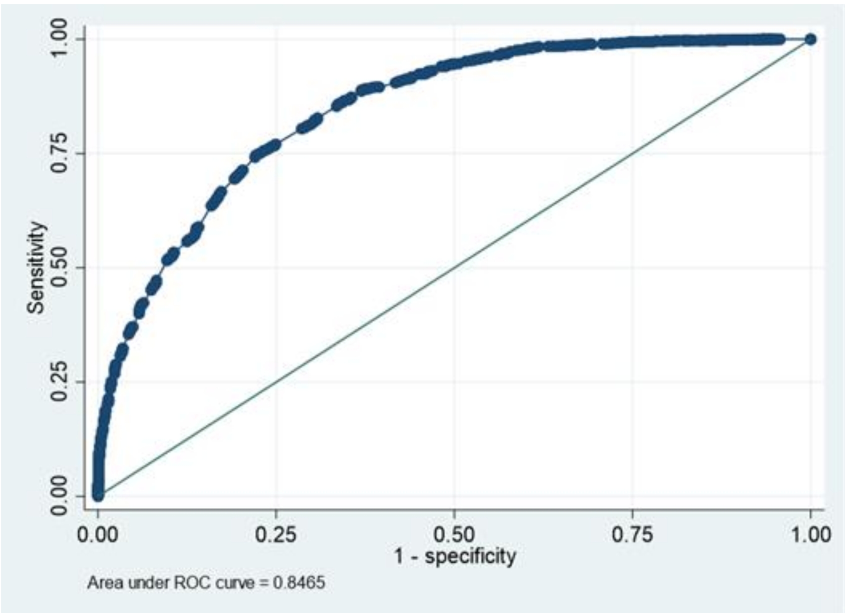

Figure 9: Output of ROC analysis showing the area under the curve of 1-specificity compared with sensitivity of the response (positive increase in WR) post-treatment.

Sensitivity was calculated as: True Positive/(True Positive + False Negative)

Where 'True positive' are animals requiring a treatment (WR less than 7) who showed an increase in WR post-treatment and 'False Negative' are those identified as requiring treatment (WR less than 7) but who did not have an increase in WR post-treatment.

Specificity was calculated as True negative/(True Negative + False Positive). Optimal WR was determined based on the maximum value of Sensitivity plus Specificity, shown in Figure 10. Maximum values of 1.521 were observed at a WR of 6.8, at which point 76% of animals treated would be expected to respond positively to treatment (increase in WR) and 24% of those not treated (above WR 7) would have responded positively. At a WR of 7 a similar value of sensitivity + specificity of 1.518 was found, with 72% of animals identified as needing treatment responding positively to treatment and 17% of animals not treated (above WR of 7) who would have responded positively if they were treated. Overall, this indicates that a WR of 7 is an appropriate treatment threshold.

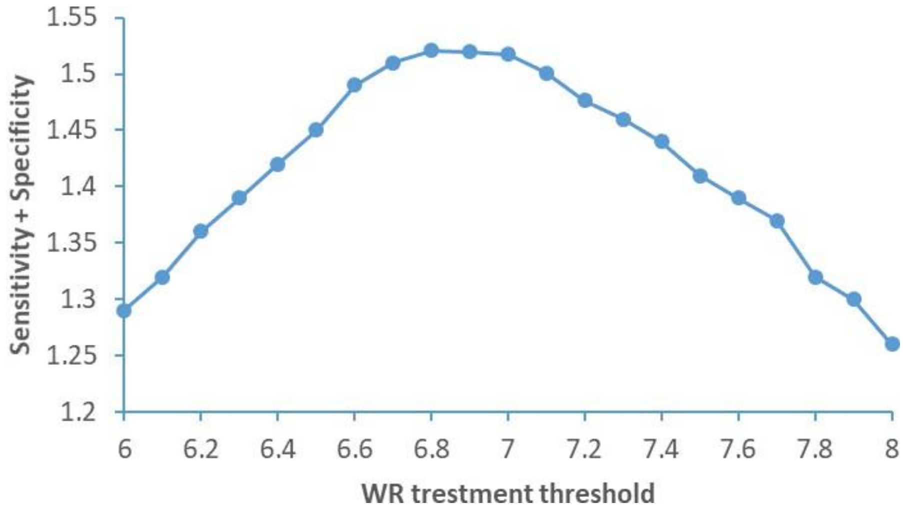

Figure 10: Sensitivity + Specificity for the change in WR post-treatment relative to the WR treatment threshold.

Subsequent impact

The previous, current and subsequent performance of treated or untreated TST animals, relative to the performance of the BT animals on the same property is given in Figure 11.

For clarity, ‘previous performance’ is the performance relative to the blanket treatment in the period before the current assessment (i.e., 4-8 weeks prior). ‘Current’ represents the performance relative to blanket during the current period (i.e., in the last 4 weeks) and ‘subsequent’ reflects the performance relative to blanket animals in the 4 weeks after the treatment decision. Overall, those that were not treated (TST-ND; WR above 7) had a greater liveweight gain than the BT group on the same property in the period when the decision was made (current) whereas those that were treated (TST-D; WR less than 7) had a lower ADG. Those that were not treated tended to have had poorer performance in the previous period (4-8 weeks prior) and had poorer performance in the subsequent (next) period, indicating a greater likelihood of requiring treatment at the next treatment time and that current performance may not provide an indicator of future need.

It is possible some of the missed performance in the subsequent period may have been avoided if TST-ND group had received a treatment. By contrast, TST-D animals had similar ADG to the BT group in the periods before and after treatment. This possibly indicates that the treatment restored growth performance but did not allow these animals to recoup the production losses experienced in the current period shown in Figure 11. It could be speculated this is the reason for the divergence in live weight between TST and BT groups.

