Final project report

SmartWorm® App Pilot Study

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Project summary

This was a pilot study to assess the potential of a proprietary software application (SmartWorm®) to reduce the use of anthelmintic under New Zealand sheep farming conditions, and to provide case studies of its use on New Zealand commercial farm systems.

The SmartWorm® application provides a recommendation of whether or not to drench an animal based on a number of variables. These include age, weight, expected growth performance and feed details. The app works with automated weighing equipment on the farm and information pre-loaded by the farmer to generate a recommendation in the format of 'red' (administer drench) or 'green' (do not administer drench), in real time, and communicates directly with auto-draft equipment to draft animals based on their treatment recommendations.

Two farms in Hawkes Bay and one in Wairarapa participated in the pilot. The animals enrolled were male winter trade lambs, grazing various forage types. Useable data was available from 1414 animals.

There were some initial technical difficulties with software compatibility with the on-farm automated weighing and drafting equipment. Once these were overcome, the processing of the animals occurred at commercial speed.

There were two treatment groups of lambs on each farm. One group was blanket treated with an effective anthelmintic at each monthly yarding as a positive control. The second group was treated with the same effective anthelmintic, or not treated, based on the targeted selective treatment (TST) decision generated by the SmartWorm® app. Lambs from both groups were run together as one mob on each farm throughout the study.

Faecal egg counts were collected from lambs prior to treatment for each of the treatment groups to determine parasite burden and effectiveness of the app, and lamb bodyweight was tracked to monitor average daily weight gain throughout the study.

Across the three properties, there was a 49% reduction in the amount of anthelmintic used in the SmartWorm® groups, relative to the blanket treatment option. Overall, cumulative liveweight gain was no different between blanket-treated and SmartWorm® lambs. The three farms in this study provided useful case studies for the use of SmartWorm® on commercial farms in New Zealand.

All three farmers believed there was merit in using the SmartWorm® app to help reduce drench use for sustainable farming of winter trade lambs. The app can be used in isolation of other tools being used to inform parasite treatment. However, we found the best approach to reduce drench use to the greatest extent was to use SmartWorm® in conjunction with faecal egg counts taken prior to each treatment, as this provided extra confidence in the app's recommendations.

It is recommended that further study is be undertaken on multiple properties with varying farming policies across New Zealand, to further assess the use of the SmartWorm® app in lambs from weaning through to June.

Rationale & background information

Anthelmintic resistance of 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 in situations where this is inadequate.

Targeted Selective Treatment (TST) is the use of drench on a selected group of animals that are identified as most in need, as opposed to blanket treatment where every animal is drenched. The benefits of TST include:

a. Reduced selection intensity for development of a drench resistant worm population by creating refugia. This is of high importance as a technique for sustainable internal parasite management by reducing the percent of a worm population exposed to drench at regular treatment events.

b. Reduced total drench used. Saves unnecessary treatment of animals which do not require it leading to savings in animal health bills and labour associated with drenching.

The recently launched SmartWorm® app is a tool for making decisions for TST. In conjunction with an electronic ID (eID) tag, liveweight gain and other relevant information about the farm, the app can indirectly identify animals most likely to require a dose of anthelmintic. The app is programmed to always select a percentage of every mob to be blanket treated, and FECs can be added to assist with the app's decision making.

SmartWorm® was developed in Ireland by Cotter Agritech. The decision-making equations that are used in the app are a modified version of the TST research carried out by A. Greer and F. Kenyon in 2009, which pioneered the development of decision support models based on animal performance (Kenyon et al 2009).

To date, there have been no practical commercial tools in New Zealand to identify which individual animals within a mob require a dose of anthelmintic when lambs are treated for worm burden. 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.

At the time of this study, the SmartWorm® app was only available for installation on Android devices but it was made available for iOS (Apple) devices in 2024. The specifications of the device do not need to be high.

It is envisioned that SmartWorm® will be a valuable tool used in conjunction with a parasite management plan developed with the farmer's local Animal Health Advisor.

Objectives

1. To assess the effectiveness of the TST methodology using the SmartWorm® app for parasite management in lambs under New Zealand commercial sheep farming conditions.
2. To provide case studies of New Zealand commercial farm systems utilising eID and TST as a means of maintaining parasite control whilst lowering their drench inputs to lambs.

Methodology

This was a comparative study design looking at the regular targeted selective use of anthelmintic treatment in a mob of lambs versus regular blanket treatment of the mob. Individual animals were weighed serially between 1 May to 30 August 2023 to determine liveweight gain and were drenched or not at each session according to treatment group.

Farms and farm management

This study was undertaken on three commercial farms: two in Hawkes Bay and one in Wairarapa.

Farms were selected for this study based on access to appropriate facilities for weighing, drafting and electronic identification (eID) over the time period of the study, flexibility to alter weighing schedules if the study required it, and a known drench efficacy of >95% by undifferentiated egg count at a drench check and 95% by larval species conducted in the month prior to the study. The starting level of parasite contamination varied across farms and was not managed prior to the start of the study. All farms kept ewe lambs as replacements.

All farms were run with all usual management outside of the drench treatment programme carried out as normal for all animals while the study was underway, including monitoring health, normal grazing behaviour and general appearance. Animal health management such as lice treatment and crutching, and any veterinary treatments, were recorded.

SmartWorm® app and equipment setup

For each farm, the SmartWorm® app was installed on an Android device and linked via Bluetooth to the eID panel or wand reader (a mix of Te Pari panel and Tru test wand) and the weigh scale unit. The app works with all weigh heads and EID readers on Android devices. The Hawkes Bay farms in this study used a $150 Samsung tablet, and the Wairarapa farm used a Samsung Galaxy phone.

Farmer input is required on setting up the TST prediction on the app. The app links weather data via information from the New Zealand MetService based on the farm's physical address. Farmers make a visual assessment of pasture quality (good, average, poor) and quantity (cm height) prior to each weigh event. There is an optional input of the approximate average weight of the mob (based on the first weigh of all animals) and the approximate heaviest animal in the mob.

In this study, FEC and larval culture data were complementary to the TST protocol and provided confidence in the cutoff point for the drench/not drench decision.

There were some initial problems encountered with the app and equipment setup, primarily with communication and time lag of receiving the information between the eID reader, the weigh scale unit and the Android device. Once performing, however, this setup allowed for highly accurate and fast tag reading, weight recording, TST decision and auto drafting.

Animals

Animal use was in accordance with an animal ethics approval by the Lincoln University Animal Ethics Committee, application number LUAEC2023-19.

A total of 1723 animals were recruited across farms and treatment groups.

Lambs were male winter trade lambs for finishing managed under autumn-winter grazing on a grass-based system with various forage types. Breed was not recorded.

All lambs were tagged with eID tags. Tags were numbered and randomly assigned to animals. Animals in the Blanket Treatment group (see below) had an additional coloured ear tag inserted for quick visual identification. Animals were managed as one single mob on each farm until the completion of the study.

Animals could be removed or their treatment altered on veterinary advice if needed, for example for poor body condition or high parasite burden. However, this was not required for any animals throughout the study.

Treatments and treatment groups

Animals were paired into two treatment groups for each farm based on weight taken at the first day of the trial so that the average group weight was similar for both treatment groups within each farm. One group on each farm (three in total for the study as a whole) was randomly assigned to be the TST Treatment (TT) group, and the other was the Blanket Treatment (BT) group.

For TT animals, the SmartWorm® app determined the treatment protocol (drench or not drench) at each weighing session.

BT animals were all drenched at each weighing session.

Drenching was with an effective drench relevant to each farm, based on a drench check conducted prior to this study in April to May 2023 (efficacy >95% by undifferentiated egg count at drench check and 95% by larval species).

Weighing and drenching treatment protocol

This study was carried out from 1 May to 30 August 2023.

All animals were brought into the yard and weighed and drenched on the first day of the trial, Visit 1 (V1), before treatments started.

Following this, all animals were yarded three further times at 28-day intervals for weighing and treatment (V2, V3 and V4), giving a total of four data recording sessions for this study. Liveweight, average daily weight gain (calculated by the app) and treatment was recorded at each session.

Animals were weighed at least one hour after yarding at each session. Depending on the weigh crate practicalities, the animals were either treated at the time of weight recording, or auto drafted three ways, TT drench, TT don't drench, or BT.

The first 30 animals drafted out of TT groups at each session were visually inspected to cross-check the decision made by the SmartWorm® app. Poorer looking animals would be expected to be allocated to TT drench, rather than to the TT not drench.

Faecal sampling

Faecal samples were collected as follows and sent to Gribbles Veterinary (now Awanui Veterinary) the same day for FEC (Faecal Egg Count) testing and larval culture.

Initial faecal samples were taken from all animals 1-2 days prior to the first day of the trial, to assist with calibrating the SmartWorm® app.

At V1, faecal samples were taken from 15 randomly selected animals from each treatment group (total 30 samples across TT and BT) and sent for individual FEC testing.