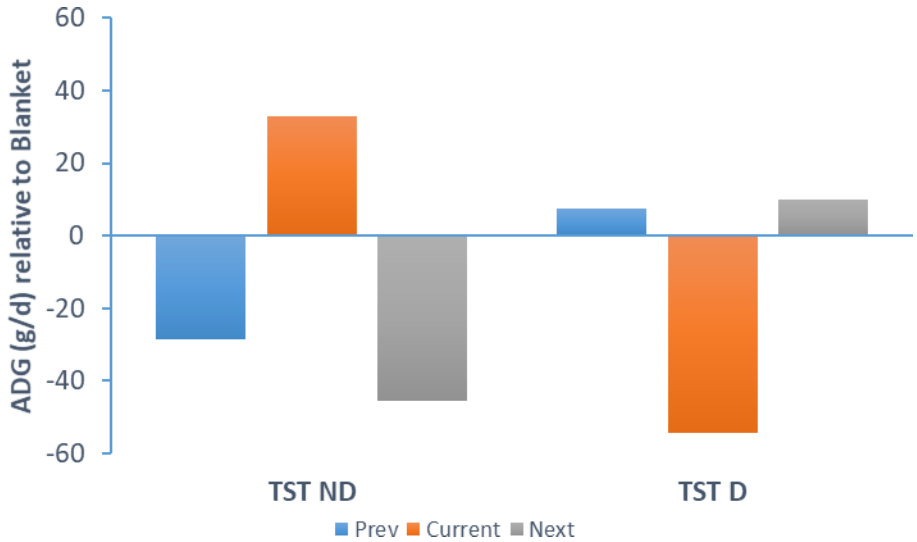

Figure 11: Average daily gain (ADG, g per d) for TST animals that were either not drenched (TST-ND) or were treated (TST-D) relative to the Blanket treatment on each farm for the period when the assessment for need for treatment took place (Current), in the period preceding the current period (Prev) or the period following the current period (Next).

The subsequent impact of treatment (D) or non-treatment (ND) on the performance and proportion treated at subsequent times for TST animals relative to visit (V1…4) is shown in Table 3. For this analysis the 5th visit from Farm F was not included as this was the only farm to have five visits.

Following treatment of all at V1, 66% of TST animals were untreated at V2, 31% at V3 and 51% at V4. 20% of animals required drenching at both V2 and V3, while 6% required drenching at all three times (V2, V3 and V4). In contrast, 17% of animals were not treated at either V2 or V3 with 3% of animals not requiring treatment at any time (V2, V3 or V4). A logistic regression model was employed to calculate odds ratios (OR). From this, animals at V3 were 48% less likely to be treated is they had been treated at V2 (OR 0.52 95% confidence interval 0.42- 0.64, $P<0.001$). At V4 they were 91% less likely to be treated if treated at V3 (OR. 0.09 95% confidence interval 0.07-0.12, $P<0.001$).

As expected, the ADG of those treated (D) at each time (regardless of previous history) was lower than those not drenched (ND), with the impact on the overall ADG relative to the BT treatments reflecting the weighted average of the proportion treated, not treated and their respective ADG. In particular, those that were deemed to be needing drench at the last sampling time (V4) had lower overall ADG, possibly reflecting changes in gut-fill associated with infection-induced inappetence that contributed to reduced ADG with no opportunity to recover post-treatment.

Table 3: Subsequent performance (ADG) and proportion treated (D) or not treated (ND) at each sampling time (V1 to V4) relative to previous history and proportion of TST treated and their performance relative to Blanket treatment for each measurement period.

V1	V2	V3	V4	Overall
n=1650 1	ND *n=1086* 0.66 206.1 g/d	ND *n=283* 0.17 58.7 g/d	ND *n=51* 0.03 58.4 g/d	**82.4 g/d**
			D *n=232* 0.14 -54.1 g/d	**61.7 g/d**
		D *n=803* 0.49 8.7 g/d	ND *n=529* 0.32 62.9 g/d	**82.2 g/d**
			D *n=274* 0.17 -21.6 g/d	**68.4 g/d**
	D *n=564* 0.34 98.3 g/d	ND *n=228* 0.14 121.7 g/d	ND *n=27* 0.02 52.9 g/d	**80.4 g/d**
			D *n=201* 0.12 -42.9 g/d	**54.0 g/d**
		D *n=336* 0.20 44.2 g/d	ND *n=229* 0.14 63.4 g/d	**74.4 g/d**
			D *n=107* 0.06 -17.9 g/d	**36.9 g/d**
TST proportion untreated	0.66	0.31	0.51	**0.48**
TST ADG	168.9 g/d	40.1 g/d	14.5 g/d	**69.6 g/d**
BT ADG	169.3 g/d	52.9 g/d	30.6 g/d	**79.9 g/d**

Parasitology

Arithmetic mean strongyle faecal egg counts (FEC) are shown in Figure 12. Due to expected variation in climate and parasite species present, each farm was analysed independently. Raw data was log10(n+1) transformed prior to being analysed with a REML for repeated measures with treatment group and time as factors.

For Farm A there was a treatment x time interaction (P=0.001) reflecting similar FEC between groups at V1 and V2 and then an increase in FEC in both TST groups but not Blanket treatments at V3 and V4.

Farm B showed no effect of time (P=0.120) or treatment (P=0.568) or interaction (P=0.158).

Farm C had consistently low FEC of less than 100 epg but did show an effect of time (P<0.001) but no time x treatment interaction (P=0.926).

Farm D showed an effect of time (P<0.001) but no effect of group (P=0.089) or time x treatment interaction (P=0.084).

For Farm E there was a treatment x time interaction (P=0.004) reflecting lower FEC for Blanket treated animals at V2 and V3, lower FEC for TSTND at V3 and lower FEC for TSTD at V4.

For Farm F there was a treatment x time interaction (P<0.001) reflecting greater FEC in TST-D animals at V3 and V4.