At subsequent treatment sessions V2, V3 and V4, faecal samples were collected from 15 randomly selected animals in each of the TT drench, TT don't drench and BT animals (total 45 samples per event) and sent for individual FEC testing the same day.

A larval culture was completed on pooled samples from each group at V1 and V3 treatment sessions.

Faecal samples were not taken from Farm 3 at V1 and V2 for practical reasons, but this did not affect later analysis.

Pasture quality analysis

Pasture samples were taken for pasture quality analysis prior to Visit 3 on all farms, in order to identify possible causes of lower-than-expected growth rate.

Blood sampling

Lower than expected growth rate was also investigated by trace mineral analysis on Farms 1 and 2. Animals were blood sampled by a veterinarian prior to Visit 3 and samples submitted for analysis of vitamin B12 and selenium.

Statistical Analysis

Data was summarised for each farm and is presented with means and range (min-max) obtained for each property. Range rather than standard error of the mean (SEM) is presented for each individual farm as statistical analysis was only performed on the combined data that was blocked for farm. SEM is provided for the combined analysis.

Analyses used for comparison between farms, groups and visits are described in results below.

Summary data is provided for the number and timing of treatments administered, the performance of animals relative to the number of treatments and the influence of quartile ranking of animals based on their initial live weight (LW) as a means of determining any bias towards heavier or lighter lambs. Different methods of assessing performance were used to try and smooth errors that may arise from the effect of erroneous measurements on either first or last weight affecting the outcome (as may occur when just calculating live weight gain (LWG)). These included calculating the following: final LW less initial LW (LWG); average LW for Visits 2-4 minus initial LW (Average LWG); and average LW across Visits 1 - 4 (Average LW).

Adequacy of the treatment threshold of the worm rating (WR) was also assessed. WR is the output given by the SmartWorm® app from which a decision to treat is based. It considers animal growth, herbage availability and quality, and climate to predict a proxy for efficiency which is then given as a WR, on a scale where animals typically have values between 1 and 10, with the larger the value the better the animal is performing relative to its prediction. Treatment threshold for this study was set at a WR of 7, where any animal with a WR less than 7 was treated. One way of determining the optimum treatment threshold is to perform Receiver Operator Characteristic (ROC) analysis whereby the ability to differentiate between true positives and false negatives of their likelihood of responding to treatment can be determined. For each animal and their corresponding WR value at each treatment they are assigned a binary code (0 or 1) based on whether their WR value decreased or increased at the next treatment time. This gives an indication of the likelihood of an animal responding to treatment but does not give the expected magnitude. For those animals treated (in both BT and TT treatments) the magnitude of the response to treatment relative to WR at the time of treatment is also given.

Results

Due to the software compatibility problems that were experienced in the first half of the trial, the first and second sessions (V1 and V2) encountered difficulties in getting robust data collection and execution of the event at commercial speed for all three farms. At V3 and V4, very accurate data were collected, and the technology difficulties previously encountered were overcome. Data was cleaned to remove incomplete sets of results and include animals that only had four full measurements. This reduced our total dataset from 1723 down to 1414.

Results are presented for all farms combined, and then as separate analyses of each farm.

Non-parasitological factors affecting growth

Pasture quality analysis on samples taken prior to V3 on all farms was within expected reference ranges.

Table 1: Pasture Quality Analysis taken in July 2023, prior to Visit 3, at three farms enrolled in SmartWorm® pilot study.

	MJ ME/kgDM	Ref Range (medium)	Crude Protein %DM	Ref Range	Dry Matter % DM	Ref Range
Farm 1	10.9	9-12	24.9	20-30	25.1	12-30
Farm 2	10.9	9-12	30	20-30	19.2	12-30
Farm 3	8.7 & 11.2	9-12	18 & 26	20-30	23 & 19	12-30

Trace element analysis on blood samples on Farms 1 and 2 shows that both B12 and Selenium were within reference ranges (Table 2).

Table 2: Trace element analysis of lambs on two farms enrolled in SmartWorm® pilot study.

	Mean B12 pmol/L	Adequate Ref Range (medium)	Mean Se nmol/L	Adequate Ref Range
Farm 1	1368	500-1500	230	140-3000
Farm 2	1199	500-1500	1655	140-3000
Farm 3	Not tested	NA	Not tested	NA

App performance

The SmartWorm® app was installed on Android devices and linked via Bluetooth to the eID panel or wand reader and the weigh scale unit, as described in the Methods. Initially there were problems with communication and a time lag in receiving the information between the eID reader, the weigh scale unit and the Android device. This was rectified by changing the data loop direction. This meant information flowed from the eID panel to the Android device and then to the weigh scale unit. This allowed for highly accurate and fast tag reading, weight recording, app decision making and auto drafting, which meant that animals could be processed at normal speed for equivalent commercial farms.

As described in the methods, farmer input is required in setting up the TST prediction on the app. This included:

- the farm physical address - required to gather weather data from the nearest weather station (MetService data is used),
- a visual assessment of the pasture quality rated as high, average or poor,
- a visual assessment of the pasture quantity in centimetres,
- the approximate average weight of the mob (based on the first weigh of all animals), and
- the approximate heaviest animal in the mob.

After the second weigh session (V2), consensus between farmers and the researchers was that these inputs were too subjective and not in familiar language for New Zealand farmers. It was also felt that visibility was needed about the predicted growth rates that were suggested by the app as being appropriate for the decision cutoff. This allowed the farmer to see the impact of manipulating the variables mentioned and to gauge if these predicted growth rates lined up with their experience. This visibility improved user confidence in using the app. The SmartWorm® app IT team updated all the researcher's recommendations promptly.

It was also decided to draft the first 30 animals manually at each session to ensure alignment between the farmers' own visual assessment and the decision that was made by the app, e.g. were the poorer looking lambs drafted into the TT drench treatment, compared to the TT no drench treatment.

Finally, it was decided to include faecal sampling for FEC 1-2 days prior to every subsequent weigh event to allow a higher growth rate cutoff point for decision-making by the app. The app itself is conservative by design (i.e. it is set to drench at a lower cutoff rate than may be needed) because it relies on no expert input and is intended to ensure adequate parasite control and good growth rates, and thus adequate commercial sales of the app.

Animal performance

For all farm data combined, each farm was included as a block in the statistical analyses. Live weight was analysed with repeated measures using restricted maximum likelihood analysis (REML) after undergoing sequential comparison of ante-dependence structures. Overall, for live weight there was an effect of time (P<0.001) but there was no effect of treatment (P=0.964) or treatment x time interaction (P=0.837), reflecting an increase in live weight with time that was not different for BT or TT lambs. With farm included as a factor there was a non-significant treatment x time x farm interaction for LW (P=0.34) that reflected similar LW across all time points for both treatments within each farm, but final live weights being 0.26 kg heavier for TT compared with BT for Farm 2 but lighter by 0.29 kg and 0.43 kg for Farm 3 and Farm 1, respectively.

Total cumulative LWG was analysed by Accumulated ANOVA with multiple comparisons made with Fishers least significant difference at the 5% level. Overall cumulative LWG was not affected by treatment (P=0.510), being 6.69 +/- 0.099 and 6.60 +/- 0.097 for BT and TT, respectively. Table 3 shows that the animals in the TT group given the highest number of treatments had lower liveweight gain.

Table 3: Liveweight Gain (LWG) in kg (LW at V4 less LW at V1) and standard error of the mean (s.e.m) relative to number of treatments administered for TT and BT groups. Values with different letters are significantly different (P<0.05).

Group	No Treatments	No Animals	LWG (kg)	s.e.m
TST	0	2	8.75 b	1.994
	1	408	7.07 c	0.140
	2	269	6.49 b	0.172
	3	44	2.92 a	0.107
Blanket	3	691	6.69 b	0.107

Parasitology

Table 4 shows results of the larval cultures of pooled faecal samples from Visit 1 (V1) and Visit 3 (V3). Haemonchus was only found on one farm on one occasion. Teladorsagia and Trichostrongylus larvae were found on all farms.

Table 4: Larval cultures at three farms enrolled in SmartWorm® pilot study (% of each pooled sample) on the first and third sessions of the trial (V1) and (V3).

	Haemonchus	*Teladorsagia*	*Trichostrongylus*	*Cooperia*	*Oesophagosto-mum/Chabertia*
Farm 1 V1	40	4	30	24	0
Farm 1 V3	0	6	94	0	0
Farm 2 V1	0	30	54	16	0
Farm 2 V3	0	12	46	18	24
Farm 3 V1*	-	-	-	-	-
Farm 3 V3	0	16	84	0	0

* Faecal samples were not taken at Farm 3 on V1 for practical reasons.

Table 5 shows the average faecal egg count for all treatment groups on each farm over the time of the study, based on 30 samples taken at V1 and 45 samples (15 per treatment group) at each subsequent treatment session except for Farm 1 at V2 where only four TSTnd lambs could be sampled.

Table 5: Average Faecal Egg Count (eggs per gram of faeces) of lambs at three farms drenched at the start of a SmartWorm® pilot study trial (V1), and then drenched in treatment groups of blanket treated (BT), or drenched (TSTd) or not drenched (TSTnd) in accordance with SmartWorm®, on three further occasions (V2-V4).