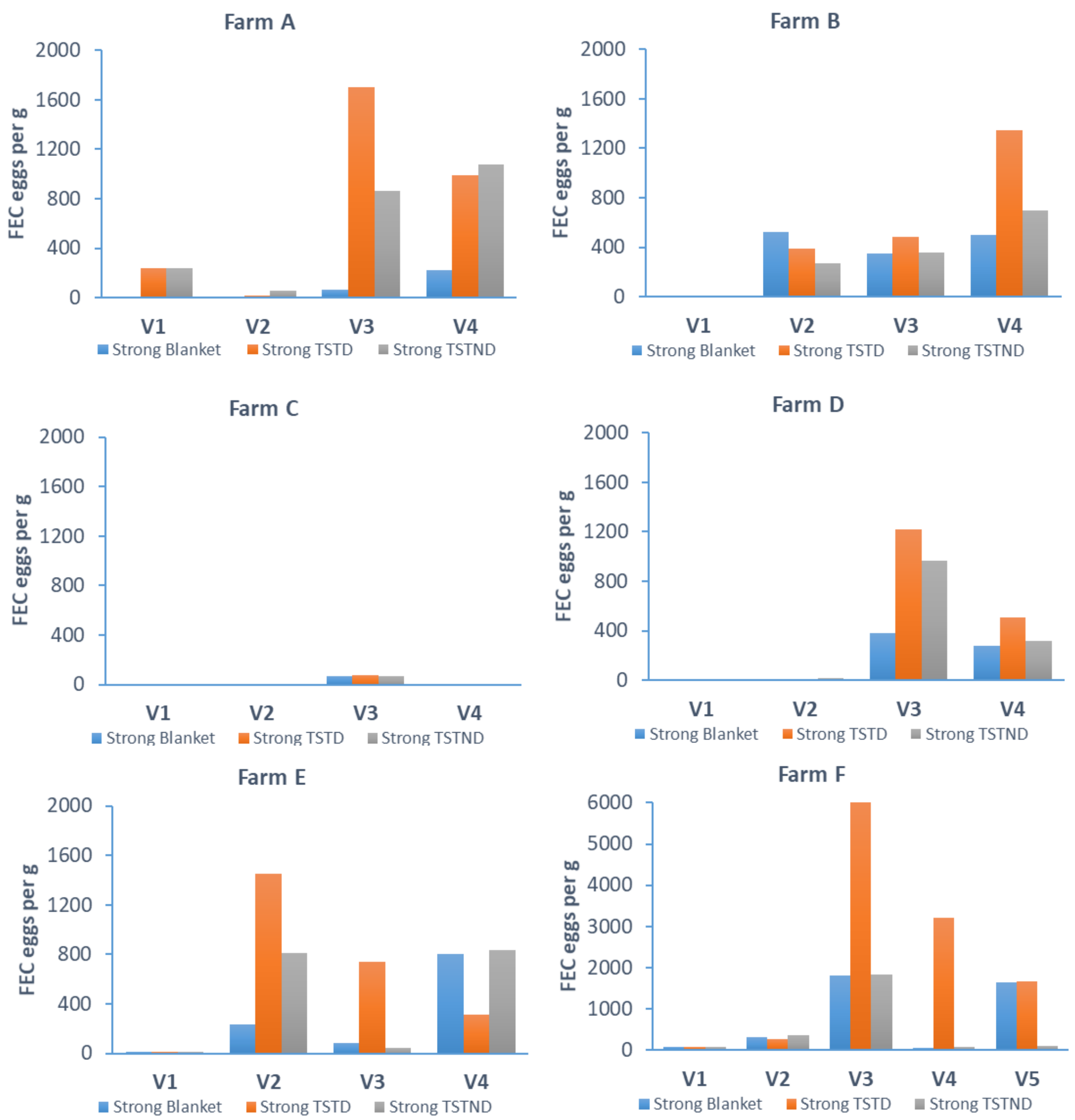

Figure 12: Arithmetic mean strongyle FEC for Blanket, TST animals that were dosed (TSTD) and TST animals that were not dosed (TSTND) for each farm (A to F) at each sampling point (V1…V5)

Arithmetic mean Nematodirus faecal egg counts (FEC) are shown in Figure 13. As per the strongyle FEC, each farm was analysed independently. Raw data was log10(n+1) transformed prior to being analysed with a REML for repeated measures with treatment group and time as factors.

For Farm A there was an effect of time ($P<0.001$) but no treatment x time interaction ($P=0.167$) reflecting greater FEC for all groups at V1.

Farm B showed an effect of time ($P<0.001$) but no interaction ($P=0.323$).

Farm C had an effect of time ($P=0.004$) but no time x treatment interaction ($P=0.457$).

Farm D showed a time x treatment interaction ($P=0.033$) reflecting a lower FEC in TSTD at V3. Due to a lack of positive values no analysis was possible for Farm E.

For Farm F there was a treatment x time interaction ($P=0.002$) reflecting slightly greater FEC in TSTD and TSTND animals at V3, although values were low, being less than 30 epg.

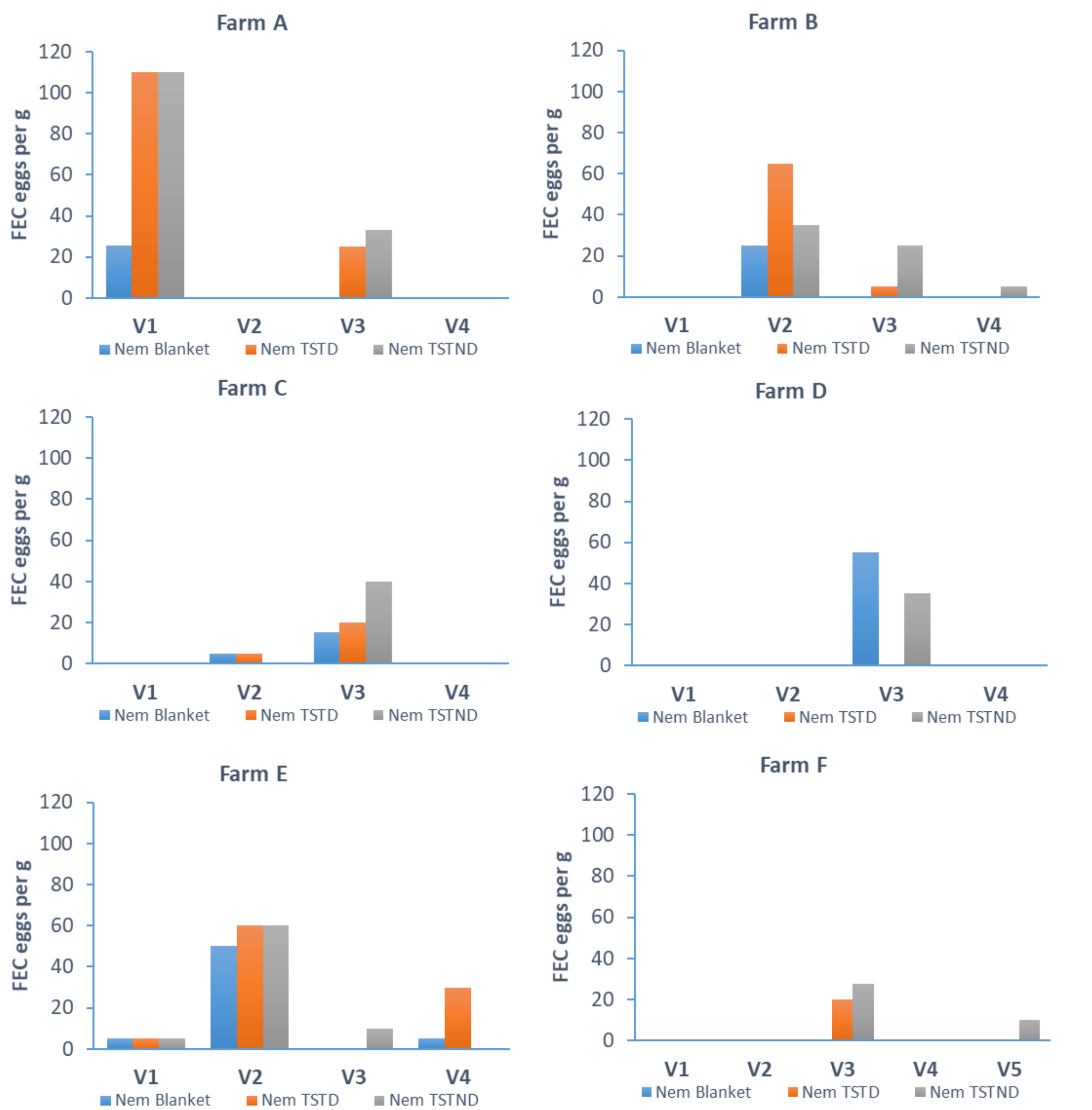

Figure 13: Arithmetic mean Nematodirus FEC for Blanket, TST animals that were dosed (TSTD) and TST animals that were not dosed (TSTND) for each farm (A to F) at each sampling point (V1 to V5)

Copro-cultures and larval speciation

Larval speciation % present from the coprocultures are shown in Figure 14. For Farm A the proportion of *Teladorsagia* species and *Haemonchus contortus* decreased with time, with *Trichostrongylus* species becoming dominant by V4. For Farm B the proportion of *Trichostrongylus* species dominated and remained relatively constant. Species varied widely for Farm C, but this was based on samples with low FEC. Farm D showed a consistent mixture of *Teladorsagia* species*, Trichostrongylus* species and *Cooperia* species. Farm E had predominantly *Trichostrongylus* species and *Cooperia* populations present with an increase of *H. contortus* to less than 20% at V2 only. Farm F showed a decrease in *H. contortus* with time that was replaced with a mixture of *Trichostronglyus* species and *Cooperia* species which then dominated by V5.