	V1	V2 BT	V2 TSTd	V2 TSTnd	V3 BT	V3 TSTd	V3 TSTnd	V4 BT	V4 TSTd	V4 TSTnd
Farm 1	2493	2267	1733	1963*	763	463	1053	243	790	353
Farm 2	3	113	67	142	50	146	113	13	177	143
Farm 3	-	-	-	-	253	157	623	277	627	347

*n=6 for this sample, but was n=15 for every other sample.

Table 5 shows the wide variation between farms over time, with Farm 1 having the highest FECs for all groups at every visit across the trial, except for BT at Visit 4. This means that the mean FECs shown on Figure 1 need to be interpreted cautiously.

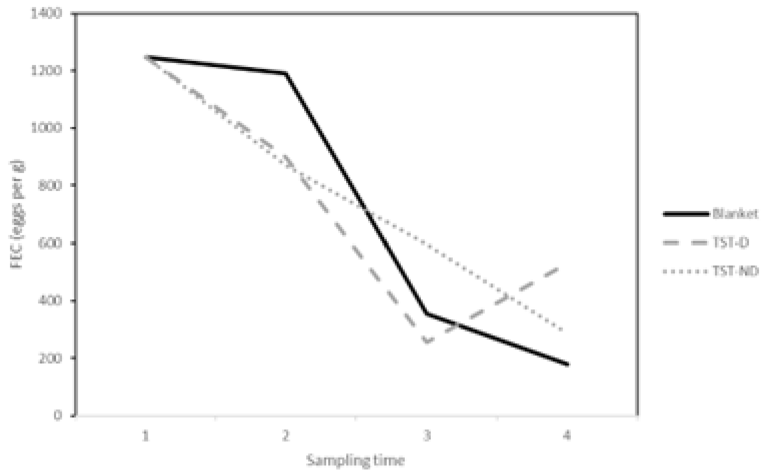

Figure 1: Arithmetic mean FEC (eggs per g of faeces) for randomly selected lambs from BT, TT-drenched and TT-not drenched groups at each Visit (sampling time) for three farms combined in a SmartWorm® pilot study.

To help with this interpretation, FEC data were transformed to understand the difference between farms and effect of treatment across visits. Log10(n+1) FEC were analysed using an unbalanced design ANOVA, with treatment, time, and farm as factors. Repeated measures was not used because faecal samples were taken from a subset of randomly-selected lambs each time, rather than from the same animals each time. Both time and farm were found to have a significant effect ($P<0.001$ for both) and data was subsequently re-analysed using a REML blocked for farm. Overall, there was an effect of treatment ($P=0.01$) and a tendency for a treatment x time interaction ($P=0.095$) reflecting slightly lower FEC for the TT drenched group on two of the four sampling times (Figure 2).

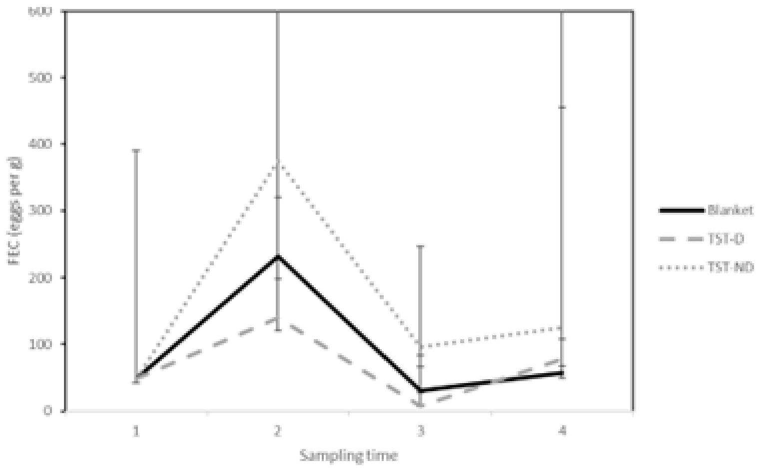

Figure 2: Back-transformed (Log10n+1) geometric mean FEC (eggs per g of faeces) and 95% confidence intervals for randomly selected lambs from BT, TT-drenched and TST-not drenched groups at each Visit (sampling time) for three farms combined.

The relationship between mob average FEC for the BT group (as a proxy for worm challenge) and the proportion of TT animals treated is given in Figure 3. Overall, a linear correlation with increasing proportion treated as FEC increased. With all data together (left figure) the R2 is 0.4022, and with the one outlier removed for Farm 2 where 99% of the animals were treated at Day 1 with a mean FEC of 133 epg (right figure) the R2 is increased to 0.8951 (y = 0.0004x + 0.1558). Which indicates even with a 0 epg, 15.6% of lambs would be expected to be treated.

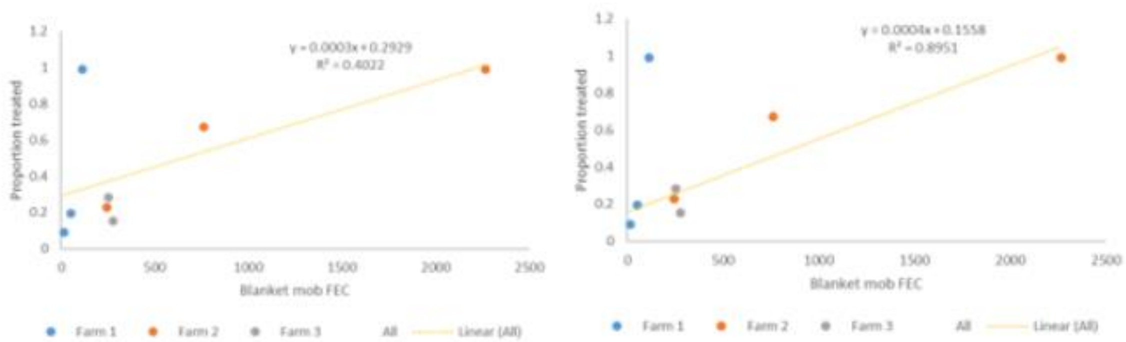

Figure 3: Relationship between mob average FEC for the BT group in three farms combined, as a proxy for worm challenge since previous treatment with all farm data included (left) and when one 'outlier' value for Farm 1 was excluded (right). Intercept of the line of best fit (linear) represents the proportion that would be treated when FEC = 0.

Drench use and live weight bias

The mean number of drenches administered per animal was analysed by unbalanced ANOVA and was greater for BT, viz, 3.00 +/- 0 than for TT, viz, 1.49 +/- 0.016 (P<0.001).

The initial LW was affected by quartile (P<0.001). The number of drenches administered to TT was affected by initial quartile (P<0.001) with those in the heaviest quartile at LW1 receiving more drenches and those in the lightest quartile for LW1 receiving the fewest drenches (Table 6). LWG was also affected by quartile (P=0.001) being greatest for those that were in the lightest quartile, which is in line with anthelmintic use (Table 7).

Table 6: Initial live weight (LW1) and standard error of the mean (s.e.m) for all TT animals across all farms in a SmartWorm® pilot study, relative to initial starting live weight (LW1) quartile (Q1 heaviest to Q4 lightest). Values with different letters are significantly different (P<0.05).

Quartile	*LW1*	*s.e.m*
1	*41.91*	*0.1108a*
2	*38.57*	*0.1105b*
3	*36.36*	*0.1081c*
4	*33.08*	*0.1092d*

Table 7: Number of drenches administered and standard error of the mean (s.e.m) for all TT animals across all farms relative to liveweight gain (LWG) quartile (Q1 heaviest… Q4 lightest). Values with different letters are significantly different (P<0.05).

Quartile	*LWG*	*s.e.m*
1	*6.18*	*0.176a*
2	*6.47*	*0.176b*
3	*6.65*	*0.173b*
4	*7.15*	*0.175c*

Response to treatment

The response to treatment was assessed based on the change in WR score (i.e. the increase or decrease of WR value) following treatment for all animals that were drenched across all times regardless of treatment group (Figure 4). As noted in the Methods, WR is the worm rating – the output given by the SmartWorm® app from which a decision to treat is based; animals typically have WR values between 1 and 10, with the larger the value the better the animal is performing relative to its prediction. The magnitude of the benefit received from drenching decreases as the WR at the treatment time increases. In other words, a larger benefit of treatment is likely from those with a low WR.

The expected magnitude of response can be observed in Figure 5 which shows that the magnitude of the benefit received from drenching decreases as the WR at the treatment time increases. In other words, a larger benefit of treatment is likely from those with a low WR.