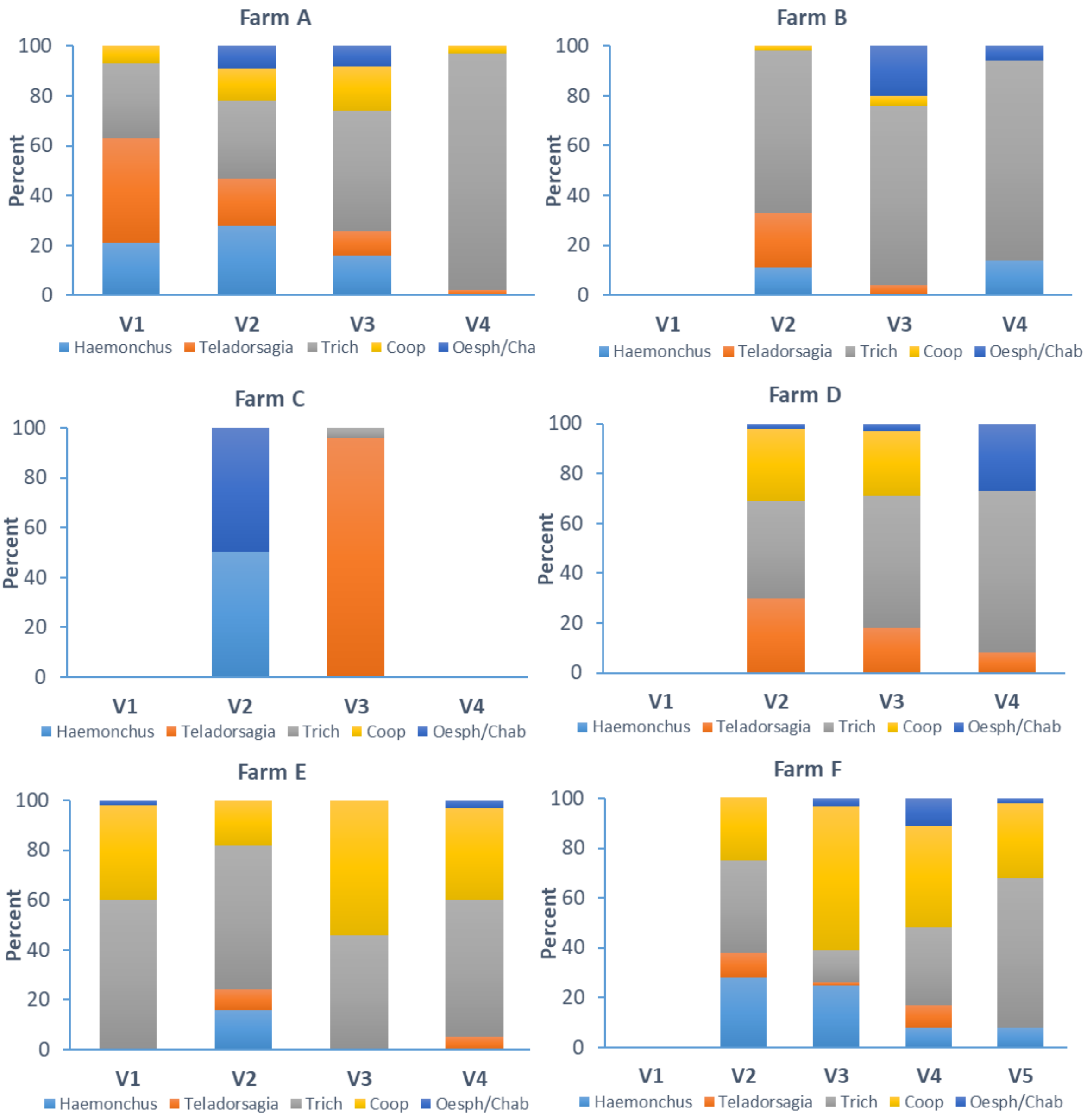

Figure 14: Percent strongyle species from coprocultures for each farm (A to F) at each sampling point (V1 to V5).

Multiple regression analysis for proportion treated
The proportion of TST-D animals were compared using a general linear regression model comparing the following parameters based on the copro-cultures and FEC: % *Haemonchus*, % *Teladorsagia*, % *Trichostrongylus*, % *Cooperia*, % Oesophagostomum/Chabertia, Strongyle TSTD and TST-ND FEC, Strongyle Blanket FEC, Average strongyle FEC (across treatment groups), Nematodirus TST (D and ND) FEC, Nematodirus Blanket FEC, average Nematodirus FEC (across all treatment groups), previous average FEC and previous *Haemonchus* %. With all terms included the model failed to reach significance (P=0.518) and was able to explain just 9.9 +/- 0.219 of the variation. Sequentially dropping the least significant terms from the model did improve the ability to account for variation to 48.9 +/- 0.165 but this still failed to reach significance (P=0.064).

Removal of one data time point from one farm that had an outlier value (Farm F, V3) did provide a better fit with 64.14% +/- 0.143 of the variation in the proportion of animals treated able to be explained by 0.029 + 0.000577 x Average FEC + 0.00513 x Average Nematodirus + 0.00841 x Oesophagostomum/Chabertia % + 0.00395 x Teladorsagia % (P=0.008) after sequentially dropping non-significant terms from the model (Figure 15 below).

Total species present (% species x FEC) was not included in the analysis as it was aliased with % species. Dropping % species and replacing it with total *Haemonchus, Teladorsagia, Trichostrongylus, Cooperia* and Oesophagostomum/Chabertia did yield a slightly different outcome with 53.3% of the variation able to be accounted for (P=0.09). The outcome of this analysis was that each of the species was negatively associated with the proportion requiring to be treated while average strongyle FEC and average Nematodirus FEC were positively associated with the proportion treated.

Further stepwise discriminant analysis with farm as a group to compare the factors influencing the proportion treated between farms showed significant effects of previous % *Haemonchus* (P<0.001) and previous % *Cooperia* (P=0.004) with an error rate after bootstrapping of 28.33%. Logically these observations presumably reflect the species composition that was previously laid onto pastures, although they did not feature as having a significant effect in the linear regression model.

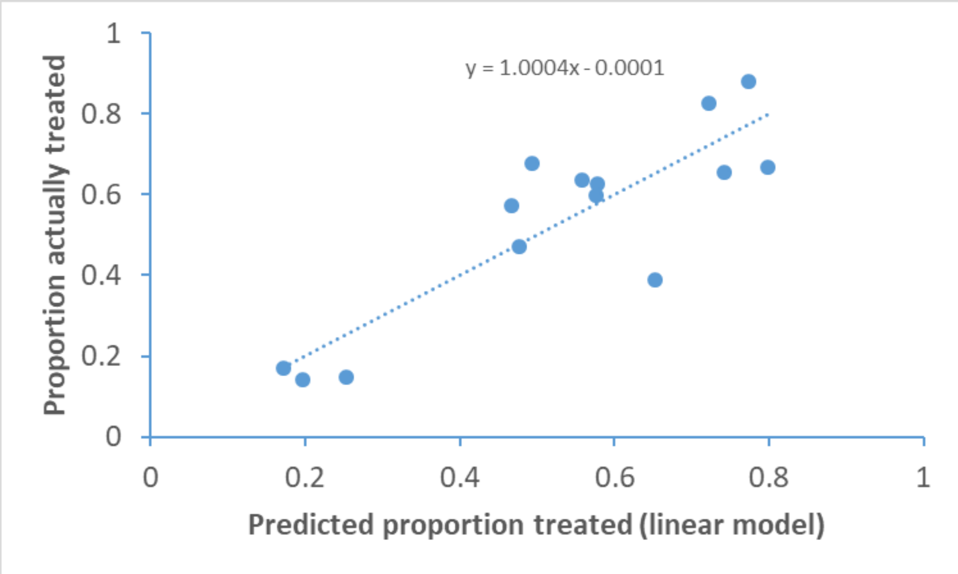

Figure 15: Proportion treated v Predicted proportion treated using a linear regression model of best fit using average stronglye FEC, average Nematodirus FEC and % Oesph/Chabertia, % Teladorsagia and % Trichostronglyus in faecal cultures.

Discussion

A change made from the previous pilot study methodology was the addition of a sample FEC from the BT group prior to each TST event. This was to give the farmer and vet confidence using familiar information, that the decisions by the application on the day were reasonable. One unintended consequence of this was that if this count was low, the farmer and vet often agreed to delay the next weigh event until the counts were considered high enough that animals would benefit from a drench. We now consider that approach to be less suitable because the ADG profile for the individual when taken over a longer period may be a less robust indicator of their current need for treatment as declining growth rates towards the end of the interval may not be identified in the algorithm prediction. A better approach would be to maintain a maximum 28-day weigh interval and drench fewer animals at each event.