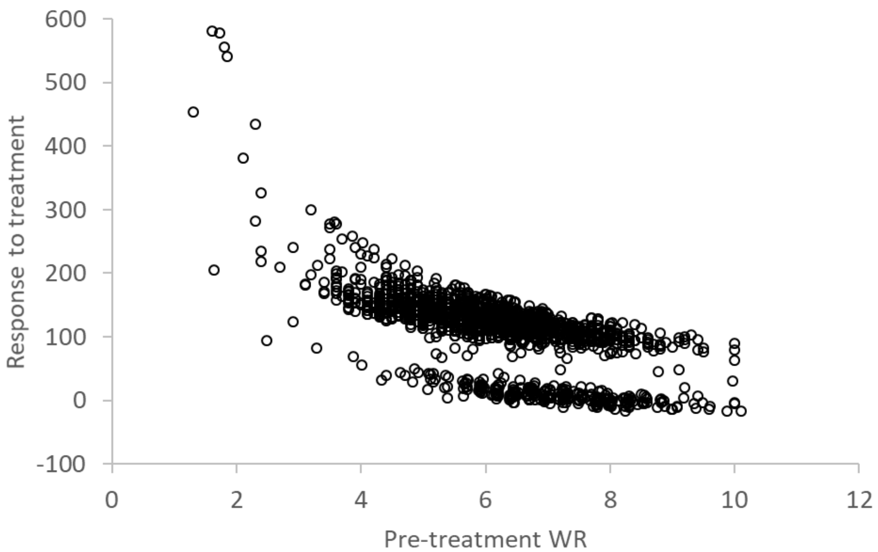

Figure 4: Response to treatment (% change) in post-treatment Worm Rating (WR) relative to the WR at the time of treatment (pre-treatment WR), for all animals and treatment groups combined on three farms enrolled in SmartWorm® pilot study. A value of 100% represents no change in WR because of treatment.

Receiver operator characteristics (ROC) analysis allowed an assessment of the adequacy of the WR. ROC analysis just considers an increase or decrease in WR, it does not factor the magnitude of the increase, or decrease. An area under the ROC curve of 0.5 (straight line) suggests no discrimination (i.e., ability to diagnose animals likely to respond positively to treatment); 0.7 to 0.8 is considered acceptable; 0.8 to 0.9 is considered very good; and more than 0.9 is considered excellent. Analysis of the data for all animals from all farms combined provided an area under the curve of 0.8957, indicating very good, almost excellent discrimination between true positives and false negatives (Figure 5).

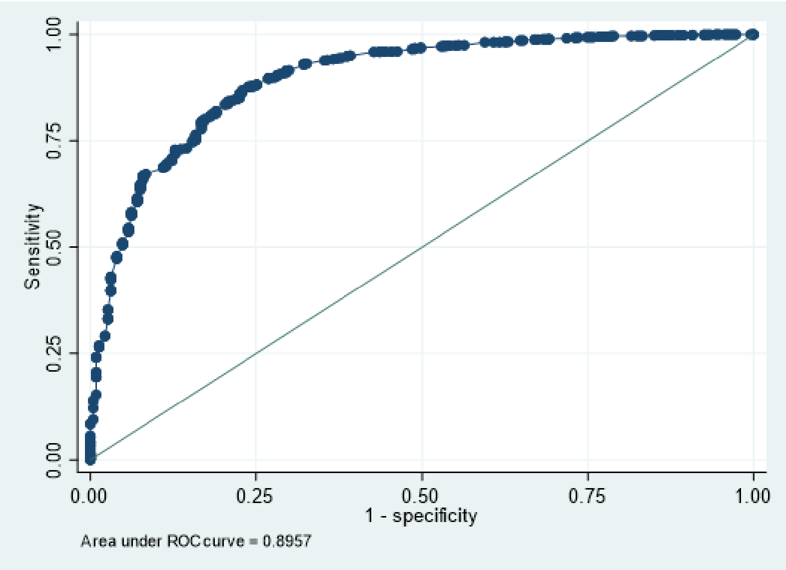

Figure 5: Output of ROC analysis, sensitivity and 1-specificity for the response to treatment of all animals on three farms combined enrolled in SmartWorm® pilot study, based on a change in the calculated Worm Rating value pre- and post-treatment.

Calculation of the maximum value of sensitivity plus specificity (Sn + Sp) is one way in which an optimum trade-off between true positives (TP) and false negatives (FN) can be evaluated, based on the likelihood of a positive response to treatment relative to the Worm Rating (WR) used as the decision threshold , where:

Sn = TP / (TP+FN)

Sp = TN / (TN+FP)

The maximum Sn+Sp value is the optimum treatment threshold.

For this pilot study, the maximum Sn + Sp for all farms combined, using data from the response to treatment for all treated animals, occurred at a pre-treatment worm rating of 7 (Figure 6). At this point 85% of those treated (i.e. a WR value of less than 7) would be expected to positively respond to treatment (i.e, an increase in their WR as a consequence of being treated) and 78% of those not treated would not respond to treatment even if they were treated.

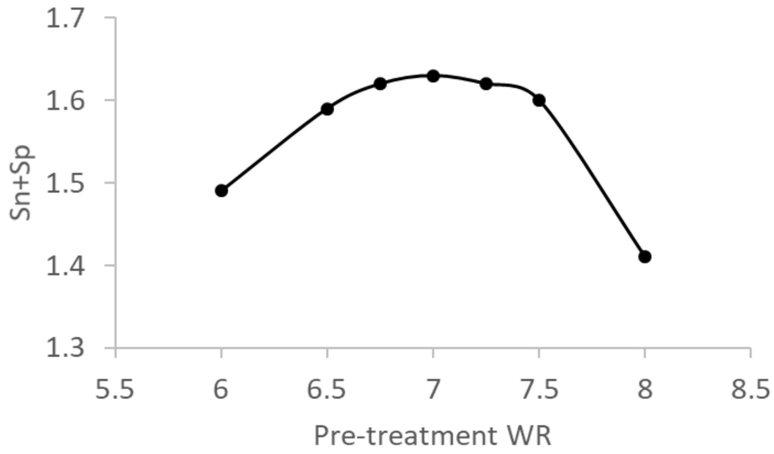

Figure 6: Relationship between pre-treatment Worm Rating (WR) and sensitivity plus specificity (Sn+Sp), for all treated animals on all farms combined in a SmartWorm® pilot study. See text for details on the derivation of scores.

Summary of Farm 1

After 'cleaning' the data by removing all animals for which there was any missing data, there was a total of 383 animals remaining, 185 from the BT group and 198 from the TT.

Overall, 555 drenches (3 per animal) were administered to the BT group on three treatment visits (V2-4). For the TT group there was a total of 374 drenches administered (average 1.89 drenches per animal). This was a reduction of 37% compared to the BT group (Table 8).

One TT animal didn't require any further treatment, 35 required one further drench, 147 required two more drenches and 15 required drenching at each event. Most of the drenches given to the TT animals were administered on V2 and V3. Of the 147 administered on V2, 118 animals required a further drench on V3, possibly indicating a large worm challenge (this suggestion is backed up by the higher FECs on Farm 1, shown on Table 5 above).

Table 8: Number of drenches given at each farm visit (V2 - V4) and total drenches for monthly BT or TT treatments relative to the total number of drenches each individual animal received (0, 1, 2 or 3).

Treatment	No Animals	Drenched V2	Drenched V3	Drenched V4	Total drenches
Blanket		**185**	**185**	**185**	**555**
3	185	185	185	185	555
TST		**196**	**133**	**45**	**374**
0	1	0	0	0	0
1	35	34	0	1	35
2	147	147	118	29	294
3	15	15	15	15	45

Blanket group, n = 185, TST group, n = 198.

Initial Live Weights (LW) at V1 were similar between groups (34.1 and 34.2 kg respectively). The performance data (growth over the three months, kg) is shown on Table 9. Overall, initial LW (LW1) and growth between BT and TT was similar. Total Live Weight Gain (LWG) was reduced by 0.5kg in TT and performance was lower for those animals that required three treatments. The performance of those that received 0 treatments is for one animal only.

Table 9: Mean and range (min-max) weight gain (kg) of lambs in BT and TT treatment groups on Farm 1, relative to the number of drenches received (0 - 3). Weights are shown as initial LW (LW1); liveweight gain calculated by final LW minus initial LW (LWG); average LW for Visits 2-4 less initial LW (Average LWG); and average LW across Visits 1 - 4 (Average LW).

Treatment	LW1	LWG	Average LWG	Average LW
Blanket	**34.1**	**8.92**	**3.25**	**37.3**
	(20.5-44.0)	**(-0.5-18.5)**	**(0.8-7.1)**	**(26.4-47.1)**
TST	**34.2**	**8.39**	**3.07**	**37.3**
	(23.5-47.5)	**(-0.5-16.0)**	**(-2.3-7.3)**	**(27.6-47.5)**
0	28.0	7.50	5.63	33.6
1	33.3	10.70	4.56	37.8
	(24.0-39.0)	(7.5-14.0)	(3.1-6.3)	(24.0-39.0)
2	34.3	8.35	2.87	37.2
	(23.5-47.5)	(2.0-16.0)	(-2.3-7.3)	(23.5-47.5)
3	35.2	3.47	1.41	36.6
	(32.0-45.5)	(-0.5-6.0)	(-0.9-2.5)	(32.0-45.5)

Blanket group, n = 185, TST group, n = 196.

Performance relative to initial weight distribution is given in the table below. Not surprisingly those in Q4 had lower average LW's than those in Q1, but performance, both in terms of growth and a lesser need for treatment didn't seem to be compromised.

Table 10: Weight gain performance (kg) and number of drenches administered (Total drenches) of monthly BT or TT animals based on quartile (heaviest Q1 - lightest Q4) grouping of their starting liveweight (Initial LW). Average LW across Visits 1 - 4 (Average LW); final LW less initial LW (LWG); average LW for Visits 2 - 4 less initial LW (Average LWG). Values given are means with the range (min-max) given in parenthesis in the row below.

	Initial LW	Average LW	LWG	Average LWG	Total drenches
Blanket	**34.1**	**37.3**	**8.92**	**3.25**	**3**
	(20.5-44.0)	**(26.4-47.1)**	**(-0.50-18.5)**	**(-0.75-7.1)**	
Q1	38.1	41.0	8.63	2.86	3
	(36.5-44.0)	(35.8-47.1)	(-0.5-13.5)	(-0.75-5.4)	
Q2	35.3	38.6	8.82	3.24	3
	(34.5-36.5)	(35.1-42.5)	(1.0-15.0)	(0.6-6.1)	
Q3	33.4	36.7	9.13	3.27	3
	(32.0-34.5)	(33.9-39.4)	(2.0-13.0)	(0.4-5.4)	
Q4	29.4	33.0	9.12	3.62	3
	(20.5-32.0)	(26.4-39.1)	(3.5-18.5)	(0.5-7.1)	
TST	**34.2**	**37.3**	**8.39**	**3.07**	**1.89**
	(23.5-47.5)	**(27.6-49.5)**	**(-0.5-7.25)**	**(-2.25-7.25)**	**(0-3)**
Q1	38.3	41.0	8.61	2.69	1.91
	(36.5-47.5)	(36.9-49.5)	(0.0-14.0)	(-2.25-6.9)	(1-3)
Q2	35.4	38.3	8.13	2.87	2.04
	(34.5-36.5)	(34.6-41.4)	(2.0-14.0)	(-0.9-5.9)	(1-3)
Q3	33.4	36.4	8.10	2.97	1.92
	(32.0-34.5)	(32.1-40.3)	(-0.50-16.0)	(-0.9-7.3)	(1-3)
Q4	29.9	33.6	8.75	3.73	1.69
	(23.5-32.0)	(27.6-37.8)	(5.0-15.0)	(1.5-6.75)	(0-2)

The response to treatment was assessed based on the increase or decrease of WR value following treatment for all animals that were drenched across all times regardless of treatment group (Figure 7). The magnitude of the benefit received from drenching decreases as the WR at the treatment time increases. In other words, a larger benefit of treatment is likely from those with a low WR.

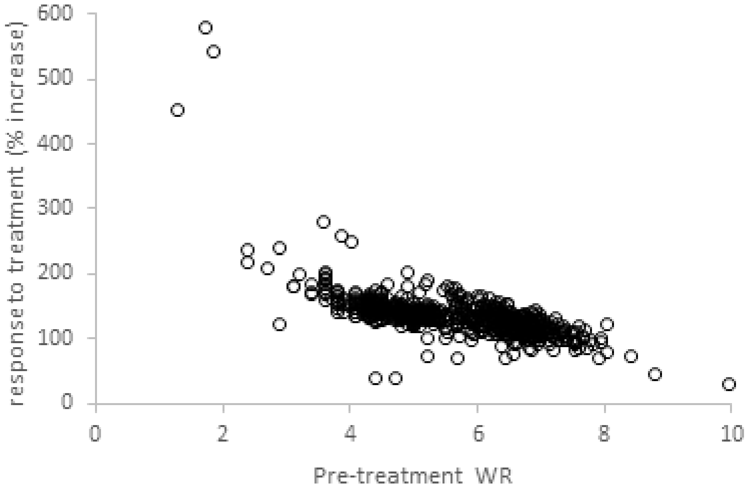

Figure 7: Response to treatment (% change) in post-treatment Worm Rating (WR) relative to the WR at the time of treatment (pre-treatment WR), for all animals and treatment groups combined on Farm 1 enrolled in SmartWorm® pilot study. A value of 100% represents no change in WR because of treatment.

ROC analysis revealed an area under the curve (AUC) of 0.8658, indicating very good differentiation between true and false positives (Figure 8).

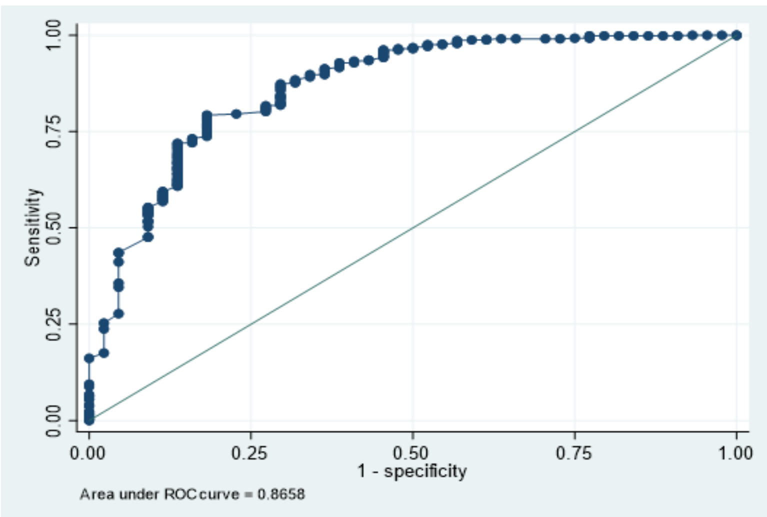

Figure 8: Output of ROC analysis, sensitivity, and 1-specificity for the response to treatment of all animals in all treatment groups on Farm 1 enrolled in SmartWorm® pilot study, based on a change in the calculated Worm Rating value pre- and post-treatment.

The maximum value of Sn + Sp showed the optimum treatment threshold to be 6.5 at which point 98% of those treated (i.e., a WR value of less than 6.5) would be expected to respond positively to treatment (i.e., an increase in their WR as a consequence of being treated) while 80% of those not treated would not respond positively if they had been treated (Figure 9).

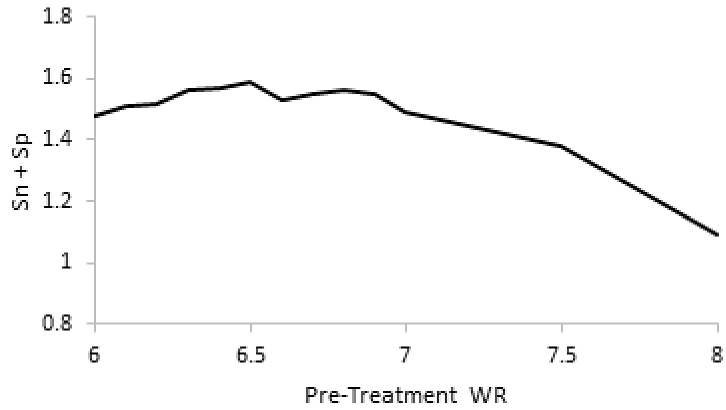

Figure 9: Relationship between pre-treatment Worm Rating (WR) and sensitivity plus specificity (Sn+Sp), for all treated animals on Farm 1. See Methods for details on the derivation of scores.

Summary of Farm 2

After 'cleaning' the data by removing all animals for which there was any missing data, there was a total of 612 animals remaining, 298 from the BT group and 314 from the TT group.

Overall, 894 drenches (3 per animal) were administered to the BT group on three treatment visits (V2-V4). For the TT group there was a total of 402 drenches given (average 1.28 per animal). This was a reduction of approximately 57% compared to the BT group (Table 11).

Of the drenches given to the TT animals a majority of these (311) were administered on V2. Of the 311 drenches administered on V2, 227 animals did not receive any further drenches. For 79 of the animals treated on V2, 55 also received a drench at V3 while 24 received their only other drench on V4. Five animals needed drenching on each occasion. One animal did not require any further drenches after V1.

Table 11: Number of drenches given at each farm Visit (V2 - V4) and total drenches for monthly BT or TT treatments relative to the total number of drenches each individual animal received (0, 1, 2 or 3).

Treatment	No animals	Drenched V2	Drenched V3	Drenched V4	Total drenches
Blanket		**298**	**298**	**298**	**894**
3	298	298	298	298	894
TST		**311**	**62**	**29**	**402**
0	1	0	0	0	0
1	229	227	2	0	229
2	79	79	55	24	158
3	5	5	5	5	15

Blanket group, n = 298, TST group, n = 314.

Initial LW's at Visit 1 were similar between treatment groups (37.4 and 37.5). Performance relative to initial weight distribution is given in Table 12 below. Q2 and Q3 are similar in LW but Q1 and Q4 have greater deviations, as may be expected with a normal distribution. Not surprisingly those in Q4 had lower average LW's than those in Q1, but they did appear to perform better, both in terms of growth and a lesser need for treatment. This may well reflect that something was the cause of the lighter LW's of the Q4 animals at the start of the trial, which was overcome, and which then allowed for a greater level of performance. A possible candidate for this may have been parasitism (this was not able to be proven as only a random sample of faeces were sampled for FEC), the impact of which was lessened due to the drench at the first drench.