Haemonchus contortus was identified as a major contributor in the larval cultures on two properties. We used an arbitrary figure of greater than 20% *H. contortus* in the larval culture as a trigger to decide on how to manage the presence of this species.

It was surprising then that *Haemonchus* % in the copro-cultures did not feature as a significant effect during the linear regression models of factors affecting the proportion of animals treated. Overall, the regression predictions may have been expected, given that FEC is the only tool we have to assess the worm burden in an animal and the concurrent presence of the pathogenic species *Teladorsagia* and *Trichostrongylus*.

However, the absence of a significant effect of *Haemonchus* % may reflect the lack of challenge, and therefore what the model perceived as important components, across all farm environments. The nature of the regression model is that features that are not consistently associated with the proportion treated (due to *H. contortus* not having a high prevalence on every farm) are not identified as significant drivers. As such, the risk or importance of an acute *H. contortus* challenge should not be underestimated. The inclusion of Oesphagostomum/Chabertia was also somewhat surprising, as these species have been believed to be uncommon in lambs on a regular drenching programme. However, a recent survey of worm species in lambs (Agresearch, unpublished), has highlighted these worms as being relatively common in lambs in New Zealand. On one property the egg counts did rise rapidly (between V3 and V4 in April) elevate and the weigh event was brought forward to a 21-day interval. Leaving animals untreated during a seasonal *H. contortus* risk period is a factor that needs to be carefully considered when implementing a TST regime, whereby even a small number of untreated lambs have the potential to create a significant larval challenge on pasture. Decisions that can be made to mitigate the risk of *H. contortus* challenge include:

a) Reducing the interval between TST events
b) Choosing an anthelmintic product with prolonged efficacy against *Haemonchus*
c) Stop using the TST decision over the risk period and treat all animals
d) Grazing management/forage allocation decisions that prevent lambs returning to areas they may have contaminated with *H. contortus* during the risk period.

Despite the lack of significance in the linear regression models we believe the 20% *H. contortus* larval composition was appropriate as a conservative trigger. There is insufficient *H. contortus* specific data from the current study to confidently change this suggestion. Further experience using the system in *H. contortus* prevalent conditions or alternative drenching/management strategies during high-risk periods are worth investigating.

The ADG of the lambs across these properties in the autumn 2024 was highly variable. A common feature on many farms was a considerably greater ADG at V2 then declining as time progressed. In part this was expected due to the change in feed availability or quality, an effect which may have been exacerbated by lower gut-fill in lambs at V1 if they were yarded for longer during the initial set-up. Yarding time prior to weighing was not recorded. Alternatively, it may reflect a gradual increase in parasite larval challenge as indicated by the general increases in FEC, greater proportion of the TST animals treated and change in species composition towards *Trichostrongylus colubriformis* dominance at V3 and V4.

In this study the ADG was reduced by 10 g per day in TST compared with BT with a range of 0-19.6 grams/day. Although statistically significant, biologically this reduction in performance is relatively modest when considered alongside the approximate halving of drench use. However, the presented mean difference here may underestimate the true epidemiological impact of the TST regime, as both BT and TST animals were grazed together, and it is likely greater contamination from the TST-ND animals may have also had a detrimental effect on the performance of the BT animals. Although we cannot say for certain, as information on grazing management was not collected, the postulated acute challenge that led to the deaths on farm F may have been exacerbated by *H contortus* contamination laid down from TST-ND animals. One of the challenges with any refugia regime is the balance between the deliberate deviation from suppressive treatment of parasite populations and the negative impact of greater pasture contamination on animal performance. It is worth noting that the LWG is less than you would expect but is actually a very common scenario across New Zealand as most farmers do not closely monitor LWG in sheep.

Conclusion & recommendations

The SmartWorm® app has performed in alignment to the previous pilot study. The threshold of worm rating of 7 was found to be appropriate and close to the optimum of 6.8 determined by the maximum sensitivity plus specificity values.

The reduction in drench usage is consistent with the previous pilot study and in agreement with overseas studies. This was able to be achieved with modest reductions in lamb performance. But, the true impact may be underestimated as the greater challenge caused by co-grazing TST and BT animals may have negatively impacted BT animals. Conversely the BT animals may have reduced the impact on the TST group.

Using the TST methodology via the SmartWorm® app can be appropriate for use under NZ farming conditions. An optimal balance of lamb growth and reduced drench use is more likely when the farm is being managed to maintain low pasture larvae contamination. There is a suggestion from the current results that the TST regime did increase parasite challenge, as may be expected with any refugia strategy where lambs are the source of that refugia. Thus, additional management strategies such as leader-follower grazing systems, grazing area swaps and use of novel forages, crops and re-grassing need to be employed to manage pasture contamination and minimise self-infection of lambs.

Incorporating additional information sources into the decision-making process for administering anthelmintic treatment, alongside traditional methods like faecal egg counts (FECs), enhances targeting of animals most likely to benefit from anthelmintic treatment. This approach reduces the overall use of drench, making it a valuable tool for integrated parasite management plans.

At times, it may be appropriate to blanket treat all animals if there are concerns about the level of contamination - any decision to implement a TST programme should not be considered all-or-nothing. Combined approaches are also valid and may be necessary to reduce risk. Smartworm® has recently added a feature which maintains a fixed proportion of the mob as the “blanket treatment group” to be able to assess the TST decisions and verify the assumptions being set up in the predictions at each TST event.

As SmartWorm® identifies those animals that require less drench over time that others in their cohort, there is the potential that this tool could be used by commercial farmers to identify replacements or in a breeding programme. A well-designed study would need to be carried out to add the use of TST into a breeding programme for resistance or resilience to parasites and we currently do not have sufficient evidence to recommend this as a breeding tool.