Table 12: Weight gain performance and number of drenches administered (Total drenches) of monthly BT or TT animals based on quartile (heaviest Q1 - lightest Q4) grouping of their starting liveweight (kg). Average LW across Visits 1 - 4 (Average LW); final LW less initial LW (LWG); average LW for Visits 2 - 4 less initial LW (Average LWG).

	Average LW	LWG	Average LWG	Total drenches
Blanket	**39.9**	**5.39**	**2.43**	**3**
	(30.0-50.8)	**(-5.0-12.5)**	**(-1.8-5.5)**	
Q1	44.5	4.82	1.98	3
	(39.8-50.8)	(-3.0-9.5)	(-1.8-4.9)	
Q2	41.0	5.21	2.37	3
	(33.4-41.3)	(-5.0-10.0)	(-1.1-4.5)	
Q4	35.4	6.02	2.85	3
	(30.0-38.8)	-4.0-12.5)	(-1.8-5.5)	
TST	**40.1**	**5.63**	**2.63**	**1.28**
	(31.5-50.5)	**(-2.5-11.5)**	**(-3.5-6.9)**	**(0.0-3.0)**
Q1	44.6	5.02	2.25	1.38
	(39.8-50.5)	(-1.5-10.5)	(-2.8-4.9)	(1.0-2.0)
Q2	41.0	5.31	2.38	1.35
	(34.5-44.1)	(-2.5-11.0)	(-3.5-5.5)	(1.0-3.0)
Q3	39.0	5.96	2.79	1.31
	(35.0-41.5)	(2.5-11.5)	(0.0-5.88)	(1.0-3.0)
Q4	35.8	6.23	3.11	1.08
	(31.5-41.4)	(2.0-10.5)	(0.8-6.9)	(0.0-2.0)

The response to treatment was assessed based on the increase or decrease of WR value following treatment for all animals that were drenched across all times regardless of treatment group (Figure 9). The magnitude of the benefit received from drenching decreases as the WR at the treatment time increases. In other words, a larger benefit of treatment is likely from those with a low WR.

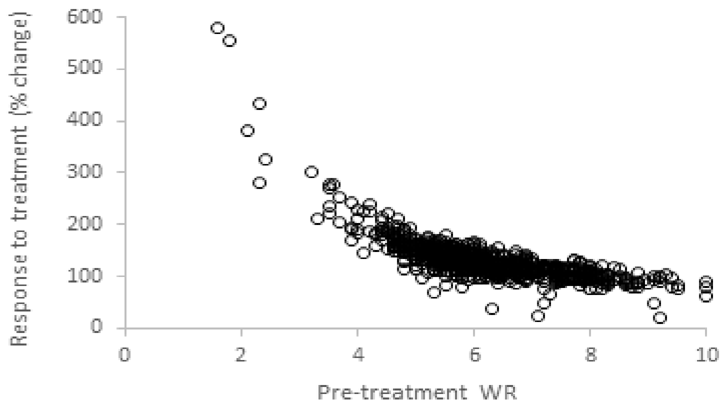

Figure 9: Response to treatment (% change) in post-treatment Worm Rating (WR) relative to the WR at the time of treatment (pre-treatment WR), for all animals and treatment groups combined on Farm 2 enrolled in SmartWorm® pilot study. A value of 100% represents no change in WR because of treatment.

ROC analysis revealed and area under the curve of 0.9130, indicating excellent differentiation between true positive and false positives (Figure 10).

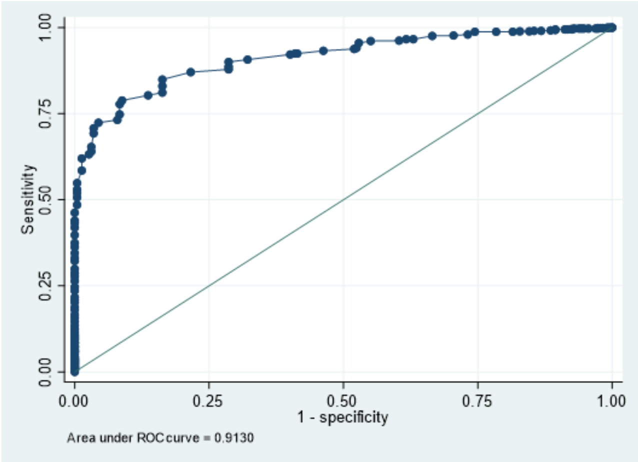

Figure 10: Output of ROC analysis, sensitivity, and 1-specificity for the response to treatment of all animals in all treatment groups on Farm 2 enrolled in SmartWorm® pilot study, based on a change in the calculated Worm Rating value pre- and post-treatment.

Sn +Sp was greatest at four points, 6.4 (30% true negative, 98% true positive), 6.8 (35% true negative, 97% true positive), 7.1 (40% true negative, 96% true positive) and 7.2 (42% true negative, 96% true positive), indicating that a treatment threshold of around 7 on the WR is appropriate although there was relatively little difference in any WR threshold between 6.4 and 7.5 (Figure 11).

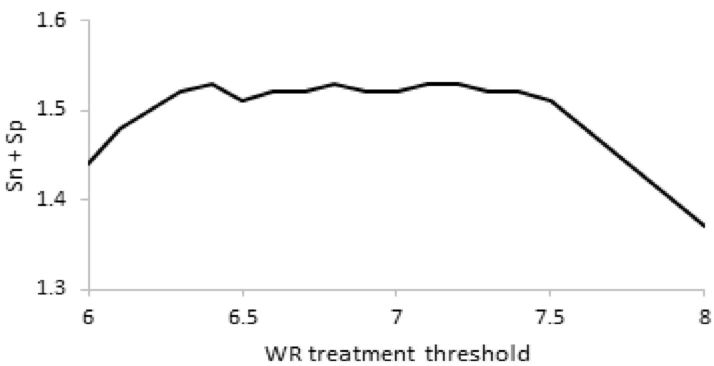

Figure 11: Relationship between pre-treatment Worm Rating (WR) and sensitivity plus specificity (Sn+Sp), for all treated animals on Farm 2. See Methods for details on the derivation of scores.

Summary of Farm 3

After 'cleaning' the data by removing all animals for which there was any missing data, there was a total of 419 animals remaining, 208 from the BT group and 211 from the TT group. Initial LW's at V1 were similar (40.6 v 40.5 kg). All animals were drenched at V1, which is not included in the analysis presented, i.e., number of treatments refers to the number of treatments in addition to V1.

Overall, there was 624 drenches administered to the BT group, being an average of 3 per animal. For the TT group there was a total of 302 drenches given, being an average of 1.43 drenches per animal. One-hundred and forty-four TT animals received a treatment at V2 and didn't require further treatment, 43 required drenching twice and 24 required drenching at all events. This was a reduction of approximately 52% compared to the BT group. Of the drenches given to the TST animals a majority of these were administered on V2 when all animals were drenched due to technology issues.

Table 13: Number of drenches given at each farm visit (V2 - V4) and total drenches for monthly BT or TT treatments relative to the total number of drenches each individual animal received (0, 1, 2 or 3).

Treatment	No animals	Drenched V2	Drenched V3	Drenched V4	Total drenches
Blanket		**208**	**208**	**208**	**624**
3	208	208	208	208	624
TST		**211**	**59**	**32**	**302**
0	0	0	0	0	0
1	144	144	0	0	144
2	43	43	35	8	86
3	24	24	24	24	72

Blanket group n = 208, TST group n = 211

The performance data (growth over the three months, kg) is shown below. Overall, initial LW (LW1) and growth between BT and TT was similar. Total LWG was reduced by 0.2 kg in TST, and performance was lower for those animals that received (required) three treatments and greatest in those that required fewer treatment.

Table 14: Weight gain performance comparing BT and TT group relative to the number of treatments received (0 - 3) (kg). Initial LW (LW1); final LW less initial LW (LWG); average LW for Visits 2 - 4 less initial LW (Average LWG); average LW across Visits 1 - 4 (Average LW). N.B. Different means of calculating performance were an attempt to smooth measurement errors associated with using just initial and final LW.

Treatment	LW1	LWG	Average LWG	Average LW
Blanket	**40.6** **(33.0-50.5)**	**6.56** **(-4.0-13.0)**	**2.59** **(-4.5-6.3)**	**43.2** **(36.3-51.4)**
TST	**40.5** **(24.5-50)**	**6.37** **(-18.5-24.5)**	**2.50** **(-3.3-14.9)**	**43.0** **(36.3-51.0)**
1	39.7 (24.5-47.0)	7.51 (4.0-24.5)	3.22 (-1.8-14.9)	43 (37.0-51.0)
2	41.2 (35.0-47.5)	4.66 (-18.5-9.0)	1.35 (-3.3-2.8)	42.5 (36.3-47.8)
3	43.5 (37.0-50.0)	2.63 (0.5-4.5)	0.27 (-1.9-1.6)	43.8 (38.4-50.1)

Performance relative to initial weight distribution is given in the table below. Not surprisingly those in Q4 had lower average LW's than those in Q1, but performance, both in terms of growth and a lesser need for treatment didn't seem to be compromised. Fewer treatments were administered to the lighter animals and LWG was greater, but this was comparable to what was observed in the BT group so may reflect catch-up performance rather than a bias in the app.

Table 15: Weight gain performance and number of drenches administered (Total drenches) of monthly BT or TT animals based on quartile (heaviest Q1 - lightest Q4) grouping of their starting liveweight (kg). Average LW across Visits 1-4 (Average LW); final LW less initial LW (LWG); average LW for Visits 2 - 4 less initial LW (Average LWG).

	Average LW	LWG	Average LWG	Total drenches
Blanket	**43.2**	**6.6**	**2.59**	**3**
	(36.3-51.4)	**(-4.0-13.0)**	**(-4.5-6.3)**	
1	46.7	6.08	2.07	3
	(42.4-51.4)	(3.0-12.0)	(-4.0-5.8)	
2	43.7	5.79	2.29	3
	(36.5-48.0)	(-4.0-11.0)	(-4.5-5.9)	
3	42.3	6.84	2.82	3
	(38.9-44.9)	(2.5-13.0)	(0.4-5.9)	
4	40.2	7.50	3.14	3
	(36.3-43.3)	(2.0-13.0)	(-0.4-6.3)	
TST	**43.0**	**6.37**	**2.50**	**1.04**
	(36.3-51.0)	**(-18.5-24.5)**	**(-3.3-14.9)**	**(0.0-3.0)**
1	46.4	5.44	1.92	1.94
	(41.8-51.0)	(0.5-12.5)	(-1.9-6.5)	(1.0-3.0)
2	43.7	6.58	2.48	1.30
	(38.8-48.9)	(2.5-10.0)	(-1.8-4.9)	(1.0-3.0)
3	41.6	5.99	2.36	1.34
	(36.3-45.5)	(-18.5-13.5)	(-3.3-6.0)	(1.0-3.0)
4	39.9	7.54	3.27	1.11
	(36.3-42.5)	(3.0-24.5)	(1.3-14.9)	(1.0-3.0)

The response to treatment was assessed based on the increase or decrease of WR value following treatment for all animals that were drenched across all times regardless of treatment group (Figure 12). As with previous farms, the magnitude of the benefit received from drenching decreases as the WR at the treatment time increases. In other words, a larger benefit of treatment is likely from those with a low WR.

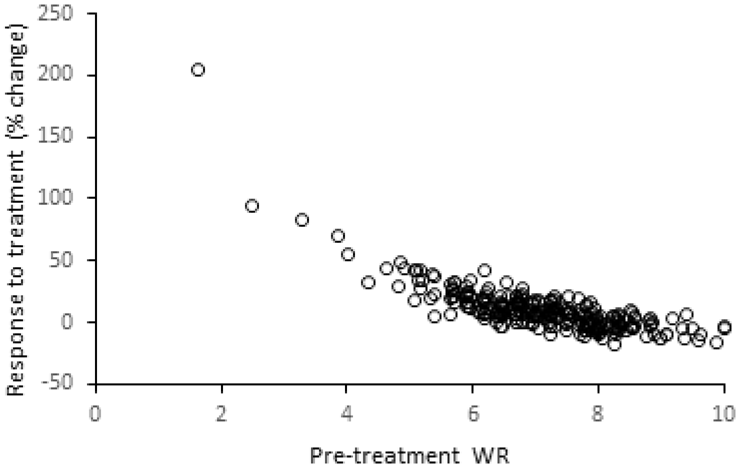

Figure 12: Response to treatment (% change) in post-treatment Worm Rating (WR) relative to the WR at the time of treatment (pre-treatment WR), for all animals and treatment groups combined on Farm 3 enrolled in SmartWorm® pilot study. A value of 100% represents no change in WR because of treatment.

ROC analysis revealed and area under the curve of 0.9025, indicating excellent differentiation between true and false positives.

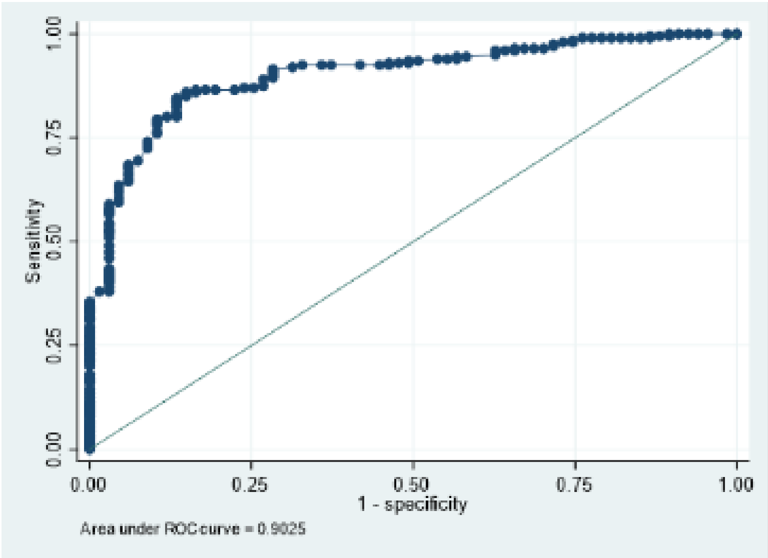

Figure 13: Output of ROC analysis, sensitivity, and 1-specificity for the response to treatment of all animals in all treatment groups on Farm 3 enrolled in SmartWorm® pilot study, based on a change in the calculated Worm Rating value pre- and post-treatment.

The maximum value of Sn + Sp showed the optimum treatment threshold to be 7.6. At this point 80% of those treated would be expected to respond positively to treatment, while 88% of those not treated would not have responded positively even if they had been drenched.

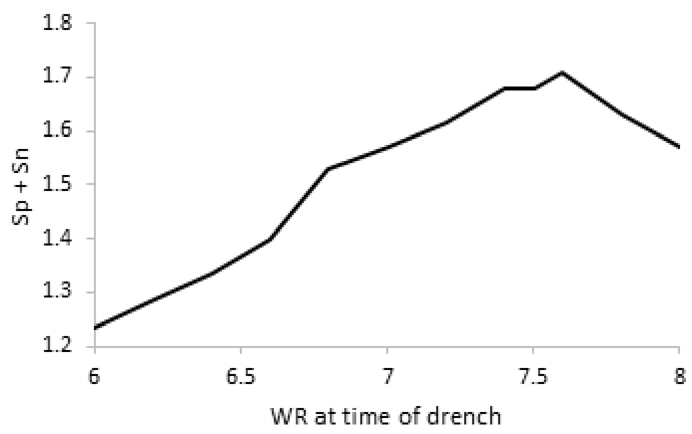

Figure 14: Relationship between pre-treatment Worm Rating (WR) and sensitivity plus specificity (Sn+Sp), for all treated animals on Farm 3 in a SmartWorm® pilot study.

Discussion

The data collection from the first two visits at all farms was not perfect due to technical difficulties at these events. At the 3rd and 4th visits, very accurate data were collected, and the technology difficulties previously encountered were overcome. As a result, the statistician had to clean the data to identify and include animals that had 4 full measurements only.

Despite the challenges with incomplete data sets that led to reduced data points, the statistical analysis presented highlights that the SmartWorm® app decisions worked well in a range of pasture larval challenge and feeding environments over this 3-month period.

It is plausible to argue, that in pasture with low levels of larval contamination such as Farm 2, decisions based on serial faecal egg counts alone would have achieved similar if not lower drench input with recommendations from the Animal Health Advisor.

Incorporating a pre-weigh sample FEC was complementary to the app process and allowed a higher degree of confidence at setting a higher threshold of growth rate to leave more TT animals undrenched without sacrificing liveweight gain. On one property initial FEC were not performed, and while this does limit the parasitological information available it does not seem to have had a large impact on the outcome as treatment decisions were independent of FEC and all farms showed similar patterns of responses.

At the 2nd weigh session (Visit 2), all three farms experienced very low weight gain/weight loss in both treatment groups. This was not expected by the farmers. The faecal egg counts only explained the poor liveweight gain on one of the three properties, with Farm 1 having high FEC which indicates high pasture larval contamination causing rapid re-infection. Pasture analysis, larval culture and trace element testing did not provide any answers. However, on Farm 2, potentially post-grazing pasture cover and quality were lower than suggested initially by the farmer and programmed into the app. It is possible that the high rainfall that occurred in Hawkes Bay and Wairarapa during June in the year of the trial had an impact on growth rates across all farms over this time.

Conclusion & recommendations

The SmartWorm® app has been successfully piloted at three properties under a range of parasite challenge and performed as predicted using a 28–30-day weigh event interval.