Acknowledgements

Nick Cotter of Cotter Agritech Ireland for the opportunity and support to use their app, B+LNZ for funding this project, Sara Sutherland of The Vet Clinic Wairarapa, Simon Marshall of Vet Services Dannevirke, Mary Bowron of The Vet Centre Marlborough, Sarah Williams of North Canterbury Vets and Andrew Cochrane of Northern Southland Vets for their collaboration. Jasmine Tanner and Andrew Greer for their statistical analysis and support, Cara Brosnahan for her mentorship through the study and the six farmers who provided stock and labour for the study.

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Sponsorship

Thankyou to MSD Allflex for their sponsorship of the eID tags, applicators and foldover tags.

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Appendix One: SmartWorm® App - Case Studies – Economic Report

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Economic Report Summary

This short report outlines savings achieved by six farms in a second SmartWorm® App - Case Studies conducted across New Zealand. The study was completed using weaned lambs over a five month duration (February, March, April, May and June 2024). On each farm, a mob of lambs grazing together were split in two:

1. A Blanket Group (control) who were blanket treated with an anthelmintic drug monthly
2. A TST (targeted selective treatment) Group who were treated according to the SmartWorm® app's dose/no dose treatment recommendation at the same monthly drench event.

All values in this paper are expressed in New Zealand Dollars ($). The savings were as follows:

- **Average direct saving of $0.65 per lamb**

  from reduced anthelmintic usage and reduced drenching labour but offset against any additional cost from having to weigh more often.

- **Average indirect saving of $1.70 per lamb**

  arising from the prevention of resistance development, i.e. the avoidance of farmers having to incorporate more of the expensive, novel drenches into their parasite control practices.[1]

- **Total average savings of $2.34 per lamb**

Electronic Identification (eID) is necessary for SmartWorm® to work. eID of sheep is not a requirement in New Zealand. 3/6 of the farms in this study voluntarily use eID, so it is a sunk business cost. For the 3 other farms, eID is an additional business cost. Both traditional ear tag eID tags, and new facial recognition technology were trialled in this study. The cost of both options and impact on the net savings were as follows:

- eID Tags: average cost of $1.68 per lamb, average net saving of $0.66 per lamb.
- Facial Recognition eID: estimated average cost of $0.71 per lamb, average net saving of $1.63 per lamb.

For a second year running, the results of the SmartWorm® case studies in New Zealand are promising. This is further evidence that a TST approach can successfully reduce drench input while maintaining animal performance compared to blanket treatment, with savings on chemical and labour for the farmer. Critically, as shown in previous studies of the TST approach, the TST approach will slow the development of resistance on farm.

Methodology

To ensure the blanket (control) and TST (targeted selective treatment i.e. SmartWorm®) study groups could be simply compared, the number of lambs was cleaned further compared to the main paper, to ensure equal numbers of lambs in each group. The analysis was completed by looking at:

1. Direct savings
   a. 'Anthelmintic Drug Saving' is the difference between the cost of Anthelmintic drugs for the Blanket and TST Groups

[1] These novel drugs are ~4 times the cost of a typical triple active.

b. 'Drench Labour Saving' is the $ value of the time difference to drench the Blanket and TST Groups

c. 'Additional Weighing Cost' is the $ cost to complete the extra weighings to implement TST, where it would not have been done in the Blanket Group.

2. Indirect savings (generated by SmartWorm® slowing resistance development)

   a. This is the difference between the cost of the current worm control programme to the Blanket Group vs. what the cost would be if the farmer had to implement one of the newer, more expensive drugs due to resistance development.

Results and discussion

Direct Savings

Table 1A shows the savings (direct and indirect) for each farm in the trial and Table 2A shows the information used for the calculations. Farm B, C and D had lower savings than the other farms due to relatively inexpensive triple active drenches being used at all drench events (Boss Triple and Matrix Hi-Min). Farm C and D had the smallest savings of these three farms, owing to having the lowest number of TST events (2). Farm B had the biggest saving of the three due to doing more TST events (3).

Farm A, E and F had the highest savings due to use of more expensive novel drenches (Zolvix and Startect) at some or all drench events. Farm A was lowest of the three as it had a smaller percentage reduction in drenching (38% vs 46% and 47%) and the slowest weighing speed (330 per hour vs 360 and 500), so additional time to weigh TST lambs was more costly. Farm E had the largest direct savings of all six farms as new generation Anthelmintic drugs (Startect and Zolvix Plus) were used at all drench events. These novel drugs are ~4 times the cost of a typical triple active. It was used due to poor triple active drug efficacy on the farm.

Table 1A. Direct savings achieved in case studies.

Farm	Number of TST lambs	% less drenching	Drench chemical saving (per lamb)	Drench labour saving (per lamb)	Additional weighing cost (per lamb	Direct savings (per lamb)	Indirect savings (per lamb)	Total savings (per lamb)	Total savings (farm rollout)
A	220	38	$1.09	$0.25	(-$0.61)	$0.73	$2.05	$2.78	$3,982
B	247	35	$0.39	$0.08	(-$0.27)	$0.20	$2.15	$2.35	$8,930
C	136	40	$0.29	$0.22	(-$0.50)	$0.01	$1.98	$1.99	$1,393
D	280	48	$0.29	$0.08	(-$0.28)	$0.09	$1.80	$1.89	$4,725
E	331	46	$0.87	$0.28	(-$0.20)	$0.95	$2.03	$2.98	$5,960
F	391	47	$2.13	$0.17	(-$0.40)	$1.90	$0.16	$2.06	$13,905
Average		42				$0.65		$2.34	