There has been insignificant impact on liveweight gain (average of 327 grams total over 90 days) when leaving the chosen animals undrenched based on the SmartWorm® app decision.

There was a significant reduction in the amount of drench used on all three properties in the TT group compared to the BT group ranging from 37 - 57% (see Appendix 1 for the economic analysis on the study at each farm).

After discussions with the three farmers involved, there is some initial setup assistance required from someone with good knowledge of the app and farm technology to be able to execute the weigh event seamlessly.

This app has significant merit for New Zealand farmers for reducing drench input in this age group of sheep.

As this pilot study showed promising results, further investigation is warranted. Preferably this would be in younger sheep, at different times of the year, across New Zealand to determine if the SmartWorm® app decisions are valid. Consideration needs to be given to environments with larger Haemonchus populations and whether there needs to be adjustment to the weigh event interval (shorter) in higher worm challenge scenarios in younger animals to maintain animal performance and still reduce drench inputs.

Acknowledgements

I would like to thank Nick Cotter of Cotter Agritech Ireland for the opportunity to use their app, B+LNZ for funding this project, Caitlin Watts of Vet Services Hawkes Bay and Sara Sutherland of The Vet Clinic Wairarapa for their collaboration.

I would also like to thank Jasmine Tanner and Andrew Greer for their statistical analysis and support, Cara Brosnahan for her mentorship through the study and the three farmers who provided stock and labour for the pilot study and Ginny Dodunski on her input throughout the study.

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Sponsorship

I would like to thank MSD Allflex for their sponsorship of the eID tags, applicators and foldover tags.

Appendix One: SmartWorm® App Pilot Study – Economic Report

Nick Cotter, Co-founder and CEO of Cotter Agritech Limited
Dromtrasna North, Abbeyfeale,
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Economic Report Summary

This short report outlines savings achieved by three farms in a SmartWorm® App Pilot Study conducted on New Zealand's North Island for 3 months (May, June & July 2023). On each farm, a mob of lambs grazing together were split into two groups:

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 a monthly interval.

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

- Average direct saving of $0.79 per lamb
- Average indirect saving of $1.43 per lamb
- Total average savings of $2.22 per lamb

Electronic Identification (EID) is necessary for SmartWorm to work. EID is not mandated in New Zealand and therefore is an additional business cost. Two options were considered in this report:

- EID Tags: average cost of $1.63 per lamb, average net saving of $0.59 per lamb.
- Facial Recognition EID: average cost of $0.62 per lamb, average net saving of $1.60 per lamb.

The results of this study are promising and warrant further investigation by deploying SmartWorm across a full grazing season. In addition, the practicalities of facial recognition EID should be explored as if it works, it significantly reduces the economic barriers to adopt SmartWorm®.

Methodology

To ensure the Blanket (control) and TST (targeted selective treatment) study groups could be compared simply, the number of lambs was cleaned further (compared to the main paper), to ensure an equal number 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.
    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.

Discussion

Direct Savings

Farm 3 had the smallest direct savings due to an inexpensive triple active drench being used on the days where drench reduction was achieved. In addition, the farm had the highest labour cost and slowest weighing speed, so any additional time to weigh TST lambs was costly.

Farm 2 had the next highest direct savings. It also used a cheap triple active drench. The main difference in savings was lower labour costs and faster weighing speed, so the additional time to weigh TST lambs was less costly.

Farm 1 had the largest direct savings as they used a new generation Anthelmintic drug (Startect) at all drench events. Startect is 3.3 - 3.5 times the cost of a typical triple active. It was used due to poor triple active drug efficacy.

Indirect Savings (generated by SmartWorm® slowing resistance development)

Farm 3 and Farm 2 achieved indirect savings of $2.17 and $1.95 per lamb. Both farms have effective triple active drenches. The saving is high as SmartWorm is enabling them to avoid moving to the higher cost new generation drugs for regular worm control.[1] This highlights that farmers who currently have effective older generation Anthelmintic drugs[2] have the most to gain financially by using SmartWorm®.

Farm 1 had much lower indirect savings of $0.18 per lamb. This farm used Startect at all drench events and therefore is already paying the cost of using new generation drugs. The saving here is a small one, as what's being avoided is moving from Startect to a slightly more expensive new generation drug (Zolvix).

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 $6.55 to $12.45 per lamb.[3]

Table 1: Savings achieved in Trial

Farm	**No of TST Lambs**	**% less drench use**	**Anthelmintic Drug Saving (per lamb)**	**Drench Labour Saving (per lamb)**	**Additional Weighing Cost (per lamb)**	**Direct Savings (per lamb)**	**Indirect Saving from using SmartWorm® (per lamb)**	**Total Savings (per lamb)**
Farm 3	195	52%	$0.69	$0.19	-$0.48	$0.40	$2.17	$2.57
Farm 2	288	57%	$0.67	$0.22	-$0.30	$0.58	$1.95	$2.53
Farm 1	166	37%	$1.49	$0.19	-$0.29	$1.38	$0.18	$1.57
AVERAGE		49%				**$0.79**	**$1.43**	**$2.22**

[1] Zolvix and Startect are 3.3 - 3.75 times more expensive than the triple active drenches used in this trial.
[2] Benzimidazole (1-BZ), Levamisole (2-LV), and Macrocyclic Lactone (3-ML) single, double or triple active drugs.
[3] 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 11th November 2023 (hUps://www.bordbia.ie/farmers-growers/prices-markets/sheep-trade-prices/deadweight-lamb-prices/).

Table 2: Farm information used in calculations.

Farm	Drug used at each weigh event (in order)	Normal Winter Weighing Frequency	Labour Cost	Weighing Speed	Drench Speed	Indirect Saving from using SmartWorm®
Farm 3	Startect (5-SI) Startect (5-SI) Alliance (Triple) Alliance (Triple)	4 weeks - sample weigh 100 lambs per batch (extra work for the TST group is weighing all lambs)	2 units $35/hr each	11 secs per lamb	600 per hour	Avoid replacing the two Alliance drenches with Zolvix (4-LV)
Farm 2	VETMED TripleMax (Triple) VETMED TripleMax (Triple) VETMED TripleMax (Triple) VETMED TripleMax (Triple)	4 weeks - sample weigh 100 lambs per batch (extra work for the TST group is weighing all lambs)	2 units $25/hr each	9 secs per lamb	400 per hour	Avoid replacing two of the TripleMax drenches with Startect (5-SI)
Farm 1	Startect (5-SI) Startect (5-SI) Startect (5-SI) Startect (5-SI)	4 weeks - sample weigh 100 lambs per batch (extra work for the TST group is weighing all lambs)	2 units $25/hr each	10 secs Per lamb	300 per hour	Avoid replacing two of the Startect drenches with Zolvix (4-LV)

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 (Figure 3), with an average cost of $1.63 per lamb. When this cost is subtracted from the savings, the average net savings are $0.59 per lamb.

An emerging alternative to traditional tag-based EID technology that has also been considered is Facial Recognition EID Cameras. This technology has the potential to lower sheep identification costs to $0.62 per lamb (Table 3). If successful, this would increase net savings to $1.60 per lamb, a near threefold increase.

Table 3: Animal Identification Costs for each Farm

Farm	Cost of EID Tags	Labour to put in EID tags	EID tags cost (per lamb)	Cost of Facial Recognition EID	Facial Recognition EID cost (per lamb)
Farm 3	$1.49 x 195 lambs Cost - $290.55	First drench takes 2x longer Cost - $22.75	$1.61	$4,316 upfront + $5,631/year*	$0.65*
Farm 2	$1.49 x 288 lambs Cost - $429.12	First drench takes 2x longer Cost - $36.00	$1.62	$7,554 upfront + $9,856/year*	$0.57*
Farm 1	$1.49 x 166 lambs Cost – $247.34	First drench takes 2x longer Cost - $27.67	$1.66	$4,316 upfront + $5,631/year*	$0.65*
AVERAGE			**$1.63**		**$0.62**

*The upfront facial recognition EID cost and annual subscription is an estimate for a whole farm set up based on the below data: Farm 3 running 10,000 lambs, Farm 2 running 20,000 lambs and Farm 1 running 10,000 lambs. The upfront cost has been set over 5 years for calculating the per lamb cost.

Conclusion

This report has highlighted the economic benefits of adopting more sustainable Anthelmintic drug use in the winter grazing months on three New Zealand North Island sheep farms. The results of this trial are promising and warrant a broader rollout on more NZ farms for the entire grazing season.

Early indications of possible results can be seen in trials of SmartWorm conducted over the last 3 years on Irish and UK sheep farms. When implemented for a full grazing season (~6 months), farmers achieved direct savings of ~$1.19/lamb and indirect savings of $2.03/lamb on average, a 50% and 20% increase versus the present trial. This means that NZ farmers could see net savings of $1.59/lamb where using EID tags, or potentially $2.61/lamb if using facial recognition EID.

On this basis, including facial recognition EID into a future trial would be worthwhile. If successful, this would represent a significant step in reducing the economic barriers to uptake of not only SmartWorm®, but all EID based technology in New Zealand.