Table 2A. Relevant information per farm used to calculate savings

Farm	Drug used at each weigh event (in order)	Normal weigh frequency	Labour for each task	Weigh and draft speed	Drench speed	Action avoided by slowing resistance
A	VETMED TripleMax (Triple) VETMED TripleMax (Triple) Zolvix Plus (4-AD) VETMED TripleMax (Triple) VETMED TripleMax (Triple)	6 weeks – all weighed (extra is weighing all lambs every 4 weeks i.e. two more times over the trial period)	2 units $50/hr each	330 per hour	600 per hour	Replacing the two VETMED Triplemax drenches with Zolvix Plus(4-LV)
B	Matrix Hi-Min (Triple) Matrix Hi-Min (Triple) Matrix Hi-Min (Triple)	6 weeks – all weighed (extra is weighing all lambs every 4 weeks i.e. one more time over the trial period)	2 units $40/hr each	300 per hour	1,000 per hour	Replacing two Matrix Hi-Min drenches with Startect (5-SI)
C	Boss Triple (Triple) Boss Triple (Triple)	5 weeks – sample weigh 40% (extra is weighing all lambs every 5 weeks)	2 units $35/hr each	250 per hour	250 per hour	Replacing two Boss Triple drenches with Startect (5-SI)
D	Matrix Hi-Min (Triple) Matrix Hi-Min (Triple)	15 weeks – weigh all (extra is weighing all lambs every 5 weeks i.e. two more times over the trial period)	2 units $35/hr each	500 per hour	800 per hour	Replacing two Matrix Hi-Min drenches with Startect (5-SI)
E	Startect (5-SI) VETMED TripleMax (Triple) VETMED TripleMax (Triple)	8 weeks – weigh all extra is weighing all lambs every 4 weeks i.e. two more times over the trial period)	2 units $50/hr each	500 per hour	500 per hour	Replacing the two VETMED Triplemax drenches with Startect (5-SI)
F	Startect (5-SI) Startect (5-SI) Startect (5-SI) Zolvix Plus (4-AD)	4 weeks - sample weigh 20% (extra is weighing all lambs in each batch)	1 unit $45/hr Each	360 per hour	500 per hour	Replacing two Startect (5-SI) drenches with Zolvix Plus (4-LV)

Indirect Savings

All farms (bar Farm F) had relatively similar indirect savings as they still have effective triple active drenches.

Therefore, the indirect saving on all farms (bar Farm F) is rather high, as SmartWorm® is enabling them to avoid moving to the higher cost new generation drugs for regular worm control. This highlights that farmers who currently have effective older generation Anthelmintic drugs have the most to gain financially by using SmartWorm®.

Farm F had much lower indirect savings of $0.16 per lamb. This farm used Startect at all drench events and therefore is already paying the cost of using new generation drugs. As such, the indirect saving is a small one, as what's being avoided is moving from Startect to a slightly more expensive new generation drug (Zolvix Plus).

What has not been considered in this indirect savings section is a scenario where blanket treatment continues to the point where there is no effective Anthelmintic available to the farms. In this case, significant production losses would result, with research indicating them to be in the order of $8.00 - $22.40 per lamb[2].

Animal Identification Costs

If New Zealand farmers want to use SmartWorm® they will need to incur the cost of electronic identification (EID) tags which are not currently mandated. This will be an additional business cost where the farm does not voluntarily use EID. The cost of the tags and associated labour to put them in for each farm is outlined (Table 3), with an average cost of $1.68 per lamb. When this cost is subtracted from the savings, the average net savings are $0.66 per lamb.

An emerging alternative to traditional tag-based EID technology that was deployed alongside ear tag EID in this project is facial Recognition EID Cameras. This technology has the potential to lower sheep identification costs to $0.62 per lamb (Table 3). The accuracy of the cameras in this year's trials is currently being evaluated but if successful, this would increase net savings to $1.60 per lamb, a near threefold increase.

Several different camera types were deployed in this pilot, including high end security cameras (Hikvision ColorVu 8MP tiixed 180 Pano Bullet), consumer security cameras (Reolink Duo 2), and high-end webcams (Huddly One and Huddly IQ). While analysis is still ongoing, it appears that the high-end webcams deployed are the most successful in providing a good quality, consistent image of a sheep's face in a race to identify them using AI. These are relatively inexpensive, costing $1,200 ex GST for the 2 cameras required for each side of the lead-in race. The cameras and AI recognition software must run on a laptop to operate, the minimum specifications of which are still being assessed.

The future direction is hoped that the cameras would plug in to an iPad running the AI facial recognition software and the SmartWorm® app, for a simple, all-in-one solution offering that is easy to set up, even if operating the cameras and SmartWorm® App in both main yards and satellite yards.

Results for this facial recognition are pending.

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[2] Leathwick (2008) and Sutherland (2010) – estimated production losses from using ineffective Anthelmintics in sheep are 1.0kg - 2.8kg lighter carcass at slaughter. Figures above based on deadweight lamb prices in New Zealand on 5th December 2024 (https://www.bordbia.ie/farmers-growers/prices-markets/sheep-trade-prices/).

Table 3. Animal identification costs for each farm

Farm	Cost of eID tags	Labour to put in eID tags	Total cost eID tags	eID tags cost (per lamb)	Cost of facial recognition	Facial recognition total cost (per lamb)
A	No cost, already uses eID					
B	No cost, already uses eID					
C	$1.49 x 136 lambs Cost - $202.64	First drench takes 2 x longer Cost - $38.08	$240.72	$1.77	$970 upfront + $343 per year	$0.95
D	No cost, already uses eID					
E	$1.49 x 338 lambs Cost - $503.63	First drench takes 2 x longer Cost - $67.60	$571.22	$1.69	$970 upfront + $980 per year	$0.65
F	$1.4 x 391 lambs Cost - $582.59	First drench takes 2 x longer Cost - $35.19	$617.78	$1.58	$970 upfront + $3,308 per year	$0.54
Average				$1.68		$0.71
NOTE: The upfront facial recognition cost + annual subscription is an estimate for the portion of the farm that the farmer, when interviewed post study, said they would use SmartWorm®: Farm C on 700 lambs, Farm E on 2,000 lambs & Farm F on 6,750 lambs. The upfront cost has been set over 3 years for calculating the per lamb cost.						

Conclusion

This second year of SmartWorm® case studies in New Zealand has showed economic benefits of adopting more sustainable anthelmintic drug use across a 5-month grazing period on six New Zealand sheep farms – reduced anthelmintic usage, reduced drenching labour and the significant slowing of drench resistance and avoidance of a ~4x more expensive worm control programme.